

Upright image Copyright © 2025 Pace Innovations Pty Ltd. All rights reserved. Used with permission.

SusProg3D Manual

Version 5.170A June 2026



SusProg3D

Suspension by Design

SusProg3D - Suspension by Design

Robert D Small

All rights reserved. No parts of this work may be reproduced in any form or by any means - graphic, electronic, or mechanical, including photocopying, recording, taping, or information storage and retrieval systems - without the written permission of the publisher.

Products that are referred to in this document may be either trademarks and/or registered trademarks of the respective owners. The publisher and the author make no claim to these trademarks.

While every precaution has been taken in the preparation of this document, the publisher and the author assume no responsibility for errors or omissions, or for damages resulting from the use of information contained in this document or from the use of programs and source code that may accompany it. In no event shall the publisher and the author be liable for any loss of profit or any other commercial damage caused or alleged to have been caused directly or indirectly by this document.

Printed: June 2026

Table of Contents

Foreword	0
Part 1 Overview	13
1 SusProg3D - Suspension by Design	13
2 PC hardware and software requirements	15
3 To run the program	16
4 Evaluation version	16
Part 2 User Interface	18
1 Screen layout	18
2 Exit	19
3 Status line	19
4 Toggle items	19
5 Keys	19
6 Dialog box	19
Buttons	19
Radio buttons	20
Check boxes	20
Labels	20
Numeric input	20
Regional settings	22
7 Error and warning boxes	22
8 Result window	22
9 Menu bar	22
File	22
Data file selection.....	23
Save the data.....	24
Print vehicle data.....	24
Print the graphic.....	25
Exit SusProg.....	25
Windows	25
Settings	26
Help	28
Part 3 Coordinate system	30
1 Vehicle coordinates.	30
2 Chassis coordinates.	32
3 Upright coordinates.	33
4 Wheel coordinates.	34
5 LH and RH coordinates.	34
Part 4 Suspension geometry types	36
1 Double A-arm, toe link	38
2 Upper "virtual A-arm", lower A-arm, toe link	39

3	Upper parallel links, trailing link, lower A-arm	41
4	Upper A-arm, lower "virtual A-arm", toe link	43
5	Upper A-arm, lower trailing and two lateral links, toe link	44
6	Upper and lower lateral links, twin trailing links, toe link	45
7	Upper and lower "virtual A-arms", toe link	47
8	Upper transverse leaf spring, lower reversed A-arm and trailing link	48
9	Upper lateral link, lower reversed A-arm, twin trailing links	49
10	Upper reversed A-arm, lower lateral link, twin trailing links	50
11	Upper lateral link, parallel lower links, twin trailing links	51
12	Aarm Caster Link	52
13	Ford Twin I-Beam	53
14	Volkswagen twin trailing links	54
15	Compound link	55
	Jaguar IRS	56
	H-arm + camber link	58
	Porsche 928	59
16	Semi-trailing arm (also includes trailing arm and swing axle)	60
17	Trailing arm, camber control and toe control links.	62
18	Trailing arm, upper and lower lateral links	63
19	Trailing arm, upper and lower lateral links, toe control link	66
20	Strut types	67
	Strut, lower A-arm, toe link	68
	Strut, lower "virtual A-arm", toe link	69
	Strut, tri-link	70
	Chapman strut	72
	Dual-axis strut	74
21	Live / de Dion / rigid axle	75
	Torque arm + 4 trailing links and birdcage + Panhard rod	77
	Torque arm + 4 trailing links and birdcage + Watts linkage	78
	Torque arm slider + Panhard rod	79
	Torque arm slider + Watts linkage	80
	Torque tube + Panhard rod	81
	Torque tube + Watts linkage	82
	Winters: 4 trailing links, 2 birdcages + Jacobs ladder	83
	2 trailing arms + Mumford linkage	84
	2 trailing arms + Panhard rod	85
	2 trailing arms + Watts linkage	87
	3 or 4 links + Mumford linkage	88
	3 or 4 links + Panhard rod	89
	3 or 4 links + Watts linkage	91
	3 or 4 links + Woblink	92
	4 links	93
22	Mono wheel - trailing arm	94
Part 5 Vehicle		95
1	Configure	95
2	Datum	96
3	Wheelbase	98
4	Ride Height	98

5	Vehicle mass and centre of gravity	99
6	Wheel and tyre	100
7	Undertray	101
8	Data	102
9	Graphic	102
10	VCalc	102
Part 6 Geometry		103
1	Configuration	103
	Double A-arm, toe link	104
	Upper "virtual A-arm", lower A-arm, toe link	106
	Upper parallel links, trailing link, lower A-arm	106
	Upper A-arm, lower "virtual A-arm", toe link	107
	Upper A-arm, lower trailing and two lateral links	108
	Upper and lower lateral links, twin trailing links, toe link	109
	Upper and lower "virtual A-arms", toe link	109
	Upper transverse leaf spring, lower reversed A-arm and trailing link	110
	Upper lateral link, lower reversed A-arm, twin trailing links	111
	Upper reversed A-arm, lower lateral link, twin trailing links	111
	Upper lateral link, parallel lower links, twin trailing links	112
	Aarm Caster Link	113
	Ford Twin I-Beam	113
	Volkswagen twin trailing links	114
	Jaguar IRS	115
	H-arm + camber link	116
	Porsche 928	117
	Semi-trailing arm (also includes trailing arm and swing axle)	118
	Trailing arm, camber control and toe control links.	118
	Trailing arm, upper and lower lateral links	119
	Trailing arm, upper and lower lateral links, toe control link	119
	Strut, lower A-arm, toe link	120
	Strut, lower 'virtual A-arm', toe link	122
	Strut tri-link	124
	Chapman strut	125
	Dual-axis strut	126
	Live axle (torque arm) - 4 trailing links and birdcage + Panhard rod	127
	Live axle (torque arm) - 4 trailing links and birdcage + Watts linkage	127
	Live axle (torque arm slider) - 2 trailing links + Panhard rod	128
	Live axle (torque arm slider) - 2 trailing links + Watts linkage	130
	Live axle (torque tube) + Panhard rod	131
	Live axle (torque tube) + Watts linkage	131
	Winters: 4 trailing links, 2 birdcages + Jacobs ladder	132
	Live axle or deDion - 2 trailing arms + Mumford linkage	133
	Live axle or deDion - 2 trailing arms + Panhard rod	134
	Live axle or deDion - 2 trailing arms + Watts linkage	135
	Live axle or deDion - 3 or 4 link + Mumford linkage	136
	Live axle or deDion - 3 or 4 link + Panhard rod	137
	Live axle or deDion - 3 or 4 link + Watts linkage	138
	Live axle or deDion - 3 or 4 link + Woblink	139
	Live axle or deDion - 4 links	140
	Mono wheel - trailing arm	141
2	Car end and car side	142
3	Chassis	142
	Double A-arm	142

Lower A-arm, upper "virtual A-arm", toe link	142
Lower A-arm, upper parallel links, trailing link	143
Upper A-arm, lower "virtual A-arm", toe link	143
Upper A-arm, lower trailing and lateral links, toe link	143
Upper and lower lateral links, twin trailing links, toe link	143
Upper and lower "virtual A-arms", toe link	143
Upper transverse leaf spring, lower reversed A-arm and trailing link	144
Upper lateral link, lower reversed A-arm, twin trailing links	144
Lower lateral link, upper reversed A-arm, twin trailing links	144
Upper lateral link, lower parallel links, twin trailing links	144
Aarm Caster Link	144
Ford Twin I-Beam	144
Volkswagen twin trailing links	144
Jaguar/H-arm + camber link/Porsche928	145
Semi-trailing arm (also includes trailing arm and swing axle)	145
Semi-trailing arm (fixed outer pivot, suspended inner pivot), toe link.	145
Trailing arm, upper and lower lateral links	145
Trailing arm, upper and lower lateral links, toe control link	145
Strut	146
Live axle (torque arm) - 4 trailing links with birdcage + Panhard rod	148
Live axle (torque arm) - 4 trailing links with birdcage + Watts linkage	149
Live axle (torque arm) - 2 trailing links and torque arm slider + Panhard rod	149
Live axle (torque arm) - 2 trailing links and torque arm slider + Watts linkage	149
Live axle (torque tube) + Panhard rod	150
Live axle (torque tube) + Watts linkage	150
Winters: 4 trailing links, 2 birdcages + Jacobs ladder	150
Live axle/deDion - twin trailing arms + Mumford linkage	151
Live axle/deDion - twin trailing arms + Panhard rod	151
Live axle/deDion - twin trailing arms + Watts linkage	151
Live axle/deDion - 3 or 4 link + Mumford linkage	152
Live axle/deDion - 3 or 4 link + Panhard rod	152
Live axle/deDion - 3 or 4 link + Watts linkage	152
Live axle/deDion - 3 or 4 link + Woblink	153
Live axle/deDion - 4 link	153
Mono wheel - trailing arm	153
4 Upright/Trailing Arm/Strut/Axle	153
Upright	154
Uprights with trunnions or kingpins.....	155
Upright camber shims.....	158
Graphic	159
Trailing arm (independent suspension)	160
Semi-trailing arm (includes trailing arm and swing axle).....	161
Trailing arm.....	161
Mono wheel - trailing arm.....	162
Graphic	163
Strut	164
Integral strut tube and knuckle.....	165
Separate strut tube and knuckle.....	167
Dual-axis strut.....	169
Graphic	170
Axle (conventional)	171
Housing, diff and hubs.....	171
Mounting brackets.....	173
Birdcage.....	174
Static alignment.....	176
Graphic	177
Axle (speedway)	178

Axle and centre section.....	178
Mounting brackets.....	179
Static alignment.....	179
Stub axle	180
Portal axle	181
5 Watts	183
6 Woblink	183
7 Mumford	184
8 Jacobs ladder	185
9 Instant Centres	187
Suspension link chassis mounting points	188
Swing axle lengths and roll/pitch centre heights	189
Swing axle lengths and roll/pitch centre heights - Strut	191
10 Link lengths	191
Link lengths	192
Ford Twin I-Beam	192
Volkswagen twin trailing links	192
Control arm (Jaguar)	193
Control arm (H-arm)	194
Control arm (Porsche 928)	194
Control arm (Aarm Caster Link)	195
11 A-arm	195
Basic A-arm	197
A-arm styles 1 & 2	197
A-arm styles 3 & 4	198
A-arm dual axis strut	201
12 Track	201
Independent suspensions	201
Live axle/deDion	202
13 Wheel and tyre	203
14 Wheel alignment	204
Wheel alignment	204
Jaguar IRS/H-arm + camber link/Porsche 928	205
Semi-trailing arm	206
Mono wheel - trailing arm	206
Trailing arm, upper and lower lateral links	206
Live axle/deDion	206
15 Turn	206
16 Travel limits	207
17 Calculate	207
18 Results	207
19 ECalc	210
Part 7 Roll and bump the chassis	211
1 Configure	211
Bump and droop increments	211
Roll increments	211
Roll centre and axis	212
2 Car end	212
3 Calculate	213

4	Results	213
5	ECalc	217
Part 8 Steering		218
1	Configure	218
2	Car end and car side	221
3	A-arm (toe control link pickup point)	222
4	Rack location (toe control link chassis pickup point)	223
5	Steering gear (centre link)	223
	Pitman arm (centre link)	224
	Idler arm (centre link)	226
	Centre link	228
	Alignment (centre link)	230
6	Steering gear (intermediate rod)	231
	Pitman arm (intermediate rod)	232
	Idler arm (intermediate rod)	234
	Intermediate rod	235
	Alignment (intermediate rod)	235
7	Steering gear (drag link)	235
	Pitman arm (lateral drag link)	236
	Pitman arm (longitudinal drag link)	238
	Idler arm (drag link)	239
	Tie rod (drag link)	239
	Drag link	239
	Alignment (drag link)	239
8	Steering gear (direct)	240
	Pitman arm (direct)	242
	Ford Twin I-Beam	244
9	Steering arm (or toe control pickup point)	245
10	Wheelbase	246
11	Calculate the optimum rack or steering arm position	246
12	Toe-out in turn increment	247
13	Calculate	248
14	Results	248
15	ECalc	251
16	Notes	251
Part 9 Driveline		254
1	Configure	254
2	Car end and car side	256
3	Driveline components - driveshaft	256
	Gearbox	256
	Hub	256
	Length	256
4	Driveline components - propshaft	257
	Length	257
5	Calculate the optimum UJ position	257
6	Calculate	257

7 Results	257
8 ECalc	258
9 Notes	259
Part 10 Spring, shockabsorber & antirollbar	260
1 Configure	260
Live axle anti-roll bar	262
2 Car end and car side	263
3 Chassis mounting	263
4 Leaf spring chassis mounting	264
5 Bellcrank mountings	265
6 Suspension actuation point	268
Actuation point on A-arm	269
Actuation point on trailing link	276
Actuation point on upright	276
Actuation point on strut	276
Actuation point on Dual-axis strut	276
Actuation point on kingpin swivel	277
7 Pushrod, pullrod & shock absorber static lengths	277
8 Anti-roll bar link dimensions	278
9 Anti-roll bar dimensions	279
10 Spring parameters	281
Coil spring parameters	281
Torsion bar parameters	287
Leaf spring parameters	288
11 Calculate	290
12 Results	290
13 ECalc	293
Part 11 Spring and anti-roll bar rate calculations	294
1 Car end and car side	294
2 Vehicle mass	294
3 Maximum suspension travel in bump and droop	294
4 Do the calculations for the complete range of bump and droop travel	295
5 Results	295
6 ECalc	299
Part 12 Weight transfer & roll-stiffness calculations	300
1 Parameters	300
2 Calculate	301
3 Dynamic Results	302
4 Notes	303

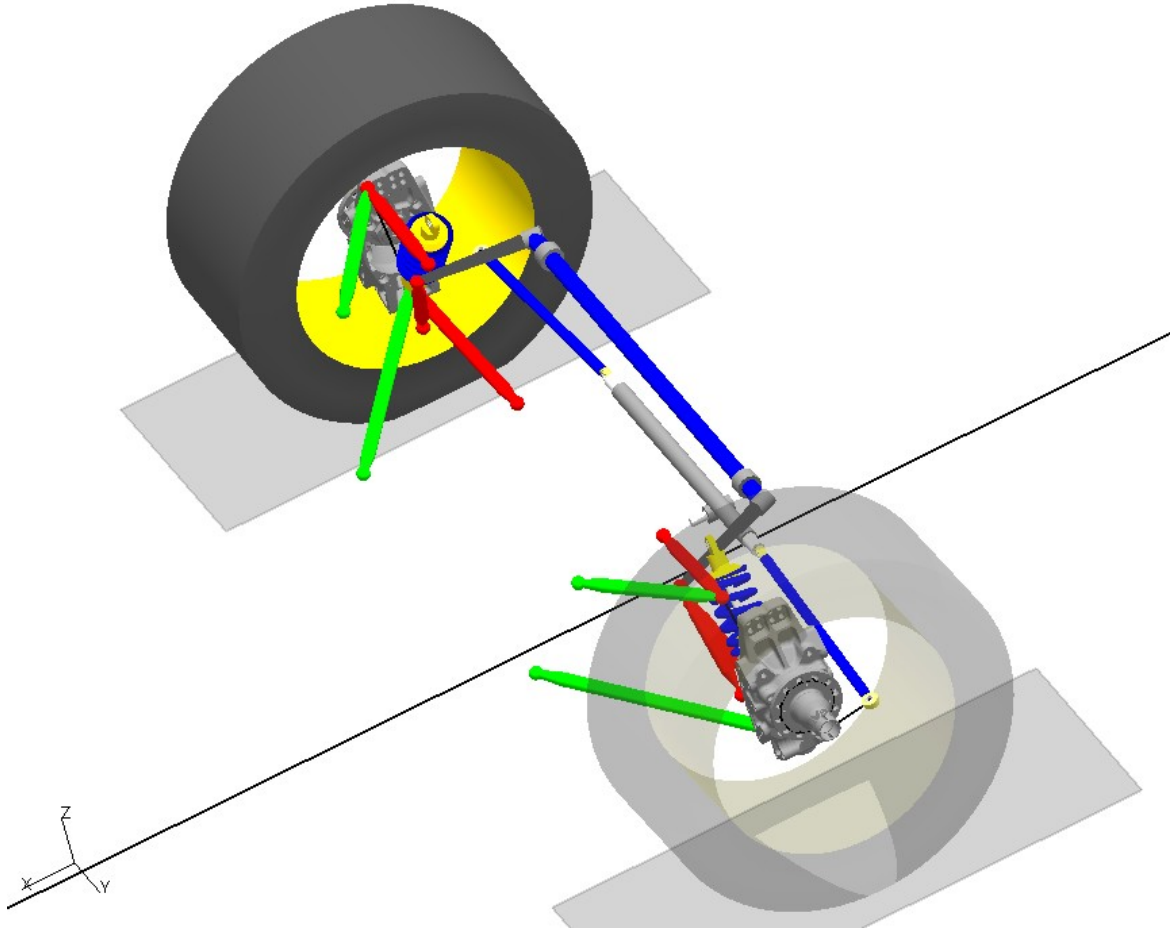
Part 13	Longitudinal pitch centre calculations	305
1	PitchData	305
2	PitchCalc	306
3	PitchResults	306
4	PitchGraphic	306
Part 14	AutoCalc	307
1	Config	307
2	Car end and car side	308
3	Chassis limits	309
	Double wishbone	309
	Strut	309
4	Upright limits	309
5	Specify the test and reporting requirements	309
6	Do all the iteration calculations	310
7	Results	311
8	Read the CSV results file with Excel	314
Part 15	Excel import and export	315
1	German language version of Excel	316
2	Creating worksheets	316
3	Creating named ranges - 1	319
4	Creating named ranges - 2	320
5	Calculated data Excel names	321
6	Input data Excel names	332
7	CAD input data Excel names	337
8	Chassis mounting points	339
9	Upright mounting points	340
10	Strut datum dimensions	342
11	Axle mounting points	345
12	Suspension link lengths	345
13	Error and warning messages	346
Part 16	Tools	347
1	Create Chassis Datum from vehicle coordinates	347
2	Realign Datum Location	348
3	CAD to SusProg3D	349
	CAD Setup	349
	CAD Upright	350
	CAD Strut	351
	CAD Trailing Arm	352
	CAD Axle	353
	CAD A-arm / CAD Control arm	353

4 Mumford linkage	354
5 Upright shim calculator	355
6 Crossmember	356
7 Coil spring design	358
8 Leaf spring design	361
Part 17 Display	364
1 Display settings	364
2 Control	364
3 ECalc	366
4 View orientation	367
Part 18 Technical and implementation notes	370
1 Acceleration anti geometry	370
2 Anti-roll bar calculations	370
3 Asymmetric suspension	373
4 Bibliography	374
5 Braking anti geometry	375
6 Caster / inclination / kingpin / KPI	375
7 Centre of gravity calculation	377
8 Convert from ground based to chassis based vertical datum.	378
9 Dimensioning chassis points using chassis based vertical datum	380
10 Dimensioning chassis points using ground based vertical datum	382
11 Display the SusProg program version	384
12 Instant centres	384
Live axle	384
Semi-trailing arm	384
Strut	384
Trailing arm, upper and lower lateral links	385
Tri-link strut	385
13 Longitudinal pitch centre calculations	386
14 Measurements	386
15 Motion ratio calculations	386
16 Pushrod and pullrod suspension.	387
17 Semi-trailing arm application	388
18 Strut application	388
19 Suspension geometry	389
20 Tri-strut application	390
21 Tyre camber parameters	391
22 Units and conversions	394
23 Upper transverse leaf spring, lower reversed A-arm and trailing link	394
24 Wheel alignment	394

Part 19 Licence agreement	396
Part 20 Evaluation version	397
Part 21 Network licensing	398

1 Overview

SusProg3D – Suspension by Design is a complete software package enabling the design, evaluation and visualization of race and road car suspension characteristics.



Upright image Copyright © 2025 Pace Innovations Pty Ltd. All rights reserved. Used with permission.

1.1 SusProg3D - Suspension by Design

SusProg3D provides for the design, evaluation and visualization of:

- Double A-arm
- Multi link suspension
 - lower A-arm, 2 upper links (virtual A-arm), toe link
 - lower A-arm, 2 upper lateral links, trailing link
 - upper A-arm, 2 lower links (virtual A-arm), toe link
 - upper A-arm, 2 lower links, trailing link
 - upper and lower lateral link, upper and lower trailing link, toe control link
 - upper and lower “virtual A-arms”, toe control link
 - upper transverse leaf spring, reversed lower A-arm and trailing link

- single top link, reversed lower A-arm, upper and lower trailing links
- single top link, parallel lower links, upper and lower trailing links
- Compound link suspensions (Porsche 928, Jaguar, Ford Thunderbird and Ford Integral Link, Ferrari 458, etc)
- Trailing arm suspension
 - semi-trailing arm
 - trailing arm with upper and lower lateral links
 - trailing arm with upper and lower lateral links and toe control link
 - Volkswagen Beetle twin trailing links and toe control link.
- Strut
 - with A-arm and single pivot
 - with two lateral links and dual pivots
 - TriLink strut suspension
 - Chapman strut suspension
 - Dual-axis strut suspension
- Live rear axle (conventional)
 - Torque arm, twin trailing links with Panhard rod or Watts links
 - Torque tube with Panhard rod or Watts links
 - 3 or 4 trailing links with Panhard rod or Mumford, Watts or Woblink links
 - twin trailing arms with Panhard rod (NASCAR style), or Mumford or Watts links
 - 4 trailing links
- Live rear axle (speedway)
 - Torque tube with 4 trailing links and Jacobs ladder on 2 birdcages
- de Dion rear axle
 - 3 or 4 trailing links with Panhard rod or Mumford, Watts or Woblink links
 - twin trailing arms with Panhard rod or Mumford or Watts links (Alfetta style)
 - 4 trailing links
- Dead (non driving) axle
 - 3 or 4 trailing links with Panhard rod or Mumford, Watts or Woblink links
 - twin trailing arms with Panhard rod or Mumford or Watts links
 - 4 trailing links
- Automatic generation of roll centre and swing axle lengths.
- Automatic generation of chassis pivot points.
- Camber adjustment location selected links.
- Store and recall suspension design data.
- Display of camber, [caster](#), toe, roll centre and wheel scrub in roll and bump.
- A choice of shock absorber actuation styles:
 - conventional outboard mounting

- inboard mounting with rocking top arm
- pushrod
- pullrod
- pushrod and floating shockabsorber
- Display of wheel rates at various stages in suspension travel
- Generation of spring design parameters
- Anti-roll bar rate calculations
- Dynamic chassis roll angle and weight transfer calculations
- Automatic generation of steering rack position to minimise bump steer
- Display of bump steer and toe-out in turn characteristics
- Driveshaft plunge
- Propshaft universal joint angles
- Weight distribution
- Automatic checking of a range of design parameters to find the "best" solution.

SusProg3D supports full 3D specification of all points.

A-arm pivot axes may be tapered in both plan view and for anti-dive/anti-squat in side view, and for any chassis location point for suspension spring units.

User specified chassis datums.

User specified axis naming and orientation.

Camber and castor adjustment on specified links.

1.2 PC hardware and software requirements

- SusProg3D will run on all current Microsoft Windows 64-bit operating systems: Windows 10 and Windows 11.
SusProg3D is only available in 64-bit.
All older operating systems are considered obsolete.
The preferred minimum OS is Windows 10 Creators Update Version 1703 Build 15063 Released March 2017

- A monitor with minimum 1024 x 768 resolution, preferred 1280 x 1024 resolution.
SusProg3D displays best at 96dpi.

- OpenGL libraries.



To run SusProg3D Viewer you will need GLU32.DLL and OPENGL32.DLL.

These DLLs come with all current versions of Windows.

For additional information about OpenGL, see www.opengl.org

You will need an OpenGL video driver that supports version 1.2 (currently) and preferably version 2.1

- To use the Excel interface, you will need Excel2002 (version 10) or later.
Excel 2016 (V16.0) is preferred
Excel2000 (version 9) and earlier are not supported.
Excel that is included with Office 365 On-line version is NOT supported.
- A Windows compatible printer

1.3 To run the program

The installation program will create three entries in the Start menu.

Select 'Start' -> 'Programs' -> 'SusProg3D' -> 'SusProg3D'

If you create a desktop shortcut for SusProg3D, you can also add the name of the data file as a parameter to the target file name. Also change the Start directory to the location of the data file.

If you do not specify a data file, or the data file specified cannot be read, SusProg3D will generate a default file name for you. The name will be SP followed by six hex numbers (ie 0-9,A-F) plus a suffix of .s3d. This name will be shown on the title bar. This file can be renamed by using the File | Save As command.

1.4 Evaluation version

Until the program is registered, SusProg3D will operate in Evaluation mode. This is indicated by the "Evaluation" comment in the lower right corner of the screen.

In Evaluation mode, following restrictions apply:

- the wheel and tyre dimensions are fixed. There is a choice of 13", 15" and 17" wheel sizes.
- the upright, strut and axle dimensions are fixed.

The sample data files will all calculate correctly in Evaluation mode. The sample data sets are provided to enable a review of the capabilities of SusProg3D, using a number of typical configurations. They are not dimensionally accurate, but provide a reasonable set of dimensions.

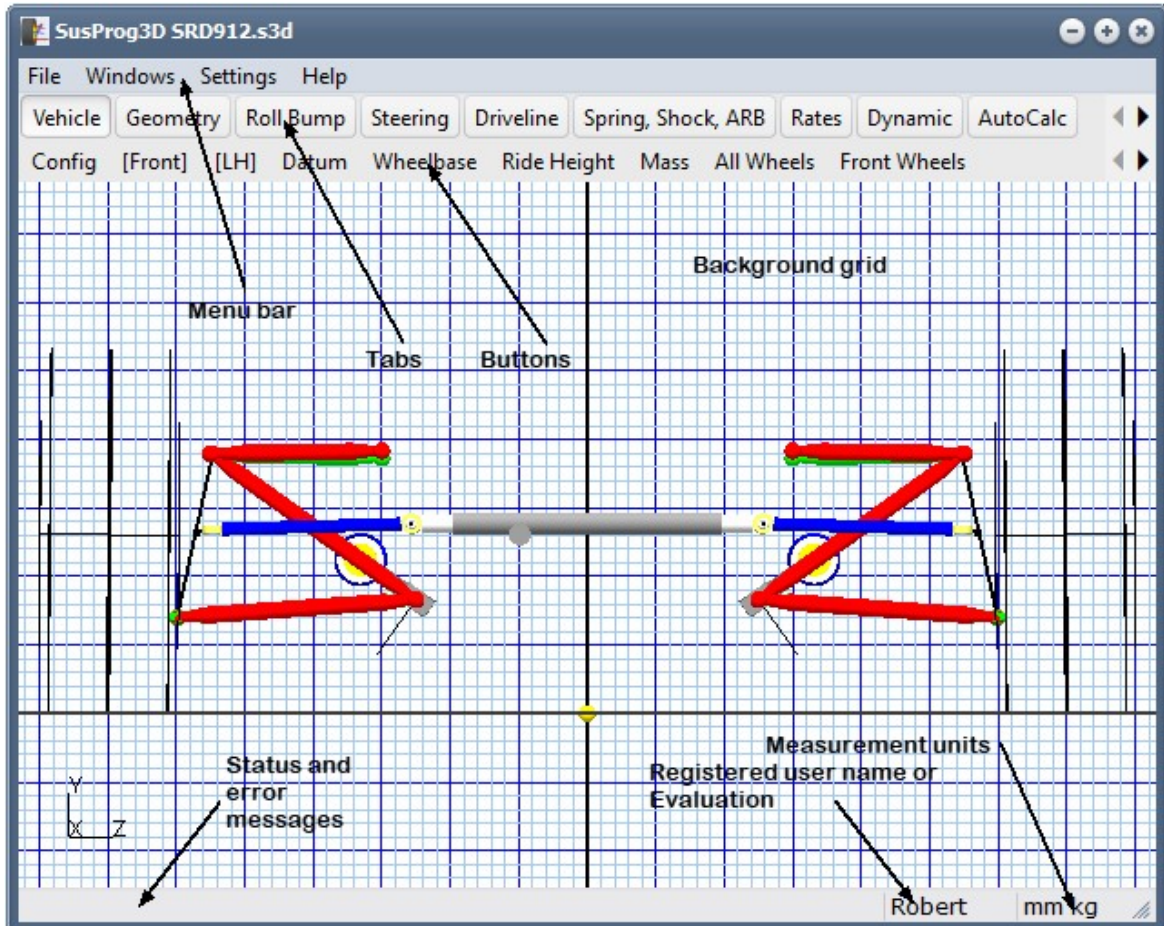
Srd912.s3d	Front	A-arm, pullrod springs. 13" wheels.
	Rear	A-arm, pushrod springs. 13" wheels.
Sedan.s3d	Front	Strut, 13" wheels
	Rear	Semi-trailing arm, 13" wheels
Subaru.s3d	Front	Strut, 13" wheels. Front wheel drive.
	Rear	Tri-strut, 13" wheels
Porsche928.s3d	Front	A-arm, 15" wheels
	Rear	Porsche axle, 15" wheels.
Jaguar.s3d	Front	A-arm, 15" wheels.
	Rear	Jaguar IRS, twin coilover shockabsorbers, 15" wheels.
LotusCortina.s3d	Front	Strut, 13" wheels
	Rear	Live axle, top trailing links, bottom A-frame, 13" wheels
GM4Link	Front	A-arm, 15" wheels
	Rear	Live axle, top trailing links (converging on the axle), bottom trailing links
FalconAU.s3d	Front	A-arm, 17" wheels
	Rear	Live axle, top and bottom trailing links, Watts linkage
HoldenVT.s3d	Front	Strut, 17" wheels
	Rear	Live axle, top and bottom trailing links, Watts linkage
Nascar.s3d	Front	Wisbone, 15" wheels, twin shocks, separate spring

Rear Live axle, twin trailing arms, panhard rod, separate springs.

2 User Interface

2.1 Screen layout

The initial SusProg3D screen consists of several regions, including a title bar, a menu bar, a set of tabs and tool bar buttons, the central display area, and a status line at the bottom.



The title bar includes the name of the data file in use, and minimize, maximize and close icons.

The menu bar has four menus - File, Windows, Settings and Help, each with a number of items.

When a menu is selected, a list of the items will appear.

The set of tabs define the different areas of interest, such as Geometry and Spring. Each tab has a corresponding set of tool bar buttons. The tool bar buttons will activate a series of dialog boxes and display windows.

Dialog boxes are used to enter data. All dialog boxes contain buttons, delimited input fields (for both text and numeric values) and choice boxes.

Result windows contain the results of calculations. Result window interiors are scrollable. Scrolling the window across the data is done by moving a scroll bar along the bottom of the window, the right side of the window, or both. The scroll bar shows the window's position compared with the entirety of the data being displayed.

2.2 Exit

To exit SusProg3D, you can either select the Exit item in the File menu, or select the Exit icon in the title bar. Exit does not automatically save the data. If you need to save, then use File | Save or File | Save As before selecting Exit.

2.3 Status line

The status line displays error messages.

2.4 Toggle items

Some tool bar buttons act as toggles. They are identified by having their text enclosed in [] brackets. Selecting them switches the tool bar button description rather than opening a dialog box. An example is "[Chassis]" in the Steering section that, when selected, switches between "[Fixed]", "[Upright]" and "[Chassis]" in turn.

2.5 Keys

The F1 key will display the help file.

The F5 key will refresh the graphic display.


The F6 key or Ctrl-C will copy the display (as a bitmap image) to the clipboard. This image can be pasted (using Ctrl-V or the Paste command) into various applications such as Paint or Wordpad. The '+' (plus) and '-' (minus) keys will zoom the display out and in.

The Print button will print the graphic direct to the printer. See [Print the graphic](#) for details.

2.6 Dialog box

However you select it, most tool bar buttons (the exceptions are toggle buttons, Result and Calculate buttons) will display a Dialog box. The Dialog box initially appears below the tab bar. You can move it around by moving the mouse pointer to the top line of the Dialog box, pressing the left mouse button, and moving the mouse while you hold the button down. When you let the button up, the Dialog box will stop where it is and remains there.

The Dialog box is a fixed size and cannot be resized or zoomed.

The Dialog box has a title on the top border line and a close icon (the  button) at its upper right corner. The close icon, when clicked by the mouse, closes the Dialog box. The [Esc] key also closes the Dialog box.

Dialog boxes contain buttons, choices, input boxes and informational data.

When the dialog box has focus, the F6 key will copy the dialog (as a bitmap image) to the clipboard. This image can be pasted (using Ctrl-V or the Paste command) into various applications such as Paint or Wordpad.

2.6.1 Buttons

Each Dialog box typically has four buttons along the bottom. Usually labelled "Apply" (meaning "Accept these input values, but leave the dialog open"), "OK" (meaning "I'm done. Close the Dialog box and accept the input values"), "Help" and "Cancel" (meaning "I want to close the Dialog box and ignore any changes made in it"). Note that if you do not change any values in a Dialog box, and

press OK to close it rather than Cancel, then SusProg3D will assume that values have changed. The close icon and the Cancel button are identical in operation.

You push a button by clicking on it with the mouse, or by pressing [Enter] to select the default button. When you release the mouse button, the action specified takes place.

Notice that the OK button has a dotted rectangle around the text. This shows that the OK button is currently the default control within the Dialog box. If you press [Enter] while OK is the default, you are in effect pressing the OK button.

The default control within a Dialog box can be changed by pressing [Tab]. The distinctive default colours move from one button to the next with each press of [Tab]. This allows the user to press a button without using a mouse, by moving the default to the chosen button with [Tab], and then pressing [Enter] or [space] to perform the actual "press of the button".

When a Dialog box is open, one control is always highlighted. That is the active, or focused, control. For example, if a button has focus, the user can "press" the button by pressing [space]. Characters can be typed into an input line, or the input line edited, only if the input line has the focus.

The user can use [Tab] to move the focus from control to control within the Dialog box. Focus is usually shown by the change in colour of the prompt text. By default, the OK button has focus when the Dialog box is opened.

2.6.2 Radio buttons

Some Dialog boxes (for example AutoCalc | Chassis Limits) contain several items, only one of which can be selected at a time. These are indicated by unfilled circles . The currently selected item will be shown with a dot within the circle . To choose an item, move the focus with the cursor key and press [space], or click on it with the mouse. Radio buttons are so named because they function the same as the pushbuttons in a car radio, only one in the set is active at a time.

2.6.3 Check boxes

Some Dialog boxes (for example AutoCalc | Test Limits) contain several items, of which you can select as many (or as few) as you want. These items are shown by unfilled squares . If an item is selected or ticked, it will be shown as or . Selection method is identical to the radio buttons.

2.6.4 Labels

All input items (be they radio buttons, check boxes or numerical data) have associated descriptive labels.

2.6.5 Numeric input

The input box will display the existing value as a two or three decimal place number, 123.45 right justified. To change a single digit, either

- place the cursor on the wrong digit, press [Delete] and then press the correct digit, or
- place the cursor on the digit immediately to the right of the wrong digit, press [<-] (backspace), and then press the correct digit.

If it is required to enter more digits than are currently displayed, then place the cursor on a blank position and delete it. The number will move left one space. This enables additional digits to be inserted. If the cursor is in the left most position (the second space from the left) and the input line has focus, then the delete key will delete the entire value.

If the [Tab] key is used to move the focus to the desired input box, then pressing any key will delete the entire existing value and replace it with the new keystroke(s).

The only valid characters allowed as part of numeric values are "-" (prefix for negative values), "+" (prefix for positive values), "." (for the decimal point) and the digits zero to nine inclusive. Any other characters will be filtered out and not shown on the input line. It is not necessary to include the "+" as all values not prefixed with minus "-" are positive. There is no need to keep the decimal points aligned, to enter a decimal point for whole numbers, or to enter any leading or trailing zeroes. If a number is incorrectly formatted (for example, has two decimal points or contains a space), then an error message will display. After clearing the error box, the cursor will remain on the input line for correction.

Similarly, there are values that are required to be positive, and if entered as negative, will cause a warning message. On clearing the warning box, the required sign conversion will be done and the correct value displayed.

Angular measurements can be entered as either "D° MM' Degree Minute" or "DD.dd Decimal degrees".

When using "D° MM' Degree Minute" there is no need to enter the degree or minute symbols. Just leave a space between the number of degrees and the number of minutes. To enter 5°15' just enter 5 space 15. If you enter a single number it will be taken as whole degrees, so if you enter 6, it will be the same as 6°00'. If you want to enter minutes only, you will need to prefix with 0 space, so to enter 30 minutes you will need to enter 0 space 30.

If the edit already contains a value showing the degree and minute characters then you need only overwrite the appropriate digit, leaving the degree and minute characters in place.

If using Imperial units, enter 11 inches as 11 or 11.0 or 11.000.

enter 3-1/4" as 3.25

enter 1200 pounds as 1200 or 1200.000.

generally, dimensions and weights will be displayed and printed to three decimal places.

Dimensions within the range -99999.999 to +99999.999 (for linear dimensions, this is approx 1-1/2 miles) will be displayed as shown. Dimensions outside this range will be shown in scientific notation. For example, 123456.789 will be shown as 1.234E+05

If using Metric units, enter 56mm as 56 or 56.0 or 56.00

enter 34 and half mm as 34.5 or 34.50

enter half mm as 0.5 or 0.50 or .5 or .50

enter minus (or negative) 34 and half mm as -34.5 or -34.50

generally, dimensions will be displayed and printed to two decimal places and weights to three decimal places.

Dimensions within the range -999999.99 to +999999.99 (for linear dimensions, this is approx 1 kilometer) will be displayed as shown. Dimensions outside this range will be shown in scientific notation. For example, 1234567.89 will be shown as 1.234E+06

See [unit settings](#) for determining the units, and [regional settings](#) for determining the decimal separator character.

2.6.6 Regional settings

Numeric values that include a decimal separator will use the decimal symbol as specified in the regional settings.

This is specified in the "Number" tab of the Regional Settings Properties under Regional Settings in the operating system Control Panel.

2.7 Error and warning boxes

If there is an error that prevents the calculation being completed, a message will display in the status bar.

Some errors may have a warning box. Clear this box by selecting OK.

Usually any errors will be caused by forgetting to enter one or more required values, or entering a value with a negative sign when only a positive sign is expected.

2.8 Result window

A Result window has a title and a close icon (the same as a Dialog box).

The Results window can be closed and moved in the same manner as the Dialog box, additionally the contents can be scrolled both vertically and horizontally.

To print a portion of the data, select it using the mouse. Then "Print". Only the selected text will be printed.

To print all of the data, clear any selection, then "Print".

Use Printer Setup, Printer Font and Page Margins to set the printer and font sizes used, and the page margins.

2.9 Menu bar

There are several menu choices.

- [File](#)
- [Windows](#)
- [Settings](#)
- [Help](#)

2.9.1 File

There are several sub menu choices.

- New
- Open (vehicle)
- Open (front)
- Open (rear)
- Save
- Save As

- Printer Setup
- Printer Font
- Page Margins
- Print Vehicle Data
- Graphic Print Quality
- Print Vehicle Graphic
- List of most recently used files
- Exit

2.9.1.1 Data file selection

The File menu includes a list of the Most Recently Opened files. Each time you open a file, it will be added to the top of this list. A maximum of 9 file names will be shown. "Double click" on a file name to open it.

Select File | Open. This will display the list of data files in the current directory. Select the file name, then select the Open button, or "double click" on the file name.

The default file suffix is .s3d. If your data file has a different suffix, either edit the default *.s3d "Name" line by changing to the desired value, or include the file name as the parameter to the SusProg3D command as shown above.

"New" will open a new data file, and reset all the data values to zero or the standard default values.

There are three alternative "Open" menu choices.

Open (Vehicle) will open a data file, overwrite all the current data, and set all the data values to those in the file. This includes data which is specific to the vehicle, plus the data which is specific to the front and rear suspensions.

This is the normal file Open behaviour from previous versions.

To facilitate the creation of new vehicle data sets by combining the front suspension from one vehicle and the rear suspension from another, two additional file options are available.

Open (Front) and Open (Rear) function differently. They will also open a data file, but will only overwrite the data for the specified front or rear suspension, leaving the data for the other end unchanged. Any vehicle specific data will also remain unchanged.

Because each data file could have different chassis datum positions, it is suggested that the chassis datum (of the secondary data file) be relocated to the same position as the primary data file before the file copy. The following steps are suggested. Step 1. Open the secondary data file using Open(Vehicle) and relocate the datum to the required position. Save the data file. Step 2. Open the primary data file using Open(Vehicle). Step 3. Open the secondary data file, using Open (Front) or Open (Rear).

Vehicle mass and mass distribution will be recalculated.

Open (Front) and Open (Rear) will not update the following items:

Vehicle comments may need to be corrected.

Centre of Gravity height (used in anti-dive, anti-squat and dynamic calculations).

Lateral Acceleration (used in dynamic calculations).

The axle to datum distance and the wheelbase may not be correct. Adjust the datum location dimensions and recalculate. The wheelbase will then be correct.

The brake force and torque splits may need to be adjusted.

Some of the Dynamic values (wheelbase, mass distribution, centre of gravity and acceleration) may need to be adjusted or reloaded from vehicle values.

2.9.1.2 Save the data

Select File | Save or File | Save As.

Save will use the file name as displayed on the status line, appended with .s3d and overwriting the old file.

Save As will open a Dialog box, and expect a file name to be entered. This can also be used as a Copy/Rename operation.

2.9.1.3 Print vehicle data

Before printing, specify the printer, font and margins.

- Select Printer Setup (from the main menu, File then Printer Setup) and specify the printer, paper size, source and orientation.
- Select Printer Font (from the main menu, File then Printer Font) and specify the font, font style, and size. Because of the length of the print lines and the necessity to keep all the print data correctly aligned, the font choices will be limited to those with fixed font spacings. A good starting point is to use Courier New, Regular, 8 point. This will ensure that all lines will fit onto an A4 portrait page. The current font selection will become the new default configuration.
- Select Page Margins (from the main menu, File then Page Margins) and specify the margins.
"Get Margins from Printer" will set the margins according to the actual page printable area. If "Wrap lines?" is ticked, then any line which would have been cut-off at the right margin will be wrapped around onto a second line. This can make the output difficult to read as the output columns will not line up.

Select Print Vehicle Data (from the main menu, File then Print Vehicle Data; or Vehicle > Data) and select which section(s) of vehicle data you wish to include. Then Print, and OK.

Geometry will include all the basic suspension data.

Spring will include all the spring actuation data.

Steering will include all the steering data.

Driveline will include all the Driveline data.

Misc will include all the miscellaneous data for the complete vehicle.

Dynamic will include all the dynamic data for the complete vehicle.

Pitch centre will include all the pitch centre data for the complete vehicle.

Because of the amount a data, it is suggested that this data be printed separately from the other data, with the printer set to landscape orientation.

Print the desired output (from the main menu, File then Print) and specify the printer (if necessary) and the number of copies. All output (as specified in the Settings) will print. If you specify 'Print to file' then Print will produce a text file. The file name will be the specified data file name with the suffix .TXT. Note that if a file already exists with the same name it will be overwritten without warning.

Besides the various values discussed in the Dialog boxes (both above and below), there are certain additional values included in the printout that are not otherwise available.

The SusProg3D program version, date and time, and the complete file name used will be printed as part of the page header.

The distance of the Ackermann point relative to the rear axle both as a dimension and a percentage of the wheelbase are also shown.

The section noted "Chassis reference dimensions" relates to an end view of the chassis, with the various points and dimensions relative to a stationary chassis, and the suspension moving up (in bump) and down (in droop).

The length of all the A-arms and links in end view is shown.

The A-arm angles are measured from the virtual pivot in end view, and may be different from the "real" A-arm angle relative to the actual A-arm pivot axis but are useful as a guide to balljoint articulation requirements.

The vehicle coordinates of all the upright pivot points and the moveable spring actuation points in full bump and full droop, relative to a stationary chassis and ground line, are shown. Note that these upright heights are different from the static upright height plus/minus the amount of wheel bump/droop. This is because the wheel travel is measured to the tyre cl, not the bottom of the upright. Due to camber change and distance from the upright pivot point to the tyre cl, usually less upright movement is required to move the tyre the required distance. The tyre contact point vertical value will be the actual maximum bump/droop dimension, and the horizontal value will be the static track position adjusted by the amount of scrub.

2.9.1.4 Print the graphic

Before printing, specify the printer and margins.

- Select Printer Setup (from the main menu, File then Printer Setup) and specify the printer, paper size, source and orientation.
- Select Page Margins (from the main menu, File then Page Margins) and specify the margins.
"Get Margins from Printer" will set the margins according to the actual page printable area.

Print the graphic (from the main menu, File then Print Vehicle Graphic; or Vehicle > Graphic; or Display > Print) and specify the printer (if necessary) and the number of copies.

The graphic (as displayed on screen) will be scaled to fit the page preserving the on-screen aspect ratio.

2.9.1.5 Exit SusProg

Select Exit (from the main menu, File then Exit).

Will exit SusProg3D.

Note that data changes are not saved (unless File | Save or File | Save As is used).

Configuration changes (such as units (ie millimetre kilogram or inch pound) and printer font name, style and size) are automatically saved on exit.

2.9.2 Windows

There are several sub menu choices.

- Cascade
- Close All

2.9.3 Settings

From the menu bar, select Settings -> Settings

- Units
- Motion Ratio
- Axis system
- Wheel toe measurement
- Angular units
- Timeout
- Save data file when calculating
- Printer font
- Display
- Start with last working file
- Save desktop on exit

Select Units to specify the units used for length and mass.

- Metric; for dimensions in millimetres and mass in kilograms.
The default number of decimal places for linear dimensions is 2. This can be increased to 3 decimal places.
- Imperial; for dimensions in inches and weights in pounds.
The default number of decimal places for linear dimensions is 3. This can be increased to 4 decimal places.

Metric is the installation default.

Note that changing the unit setting does not change the data.

For example, if you are currently working in metric and have an open data file, and then decide to switch to working in imperial, you need to 1) save the data file, 2) change settings to imperial, then 3) reopen the the data file. You will get a message regarding the difference in units, so click "Cancel" (to keep SusProg3D as imperial, and to convert the data file from metric to imperial).

It is easiest if you change the unit setting before doing any work or opening a data file.

Select Motion Ratio to specify the method of displaying the shockabsorber and spring motion ratio.

- Wheel:Shock; the ratio will be the wheel travel divided by the shockabsorber travel. For example, if the wheel moves 25.0mm (1.0") and the shockabsorber moves 20.0mm (0.787") then the motion ratio will be 1.25
- Shock:Wheel; the ratio will be the shockabsorber travel divided by the wheel travel. For example, if the wheel moves 25.0mm (1.0") and the shockabsorber moves 20.0mm (0.787") then the motion ratio will be 0.8

Wheel:Shock is the installation default.

Select Axis System to specify the axis nomenclature and orientation.

For each axis, horizontal, vertical and longitudinal, select the identifier (X, Y or Z) and the positive direction.

Imagine sitting in the vehicle, looking directly at the front of the vehicle. Horizontal values are measured from the vehicle centreline, and are either positive to the left (and negative to the right),

or positive to the right (and negative to the left). Vertical values are measured vertically from the ground or vertical datum plane, and are either positive upwards (and negative downwards), or positive downwards (and negative upwards). Longitudinal values are forward and backward values measured from the longitudinal datum, and are either positive values rearward (and negative forward), or positive forward (and negative rearward).

If the longitudinal axis is positive rearward, a negative value means the item is forward from the longitudinal datum reference point, and a positive value means the item is rearward from the longitudinal datum reference point; if the longitudinal axis is positive forward, a positive value means the item is forward from the longitudinal datum reference point, and a negative value means the item is rearward from the longitudinal datum reference point.

The SAE Recommended Practice, SAE J670e, uses a right-hand orthogonal axis system such that the X axis points forward, the Y axis points to the driver's right and the Z axis points downward. The setting parameters for this axis system are horizontal Y with +ve RH, vertical Z with +ve downward, and longitudinal X, with +ve forward.

ISO 4130 and DIN 70000 as well as some CAD/CAM packages use a right-hand orthogonal axis system such that the X axis points forward, the Y axis points to the driver's left and the Z axis points upward. The setting parameters for this axis system are horizontal Y with +ve LH, vertical Z with +ve upward, and longitudinal X, with +ve forward.

The SusProg3D default is a left-hand orthogonal axis system such that the Z axis points rearward, the X axis points to the driver's left and the Y axis points upward. The setting parameters are horizontal X with +ve LH, vertical Y with +ve upward, and longitudinal Z, with +ve rearward.

All examples in this help file refer to the various axis as H (horizontal axis), V (vertical axis) and L (longitudinal axis).

When entering point co-ordinates, most inputs will require the X, Y and Z values.

The SusProg3D default is to have these ordered as Horizontal, Vertical, Longitudinal (reading from left to right) which matches the default X, Y and Z.

But it may be more convenient if the sequence matched the source data sequence.

So, for example, to match your source data system, you have X for the longitudinal axis, Y for the horizontal axis and Z for the vertical axis, then, by default, the input would be sequenced Y, Z, X. But if your source data has the co-ordinates sequenced X, Y, Z then it may be confusing and lead to errors if you have to enter the data in Y, Z, X sequence.

To change the SusProg3D sequence just drag the axis group box and drop it onto the preferred location.

Hint: First set each axis to the required identifier, then sort them into the required sequence. For example, to move the Horizontal axis from the top to the bottom, with the mouse cursor on the words "Horizontal axis", hold the left mouse button down. Drag the cursor onto the words "Longitudinal axis" and release the mouse button. The horizontal axis box will move to the bottom, and the vertical and longitudinal axis boxes will both move up.

Select WheelToeMeasurement and then either "Degree" or "Offset and Length".

If you are using a laser wheel alignment tool (or similar) then these usually show the toe setting in degrees; if you are measuring the offset difference across the wheel then use "Offset and Length".

Select Angular units and then either "DD.dd Decimal degrees" or "D° MM' Degree Minute".

When using "D° MM' Degree Minute" there is no need to enter the degree or minute symbols. Just leave a space between the number of degrees and the number of minutes. To enter 5°15' just enter 5 space 15. If you enter a single number it will be taken as whole degrees, so if you enter 6, it will be the same as 6°00'. If you want to enter minutes only, you will need to prefix with 0 space, so to enter 30 minutes you will need to enter 0 space 30.

If the edit already contains a value showing the degree and minute characters then you need only overwrite the appropriate digit, leaving the degree and minute characters in place. When using "DD.dd Decimal degrees" all calculated values are rounded to 0.01 of a degree; when using "D° MM' Degree Minute" all calculated values are rounded to 1 minute. Note that 1 minute is approximately the same as 0.017 degree, so using "DD.dd Decimal degrees" is a slightly finer resolution.

Select Timeout to specify the calculation timeout period, in seconds. The default is 10 seconds. If a calculation has not completed within this period, then it will be terminated and an error message shown. This is a fatal condition and SusProg3D will be terminated. To avoid losing any data changes either do a Save before doing the calculation, or tick the Save data file when calculating setting option.

Select "Save data file when calculating" to automatically save the data file when any calculation is performed.

Select Edit Font to choose the font used for all numeric inputs. The font size is fixed.

Select Result Font to choose the font used for all 'on screen' results outputs. In order to correctly align the data, the fonts are limited to those with fixed character spacing.

Select Printer Font to choose the font used for all print outs. In order to correctly align the data, the fonts are limited to those with fixed character spacing.

Display settings, see [Display settings](#) for details.

Start with last working file. Tick this if you want Susprog3D to automatically load the last used data file, otherwise Susprog3D will open with a new data set.

2.9.4 Help

There are several sub menu choices.

- Contents
- About
- OpenGL

From the menu bar, select Help | Contents to open this help file.

From the menu bar, select Help | About to open a message box displaying details about SusProg3D and the operating system.

The details include the SusProg3D version and build number

From the menu bar, select Help | OpenGL to open a message box displaying details about the OpenGL environment.



OpenGL hardware acceleration is dependant on correctly installed drivers, screen resolution and colour depth. Consult the documentation provided by the manufacturer of your video card. If your video card does not support OpenGL with

either an ICD or MCD, then the default software emulation provided by the Microsoft OpenGL drivers will be used.

To enable OpenGL hardware acceleration with 3dfx video cards, consult the vendor's documentation. SusProg3D has not been tested and may not run correctly with any 3dfx implementation of OpenGL libraries.

For additional information about OpenGL, see www.opengl.org

3 Coordinate system

All coordinates are represented with three dimensional horizontal, vertical and longitudinal values.

The SAE Recommended Practice, SAE J670e, uses a right-hand orthogonal axis system such that the X axis points forward, the Y axis points to the driver's right and the Z axis points downward. The setting parameters for this axis system are horizontal Y with +ve RH, vertical Z with +ve downward, and longitudinal X, with +ve forward.

ISO 4130 and DIN 70000 as well as some CAD/CAM packages use a right-hand orthogonal axis system such that the X axis points forward, the Y axis points to the driver's left and the Z axis points upward. The setting parameters for this axis system are horizontal Y with +ve LH, vertical Z with +ve upward, and longitudinal X, with +ve forward.

The SusProg3D default is a left-hand orthogonal axis system such that the Z axis points rearward, the X axis points to the driver's left and the Y axis points upward. The setting parameters are horizontal X with +ve LH, vertical Y with +ve upward, and longitudinal Z, with +ve rearward.

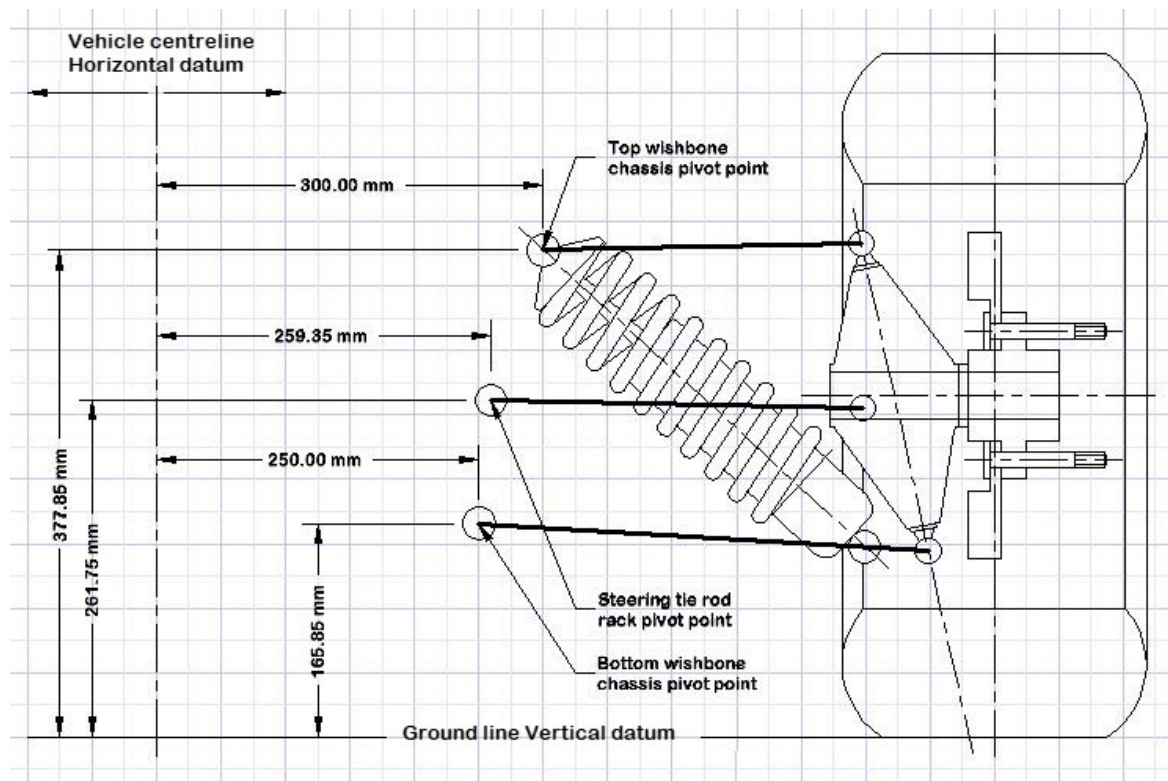
All examples in this help file refer to the various axis as H (horizontal axis), V (vertical axis) and L (longitudinal axis).

There are vehicle, chassis, upright and wheel coordinates.

Refer to [Settings](#) for additional details.

If you have 3D Coordinate Measuring Machine, CAD or world coordinates for the upright/axle/strut points, and need to convert those coordinates to upright/axle/strut datum points, go to [CAD2SusProg](#).

3.1 Vehicle coordinates.

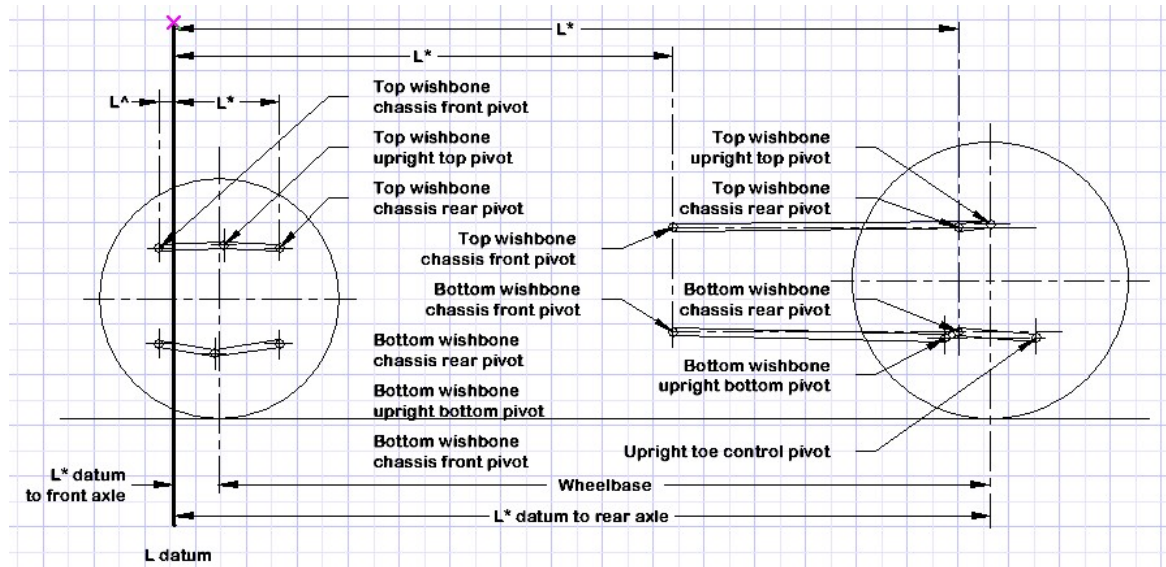


Vehicle coordinates, Horizontal and Vertical

Horizontal values measured left and right from the vehicle centreline, vertical values are measured vertically from the ground line, and longitudinal values are measured fore and aft from the longitudinal datum.

For example, consider the ball joint on the end of the steering rack, where the steering rack is mounted behind the front axle (in plan view) and the chosen longitudinal datum corresponds to the nominal axle centreline. Then the horizontal dimension is 259.4 (ie the distance the rack ball joint is from the vehicle centreline in plan view), the vertical dimension is 261.7 (ie the height of the rack ball joint from the ground line datum) and the longitudinal dimension is 100.1 (ie the distance the rack ball joint is from the datum).

Depending on the chosen datum system, the horizontal values will be shown as positive values for one side of the vehicle, and negative for the other.



Vehicle coordinates, Longitudinal

Chassis mounting / pivot points are defined for each suspension linkage location, with each point having horizontal, vertical and longitudinal dimensions

If the chosen longitudinal axis is +ve rearward, then L^* values will be +ve; L^{\wedge} values will be -ve. If the chosen longitudinal axis is +ve forwards, then L^* values will be negative; L^{\wedge} values will be positive.

Each A-arm pivots about an axis that passes through the front and rear pivot points.

The chassis virtual pivot point is the intersection of the A-arm pivot axis and a front view plane on the axle centreline. This is the point about which it can be considered that the A-arm is pivoting in front view and defines the effective front view A-arm length (also known as the virtual length) of the A-arm.

The upright virtual pivot point is that point where a vertical from the centre of the tyre contact point intersects the plane of the front & rear chassis pivot points and the upright pivot point.

In front view, the intersection of the lines through the top A-arm front view chassis virtual pivot point & upright virtual pivot point and the bottom A-arm front view chassis virtual pivot point & upright virtual pivot point together define the front view instant centre. The distance of the front view instant centre from the wheel contact centre is the front view swing axle length, and its height is the front view instant centre height. The roll centre is the point where the line from the front view instant centre to the wheel contact centre intersects a vertical on the vehicle centreline.

Similarly, there are the equivalent points in the side view plane which define the side view instant centre length, height and angle.

The A-arm normal point is that point where a line from the upright pivot point intersects the A-arm axis at 90 degrees and is used to define the shock absorber and antiroll bar link pickup points.

If the A-arm pivots are not in line, the chassis virtual points will move slightly in bump and droop due to backward and forward movement of the upright pivot point. If the A-arm pivot points are in line, the horizontal and vertical values of both pivot points will be identical.

3.2 Chassis coordinates.

As an aid for chassis design and construction, most chassis are dimensioned from a convenient datum plane and this datum plane is then used for the chassis build, in either a jig or on a surface plate.

Chassis coordinates are vehicle independent and are represented with horizontal, vertical and longitudinal values. The datums for the chassis are the chassis centreline (the horizontal datum), a convenient horizontal surface, such as the plane of the undertray or the side sills (the vertical datum) and a single convenient point, such as a jig hole or other fixed point (which locates the longitudinal datum).

All chassis points (such as the A-arm mounting points) are then referenced to these datums.

For convenience, both LH and RH horizontal values are entered as positive values (measured outwards from the chassis centreline).

To “position” the chassis at the required static ride heights, a front and rear ride height reference point must be specified. These can be any convenient “hard” point, such as a A-arm mounting bolt, and are dimensioned from the chassis datums. For each of the reference points, the actual ground based ride height must also be specified.

This provides for the common practice of designing and building the chassis in a horizontal position, but having the completed vehicle adopt a static ride position with the chassis is raked, usually nose down.

SusProg3D will then show, for all the chassis points, both the ground based vehicle coordinates and the chassis coordinates.

The default vertical datum is the ground plane, and the default longitudinal datum is the front axle centreline.

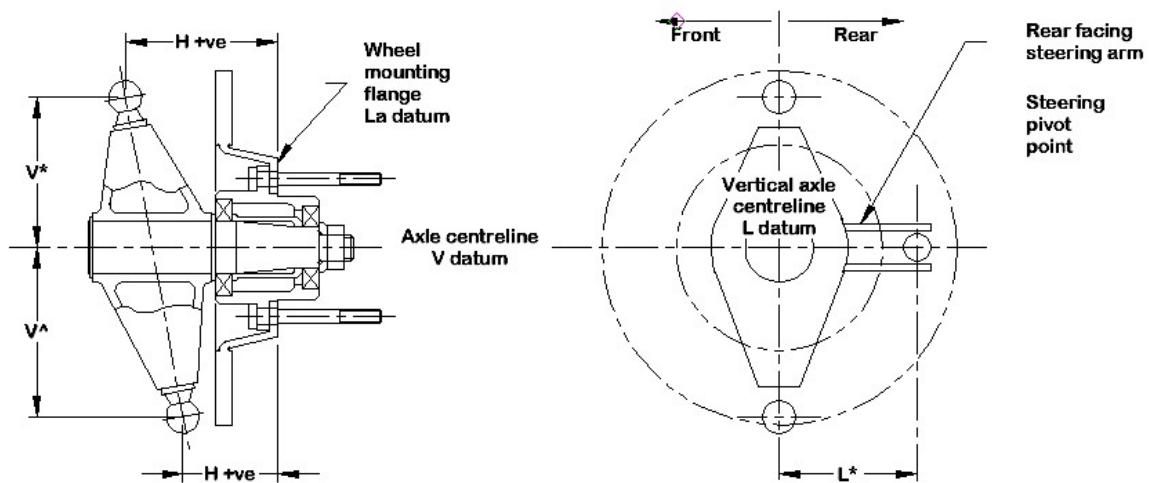
If you prefer to use the ground datum as the chassis vertical datum, particularly if you are measuring an existing completed vehicle, then note the vertical datum as “ground” and measure all chassis points from the ground. You may find it convenient to specify the ride height reference points and their ride heights, as this will provide an easy means of adjusting the ground clearance and rake, while maintaining all the chassis points relative to each other.

For further details on using a [ground based vertical datum](#).

For further details on [converting from a ground based to a chassis based vertical datum](#).

For further details on using a [chassis based vertical datum](#).

3.3 Upright coordinates.



Upright coordinates, Horizontal, Vertical and Longitudinal

Upright coordinates are vehicle independent and are represented with horizontal, vertical and longitudinal values. The datums for the upright are the wheel mounting flange and the axle (or hub) centreline.

All upright measurements are with the upright at zero camber, castor and toe position.

Again, imagine the upright viewed from the front of the vehicle. Horizontal values are positive inboard of the wheel mounting flange, vertical and longitudinal values are measured from the axle centreline.

For the usual design of upright, the top pivot point(s) is above the axle centreline, and the bottom pivot point(s) is below the axle centreline. If the vertical axis is positive upward, then the top pivot vertical dimension V^* will be positive and the bottom pivot vertical dimension V^{\wedge} will be negative; if the vertical axis is positive downward, then the top pivot vertical dimension V^* will be negative and the bottom pivot vertical dimension V^{\wedge} will be positive.

Longitudinal values are measured from the axle centreline in side view, and will be positive to the rear, negative to the front (if the longitudinal axis is specified as +ve rear); or will be positive to the front, negative to the rear (if the longitudinal axis is specified as +ve front).

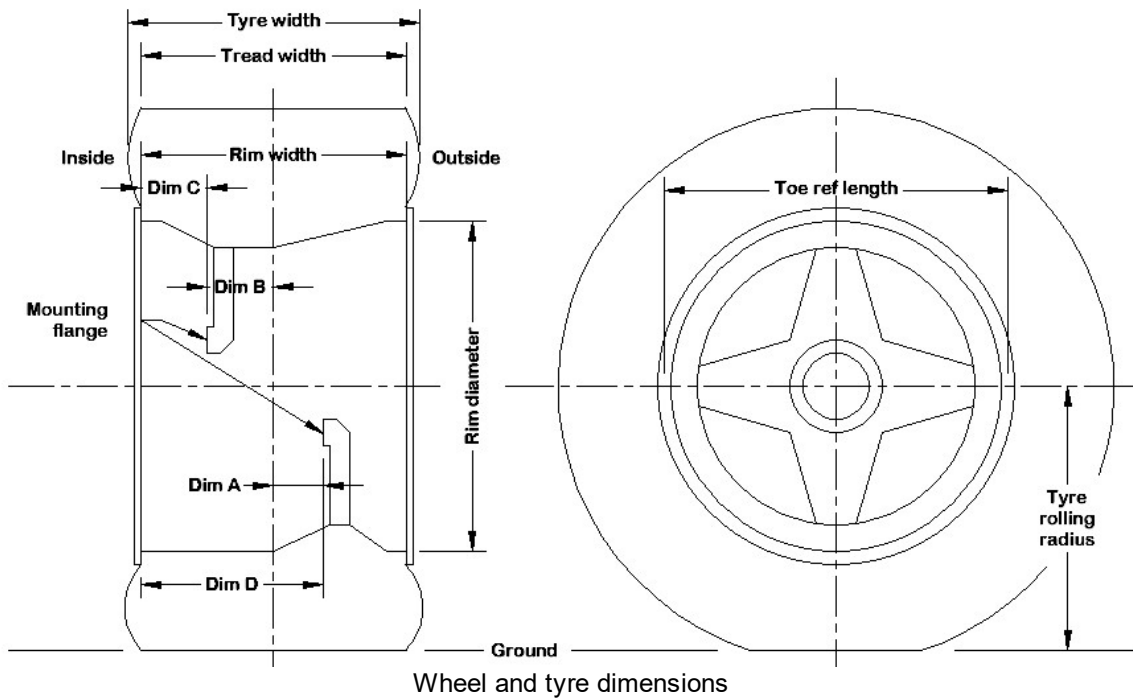
Usually, both upright pivot points will have +ve horizontal dimensions, H.

Depending on the particular geometry type, there will be 3, 4 or 5 pivot mounting points.

For a front suspension with upper and lower A-arms, some upright designs do not use a ball joint, but instead use a kingpin swivel (sometimes called a trunnion). The kingpin swivel is arranged such that it can only rotate about the kingpin axis, usually on some kind of bush or bearing. Some uprights use a thread.

See [Uprights with trunnions or kingpins](#)

3.4 Wheel coordinates.



Wheels have an offset value which determines the location of the wheel mounting flange relative to the wheel rim.

Offset / ET The datum is the rim centreline. Offset is positive when the mounting flange (or face) is closer to the outside of the wheel, and negative when the mounting flange is closer to the inside of the wheel.

For the wheel in the lower half of the above diagram, Dim A is positive.

For the wheel in the upper half of the above diagram, Dim B is negative.

The use of the designation "ET" originated with German standard DIN 7829 and refers to this dimension as "Einpresstiefe" which translates as "insertion depth".

Although the the more common terminology is "offset", note that some wheel manufacturers (such as ENKEI) refer to this dimension as "inset"

3.5 LH and RH coordinates.

All chassis and vehicle reference points can be specified different LH and RH.

The [LH] or [RH] tab choice will indicate the currently selected vehicle side.

This tab acts as a toggle, and selecting this tab will switch LH to RH, and RH to LH.

When a dialog box is opened, the title will include the currently selected car side. If the car side is not shown, then the dialog box applies to both sides.

Where points can be specified differently for each side of the vehicle, there will be a "RH identical?" (if inputting the LH side) or "LH identical?" (if inputting the RH side) check box.

If both sides are currently the same, this box will be "ticked". If there is a difference between the LH and RH side, then this box will be "clear" or "not ticked".

If the dimensions you enter are to be applied to both sides, "tick" this box.

If you do not wish to apply the dimensions to the other side, "untick" or "clear" this box.

It is suggested that the side of the vehicle with the positive horizontal axis be used.

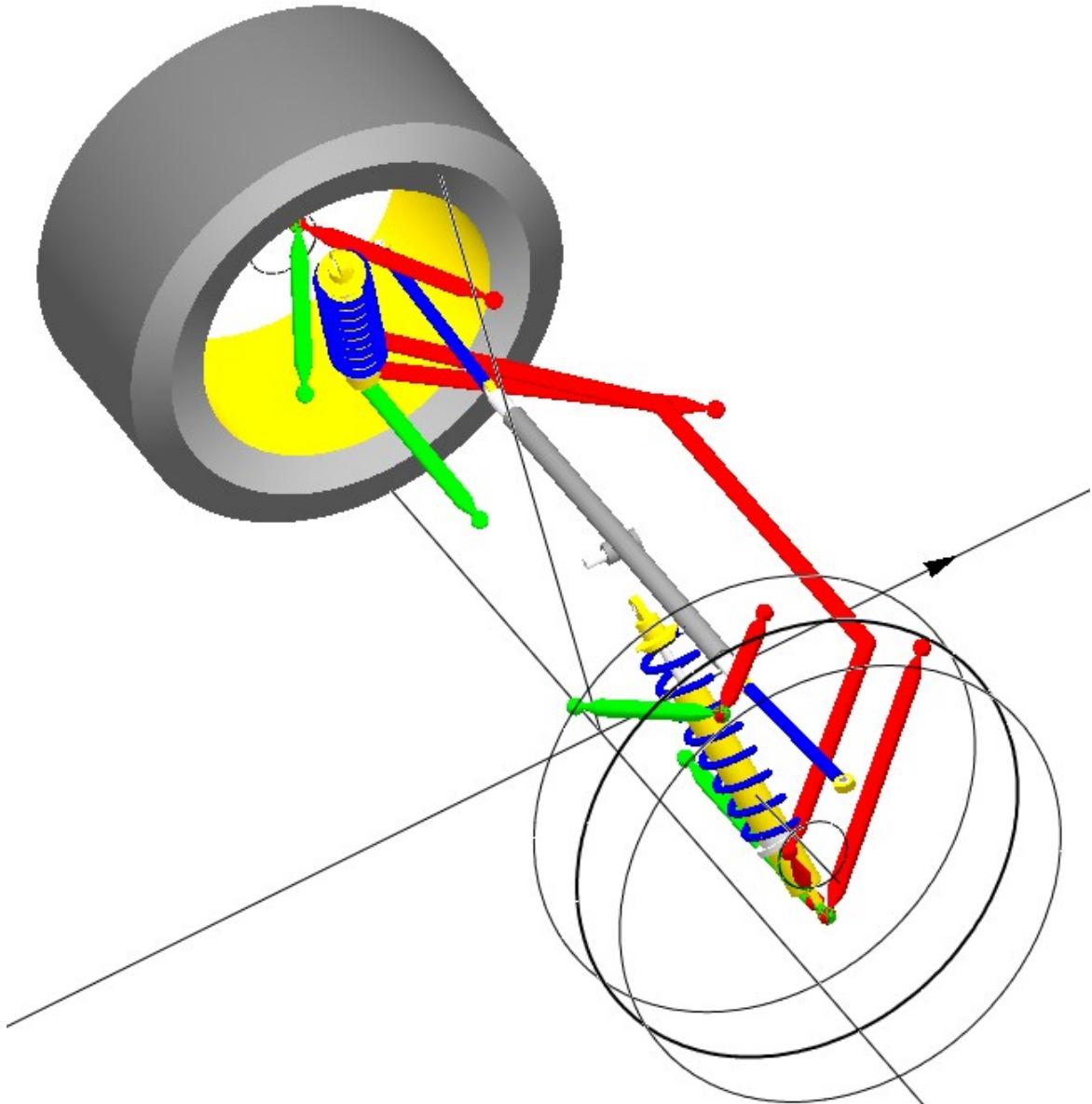
4 Suspension geometry types

SusProg3D supports the following suspension geometry types.

Description	Front	Rear
Double A-arm, toe link	Yes	Yes
The classic unequal length, non parallel A-arm format		
Lower A-arm, upper virtual A-arm, toe link.	Yes	Yes
A typical example is the Porsche GT3 rear suspension.		
Lower A-arm, upper parallel links, trailing link.	No	Yes
A typical example is the Plymouth Prowler rear suspension.		
Upper A-arm, lower virtual A-arm, toe link.	Yes	Yes
A typical example is the Mitsubishi Galant front suspension.		
Upper A-arm, lower trailing and lateral links, toe link.	No	Yes
A typical example is the Mitsubishi Galant rear suspension.		
Upper and lower lateral links, twin trailing links, toe link.	No	Yes
A typical example is the Chevrolet Corvette C4 rear suspension.		
Upper and lower virtual A-arms toe link.	Yes	Yes
A typical example the Mercedes multilink rear suspension.		
Upper transverse leaf spring, lower reversed A-arm and trailing link	No	Yes
As used on the Triumph GT6		
Upper lateral link, lower reversed A-arm, twin trailing links.	No	Yes
The classic '60s sports and racing cars rear suspension.		
Lower lateral link, upper reversed A-arm, twin trailing links	No	Yes
An alternative version of the classic '60s sports and racing cars rear suspension.		
Upper lateral link, lower parallel links, twin trailing links.	No	Yes
A variation of the reversed lower A-arm.		
Aarm Caster Link	No	Yes
As used on the 2015 Mustang and other Ford platforms, also various Ferrari models		
Ford Twin I-Beam	Yes	No
As used on various Ford trucks and SUVs		
Volkswagen twin trailing links	Yes	No
As used on the original Beetle		
Jaguar IRS	No	Yes
with the driveshaft as the camber control link.		
H-arm and camber control link	No	Yes
as used on the Ford Thunderbird		

Porsche 928	No	Yes
Semi-trailing arm	No	Yes
Semi-trailing arm, camber control and toe control links.	No	Yes
As used on the Mazda RX7		
Trailing arm, upper and lower lateral links.	No	Yes
Typical examples are the pre '84 Chevrolet Corvette, the BMW E36 and the Lotus Europa.		
Trailing arm, upper and lower lateral links, toe control link	No	Yes
Typical examples are the Honda Civic and Integra.		
Macpherson strut	Yes	Yes
with lower A-arm or the typical lateral link and anti-roll bar		
Strut, lower "virtual A-arm", toe link	Yes	Yes
Used on some BMW models		
Tri-link strut	No	Yes
with single trailing link and two lateral links		
Chapman strut	No	Yes
with trailing links and driveshaft		
Dual-axis strut	Yes	No
with separate hub carrier, A-arm and strut alignment link		
Live axle (torque arm), 4 trailing links (birdcage) + Panhard rod	No	Yes
Live axle (torque arm), 4 trailing links (birdcage) + Watts linkage	No	Yes
Live axle (torque arm), 2 trailing links (torque arm slider) + Panhard rod	No	Yes
Live axle (torque arm), 2 trailing links (torque arm slider) + Watts linkage	No	Yes
Live axle (torque tube) + Panhard rod	No	Yes
Live axle (torque tube) + Watts linkage	No	Yes
Winters: 4 trailing links, 2 birdcages + Jacobs ladder	No	Yes
the typical speedway rear suspension		
Live /de Dion / rigid axle, 2 trailing arms + Mumford linkage	Yes	Yes
Live / de Dion / rigid axle, 2 trailing arms + Panhard rod Nascar style	Yes	Yes
Live / de Dion / rigid axle, 2 trailing arms + Watts linkage	Yes	Yes
Live / de Dion / rigid axle, 3 or 4 trailing links + Panhard rod	Yes	Yes
Live / de Dion / rigid axle, 3 or 4 trailing links + Mumford linkage	Yes	Yes
Live / de Dion / rigid axle, 3 or 4 trailing links + Watts linkage	Yes	Yes
Live / de Dion / rigid axle, 4 trailing links	Yes	Yes

4.1 Double A-arm, toe link



The classic double A-arm with a separate toe control link. Usually configured with unequal length non parallel A-arms, but can also be parallel A-arms, either equal or unequal length.

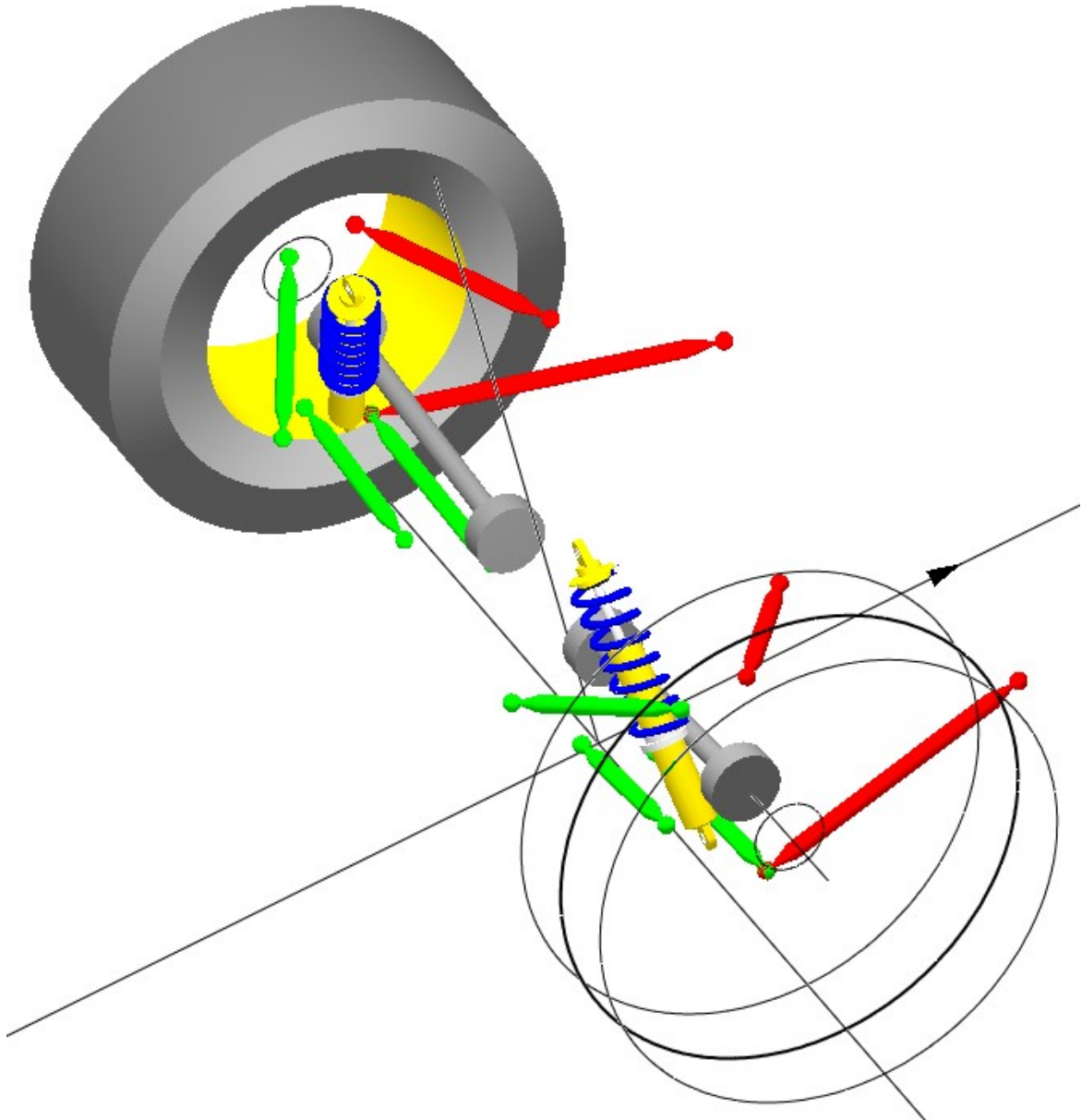
Five chassis mounting points.

When used as a front suspension there are two chassis mounting points for each A-arm and one for the steering tie rod (which can be either the end of the steering rack or the tie rod mounting on the steering linkage).

When used as a rear suspension there either four or five chassis mounting points. Two chassis mounting points for each A-arm plus the toe control link can be a fifth chassis mounting point, or the toe link mounting can be common with one of the A-arm link mountings, or it can be on one of the A-arm links.

Three upright mounting points, one top A-arm, one bottom A-arm and either a steering arm or a toe control link mounting.

4.2 Upper "virtual A-arm", lower A-arm, toe link



Five chassis mounting points.

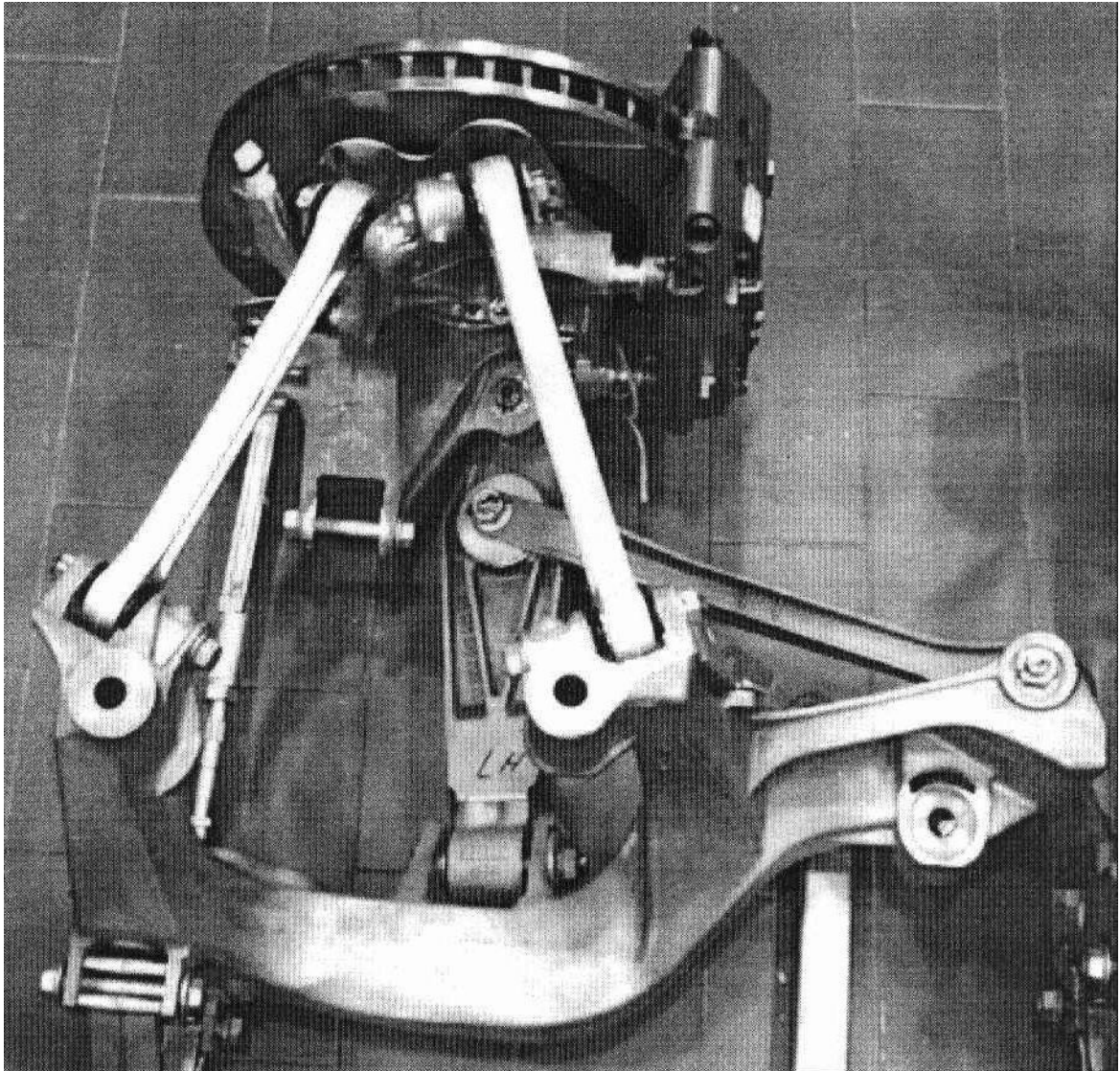
When used as a front suspension there are five chassis mounting points, two for each A-arm and one for the steering tie rod (which can be either the end of the steering rack or the tie rod mounting on the steering linkage).

When used as a rear suspension there either four or five chassis mounting points. Two chassis mounting points for each A-arm plus the toe control link can be a fifth chassis mounting point, or the toe link mounting can be common with one of the A-arm link mountings, or it can be on one of the A-arm links.

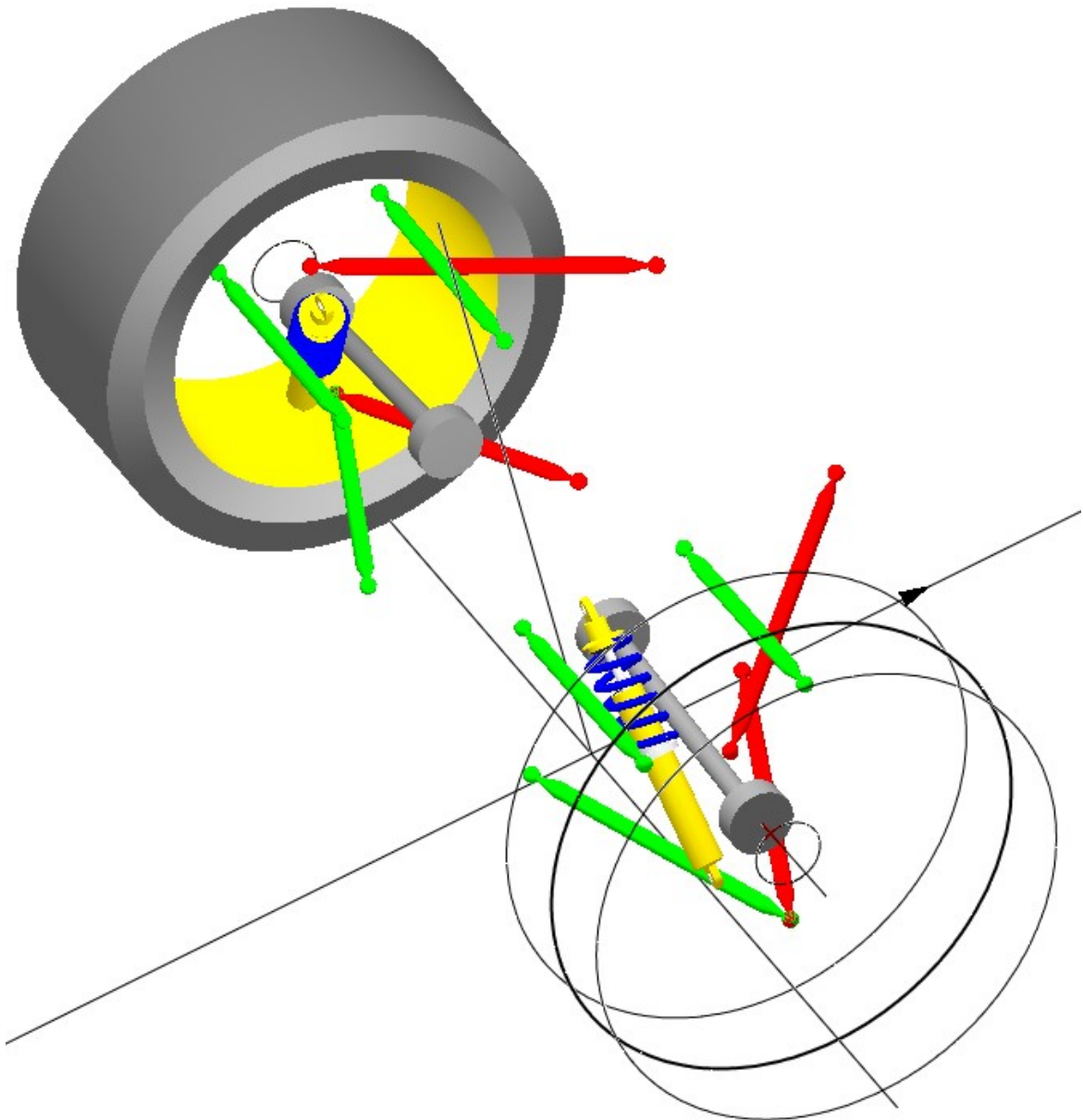
Four upright mounting points, one for the lower A-arm, one for each link of the upper "virtual A-arm", and one for the toe link.

In the PorscheGT3 rear suspension the lower lateral link and the lower trailing link act as a lower A-arm, with two chassis mounting points and a single upright mounting point. The pair of angled (in plan view) upper links converge to form a "virtual" A-arm, and the toe control link controls the toe.

In the case of the PorscheGT3, the lower A-arm is implemented as a trailing link connecting part way along the lateral link. However, for calculation purposes, the lower link lengths need to be specified as the distance from chassis pivot to the upright pivot.



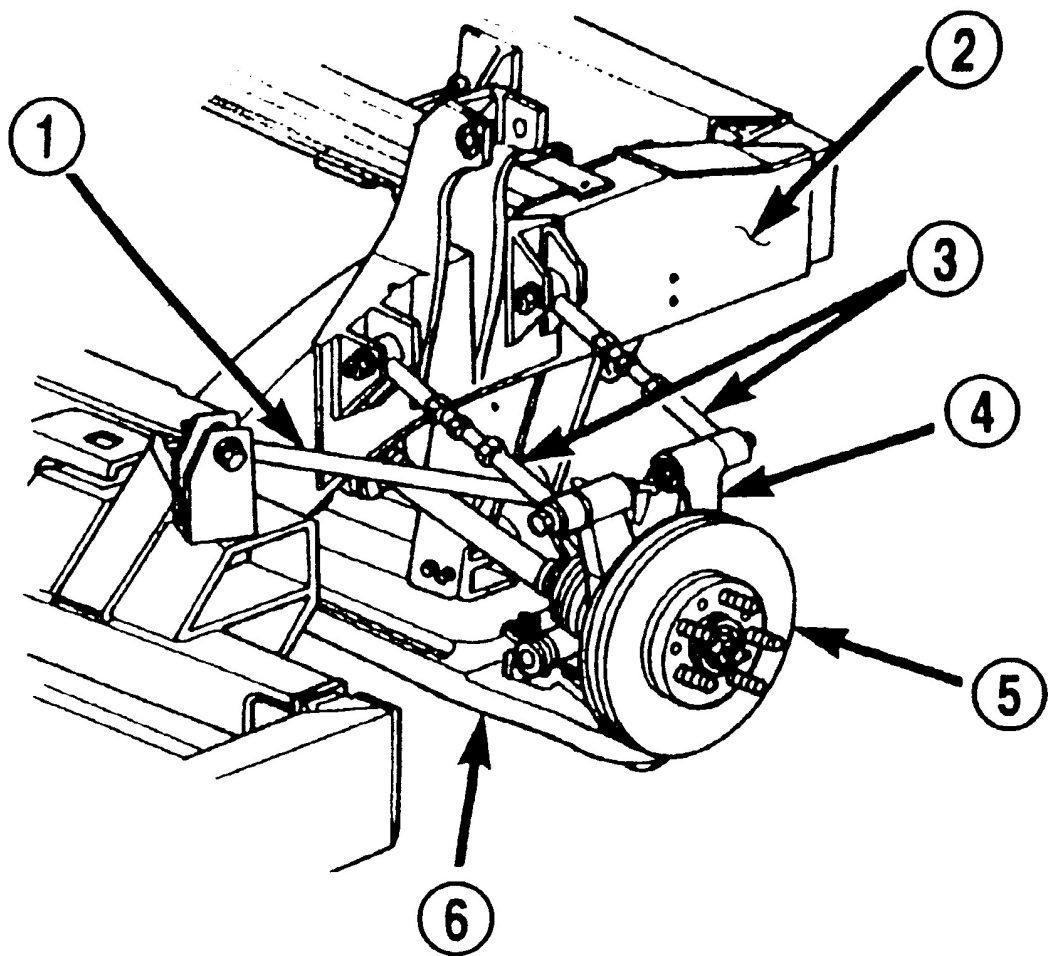
4.3 Upper parallel links, trailing link, lower A-arm



Five chassis mounting points, two for the lower A-arm, one for each of the upper lateral links, and one for the trailing link. The upper lateral links are generally parallel (in plan view) and symmetrically disposed about the axle centreline.

Four upright mounting points, one for the lower A-arm, one for each upper lateral link, and one for the trailing link.

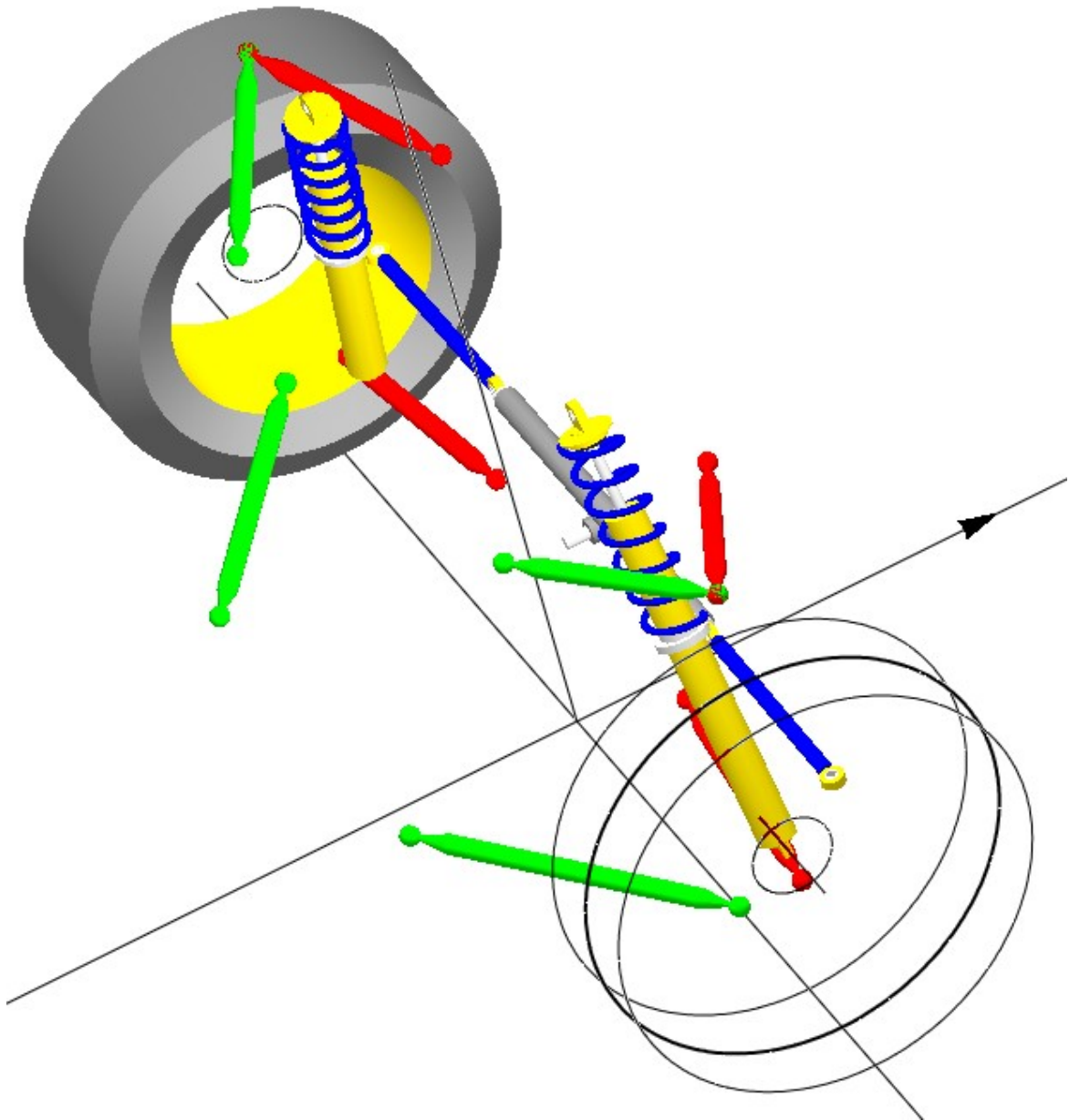
The Plymouth Prowler rear suspension is typical of this configuration.



8

- 1 Trailing link
- 2 Chassis
- 3 Upper lateral links
- 4 Upright
- 5 Disk rotor and wheel hub
- 6 Lower A-arm

4.4 Upper A-arm, lower "virtual A-arm", toe link



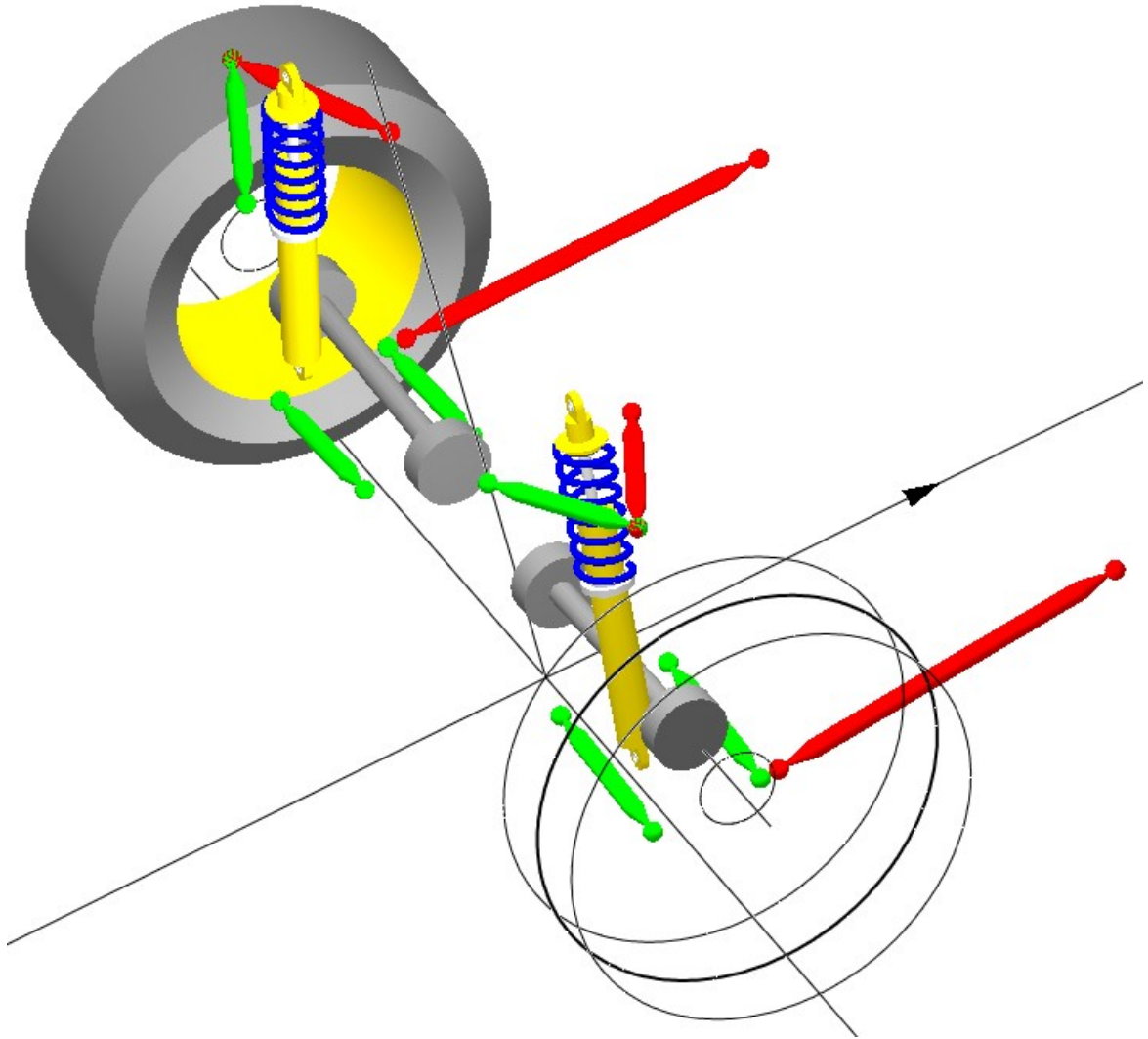
Five chassis mounting points.

When used as a front suspension there are five chassis mounting points, two for each A-arm and one for the steering tie rod (which can be either the end of the steering rack or the tie rod mounting on the steering linkage).

When used as a rear suspension there either four or five chassis mounting points. Two chassis mounting points for each A-arm plus the toe control link can be a fifth chassis mounting point, or the toe link mounting can be common with one of the A-arm link mountings, or it can be on one of the A-arm links.

Four upright mounting points, one for the upper A-arm, one for each link of the lower "virtual A-arm", and one for the tie rod pivot (on the steering arm).

4.5 Upper A-arm, lower trailing and two lateral links, toe link

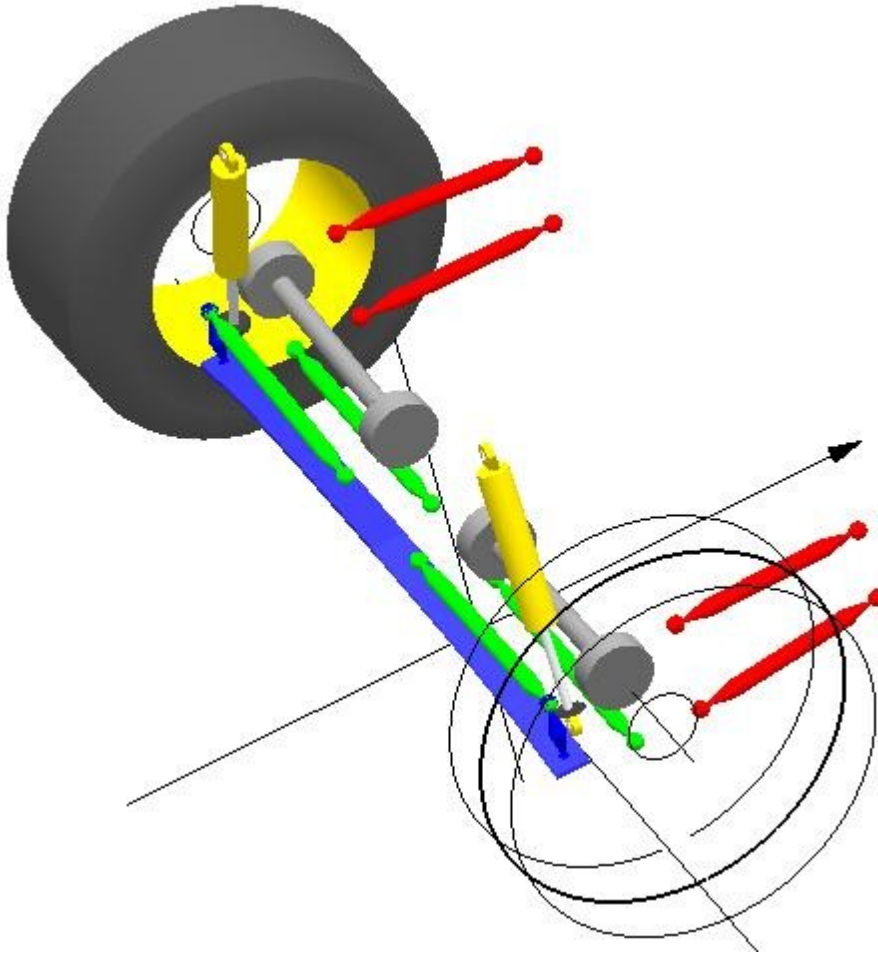


Five chassis mounting points, two for the upper A-arm, one for each of the lower trailing and lateral links, and one for the toe control link.

Five upright mounting points, two for the upper A-arm, one for each of the lower trailing and lateral links, and one for the toe control link.

The Mitsubishi Galant has the lower trailing and lateral links arranged as a "virtual A-arm".

4.6 Upper and lower lateral links, twin trailing links, toe link



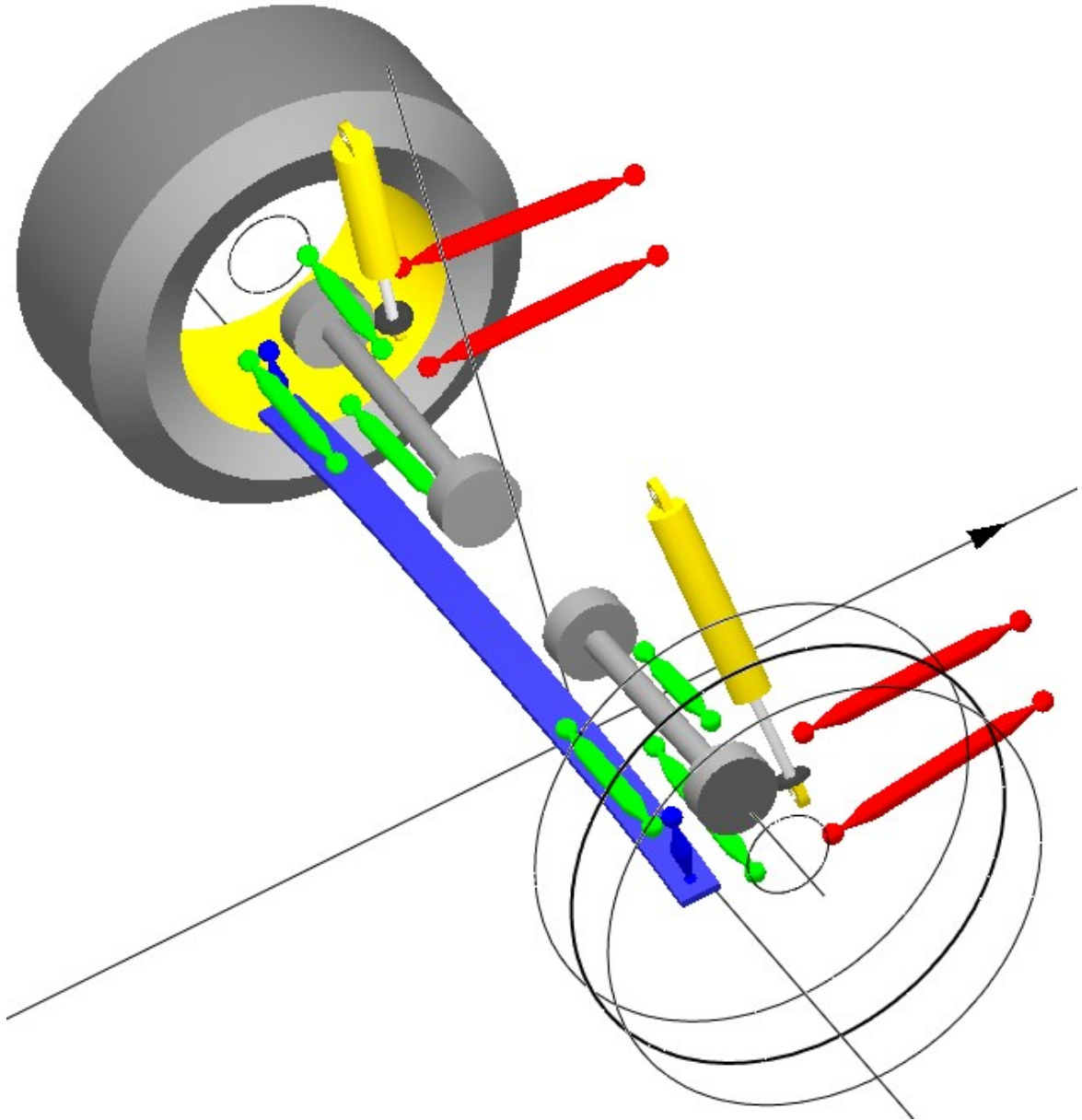
Five chassis mounting points, one for each lateral link, one for each trailing link, and one for the toe control link.

Five upright mounting points, one for each lateral link, one for each trailing link, and one for the toe control link.

The top lateral link can be either a bespoke link, or the driveshaft can act as the suspension link.

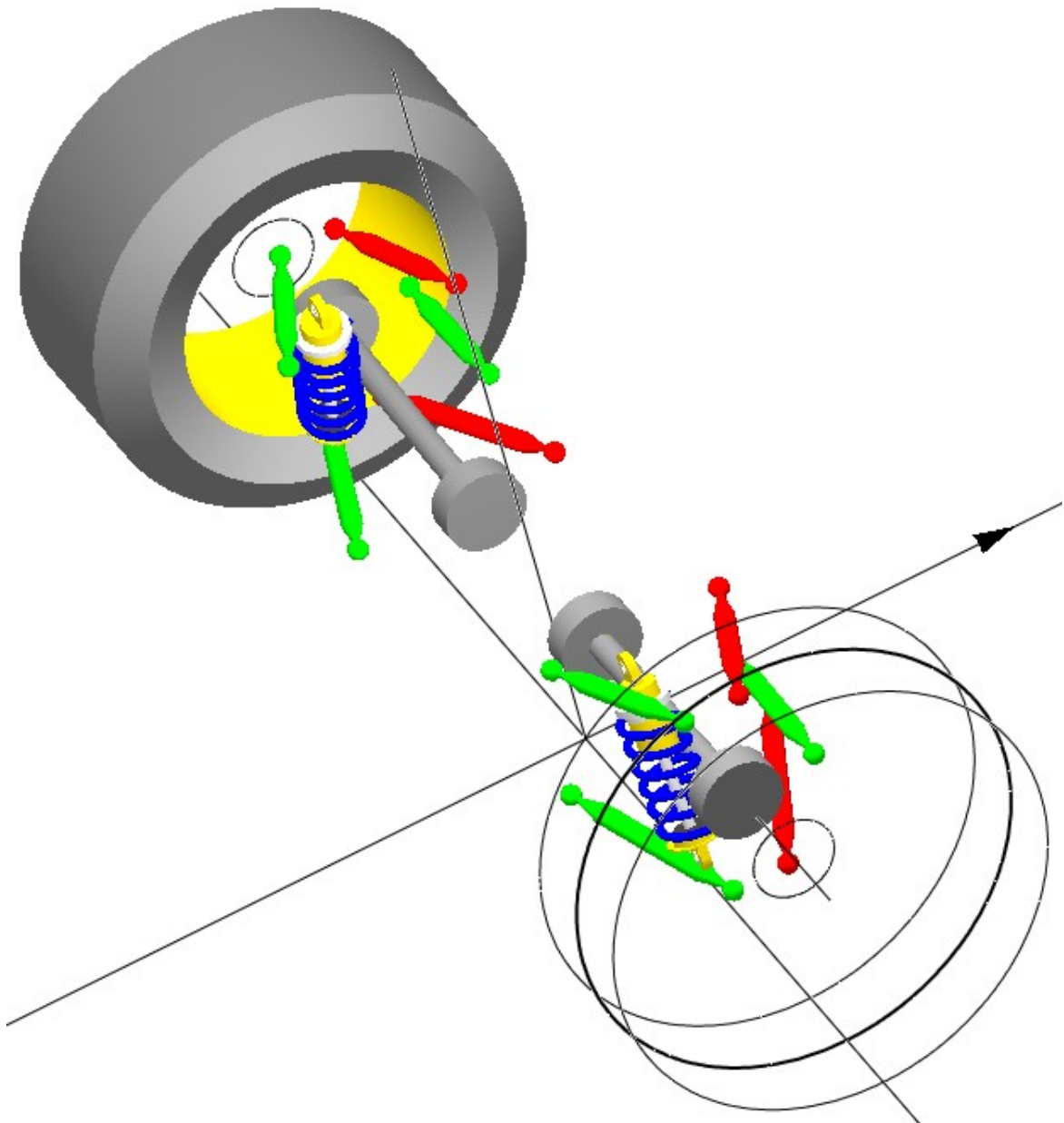
Specify the driveshaft as "Fixed length driveshaft (top lateral link)" to have the driveshaft as a suspension link, or specify the driveshaft as either "Variable (splined)" or "Variable (plunging joint)" to use a bespoke top lateral link.

The Corvette C4 uses the driveshaft as the upper lateral link. Specify the driveshaft as "Fixed length driveshaft (top lateral link)".



The modified design uses a separate lateral link as the suspension lateral link. This relieves the drive shaft of the suspension loads and enables the use of CV joints. Specify the driveshaft as either "Variable (splined)" or "Variable (plunging joint)".

4.7 Upper and lower "virtual A-arms", toe link



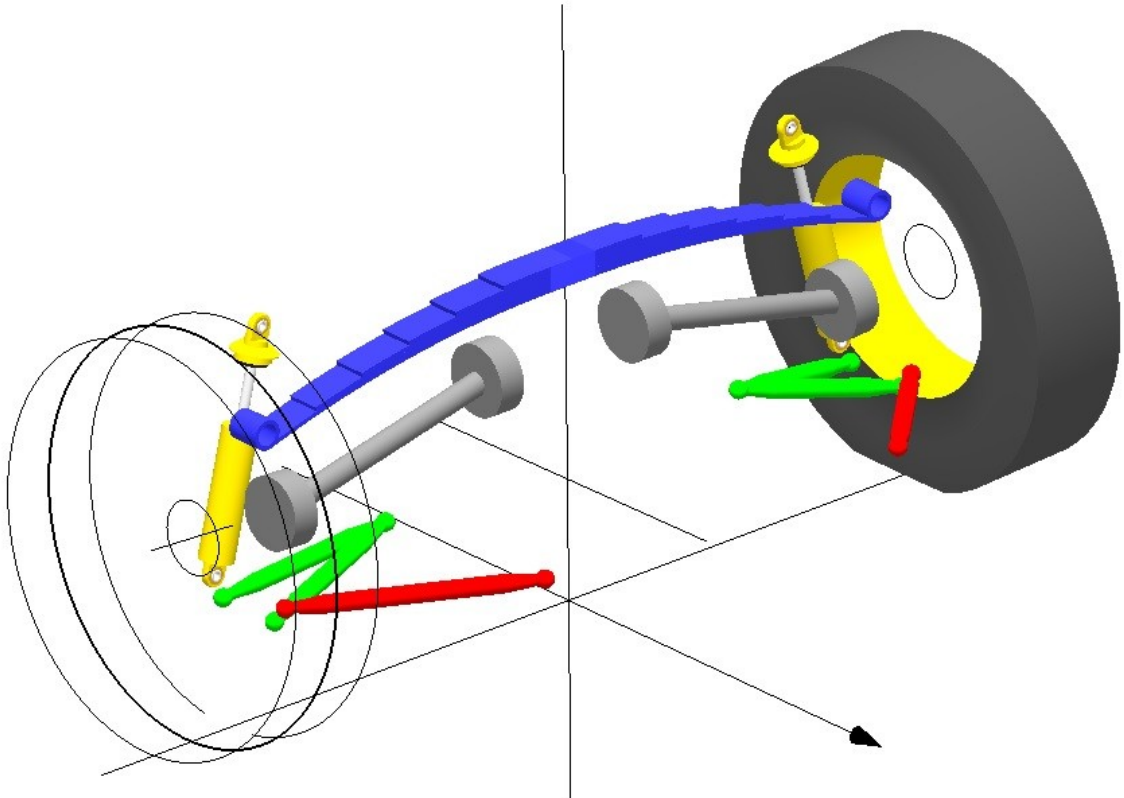
Five chassis mounting points

When used as a front suspension there are five chassis mounting points, two for each A-arm and one for the steering tie rod (which can be either the end of the steering rack or the tie rod mounting on the steering linkage).

When used as a rear suspension there either four or five chassis mounting points. Two chassis mounting points for each A-arm plus the toe control link can be a fifth chassis mounting point, or the toe link mounting can be common with one of the A-arm link mountings, or it can be on one of the A-arm links.

Five upright mounting points, one for each link of the upper "virtual A-arm", one for each link of the lower "virtual A-arm", and one for the toe control link.

4.8 Upper transverse leaf spring, lower reversed A-arm and trailing link

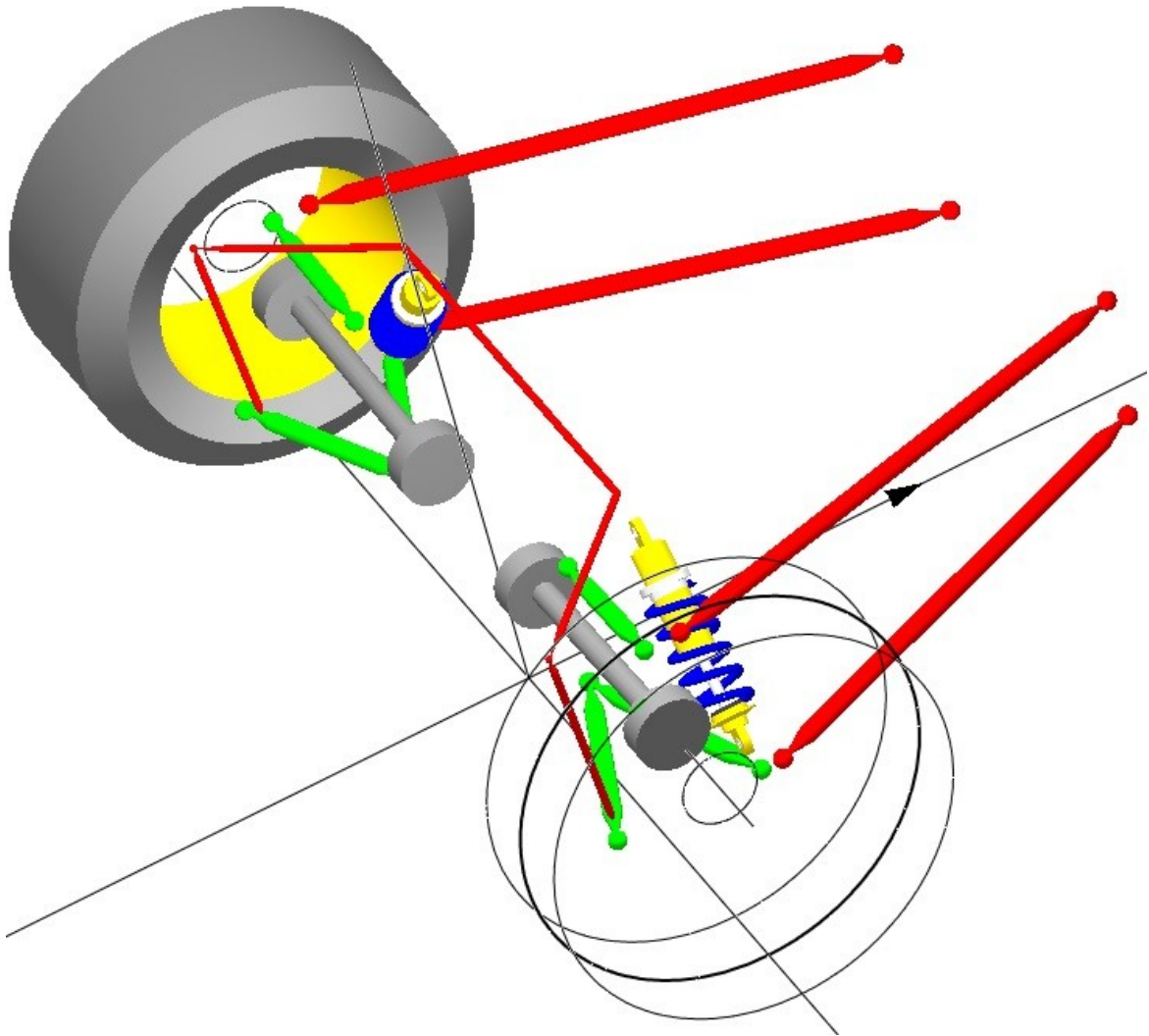


As used on the TriumphGT6.

Three chassis mounting points, one for the transverse leaf spring, one for the lower reversed A-arm, and one for the trailing link.

Four upright mounting points, one for the transverse leaf spring, one for each link of the lower reversed A-arm, and one for the trailing link.

4.9 Upper lateral link, lower reversed A-arm, twin trailing links

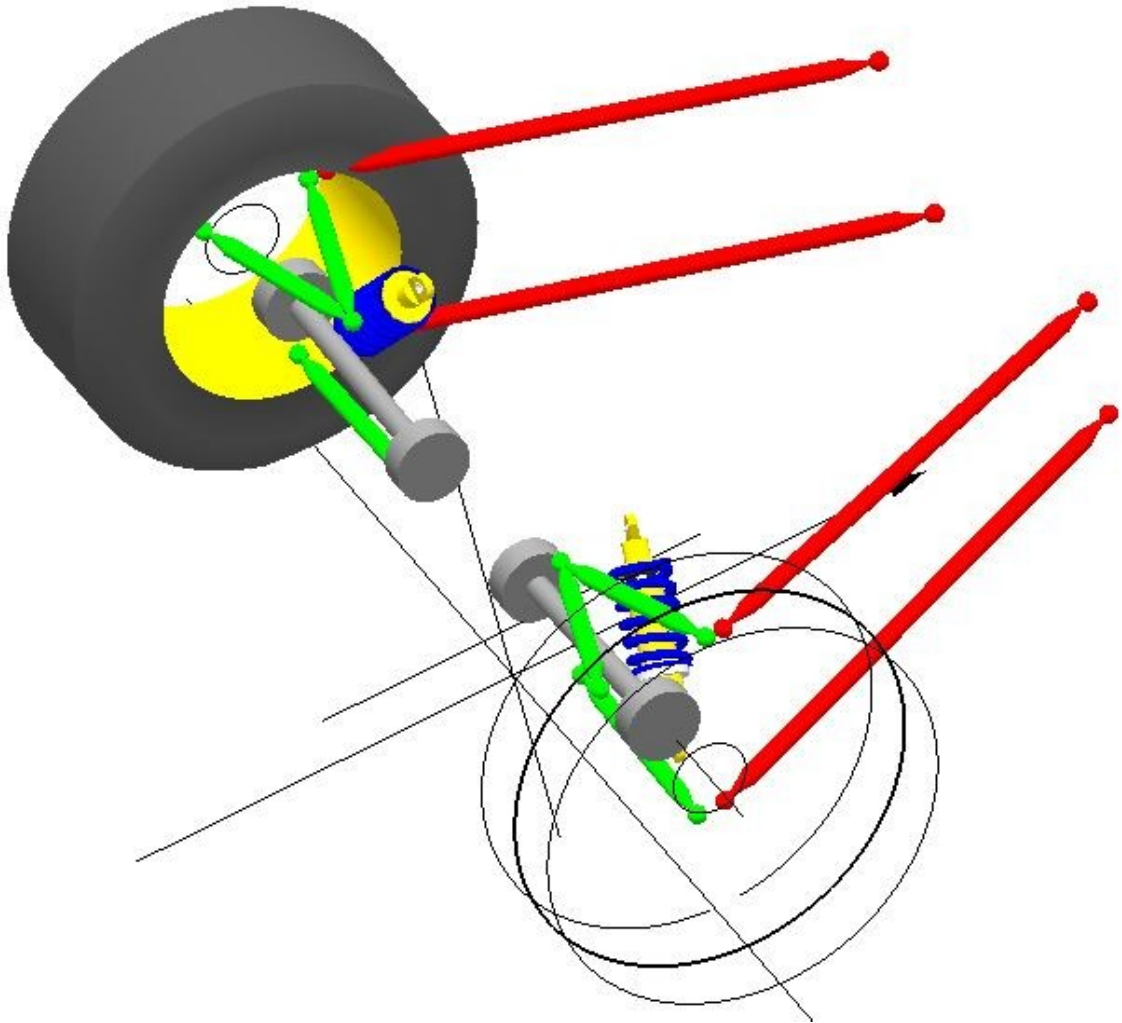


The classic '60s sports and racing cars rear suspension.

Four chassis mounting points, one for the upper lateral link, one for the lower reversed A-arm, and one for each of the trailing links.

Five upright mounting points, one for the upper lateral link, one for each link of the lower reversed A-arm, and one for each of the trailing links.

4.10 Upper reversed A-arm, lower lateral link, twin trailing links

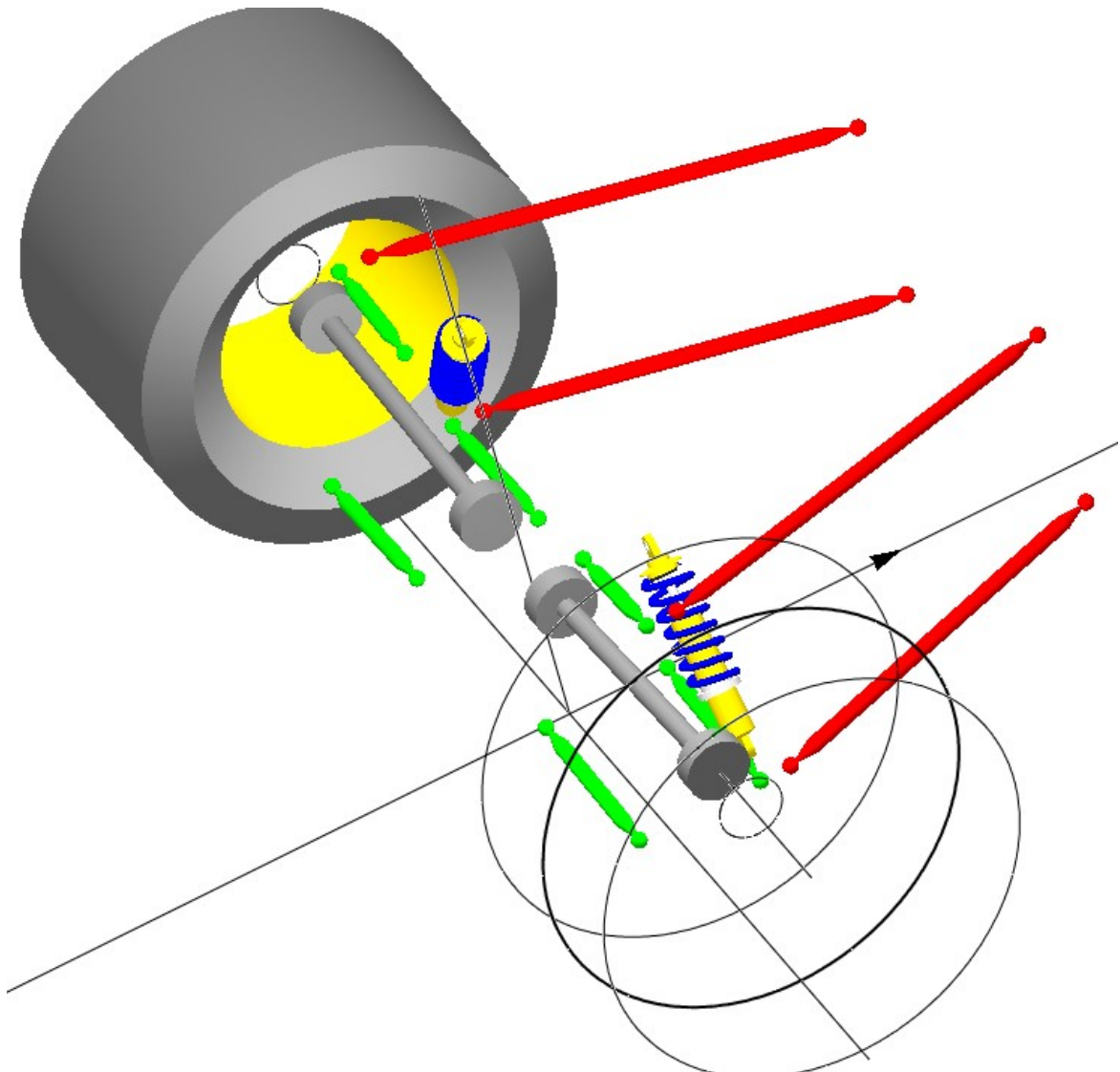


An alternative version of the classic '60s sports and racing cars rear suspension.

Four chassis mounting points, one for the upper reversed A-arm, one for the lower lateral link, and one for each of the trailing links.

Five upright mounting points, one for each link of the upper reversed A-arm, one for the lower lateral link, and one for each of the trailing links.

4.11 Upper lateral link, parallel lower links, twin trailing links

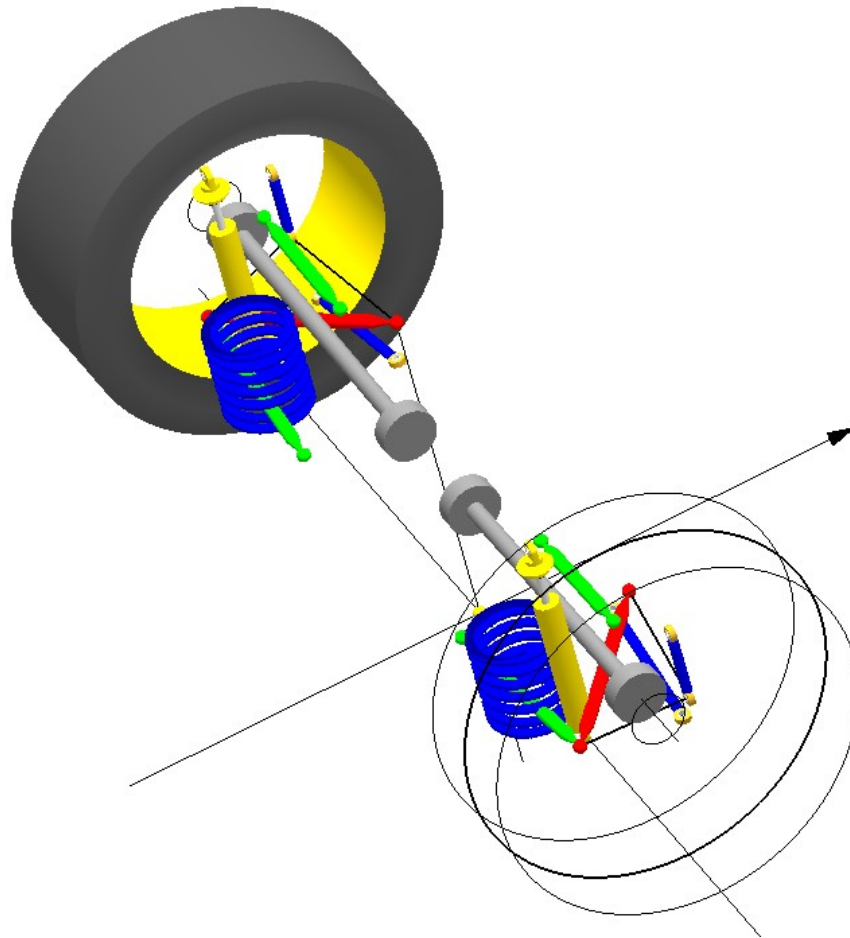


A variation of the reversed lower A-arm.

Five chassis mounting points, one for the upper lateral link, one for each lower lateral links, and one for each of the trailing links. The lower lateral links are generally parallel (in plan view) and symmetrically disposed about the axle centreline.

Five upright mounting points, one for the upper lateral link, one for each lower lateral link, and one for each of the trailing links.

4.12 Arm Caster Link

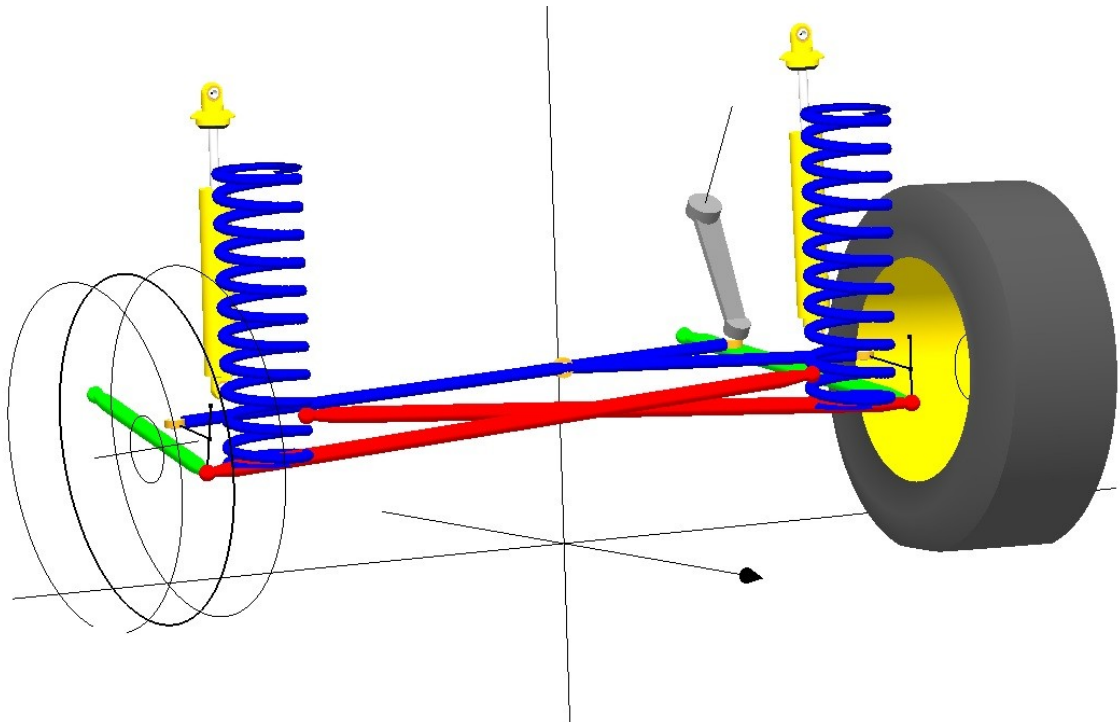


The Arm Caster Link consists of the following components:

- The single top link controls the wheel camber.
- The bottom control arm controls wheelbase and, in conjunction with the integral link, [caster](#).
- The toe link controls wheel toe.
- The knuckle supports the wheel hub and bearing. There is mounting point for the camber control link, the [caster](#) control link, the toe control link, and the lower control arm.

The static camber, [caster](#) and toe can be set via the Geometry | Alignment menu.

4.13 Ford Twin I-Beam



The Ford Integral Link consists of the following components:

- The I-Beam controls wheelbase and the camber and [caster](#). On some models, the camber and [caster](#) can be adjusted by offset bushes. This functionality is not modelled by SusProg3D.
- The radius rod controls the wheelbase, and, in the actual vehicle, controls the I-Beam radially.
- The toe link controls wheel toe.
- The stub axle supports the wheel hub and bearing and the steering arm. Early model stub axles used a [kingpin](#), later models upper and lower ball joints.

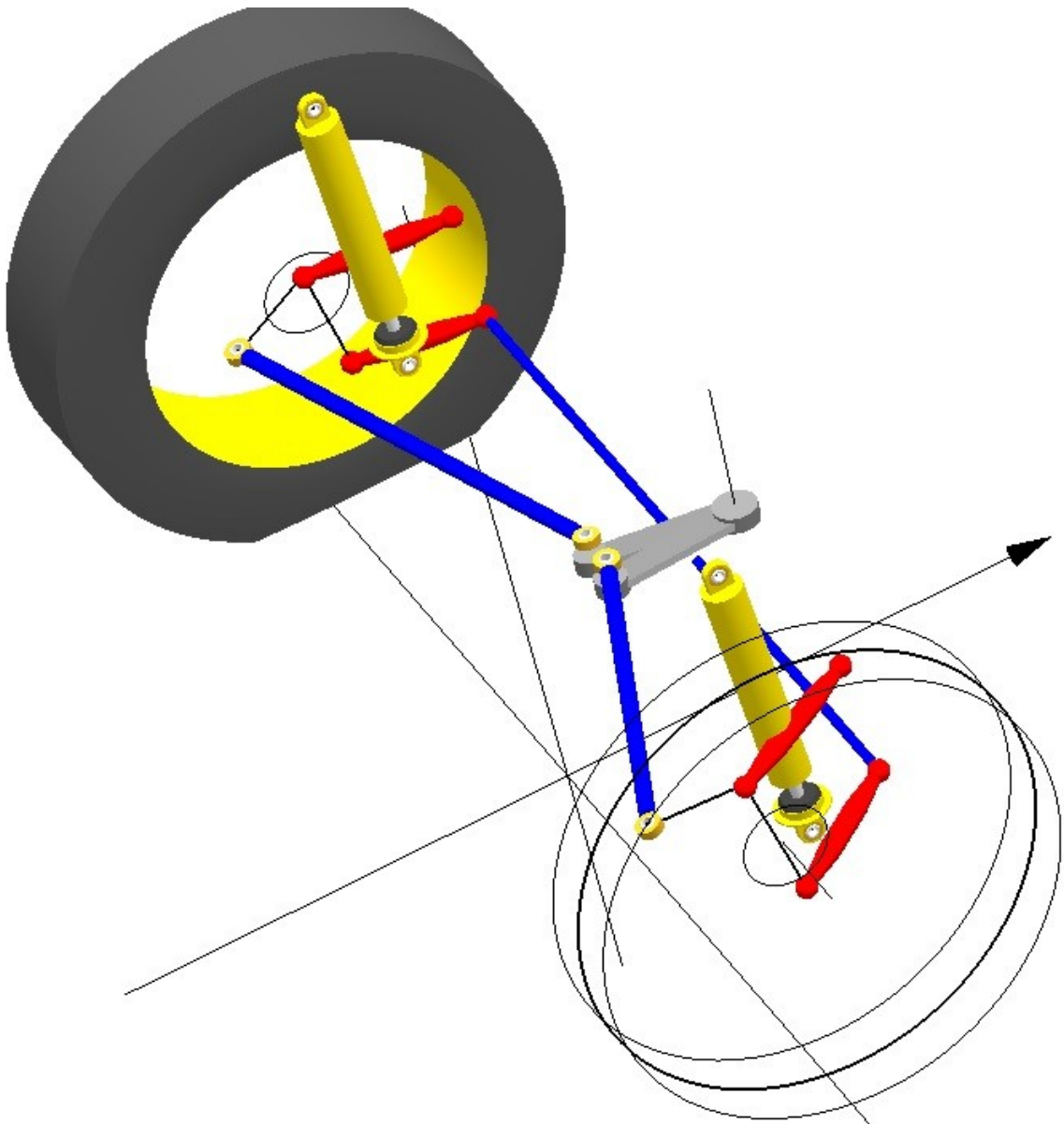
The static camber, [caster](#) and toe can be set via the Geometry | Alignment menu.

Geometrically the combination of I-Beam and radius rod is equivalent to a pair of A-arms with common chassis mounting points, one A-arm connecting to the top of the [kingpin](#) (or top balljoint) and the other A-arm connecting to the bottom of the [kingpin](#) (or bottom balljoint).

For simplicity, SusProg3D shows the suspension as a single A-arm, and dimensions the links accordingly.

The steering is also simplified with both tie rods considered to be straight, and the connection from the primary tie rod to the secondary tie rod on the centreline of the primary tie rod.

4.14 Volkswagen twin trailing links



The Volkswagen twin trailing link consists of the following components:

- Twin upper and lower trailing links.
- The toe link controls wheel toe.
- The upright supports the wheel hub and bearings and the steering arm. Early model stub axles used trunnions, later models upper and lower ball joints.

The static camber, [caster](#) and toe can be set via the Geometry | Alignment menu.

Geometrically each trailing link is equivalent to an A-arm with lateral axis. One end of the A-arm axis is the trailing link chassis mounting point.

With a conventional suspension, the other end of the A-arm axis is any convenient point along the line between the trailing link chassis mounting point and the trailing link chassis mounting point on the opposite side.

For the Porsche 718 K suspension, the other end of the A-arm axis is usually on the vehicle centreline, and lower down, resulting in an inclined pivot axis in front view.

4.15 Compound link

Compound link designs are those where the suspension linkages are asked to perform additional functions instead of tension or compression loadings.

The currently supported configurations are

- [Jaguar IRS](#)
- [H-arm + camber link](#), similar to the Ford Thunderbird
- [Porsche 928](#)

The top link (or driveshaft) controls the wheel camber.

The bottom A-arm controls wheelbase and both [caster](#) and toe.

The static camber, [caster](#) and toe can be set via the Geometry | Alignment menu.

For the bottom link lengths, the front link length is the length from the front chassis pivot to the front upright pivot, the diagonal link length is from the rear chassis pivot to the front upright pivot, and the rear (toe) link length is the length from the rear chassis pivot to the rear upright pivot.

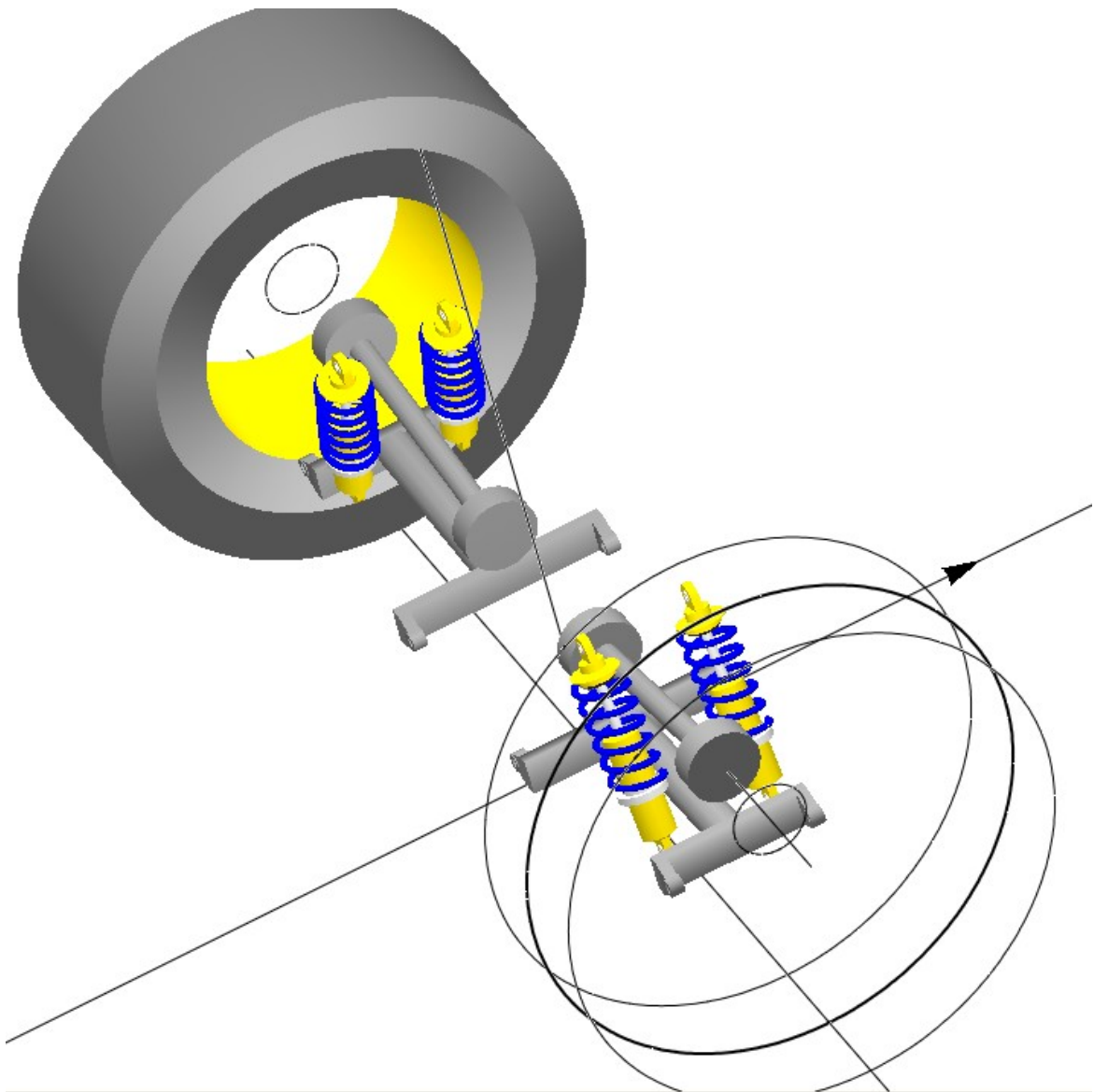
The twist offset and upright base length are used to specify the location of the bottom A-arm rear upright pivot point, relative to the plane of the other three A-arm points (ie front and rear chassis mountings and the front upright mounting point) in side view. If the rear upright mounting point is in the same plane (as the other three points) then the twist offset is zero; if the rear upright mounting point is above the plane (of the other three points) then the twist offset is positive; and if the rear upright mounting point is below the plane (of the other three points) then the twist offset is negative.

If the bottom A-arm rear (toe) link length is specified, then this will determine the static wheel toe alignment.

If the bottom A-arm twist offset is specified, then this will determine the static wheel [caster](#) alignment.

The toe reference length will default to the tyre diameter if it is not specified.

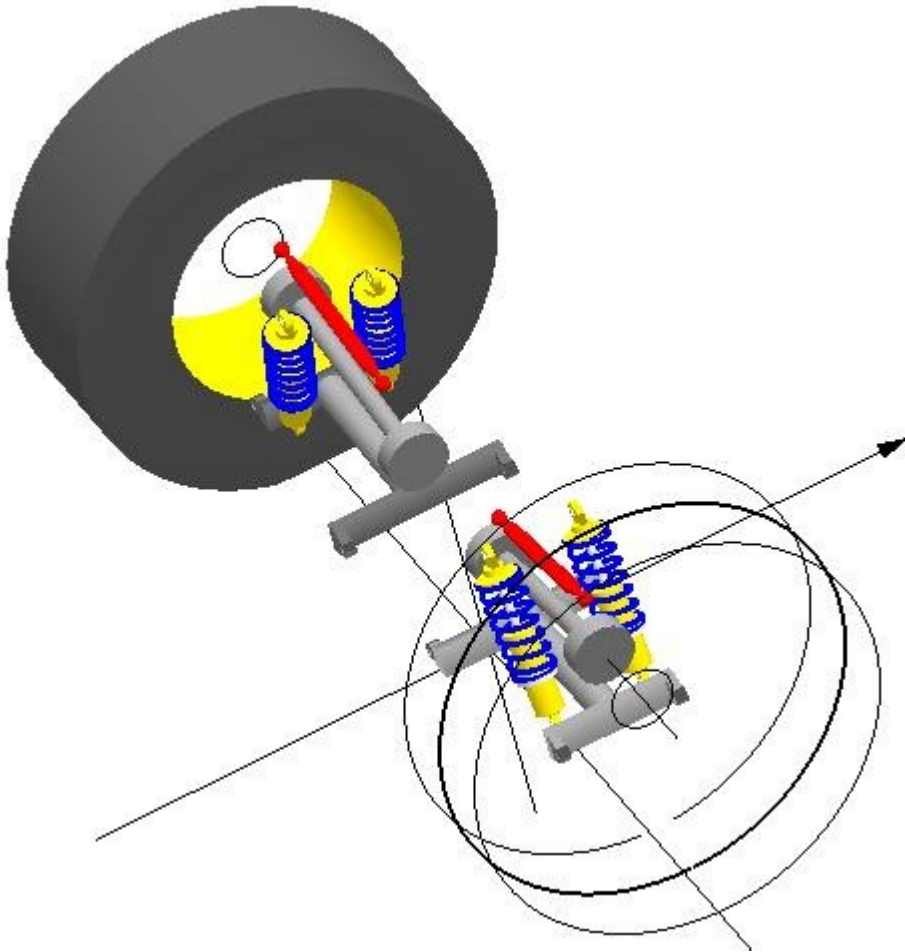
4.15.1 Jaguar IRS



The original OEM design uses the drive shaft as the suspension lateral link.

Three chassis mounting points, one for the driveshaft, two for the I-arm.

Three upright mounting points, one for the driveshaft, two for the I-arm.



The modified design uses a separate lateral link as the suspension lateral link. This relieves the drive shaft of the suspension loads and enables the use of CV joints.

Three chassis mounting points, one for the lateral link, two for the I-arm.

Three upright mounting points, one for the lateral link, two for the I-arm.

For the OEM design, specify the driveshaft as "Fixed length driveshaft (top lateral link).

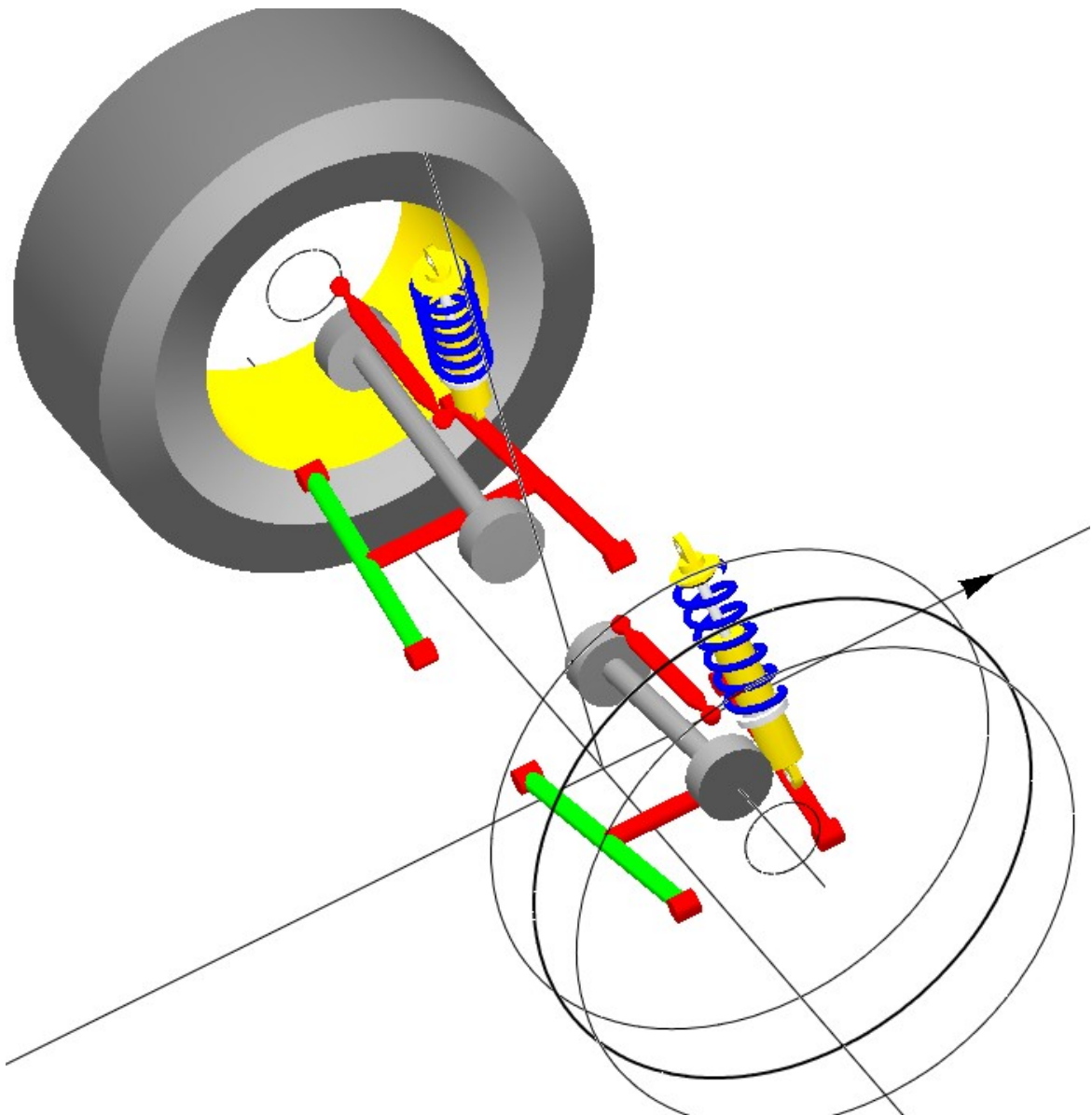
For the modified design, specify the driveshaft as either "Variable (splined)" or "Variable (plunging joint)".

In the Jaguar IRS all driving and braking loads are reacted by the lower lateral I-arm in torsion and bending. Reactions to all wheel centre inputs in the longitudinal direction result in torsional loading of the lower member. In the OEM design the fixed length (and fixed universal joints) driveshaft acts as the upper camber control link and controls the front view instant centre. The side view instant centre is controlled solely by the lower member.

In the OEM design the chassis top pivot point corresponds to the inboard driveshaft universal joint centre, and the upright top pivot point corresponds to the outboard driveshaft universal joint centre, and only the lateral value is entered.

The toe control pivot points are already established as part of the basic suspension geometry. There is only the capability to display the toe changes.

4.15.2 H-arm + camber link



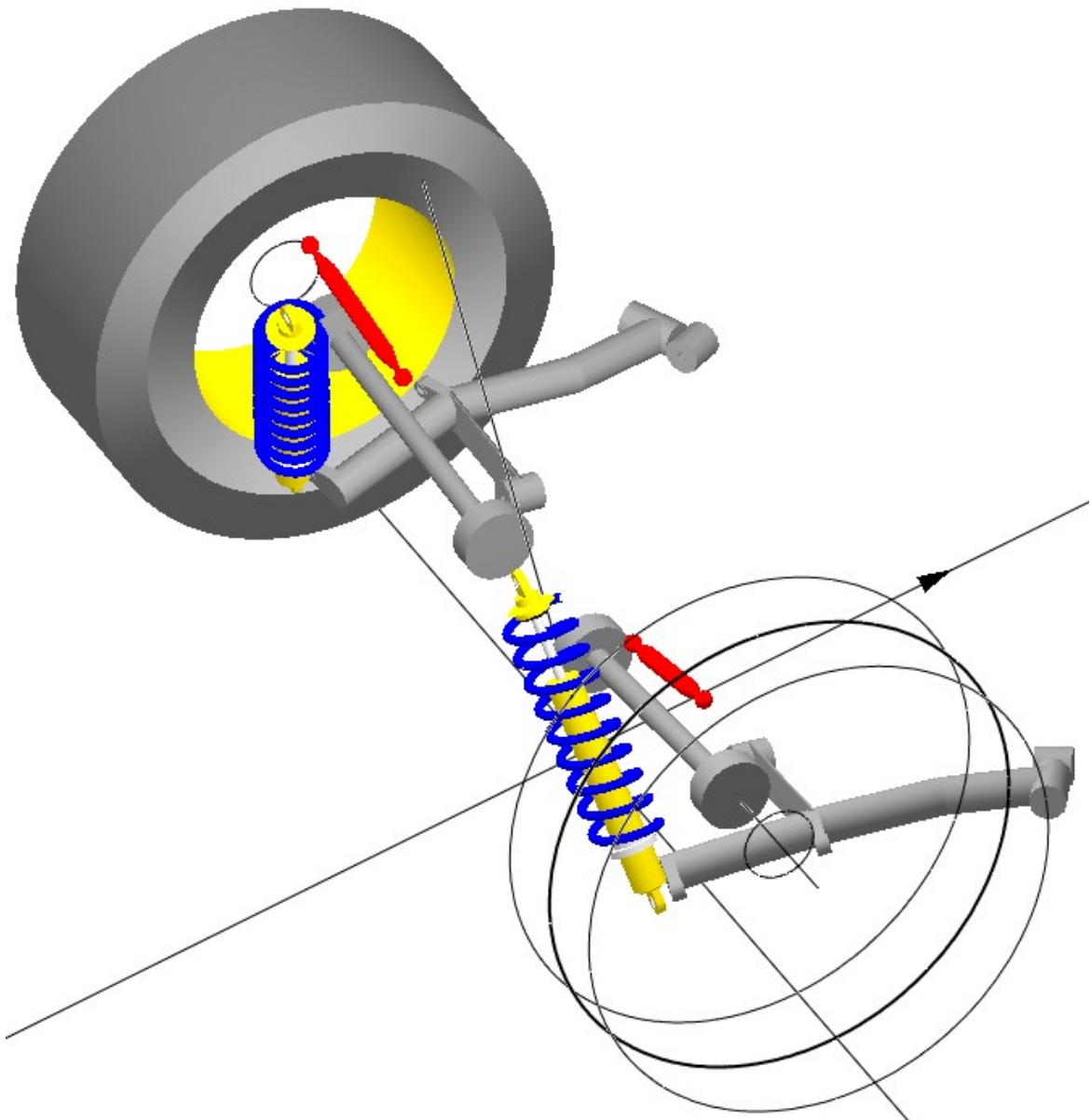
Three chassis mounting points, one for the top camber control link, two for the H-arm.

Three upright mounting points, one for the top camber control link, two for the H-arm.

In the H-arm IRS all driving and braking loads are reacted by the lower lateral H-arm in torsion and bending. Reactions to all wheel centre inputs in the longitudinal direction result in torsional loading of the H-arm. The upper camber control link controls the front view instant centre. The side view instant centre is controlled solely by the H-arm.

This can also be inverted, with an upper H-arm and lower camber control link.

4.15.3 Porsche 928



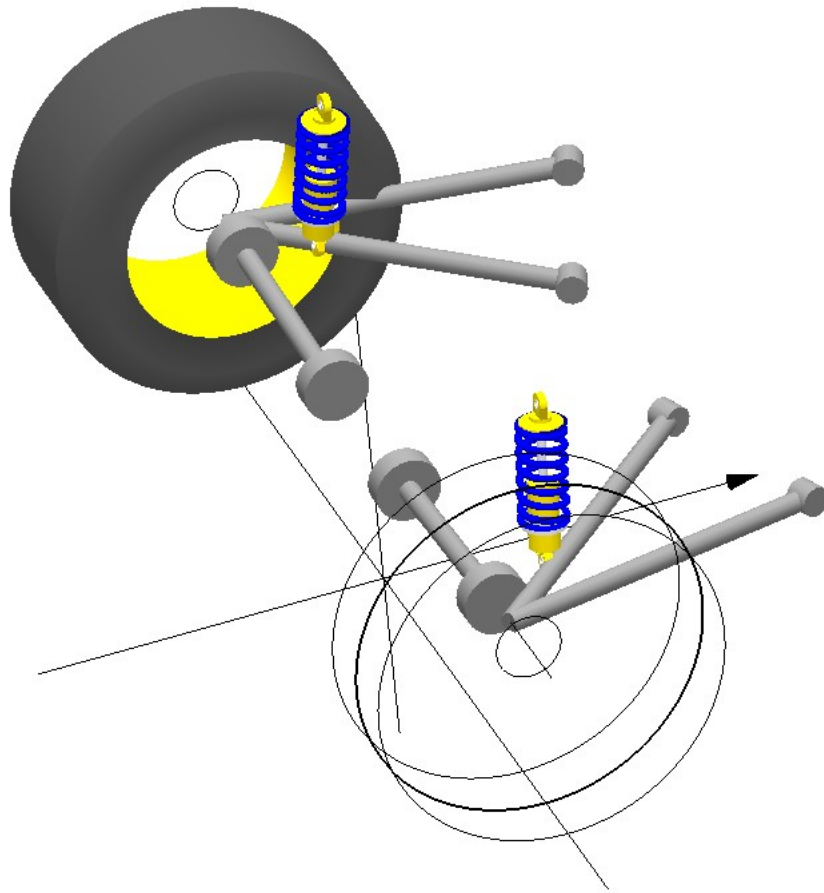
Three chassis mounting points, one for the top camber control link, two for the trailing arm.

Three upright mounting points, one for the top camber control link, two for the trailing arm.

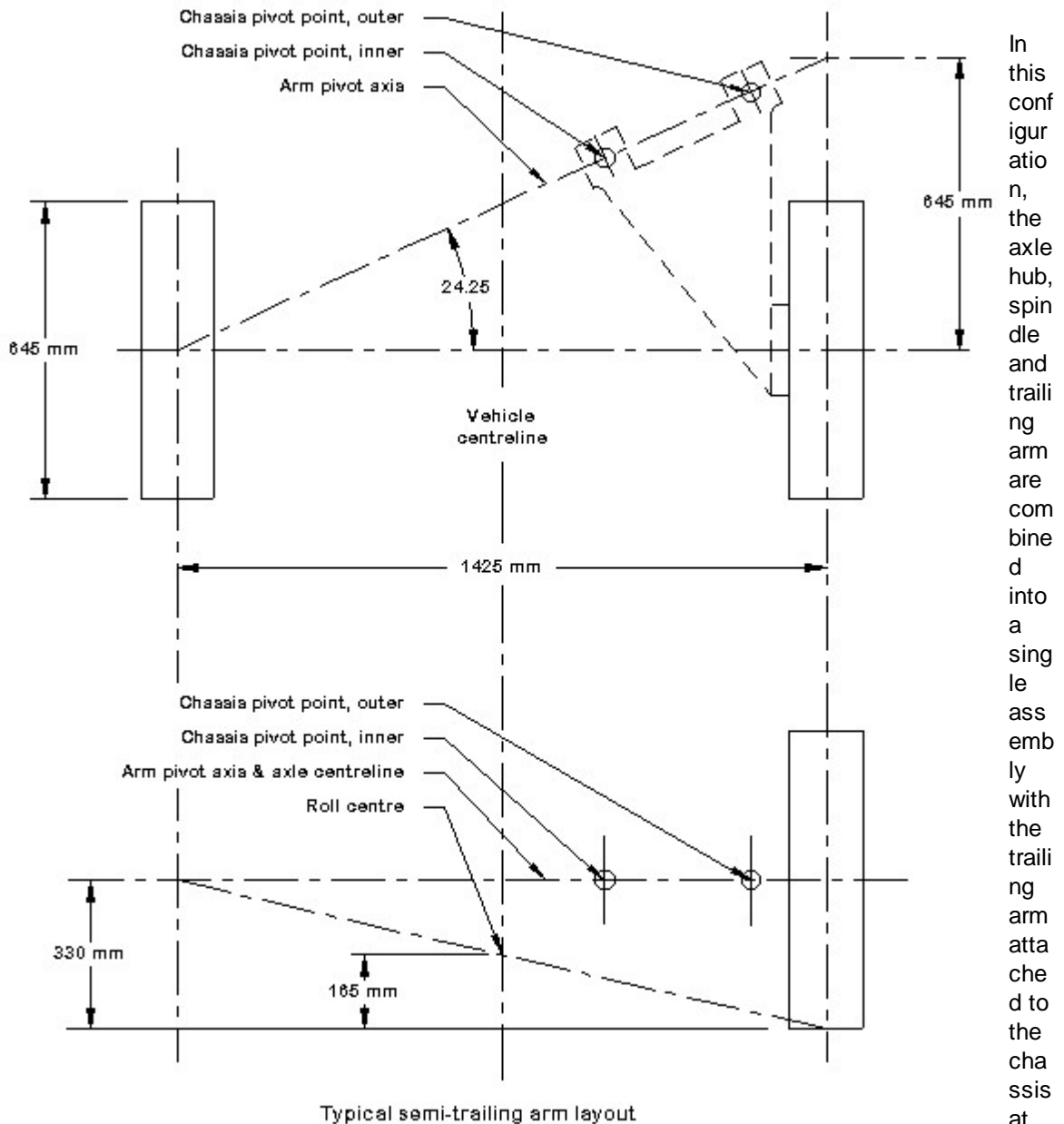
With the Porsche 928 IRS, the lower trailing arm reacts longitudinal and lateral loads largely in bending. The lower lateral link reacts only camber control loads, and contributes virtually nothing to the longitudinal and toe loads. The upper camber control link controls the front view instant centre. The side view instant centre is controlled solely by the lower member.

There is no allowance for the articulation of the Porsche 928 trailing arm chassis pivot.

4.16 Semi-trailing arm (also includes trailing arm and swing axle)



Two chassis mounting points for the trailing arm.



mounting points, and these define both the front view instant centre (roll centre) and side view instant centre.

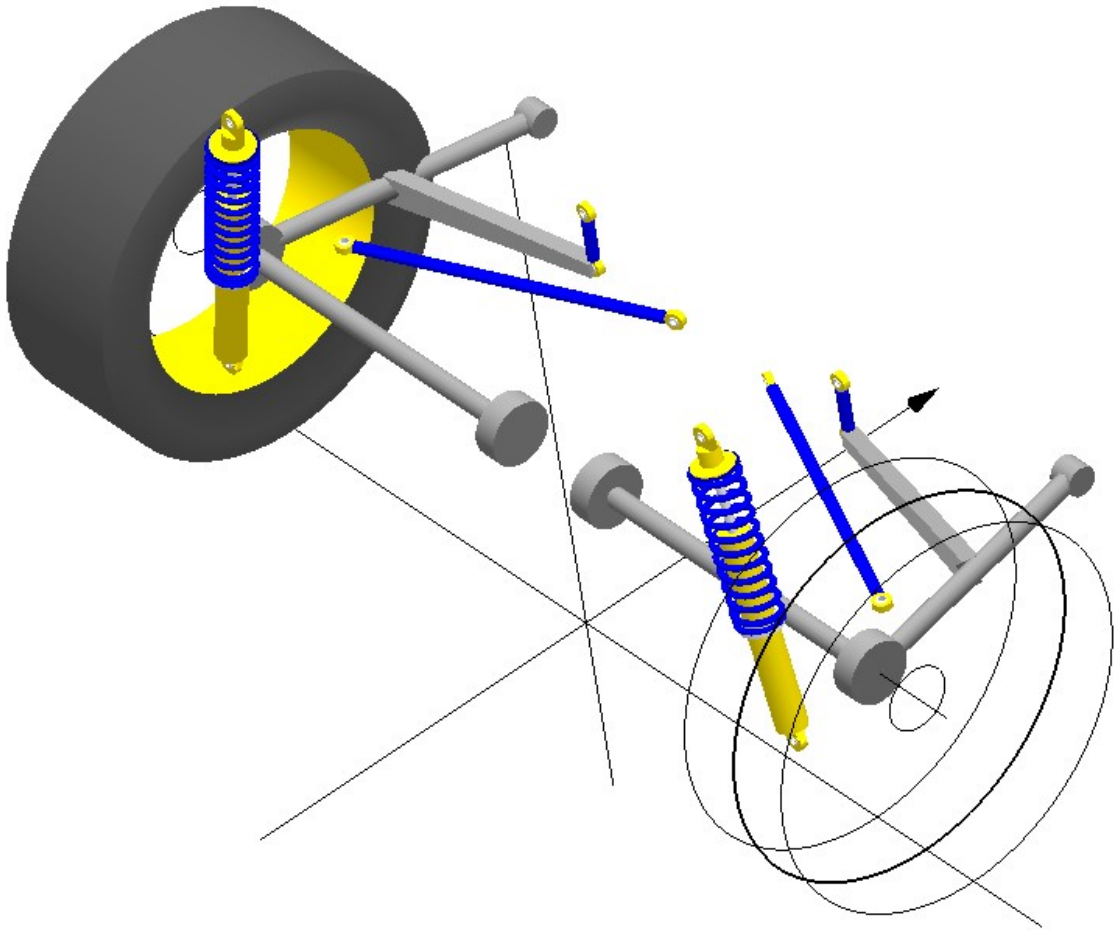
Generally, the semi-trailing arm has a pivot axis angle around 20 to 30 degrees.

If both pivots are on, or very close to, a line at right angles to the vehicle centreline, then this is referred to as a "Trailing arm". The rear suspension on the original Austin/Morris Mini is a typical example.

If both pivots are on, or very close to, a line parallel to the vehicle centreline, then this is referred to as a "Swing axle".

Note that the original Volkswagen rear suspension, which is usually called a "Swing axle" is actually more of a "Semi-swing axle" as the pivot axis angle is around 60 degrees. The trailing arm which connects to the torsion bar acts as the outboard pivot, with the driveshaft universal joint acting as the inner pivot.

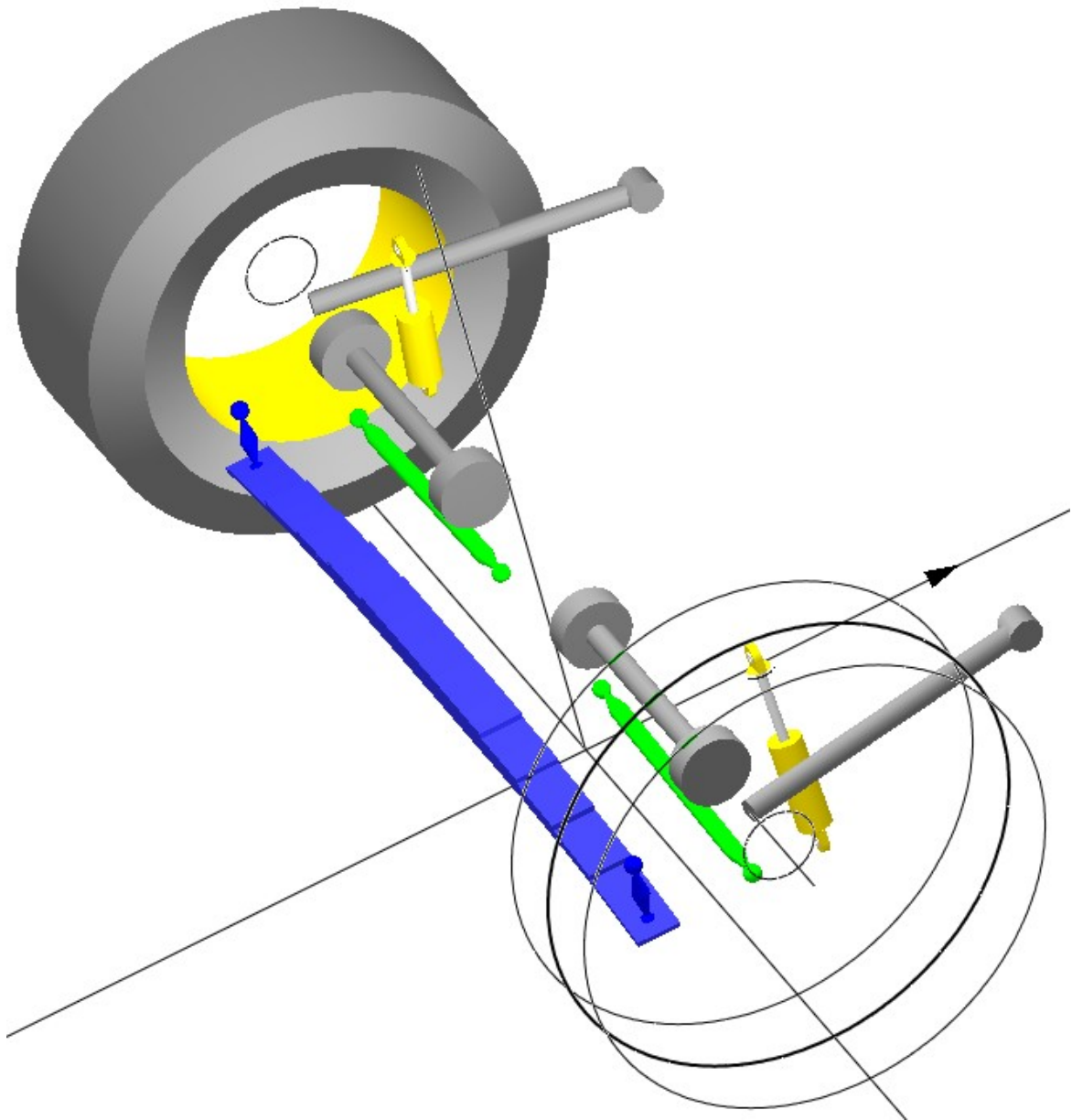
4.17 Trailing arm, camber control and toe control links.



Three chassis mounting points. One for the trailing arm, one for the camber control link, one for the toe control link.

In this configuration, the axle hub and spindle assembly (Mazda refer to this as the “triaxial floating hub outer assembly”) and trailing arm are combined into a single assembly with the trailing arm attached to the chassis at one mounting point, which defines the side view instant centre.

4.18 Trailing arm, upper and lower lateral links

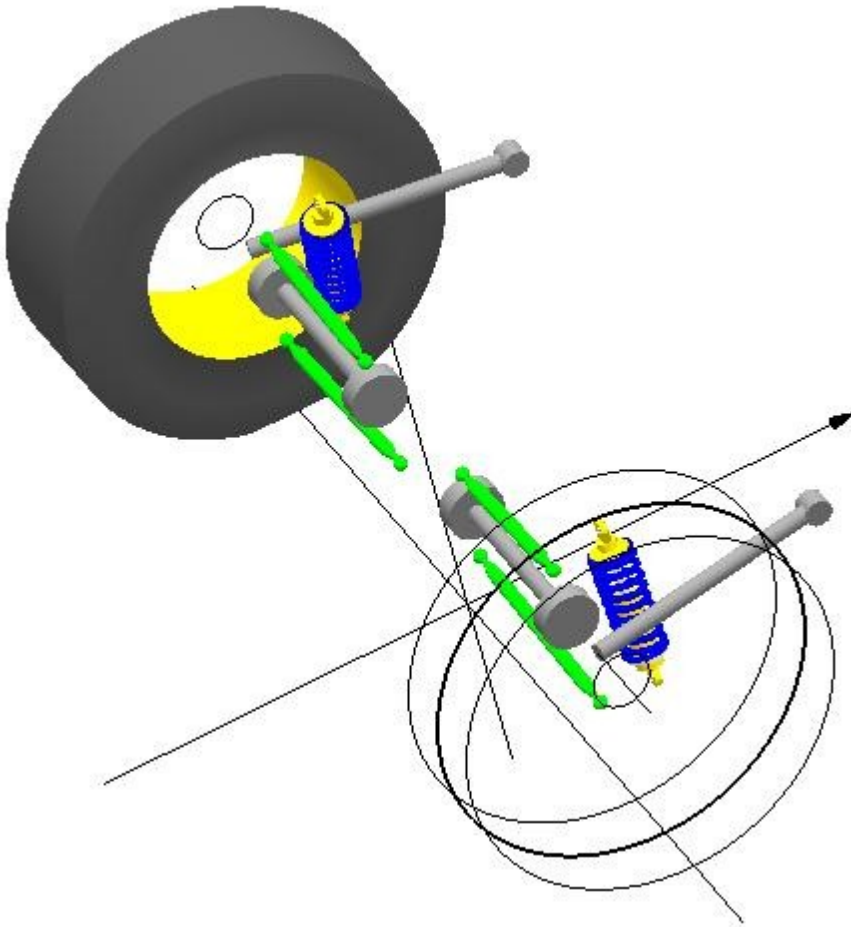


Three chassis mounting points, one for each lateral link, one for the trailing arm.

Three trailing arm mounting points, one for each lateral link and one for the trailing arm.

The top lateral link can be either a bespoke link, or the driveshaft can act as the suspension link.

Specify the driveshaft as "Fixed length driveshaft (top lateral link) to have the driveshaft as a suspension link, or specify the driveshaft as either "Variable (splined)" or "Variable (plunging joint)" to use a bespoke top lateral link.

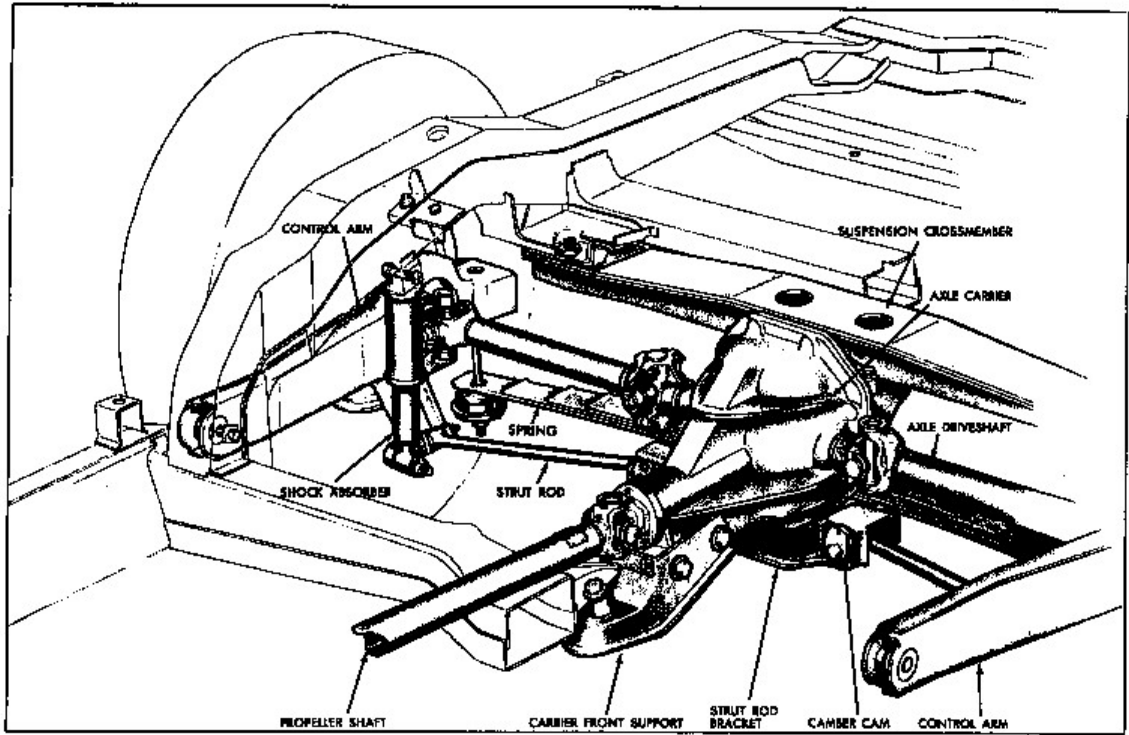


In this configuration, the axle hub and spindle and trailing arm are combined into a single assembly with the trailing arm attached to the chassis. There are two lateral control links which attach to the chassis and to the trailing arm assembly. The lateral control links are generally positioned on the axle centreline (in plan view).

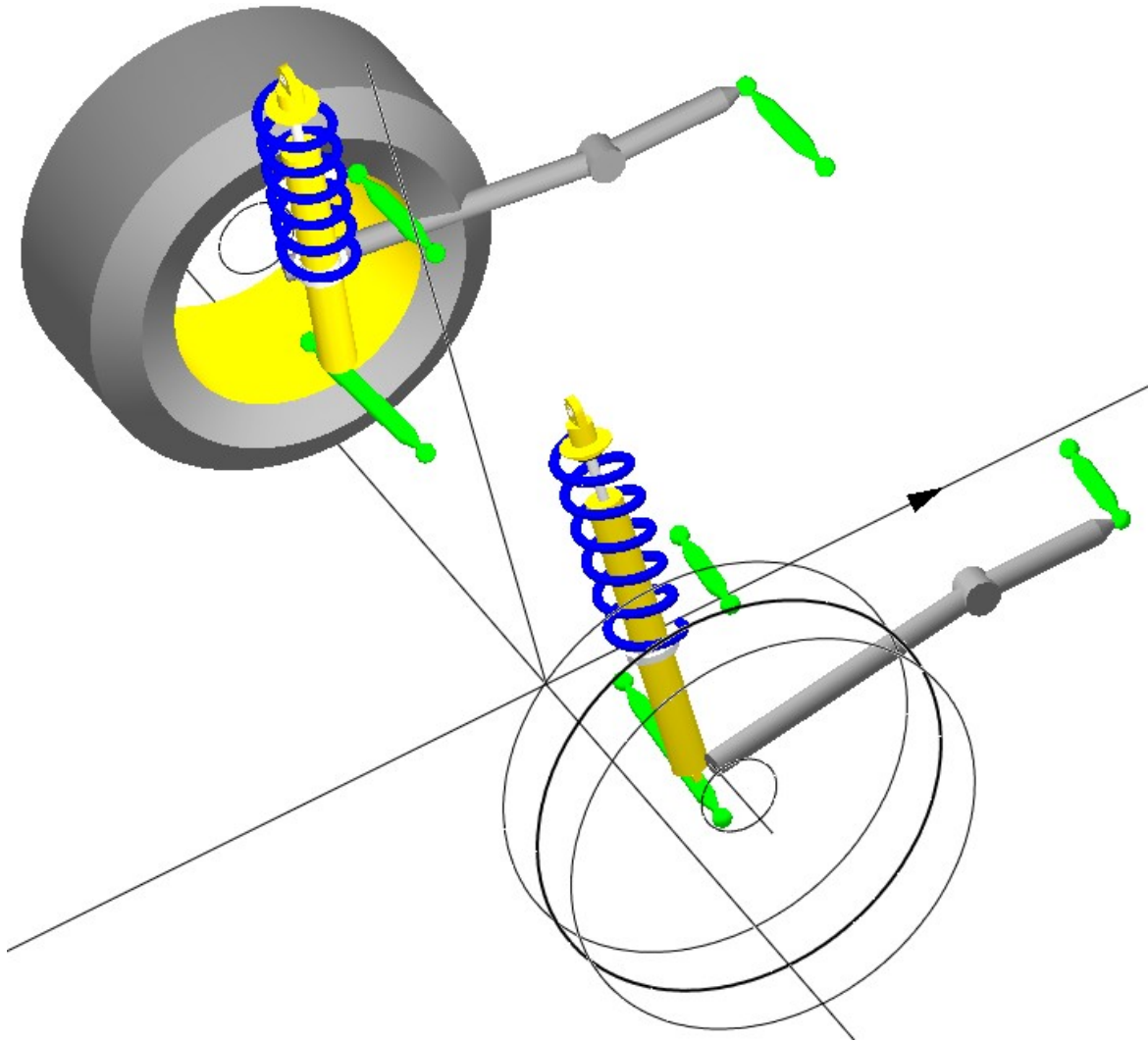
Vehicles with this type of rear suspension include the Lotus Europa and BMW E36 (both with coil springs) and pre '84 Chevrolet Corvette (with transverse leaf spring).

Both the Corvette and the Lotus Europa use the driveshaft as the top lateral link. Make sure that the driveshaft is set to "Fixed length driveshaft (top lateral link)".

Camber (and roll centre location) is primarily controlled by the pair of lateral links. [Caster](#) (and side view instant centre location) is primarily controlled by the trailing arm chassis mounting. Toe is primarily controlled by the chassis trailing arm mounting.



4.19 Trailing arm, upper and lower lateral links, toe control link



Four chassis mounting points, one for each lateral link, one for the trailing arm and one for the toe control link.

Four trailing arm mounting points, one for each lateral link, one for the trailing arm, and one for the toe control link.

In this configuration, the axle hub and trailing arm are combined into a single assembly with the trailing arm attached to the chassis. There are two lateral control links which attach to the chassis and to the trailing arm assembly. The lateral control links are generally positioned close to the axle centreline (in plan view).

Camber (and roll centre location) is primarily controlled by the pair of lateral links.

[Caster](#) (and side view instant centre location) is primarily controlled by the trailing arm chassis mounting.

Toe is primarily controlled by the toe control link, and consequently there is some lateral compliance and sideways movement of the trailing arm mounting on the chassis.

Vehicles with this type of rear suspension include Honda Civic and Integra.

The toe is controlled by the toe control link which connects to the trailing arm forward of the trailing arm chassis mounting point

The Kia Carnival has a slight variation in that the toe control link is located closer to the axle centreline.

4.20 Strut types

There are variations of the strut suspension:

- [Macpherson strut](#)
- [Strut, lower "virtual A-arm", toe link](#)
- [Tri-link strut](#).

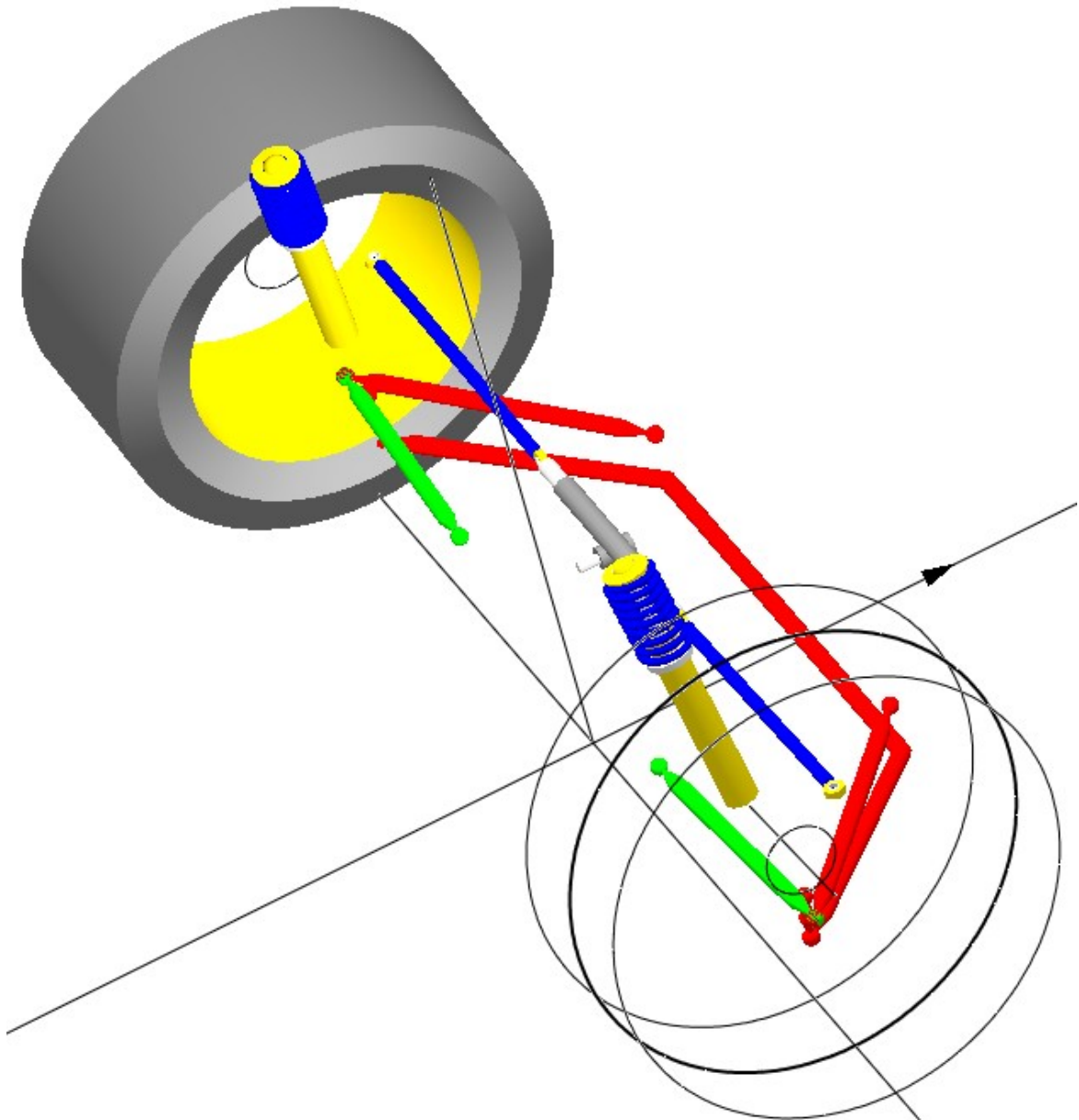
The strut and knuckle can be one of two basic styles,

- [Integral strut tube and knuckle](#), where the strut tube is pressed into and often welded onto, the knuckle. This is typical of older vehicles.
- [Separate strut tube and knuckle](#), where the knuckle is bolted to the strut tube, usually with one hole elongated to allow for a small amount of camber adjustment. This is typical of current vehicles.

The steering arm can be attached to either the knuckle or the strut tube.

When the spring is specified as "Coilover", the only applicable input values for the are for Mass and Spring Parameters.

4.20.1 Strut, lower A-arm, toe link



The classic production car Macperson strut.

When used as a front suspension there are four chassis mounting points, one for the strut rod top mounting, two for the lower A-arm and one for the steering tie rod (which can be either the end of the steering rack or the tie rod mounting on the steering linkage).

When used as a rear suspension there are either three or four mounting points, one for the strut rod top mounting, two for the lower A-arm, and either a separate toe link mounting, or the toe link mounting can be common with one of the A-arm link mountings.

Three strut mounting points, one for the strut rod top mounting, one bottom A-arm and either a steering arm or a toe control link mounting.

The coil spring is most commonly mounted on the strut, but it can also be specified as a separate spring.

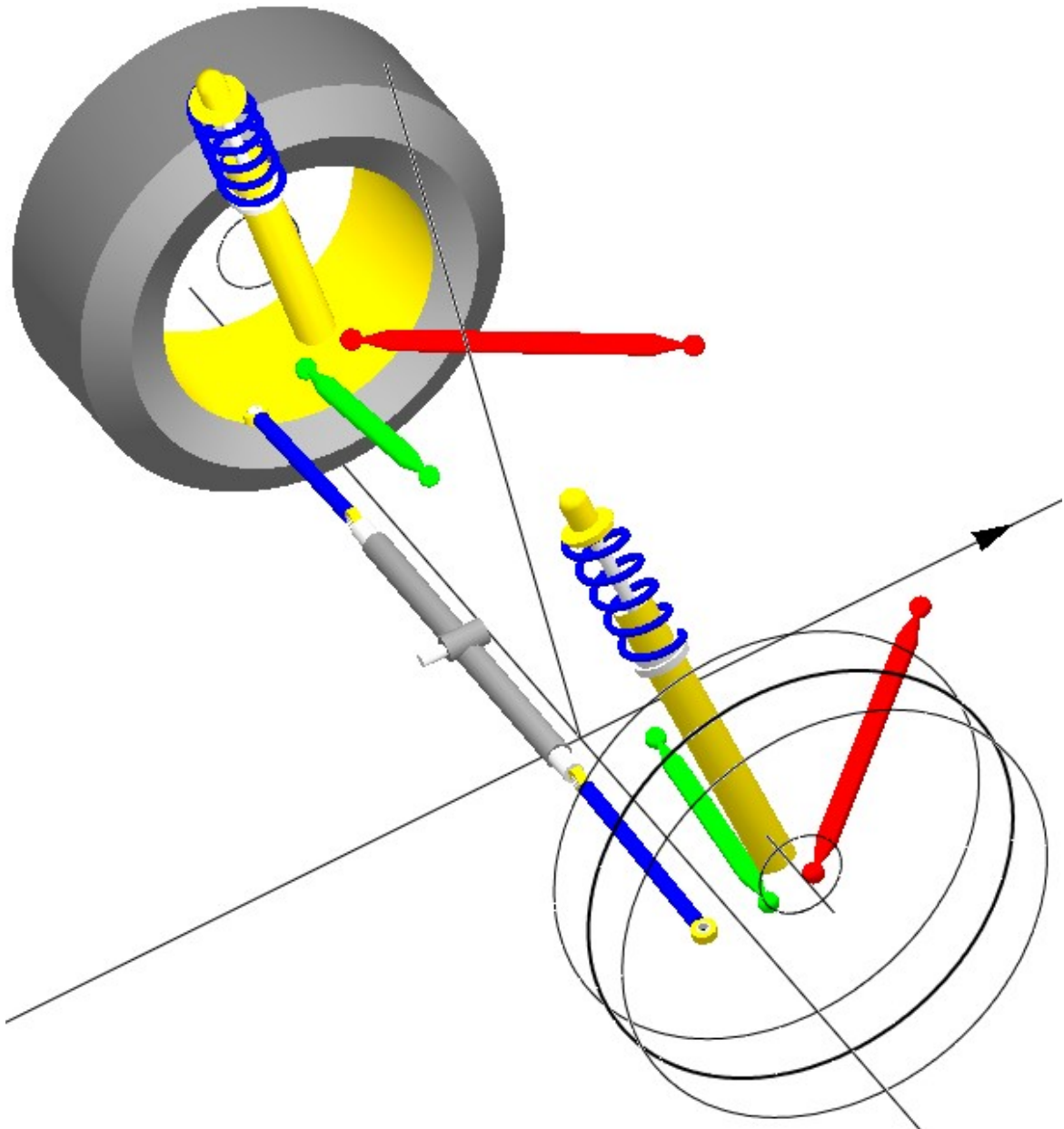
The design of the A-arm can take several forms.

Two of the most common styles are

- a single lateral control arm with a trailing link (where the anti-roll bar is used as the trailing link in which case this is the class "Macpherson strut")
- a one-piece 'sickle' or 'L' shaped arm

The [kingpin inclination \(KPI\)](#) and [caster](#) are measured from the strut rod mounting point on the chassis and the bottom A-arm strut ball joint.

4.20.2 Strut, lower "virtual A-arm", toe link



When used as a front suspension there are four chassis mounting points, one for the strut rod top mounting, one for each lower link and one for the steering tie rod (which can be either the end of the steering rack, or the tie rod mounting on the steering linkage).

When used as a rear suspension there are either three or four mounting points, one for the strut rod top mounting, one for each lower link, and either a separate toe link mounting, or the toe link mounting can be common with one of the lower link mountings.

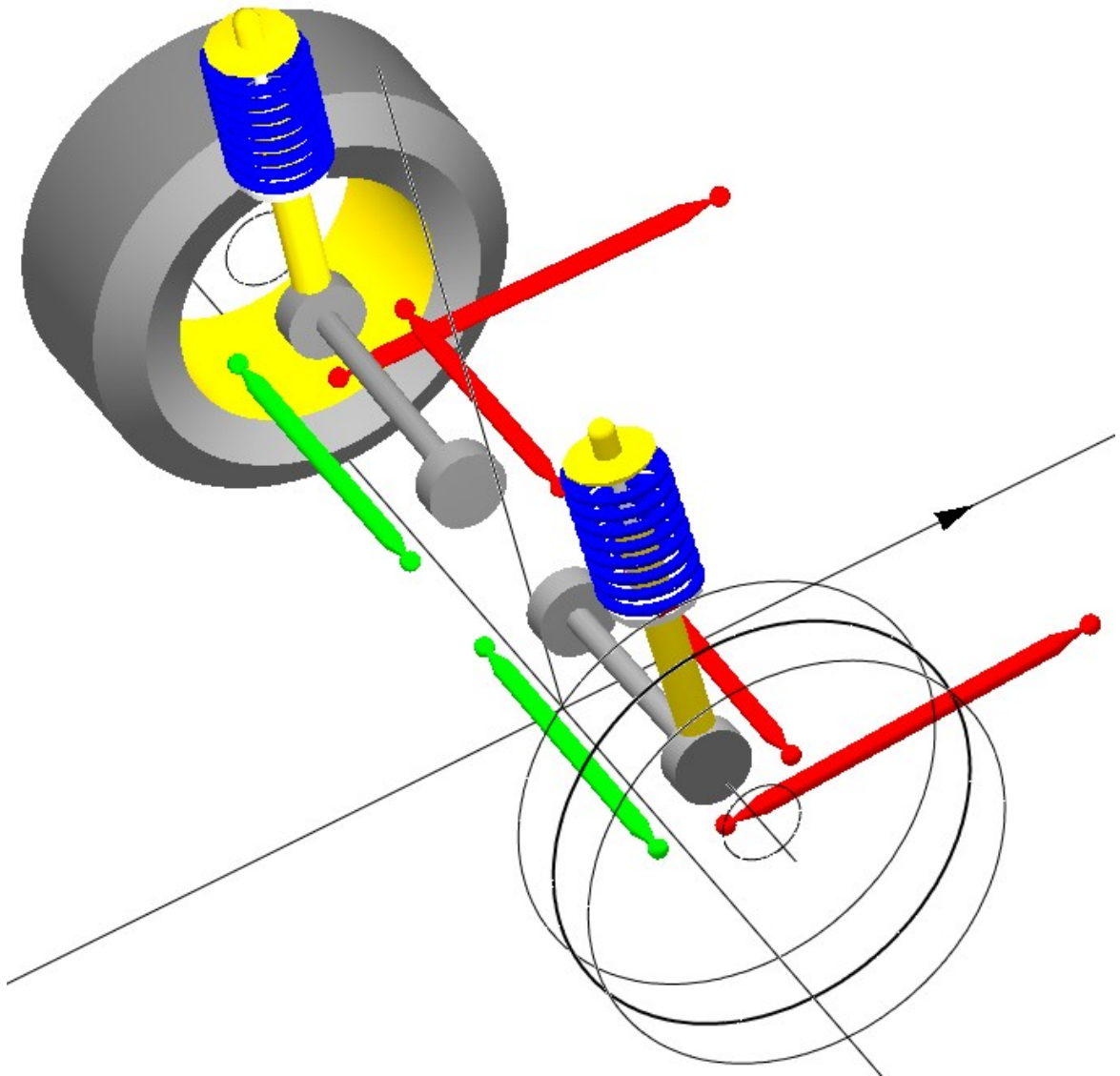
Four strut mounting points, one for the strut rod top mounting, one for each lower link and either a steering arm or a toe control link mounting.

In this configuration, commonly used on some BMW models, the bottom of the strut is located by two links, each with their own ball joint pivot, with the links angled (in plan view) to meet at a "virtual pivot" point. This makes it easier to package the components such that the steering axis (which passes through the virtual pivot point) can be moved further outboard than would otherwise be possible.

The two links are usually arranged as a lateral link (which controls camber) and a diagonal link (which controls [caster](#)). Where these two links meet (in plan view) is the "virtual pivot point".

The [kingpin inclination \(KPI\)](#) and [caster](#) are measured from the strut rod mounting point on the chassis and the "virtual pivot point".

4.20.3 Strut, tri-link



Four chassis mounting points, one for the strut rod top mounting, one for each lateral link, one for the trailing link. The arrangement of the links consists of two lateral links (usually parallel in plan view and of equal lengths) and a single trailing link. The strut top mounting needs only to provide minimal (or no) rotational capability. This is only suitable for rear suspension systems.

Four strut mounting points, one for the strut rod top mounting, one for each lower lateral link and one for the trailing link.

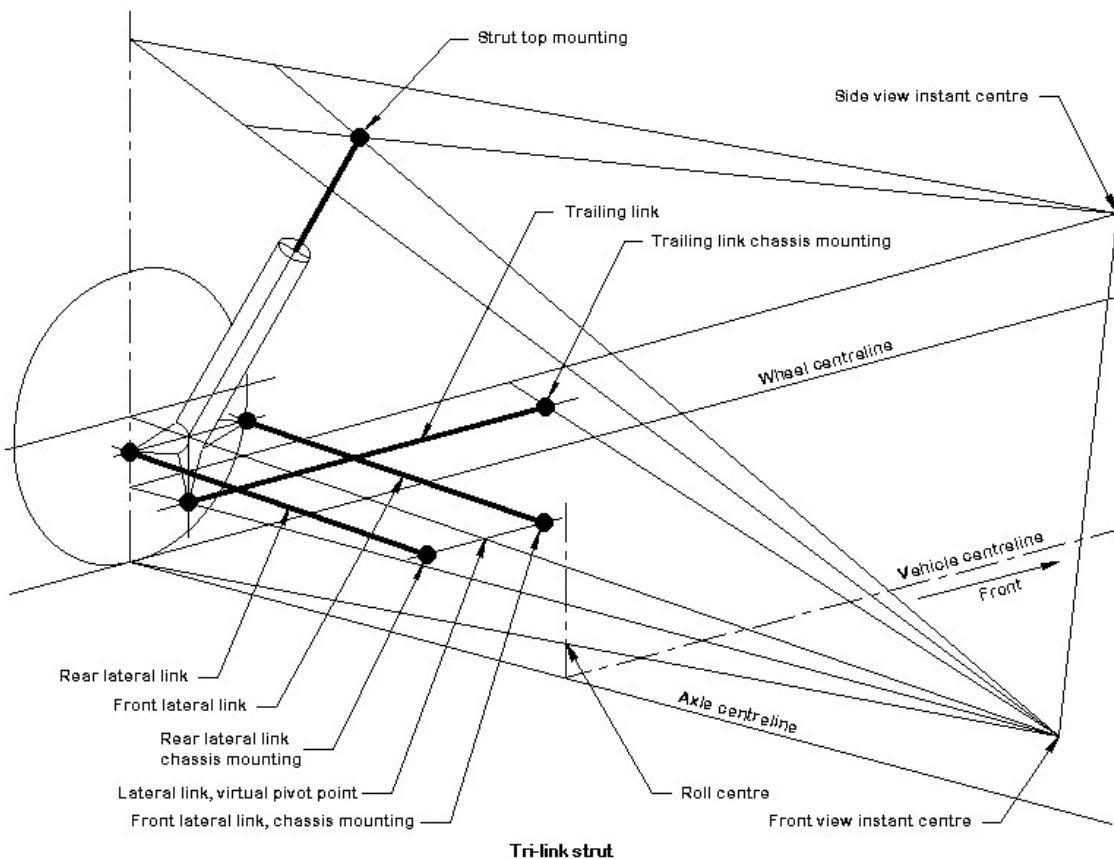
The tri-link strut is dimensioned the same as a normal strut, except that the trailing link and lateral link mountings are all part of, and dimensioned relative to, the knuckle.

The strut and knuckle can be integral or separate.

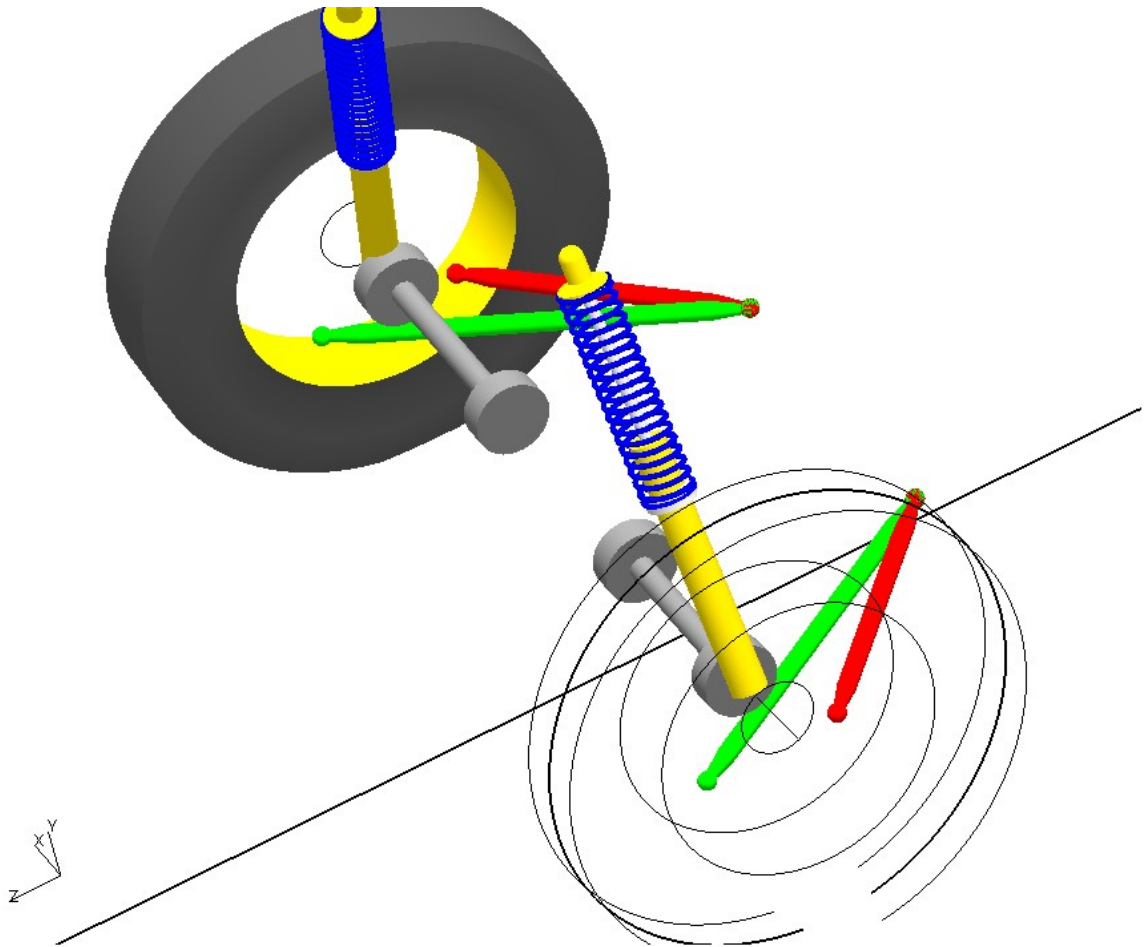
The kingpin inclination (KPI) is not applicable. [Caster](#) is defined as the amount the strut assembly is 'tilted' (in side view) from the strut datum position.

The front view instant centre (roll centre) is defined by the strut rod axis and the lateral links.

The side view instant centre is defined by the strut rod axis and the trailing link.



4.20.4 Chapman strut



Three chassis mounting points, one for the strut rod top mounting, one for the trailing links, one for the driveshaft. The strut top mounting needs only to provide minimal (or no) rotational capability. This is only suitable for rear suspension systems.

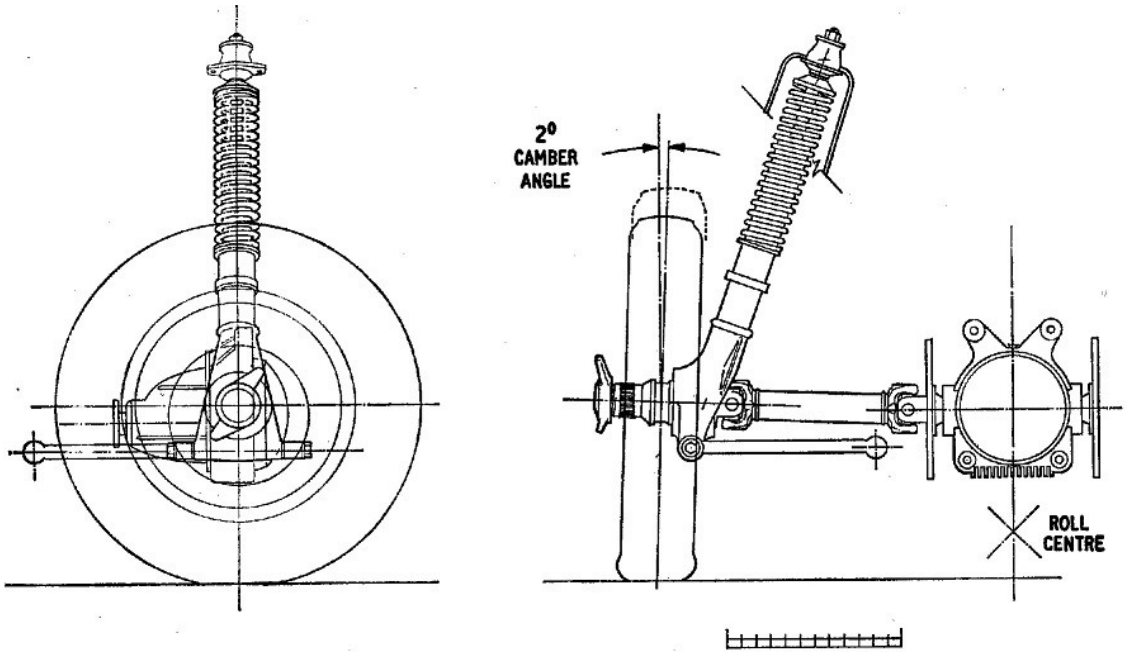
Four strut mounting points, one for the strut rod top mounting, one for each trailing link, and the axle universal joint centre.

The Chapman strut is dimensioned the same as a normal strut, except that the trailing link mountings are all part of, and dimensioned relative to, the knuckle.

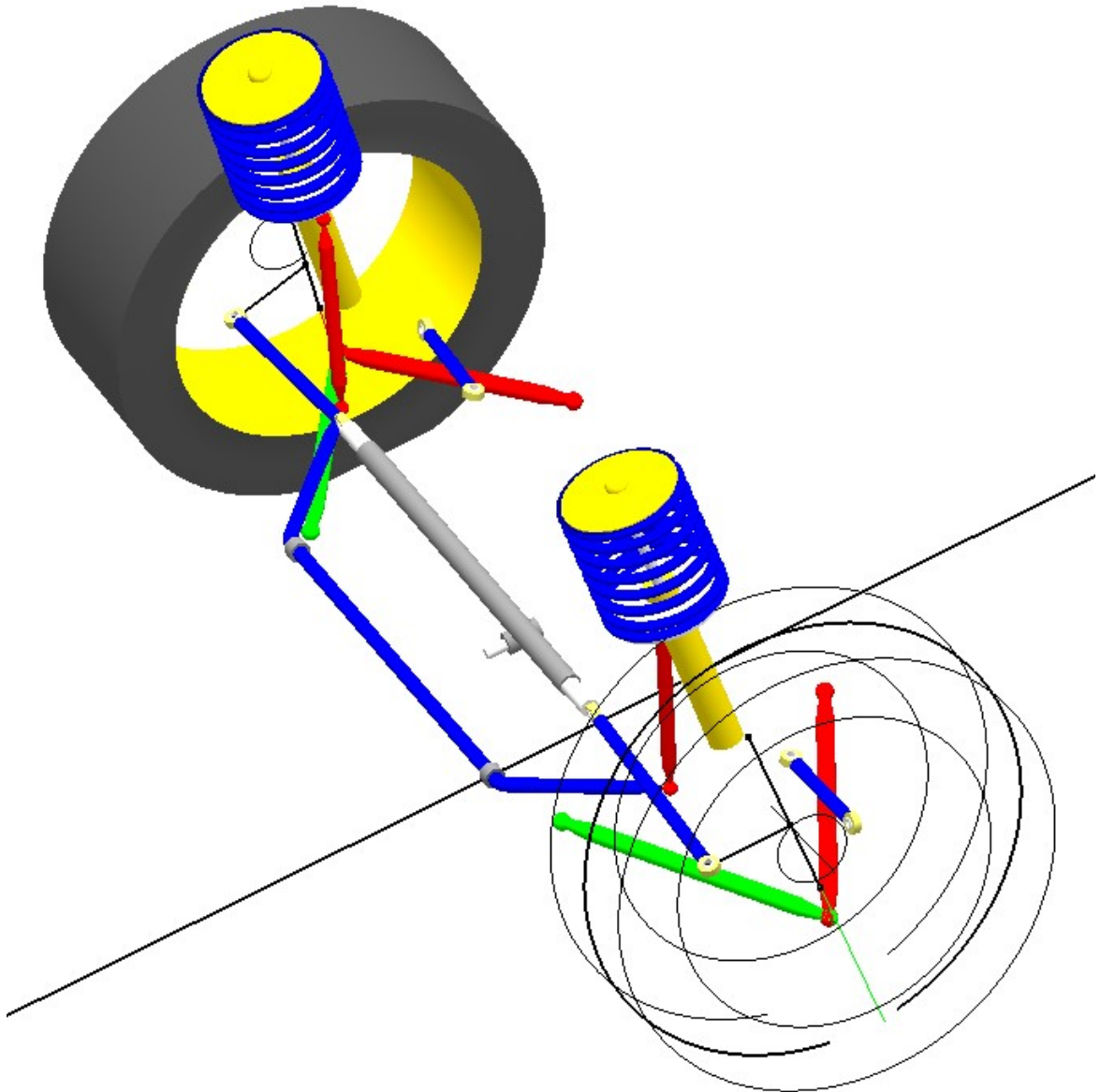
The kingpin inclination (KPI) is not applicable. [Caster](#) is defined as the amount the strut assembly is 'tilted' (in side view) from the strut datum position.

The front view instant centre (roll centre) is approximated by the strut rod axis and the driveshaft.

The side view instant centre is approximated by the strut rod axis and the trailing links.



4.20.5 Dual-axis strut



A variation of the classic strut with a separate hub carrier. The strut is held in alignment with an anti-rotation link, and the hub carrier is steered in the conventional way by the steering linkage.

There are four chassis mounting points, one for the strut rod top mounting, two for the lower A-arm and one for the steering tie rod (which can be either the end of the steering rack or the tie rod mounting on the steering linkage).

The strut has two mounting points for the hub carrier (which are equivalent to the upper and lower kingpin points), one for the strut rod top mounting, one bottom A-arm and the anti-rotation link.

The hub carrier has two mounting points for the upper and lower attachment to the strut, and one for the steering tie rod.

The coil spring is most commonly mounted on the strut, but it can also be specified as a separate spring.

The A-arm has an additional mounting point for the anti-rotation link.

The [kingpin inclination \(KPI\)](#) and [caster](#) are measured from the hub carrier upper and lower mounting points.

4.21 Live / de Dion / rigid axle

There are four basic configurations, with each configuration as either "live axle", "de Dion" or "Rigid" or "Winters"

A live axle includes a crown wheel and pinion and provides drive to the wheels.

A de Dion axle has a separate (generally chassis mounted) differential with universal jointed driveshafts to the wheels.

A rigid axle (also known as a dead axle) has no provision for driving the wheels.

The Winters, or speedway, axle combines a torque tube and centre section with a single open axle shaft. The locating links are all attached to birdcages.

For front suspensions, the longitudinal links lead from the chassis forwards to the axle and are known as "leading links"; for rear suspensions, the longitudinal links trail from the chassis rearwards to the axle and are known as "trailing links".

The following configurations are supported for front suspension

- 2 leading arms with Mumford linkage, Panhard rod, or Watts linkage.
- 3 or 4 leading links with Mumford linkage, Panhard rod, or Watts linkage.

The following configurations are supported for rear suspension

- 2 trailing arms with Mumford linkage, Panhard rod (NASCAR style) or Watts linkage (Alfetta style).
- 3 or 4 trailing links with Mumford linkage, Panhard rod, or Watts linkage.
- 4 trailing links, with at least one pair converging (in plan view) to provide the lateral location.
- Torque arm, four trailing links and birdcage with Panhard rod or Watts linkage (live axle only)
- Torque arm, two trailing links and torque arm slider with Panhard rod or Watts linkage (live axle only)
- Torque tube with Panhard rod or Watts linkage (live axle only)
- Winters axle, four trailing links, 2 birdcages and Jacobs ladder

When a torque arm axle is specified (in conjunction with a Panhard rod or Watts linkage) the lateral location of the axle is determined by the Panhard rod or Watts linkage and the torque arm slider; the primary fore and aft location of the axle is by the two trailing links; and the "tilt" of the axle is controlled by the torque arm slider in its chassis mounting.

The axle housing and the torque arm are considered to be a single rigid entity.

The torque arm is generally on the vehicle centreline in plan view.

When a torque tube axle is specified (in conjunction with a Panhard rod or Watts linkage) the lateral location of the axle is determined by the Panhard rod or Watts linkage and the torque tube ball joint; the primary fore and aft location of the axle is by torque tube ball joint; and the "tilt" of the axle is controlled by the torque tube.

The axle housing and the torque tube are considered to be a single rigid entity.

The torque tube is generally on the vehicle centreline in plan view.

With the Winters style torque tube axle the lateral location is determined by the Jacobs ladder, the fore and aft location by the four trailing links (which are often arranged in a Z with the top link trailing and the bottom link leading) and the "tilt" of the axle is controlled by the torque tube. There is a small amount of variation in the torque tube length and in deflection of the torque tube to the centre

section. The internal driveshaft is usually splined at the torque tube ball end and connected to a "spherical" spline at the centre section end to allow for this.

When 2 trailing / leading arms are specified (in conjunction with a Mumford linkage, Panhard rod or Watts linkage) the lateral location of the axle is determined by the Mumford linkage, Panhard rod or Watts linkage; the primary fore and aft location of the axle is by the pair of trailing / leading arms; and the "tilt" of the axle is controlled by the trailing / leading arms.

The trailing / leading arms generally converge (in plan view) and can mount to a common or individual chassis mounting(s).

When 3 or 4 trailing / leading links are specified (in conjunction with a Panhard rod, Mumford or Watts linkage) the lateral location of the axle is determined by the Panhard rod, Mumford or Watts linkage; the primary fore and aft location of the axle is by the lower pair of trailing / leading links; and the "tilt" of the axle is controlled by the upper trailing / leading link(s).

Any compliance will be in the upper pair of links.

The trailing / leading links are generally parallel to the vehicle centreline in plan view.

When 4 trailing links are specified (without a Panhard rod, Mumford or Watts linkage) it will be assumed that the lateral location of the axle is determined by the pair of trailing links with the smaller axle separation distance – the lateral link pair; the primary fore and aft location of the axle is by the pair of trailing links with the greater axle separation distance – the fore and aft link pair; and the "tilt" of the axle is controlled by the lateral link pair.

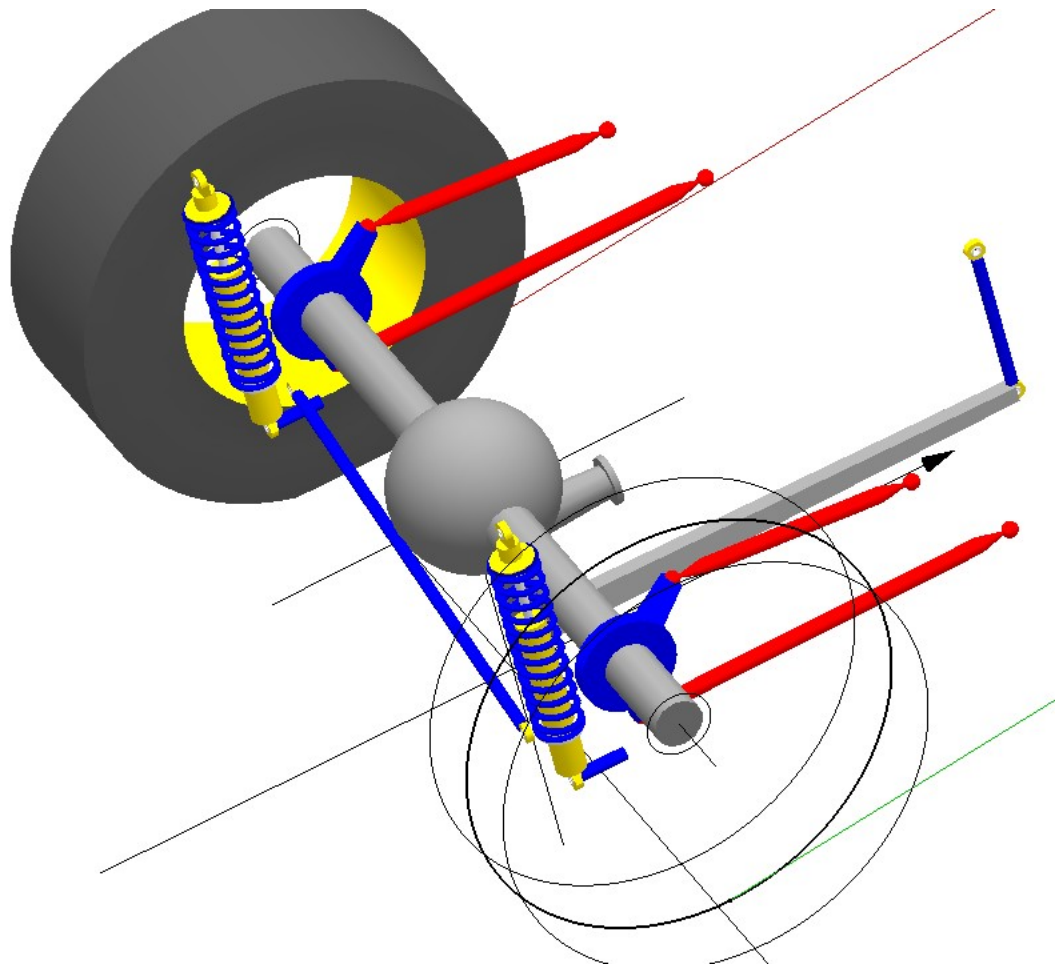
Any compliance will be in the lateral link pair.

Where it is not possible to locate the axle such that all links would connect without error, then the axle will adopt a "mid way" position, so that the amount that one link is "compressed" is equal to the amount the other link is "extended". This presumes that the axle is torsionally stiff and that this deflection (compliance) is accommodated in the links themselves or in the link bushes.

The total of this "compression" and "extension" is called "compliance" and will be shown in the roll and bump output.

This also applies to the "bottom A arm" configuration as used by the early Lotus Cortina, where the bottom pair of links provides lateral location, with the upper pair of links providing both fore and aft and the "rotation" location. In this configuration, there will not be any link error in the upper links.

4.21.1 Torque arm + 4 trailing links and birdcage + Panhard rod



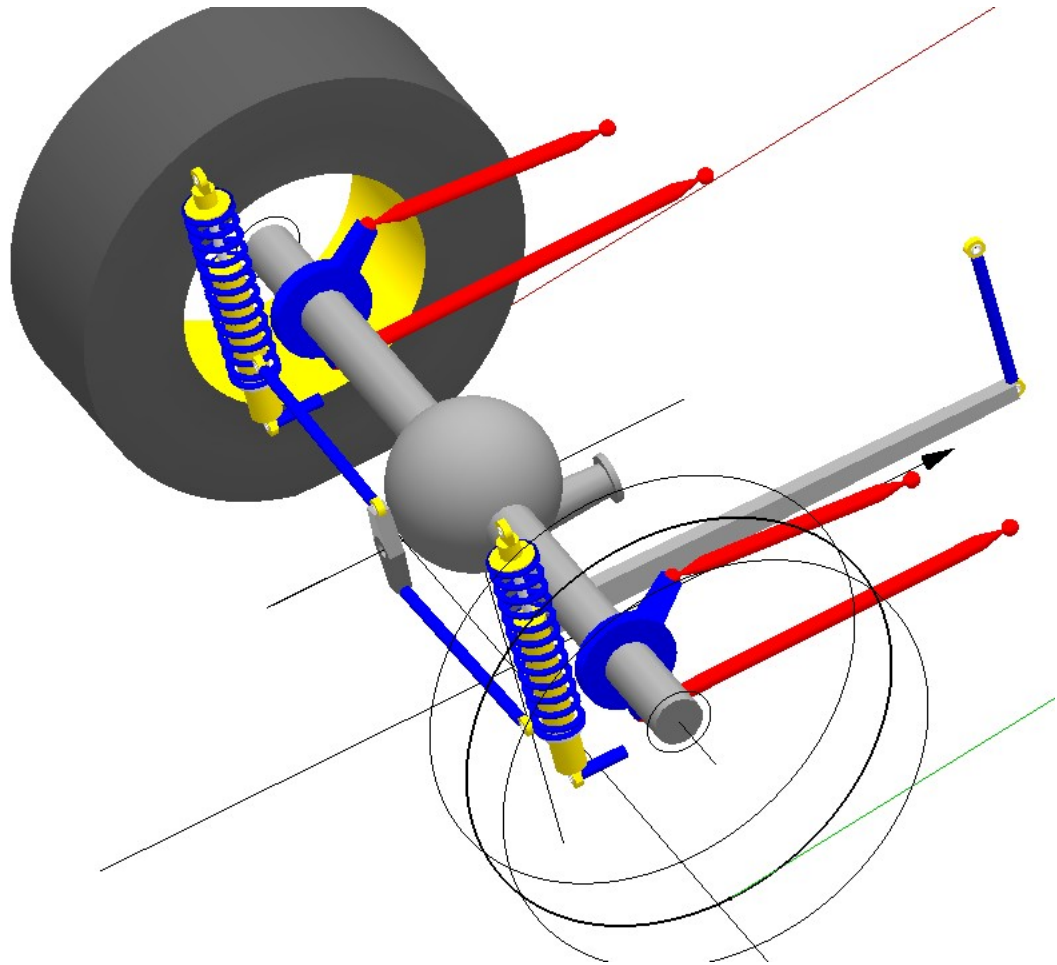
The four trailing links are connected to the axle with a birdcage. The birdcage is axially located and free to rotate on the axle tube.

The axle is located sideways with a Panhard rod and vertically with a link from the torque arm to the chassis.

Six chassis mounting points: four for the trailing links, one for the torque arm link, and one for the Panhard rod.

Six axle mounting points: four for the trailing links (on the birdcage), one for the the torque arm link, and one for the Panhard rod (on the axle).

4.21.2 Torque arm + 4 trailing links and birdcage + Watts linkage



The four trailing links are connected to the axle with a birdcage. The birdcage is axially located and free to rotate on the axle tube.

The axle is located sideways with a Watts linkage and vertically with a link from the torque arm to the chassis.

The Watts linkage can be either “axle mounted” or “chassis mounted”. This refers to the location of the Watts lever pivot axis.

Axle mounted Watts link pivot.

Seven chassis mounting points: four for the trailing links, one for the torque arm link, and two for the Watts links.

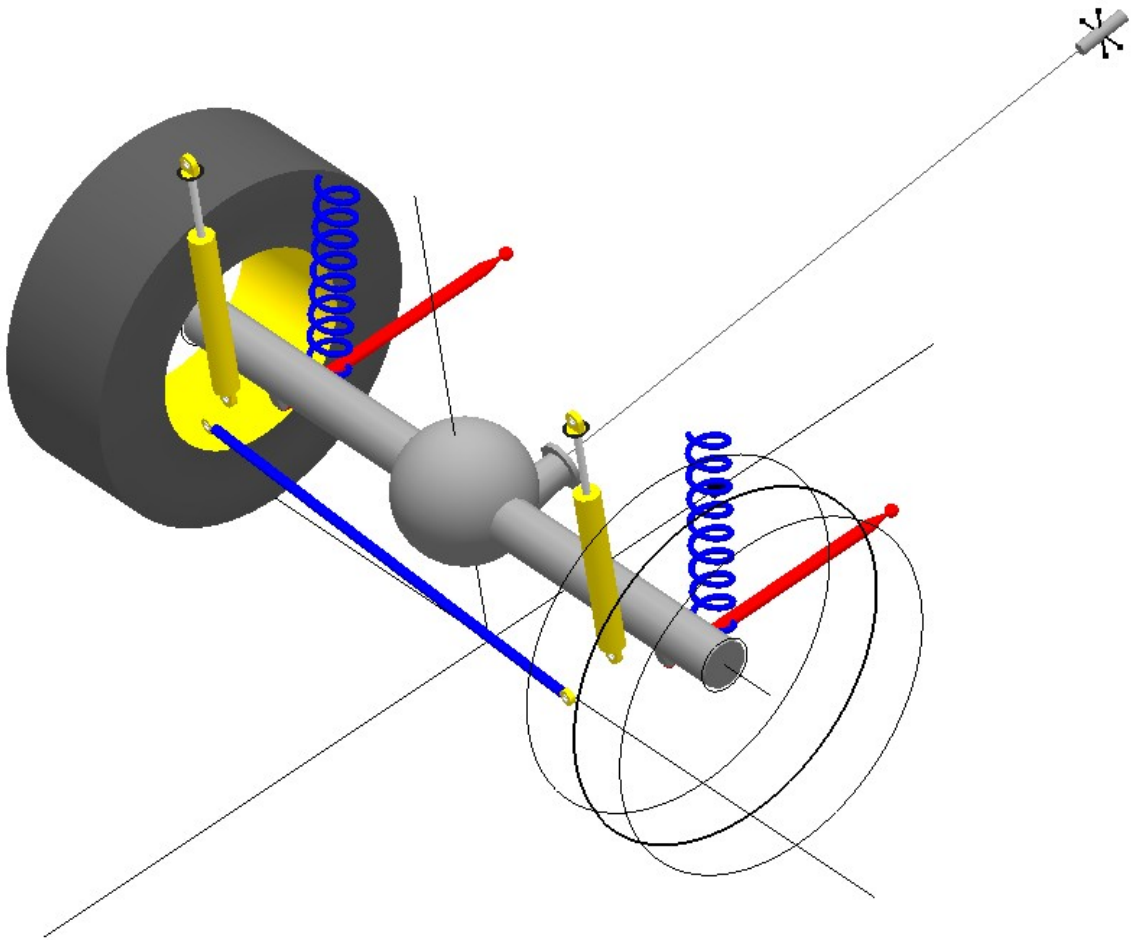
Seven axle mounting points: four for the trailing links (on the birdcage), one for the the torque arm link, and two for the Watts pivot of which one is a reference point to determine the Watts pivot axis.

Chassis mounted Watts link pivot.

Seven chassis mounting points: four for the trailing links, one for the torque arm link, and two for the Watts pivot of which one is a reference point to determine the Watts pivot axis.

Seven axle mounting points: four for the trailing links (on the birdcage), one for the the torque arm link, and two for the Watts links (on the axle).

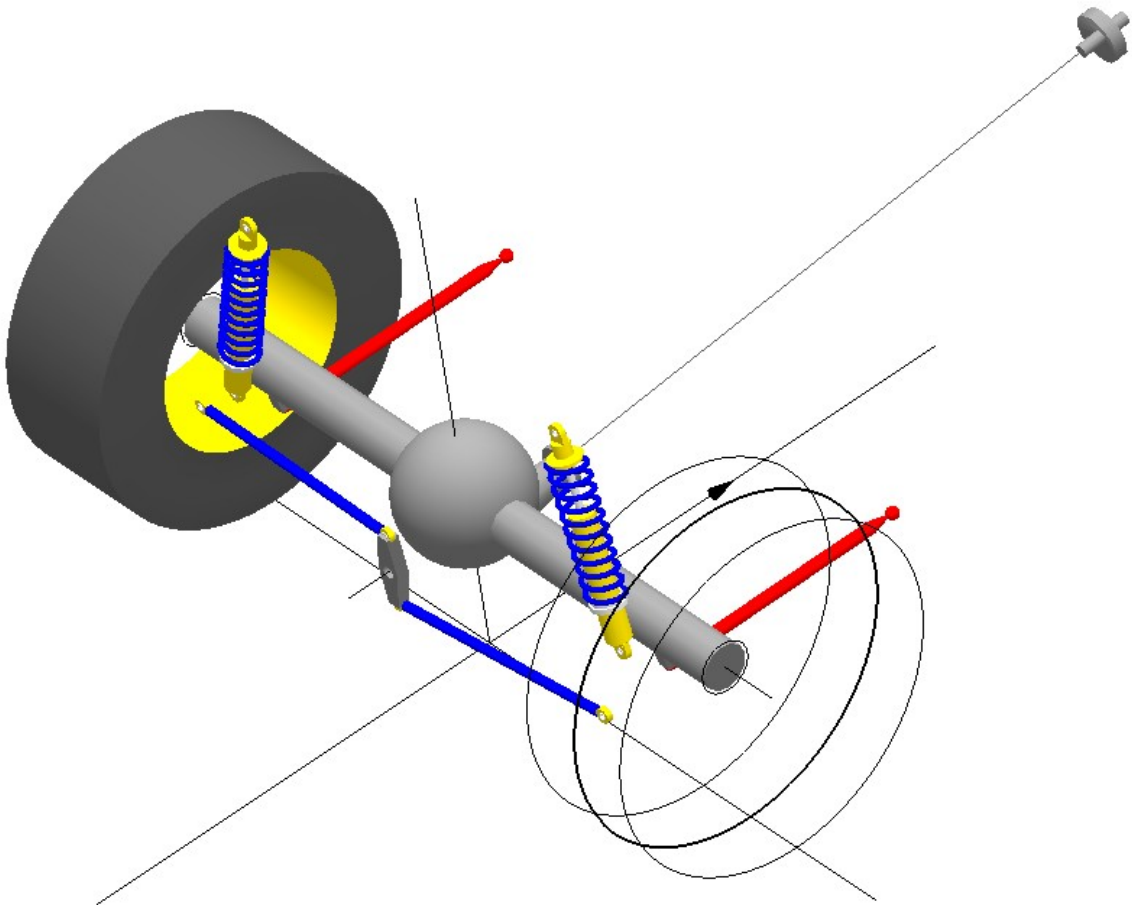
4.21.3 Torque arm slider + Panhard rod



Four chassis mounting points: one for the torque arm slider bearing, one for each trailing link, one for the Panhard rod.

Five axle mounting points: two for the torque arm slider of which one is reference point to determine the slider axis, one for each trailing link, one for the Panhard rod.

4.21.4 Torque arm slider + Watts linkage



The Watts linkage can be either “axle mounted” or “chassis mounted”. This refers to the location of the Watts lever pivot axis.

Axle mounted Watts link pivot.

Five chassis mounting points: one for the torque arm slider bearing, one for each trailing link, one for each Watts lateral link.

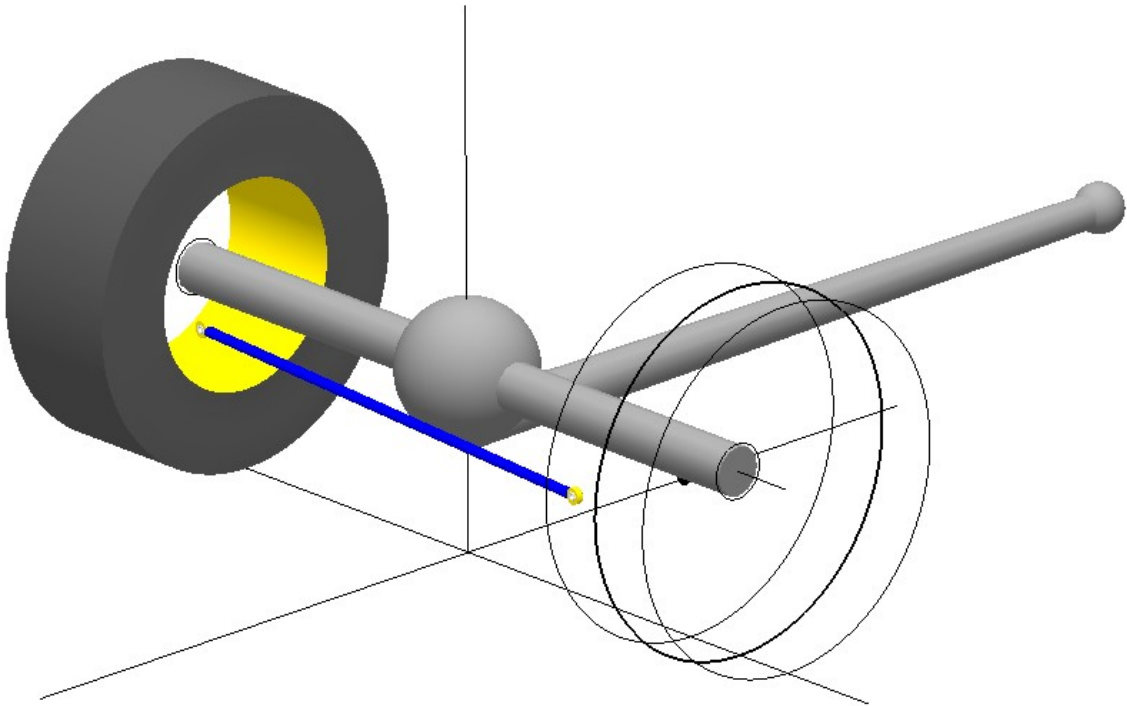
Six axle mounting points: two for the torque arm slider of which one is a reference point to determine the slider axis, one for each trailing link, and two for the Watts pivot of which one is a reference point to determine the pivot axis.

Chassis mounted Watts link pivot.

Five chassis mounting points: one for the torque arm slider bearing, one for each trailing link, and two for the Watts pivot of which one is a reference point to determine the pivot axis.

Six axle mounting points: two for the torque arm slider of which one is a reference point to determine the slider axis, one for each trailing link, one for each Watts lateral link.

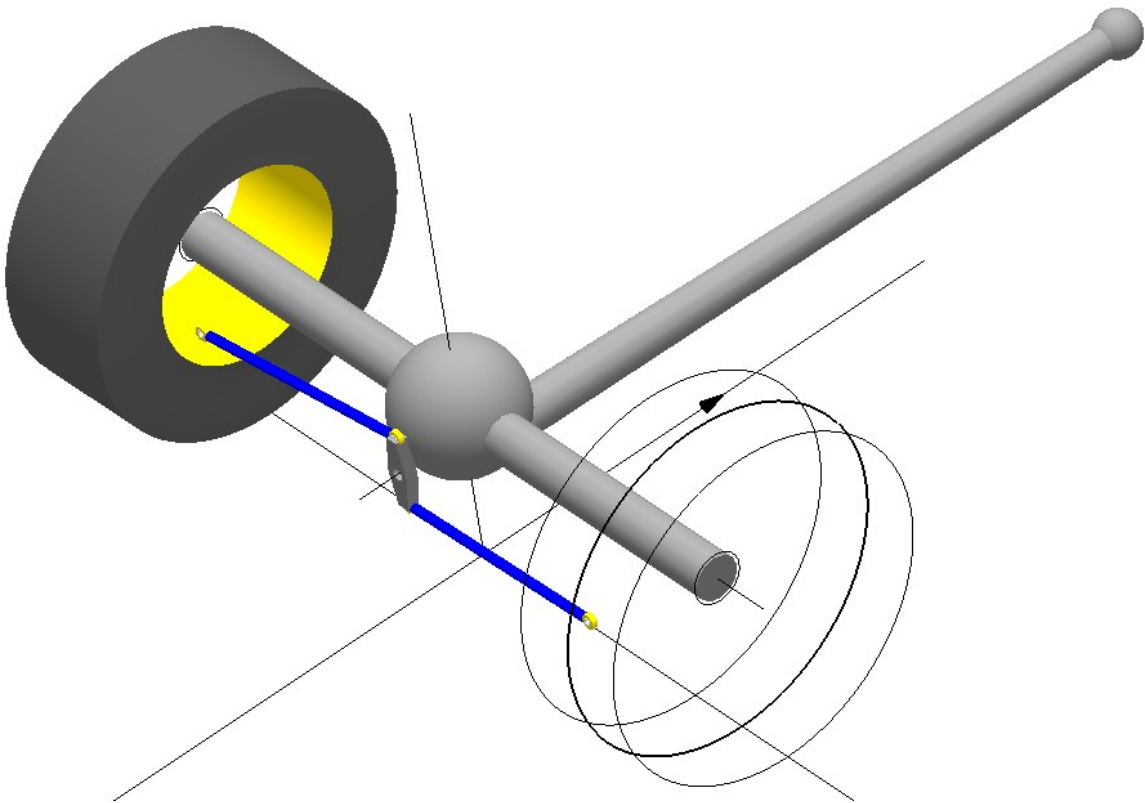
4.21.5 Torque tube + Panhard rod



Two chassis mounting points, one for the torque tube ball joint, and one for the Panhard rod. The torque tube mounting can be the same point as the rear gearbox universal.

Two axle mounting points, one for torque tube ball joint, one for the Panhard rod.

4.21.6 Torque tube + Watts linkage



The Watts linkage can be either “axle mounted” or “chassis mounted”. This refers to the location of the Watts lever pivot axis.

Axle mounted Watts link pivot.

Three chassis mounting points: one for the torque tube ball joint, one for each Watts lateral link.

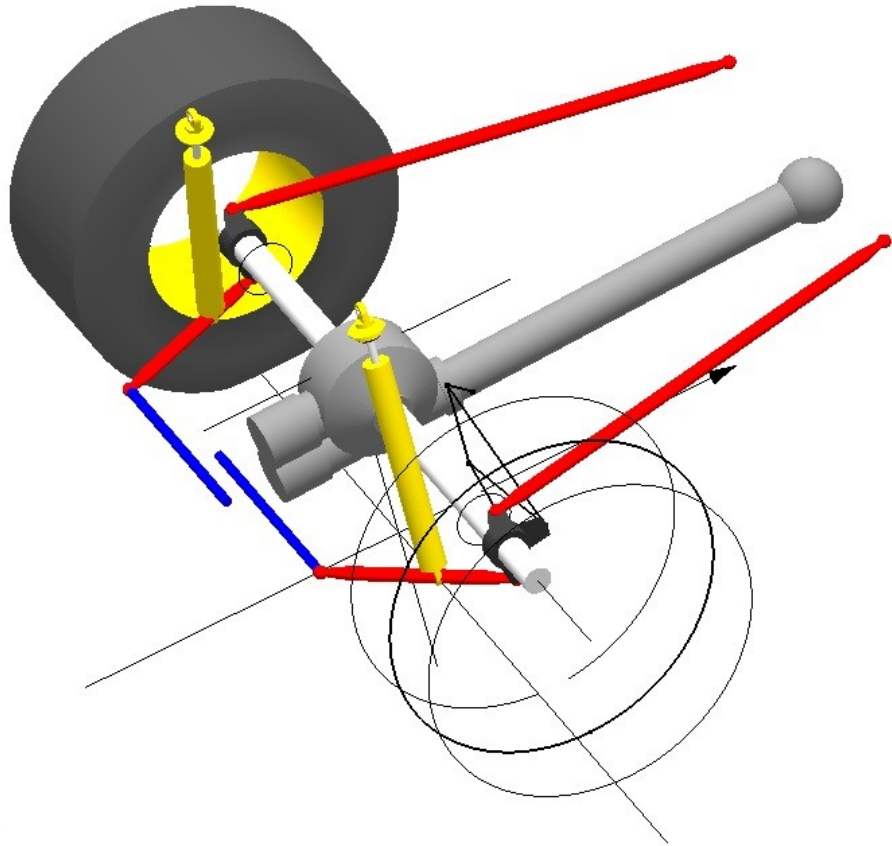
Three axle mounting points: one for torque tube ball joint, and two for the Watts pivot of which one is a reference point to determine the pivot axis.

Chassis mounted Watts link pivot.

Three chassis mounting points: one for the torque tube ball joint, and two for the Watts pivot of which one is a reference point to determine the pivot axis.

Three axle mounting points, one for torque tube ball joint, one for each Watts lateral link.

4.21.7 Winters: 4 trailing links, 2 birdcages + Jacobs ladder



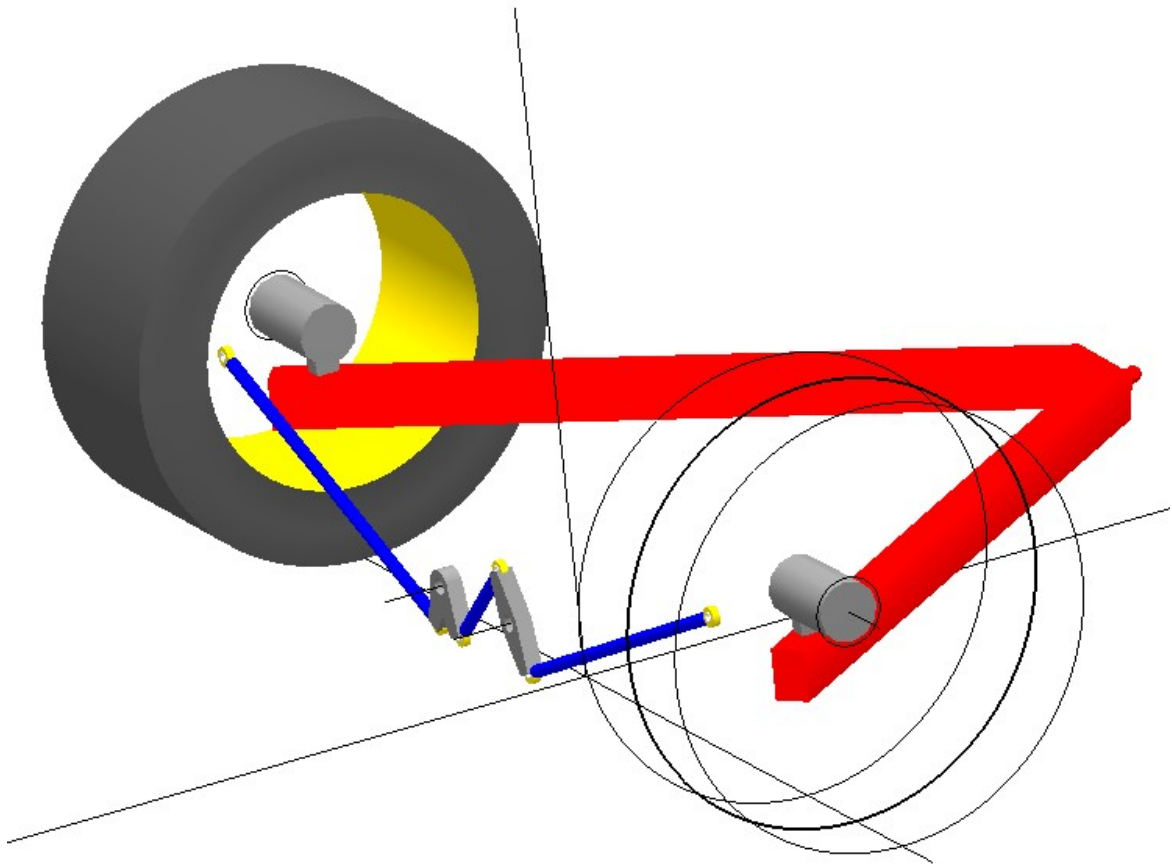
This is the typical speedway midget rear suspension. The axle is open style with the suspension links attached to a birdcage on each side. A Jacobs ladder is used for lateral location. The longitudinal links are usually arranged in a "Z" with the top link trailing and the bottom link leading.

The Winters rear axle is typical with the torque tube ball joint located just behind the crankshaft and offset to the left.

There are seven chassis mounting points: one for each trailing / leading link, two for the Jacobs ladder, and one for the torque tube ball joint.

There are six axle mounting points: one for each trailing / leading link, one for the Jacobs ladder, all on a birdcage, plus the torque tube ball joint.

4.21.8 2 trailing arms + Mumford linkage



Rear suspension is configured with two trailing arms.

The two trailing / leading arm mountings can be a single point.

The Mumford linkage can be either “axle mounted” or “chassis mounted”. This refers to the location of the Mumford bellcrank and lever pivots.

Chassis mounted Mumford linkage.

Four or five chassis mounting points: one for each trailing arm(s), three for the Mumford pivots of which one is a reference point to determine the bellcrank pivot axis.

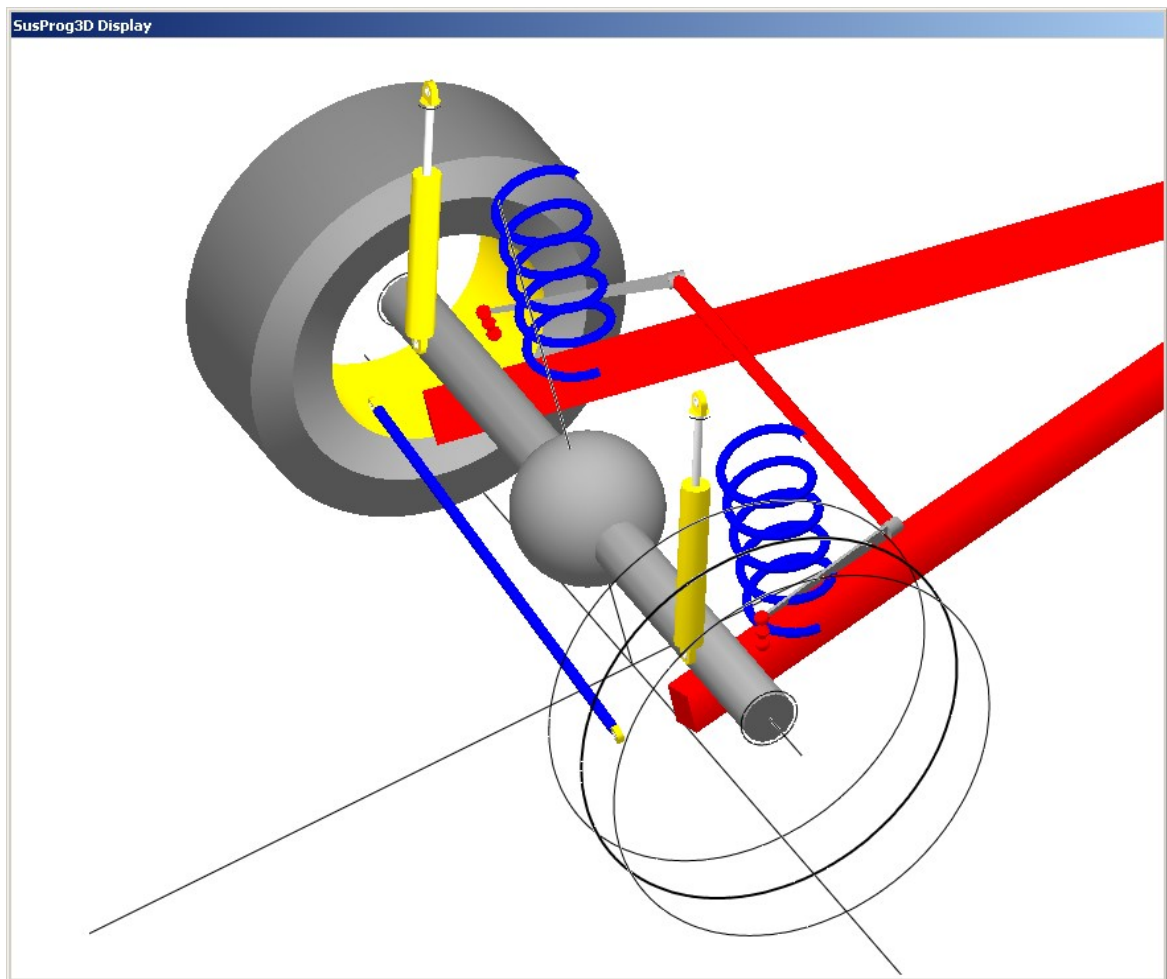
Four axle mounting points: one for each trailing arm, one for each Mumford lateral link.

Axle mounted Mumford linkage.

Three or four chassis mounting points: one for each trailing arm(s), one for each Mumford lateral link.

Five axle mounting points: one for each trailing arm(s), three for the Mumford pivots of which one is a reference point to determine the bellcrank pivot axis.

4.21.9 2 trailing arms + Panhard rod

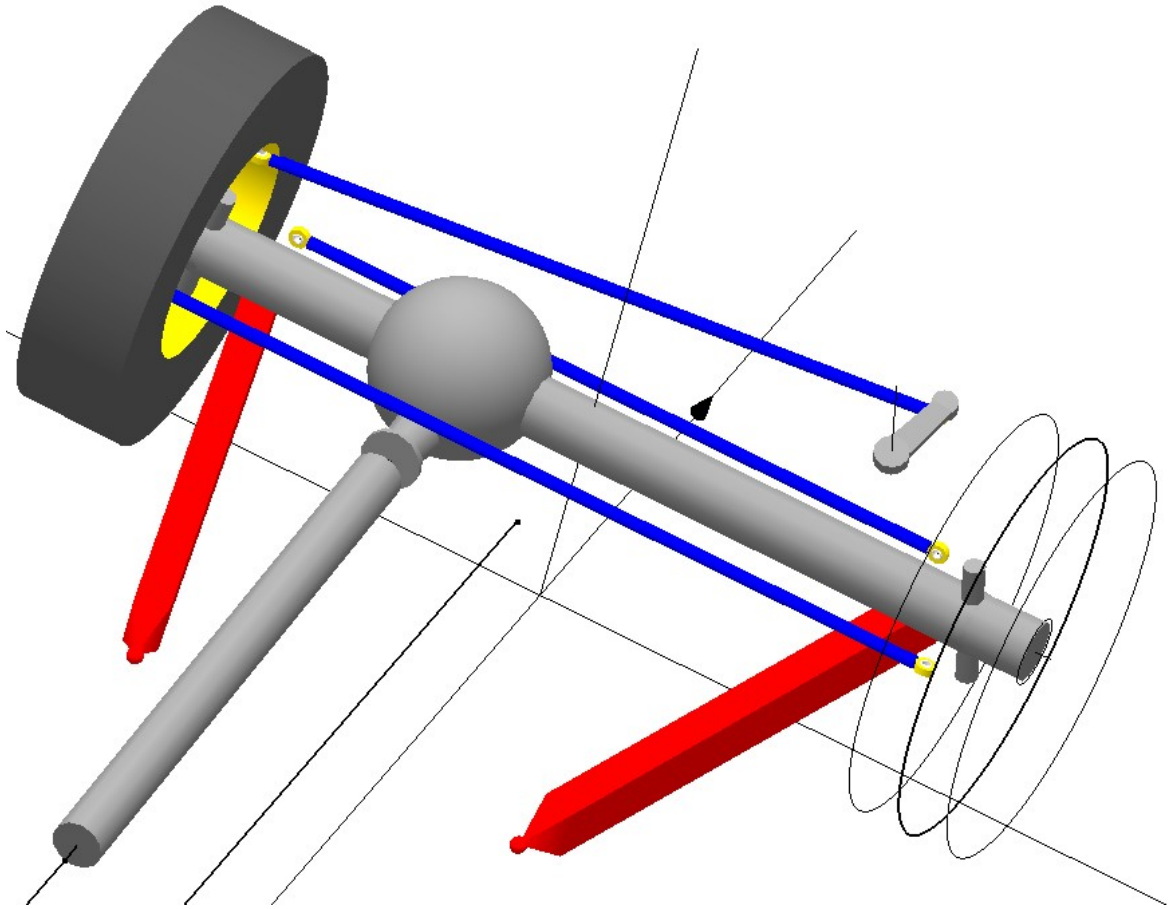


Typical twin trailing arm and Panhard rod rear suspension configured with two trailing arms.

The two trailing / leading arm mountings can be a single point.

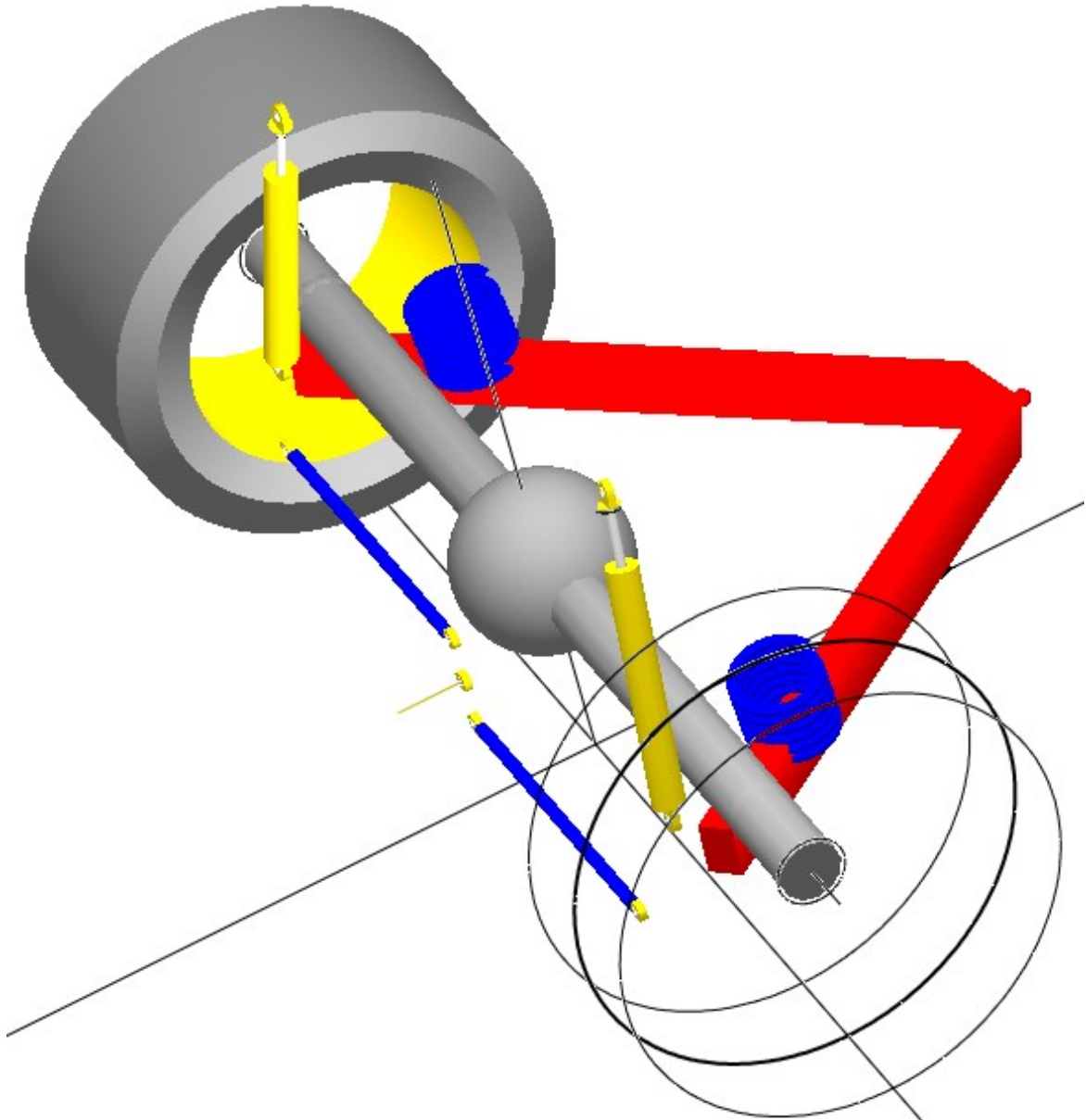
Two or three chassis mounting points: one for each trailing / leading arm(s), one for the Panhard rod.

Three axle mounting points: one for each trailing / leading arm, one for the Panhard rod.



Typical twin trailing arm and Panhard rod front suspension configured with two leading arms.

4.21.10 2 trailing arms + Watts linkage



The two trailing arm mountings can be a single point.

The Watts linkage can be either “axle mounted” or “chassis mounted”. This refers to the location of the Watts lever pivot axis.

Axle mounted Watts link pivot.

Three or four chassis mounting points: one for each trailing arm(s), one for each Watts lateral link.

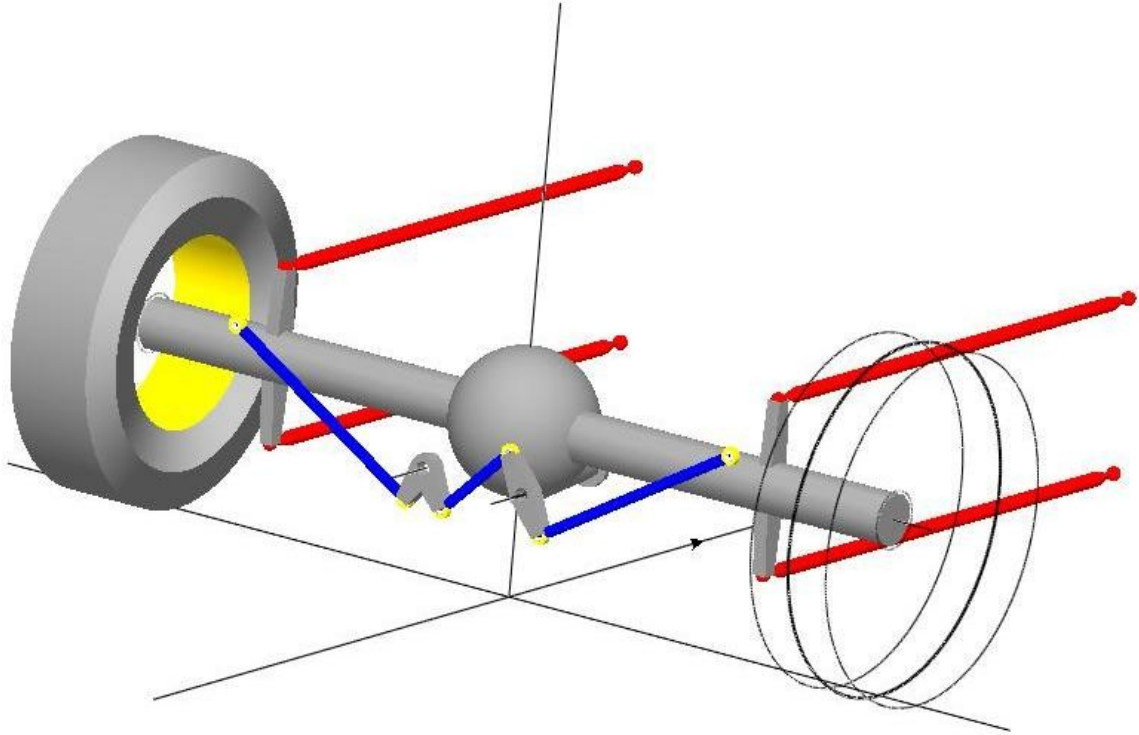
Four axle mounting points, one for each trailing arm, and two for the Watts pivot of which one is a reference point to determine the pivot axis.

Chassis mounted Watts link pivot.

Four chassis mounting points: one for each trailing arm, and two for the Watts pivot of which one is a reference point to determine the pivot axis.

Three or four chassis mounting points: one for each trailing arm, one for each Watts lateral link.

4.21.11 3 or 4 links + Mumford linkage



The 3 trailing link configuration has only one top link which can be located on the left or right side, or centrally.

The Mumford linkage can be either “axle mounted” or “chassis mounted”. This refers to the location of the Mumford bellcrank and lever pivots.

Chassis mounted Mumford linkage.

Six or seven chassis mounting points: three or four for the trailing links, three for the Mumford pivots of which one which is a reference point to determine the bellcrank pivot axis.

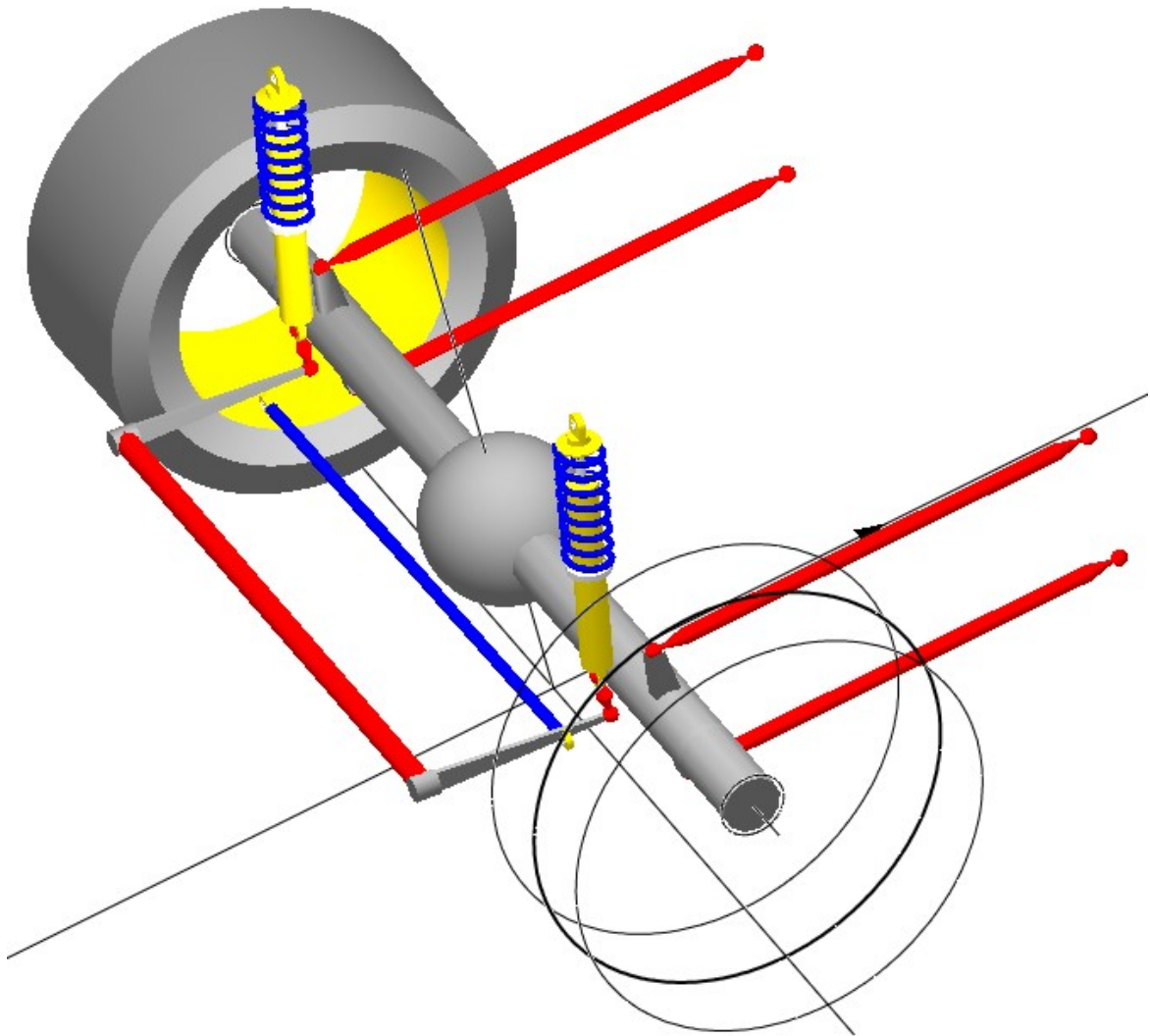
Five or six axle mounting points: three or four for the trailing links, one for each Mumford lateral link.

Axle mounted Mumford linkage.

Five or six chassis mounting points: three or four for the trailing links, one for each Mumford lateral link.

Six or seven axle mounting points: three or four for the trailing links, three for the Mumford pivots of which one is a reference point to determine the bellcrank pivot axis.

4.21.12 3 or 4 links + Panhard rod

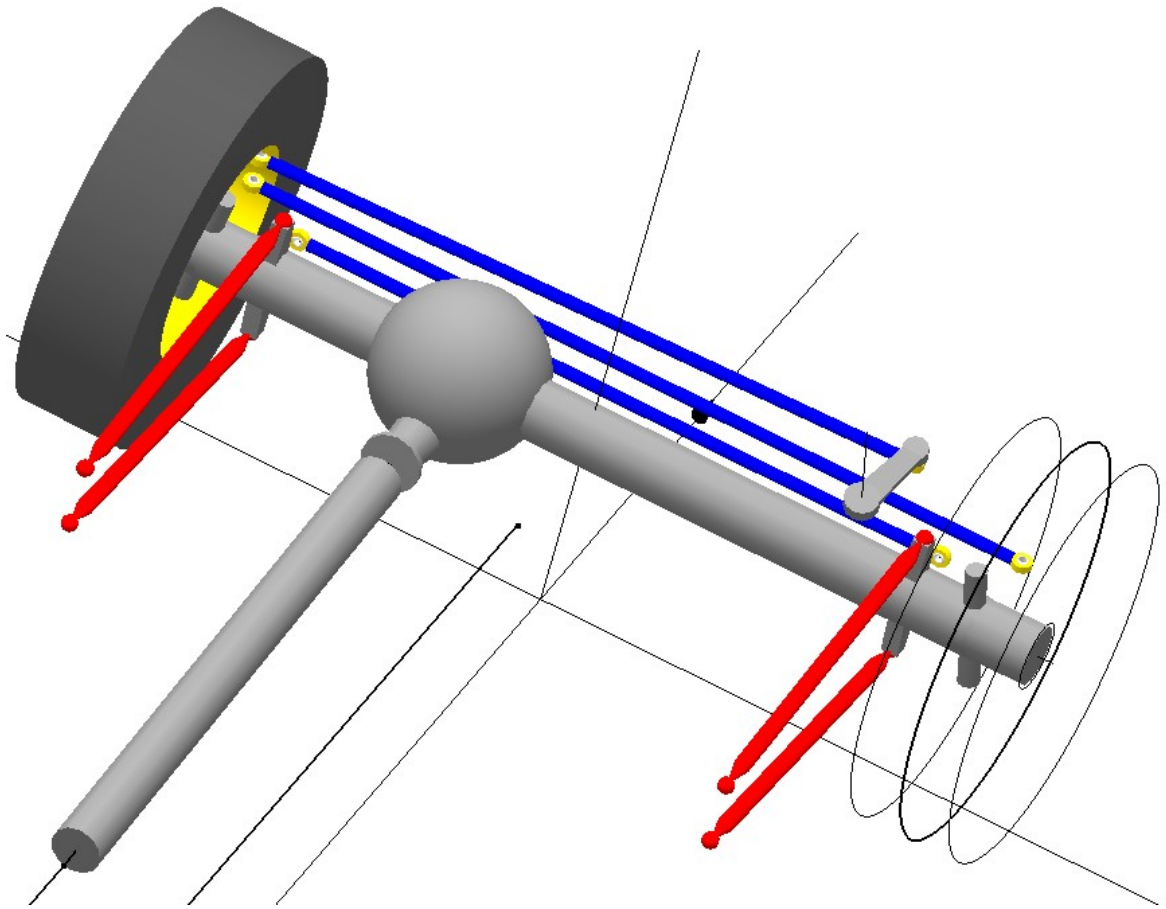


Typical rear suspension with 4 trailing links and Panhard rod.

The 3 trailing / leading link configuration has only one top link which can be located on the left or right side, or centrally.

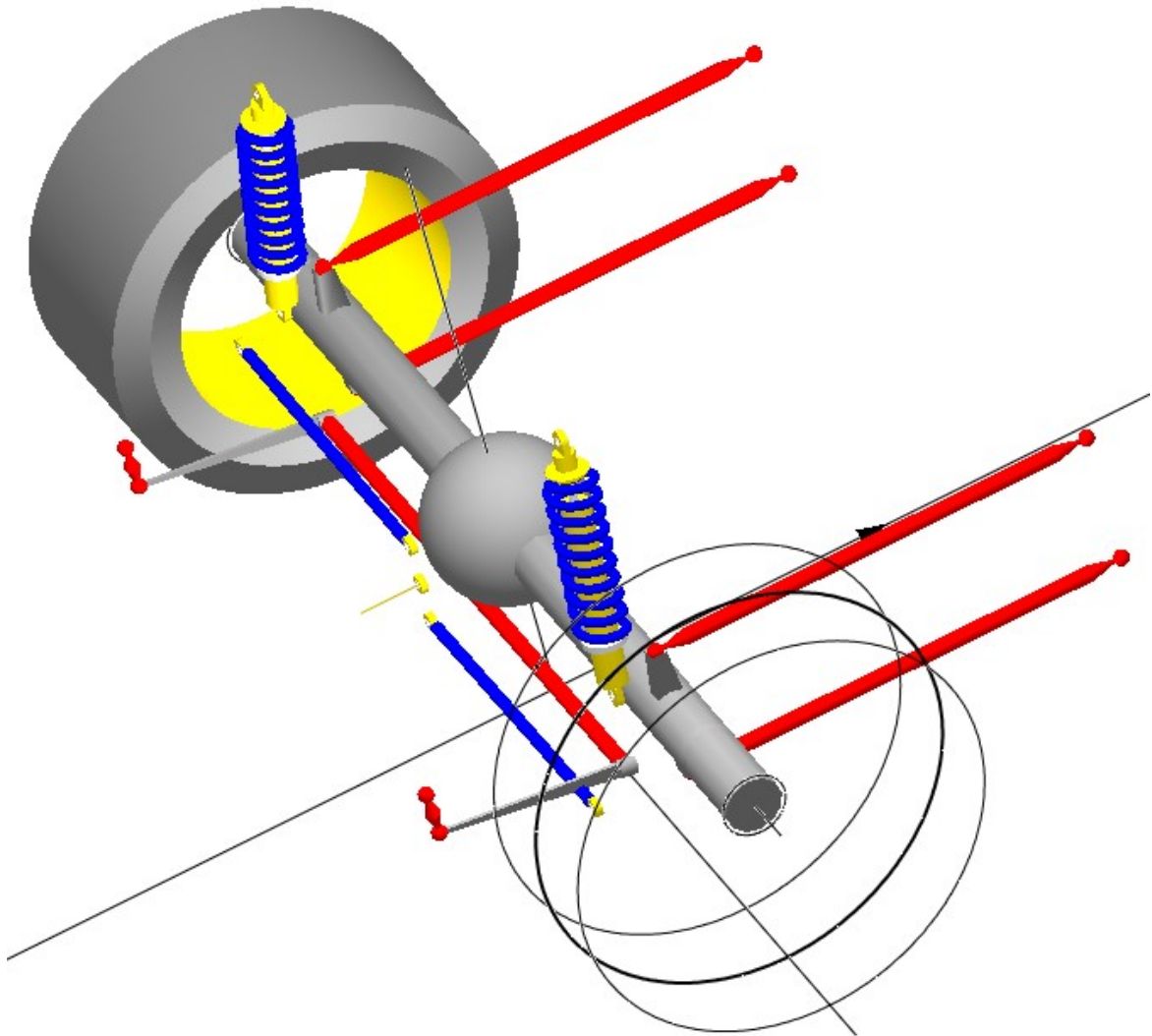
Four or five chassis mounting points: one for each trailing / leading link, one for the Panhard rod.

Four or five axle mounting points: one for each trailing / leading link, one for the Panhard rod.



Typical front suspension with 4 leading links and Panhard rod.

4.21.13 3 or 4 links + Watts linkage



The 3 trailing link configuration has only one top link which can be located on the left or right side, or centrally.

The Watts linkage can be either “axle mounted” or “chassis mounted”. This refers to the location of the Watts lever pivot axis.

Axle mounted Watts link pivot.

Five or six chassis mounting points: one for each trailing link, one for each Watts lateral link.

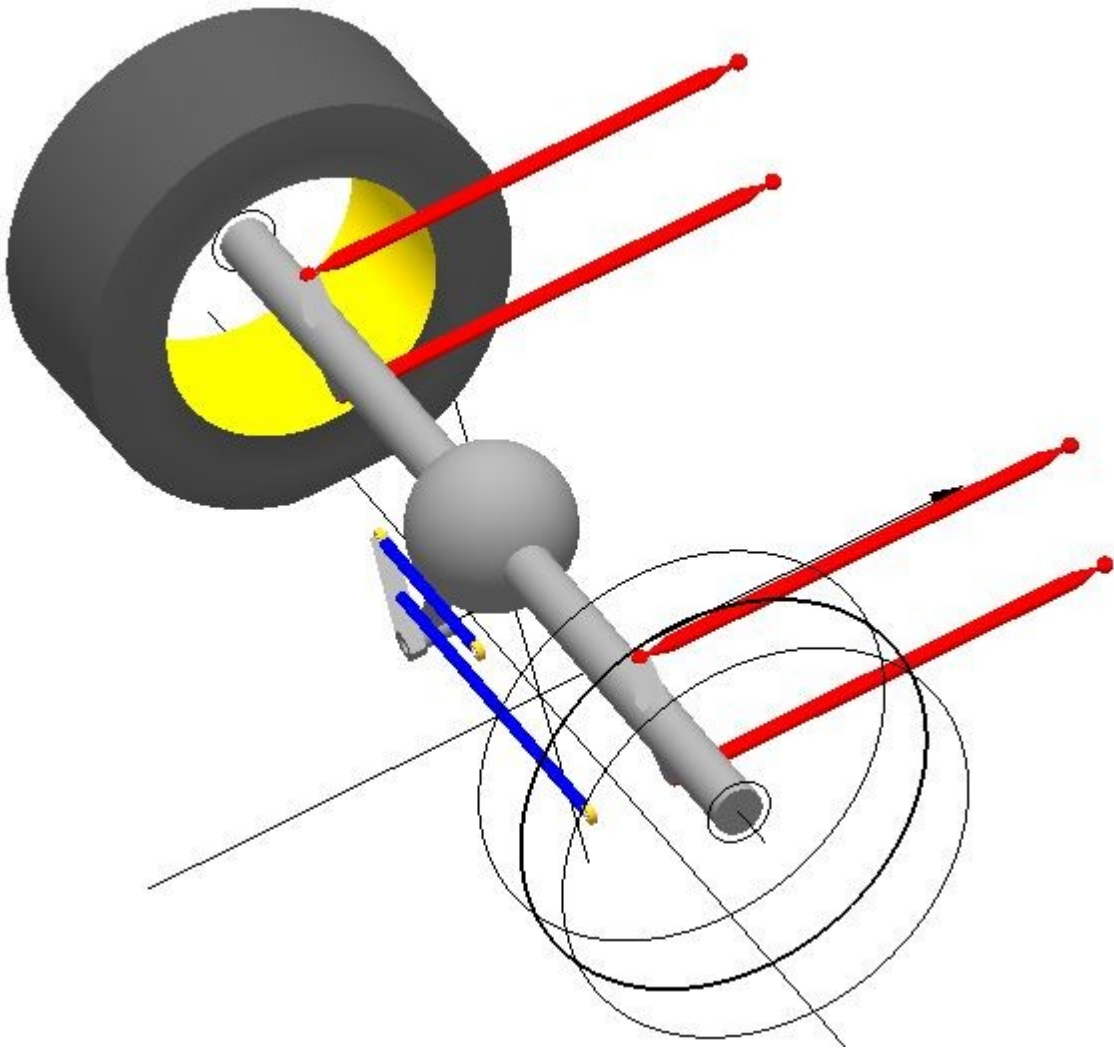
Five or six axle mounting points: one for each trailing link, and two for the Watts pivot of which one is a reference point to determine the pivot axis.

Chassis mounted Watts link pivot.

Five or six chassis mounting points: one for each trailing link, and two for the Watts pivot of which one is a reference point to determine the pivot axis.

Five or six chassis mounting points: one for each trailing link, one for each Watts lateral link.

4.21.14 3 or 4 links + Woblink



The 3 trailing link configuration has only one top link which can be located on the left or right side, or centrally.

The Woblink can be either “axle mounted” or “chassis mounted”. This refers to the location of the Woblink lever pivot axis.

Axle mounted Woblink pivot.

Five or six chassis mounting points: one for each trailing link, one for each Woblink lateral link.

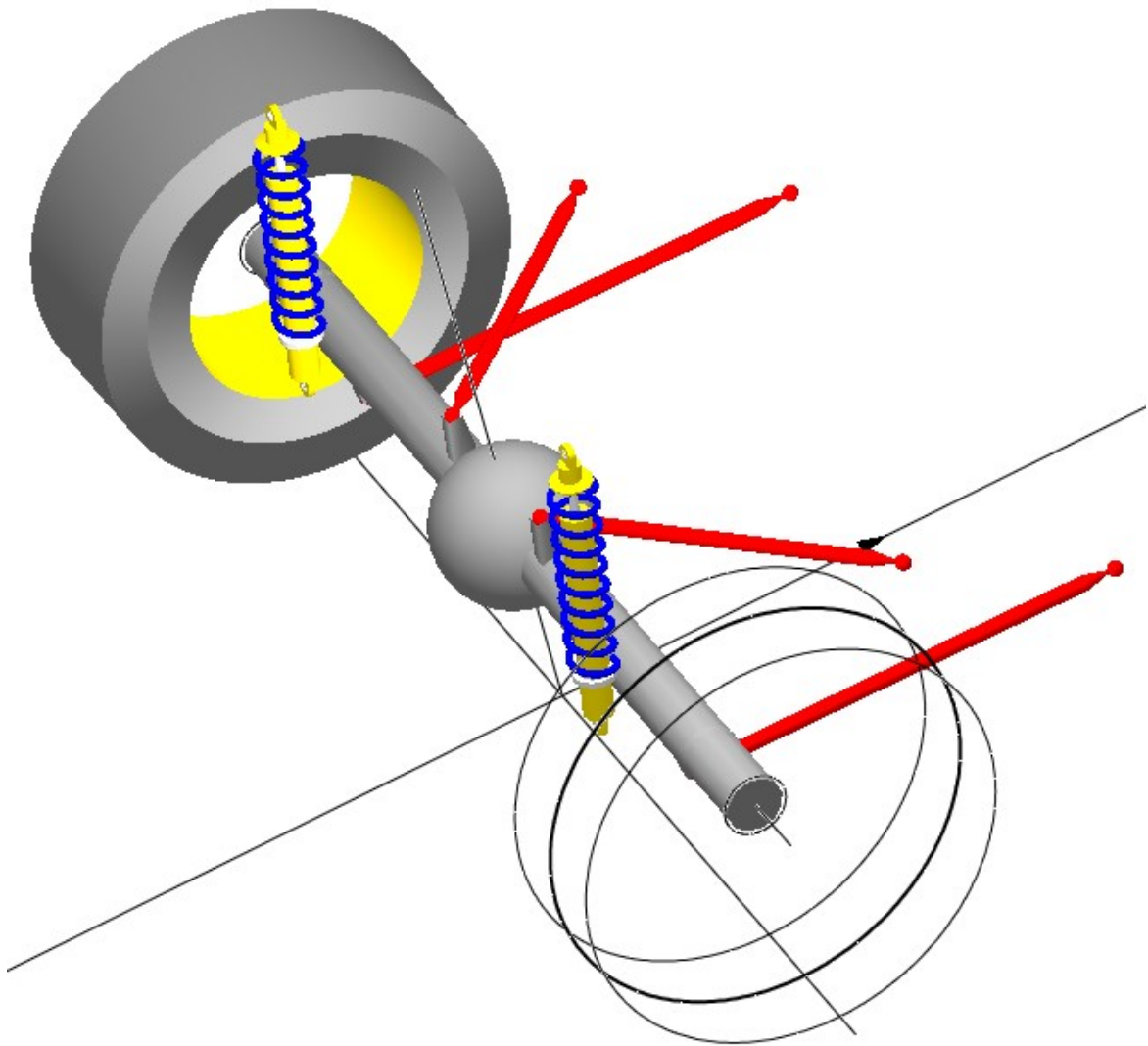
Five or six axle mounting points: one for each trailing link, and two for the Woblink pivot of which one is a reference point to determine the pivot axis.

Chassis mounted Woblink pivot.

Five or six chassis mounting points: one for each trailing link, and two for the Woblink pivot of which one is a reference point to determine the pivot axis.

Five or six axle mounting points: one for each trailing link, one for each Woblink lateral link.

4.21.15 4 links

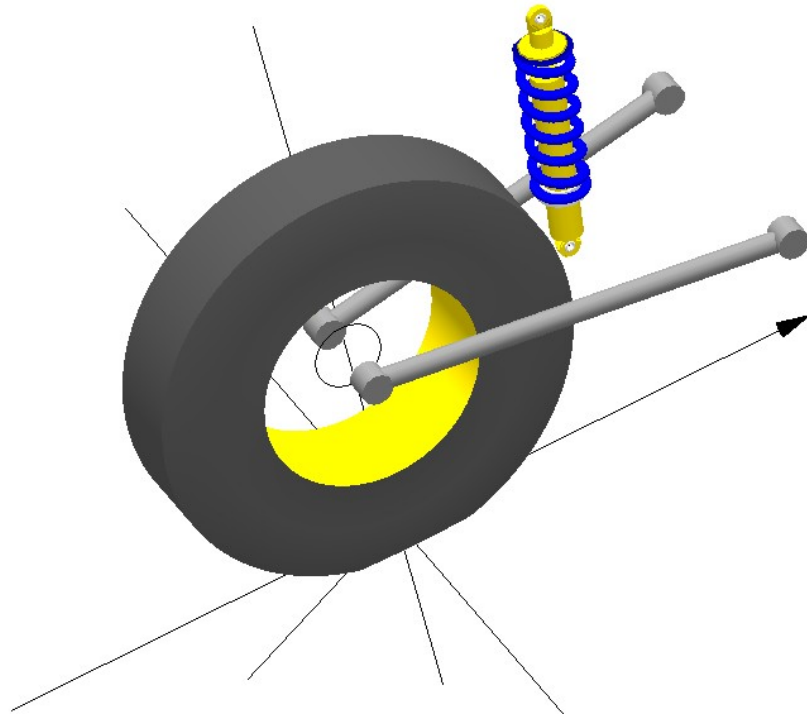


In some configurations, either the upper pair or the lower pair of links is arranged as an A-arm with a single mounting.

There are four chassis mounting points, one for each trailing link.

There are four axle mounting points, one for each trailing link.

4.22 Mono wheel - trailing arm



Two chassis mounting points for the trailing arm.

In this configuration, the axle hub, spindle and trailing arm are combined into a single assembly with the trailing arm attached to the chassis at two mounting points. The front view instant centre (roll centre) is on the ground on the wheel centreline, and the side view instant centre is on the trailing arm chassis pivot.

Generally, the trailing arm has a pivot axis at right angles to the vehicle centreline. The rear suspension on most motorcycles and quad bikes is a typical example.

5 Vehicle

Sets the basic vehicle parameters

Config	Specify the basic vehicle suspension
Datum	Specify the chassis measurement datum
Wheelbase	Specify the wheelbase
Ride height	Specify the ride height location points, and the ride height
Mass	Specify and calculate the mass distributions
Wheel and tyre	Specify the wheel and tyre sizes
Data	Print the vehicle data
Graphic	Print the vehicle graphic
ECalc	Specify the modules and calculate

5.1 Configure

From the Vehicle tab, select Config.

For each of the front and rear of the vehicle,

- select the [suspension type](#)
- specify where the brakes are located, either inboard or outboard. Live and rigid rear axles will default to outboard brake location.
- enter the front wheel brake force percentage. This can be done by either entering a value (in the range 0 to 100) in the "front %" edit box,

or by picking the slider and moving it left (to decrease the front brake %) or right (to increase the front brake %).

- specify if the vehicle is front wheel drive or rear wheel drive.
Select both for four wheel drive.
Both Jaguar, de Dion and live axle rear suspensions will default to rear wheel drive.
Rigid axles will disable drive at that end of the vehicle.
- if the vehicle is 4WD, enter the front axle drive torque percentage.
This can be done by either entering a value (in the range 0 to 100) in the "front %" edit box, or by picking the slider and moving it left (to decrease the front torque %) or right (to increase the front torque %).

Optionally, descriptive comments can be added for each of

- general, for the vehicle or project itself
- front suspension,
- rear suspension
- front wheel and tyre
- rear wheel and tyre

Vehicle configuration must be specified before any data is entered or calculated.

Depending on the particular components selected, some tab items may not be available.

5.2 Datum

From the Vehicle tab, select Datum.

The vehicle reference datums are fixed. The vertical datum is the ground, the horizontal datum is the vehicle centreline, and the longitudinal datum is a plane through the chassis longitudinal datum reference point. There is only one set of vehicle datum axes and it is used for both front and rear suspensions.

The chassis vertical and longitudinal datums can be specified; the chassis horizontal datum is the chassis centreline.

- The chassis vertical datum is a horizontal plane, usually the ground plane, chassis undertray, or some other convenient flat reference plane.
- The chassis longitudinal datum is controlled by specifying a single point, the longitudinal datum reference point.
This is a convenient point from which all longitudinal dimensions are taken. This point need not be on the chosen vertical datum plane, and can be at any convenient height. It can be on the right or the left side of the vehicle.

The chassis points are dimensioned from the chassis datum.

Both the front and rear longitudinal datum to axle centreline dimensions must be entered. These can initially be an approximation, and are used to calculate the wheelbase. Depending on the chosen Geometry configuration, a more accurate figure may be required as part of the Alignment settings.

Chassis datum:

Vertical datum	Identify the vertical datum plane by name.
Longitudinal datum	Identify the longitudinal datum reference point by name. This could be a suspension mounting point or any convenient hard point on the chassis structure.

Longitudinal datum reference point	<p>Specify the distance the point is from the vehicle centreline (the horizontal dimension) and the height the point is above or below the vertical datum reference plane (the vertical dimension).</p> <p>A positive horizontal dimension is on the side of the vehicle with the positive horizontal axis; a negative horizontal dimension is on the side of the vehicle with the negative horizontal axis.</p> <p>If the vertical axis is +ve upward, then a positive vertical dimension is above the vertical datum plane, negative vertical dimension is below the vertical datum plane.</p> <p>If the vertical axis is +ve downward, then a negative vertical dimension is above the vertical datum plane, positive vertical dimension is below the vertical datum plane.</p>
Longitudinal datum to front axle centreline	<p>Specify the nominal distance from the longitudinal datum reference point, horizontally, to the front axle centreline.</p> <p>If the longitudinal axis is +ve rearward, then a negative dimension indicates the axle centreline is forward from the longitudinal datum reference point, and a positive dimension indicates the axle centreline is rearward from the longitudinal datum reference point.</p> <p>If the longitudinal axis is +ve forward, then a positive dimension indicates the axle centreline is forward from the longitudinal datum reference point, and a negative dimension indicates the axle centreline is rearward from the longitudinal datum reference point.</p>
Longitudinal datum to rear axle centreline	<p>Specify the nominal distance from the longitudinal datum reference point, horizontally, to the rear axle centreline.</p> <p>If the longitudinal axis is +ve rearward, then a negative dimension indicates the axle centreline is forward from the longitudinal datum reference point, and a positive dimension indicates the axle centreline is rearward from the longitudinal datum reference point.</p> <p>If the longitudinal axis is +ve forward, then a positive dimension indicates the axle centreline is forward from the longitudinal datum reference point, and a negative dimension indicates the axle centreline is rearward from the longitudinal datum reference point.</p>

Chassis datum surface:

This defines the size of the chassis datum surface. If using a ground based datum, then leave all these dimensions zero. If using a actual chassis datum, like a surface plate or a build table or jig, then this will define a rectangular surface representative of the actual chassis datum surface.

Front edge of datum surface The distance the front edge of the chassis build surface is from the longitudinal datum.

Rear edge of datum surface The distance the rear edge of the chassis build surface is from the longitudinal datum.

Datum surface width The chassis build surface width.

For further details on using a [ground based vertical datum](#).

For further details on [converting from a ground based to a chassis based vertical datum](#).

For further details on using a [chassis based vertical datum](#).

The specified [datum location can be realigned](#).

5.3 Wheelbase

From the Vehicle tab, select Wheelbase.

The vehicle wheelbase is calculated from the calculated front and rear wheel positions.

If the [wheel location point](#) is specified as "Wheel centre / axle" then the wheelbase will be shown with two sets of dimensions, one will be the "on ground" dimension and the other will be the "Wheel centre / axle" dimension.

If the wheel location point is specified as "On ground" then the wheelbase is measured on the ground between the tyre contact patch centrelines with the specified camber, castor and toe.

If the wheel location point is specified as "Wheel centre / axle" then the wheelbase is measured between then wheel centres at hub height, with the specified camber, castor and toe.

If the wheelbase is not identical on both sides, or the front wheels are not inline, or the rear wheels are not inline, then the wheelbase will be shown for both sides of the vehicle, the difference between them, and the relative positions of the front and rear wheels.

Initially, the front and rear wheels are specified relative to the chosen longitudinal datum, and these dimensions will determine the wheelbase.

The Geometry calculations can also change the longitudinal position of the wheels, and this will recalculate the wheelbase.

5.4 Ride Height

From the Vehicle tab, select Ride Height.

Specify the number and location of the ride height reference points.

If only two points are specified, the chassis will be located relative to the ground with no side rake.

Even if you are only designing one end of the vehicle, both front and rear ride height reference points must be entered, together with their static ride heights, as these dimensions control the vehicle attitude and the height of all chassis location points from the ground.

Enter the coordinates and the description of the front and rear ride height reference points relative to the chassis horizontal, vertical and longitudinal datums. These can be any convenient chassis or body point.

Ideally, the front ride height reference point(s) should be in the region of the front axle, and the rear ride height reference point(s) should be in the region of the rear axle.

Specify the height of each ride height reference point from the ground, with the vehicle in the static ride position. This will determine the all the chassis dimensions relative to the ground plane.

When the static geometry is calculated, the chassis will be aligned to the specified ride heights and all the chassis mounting points recalculated relative to the ground, with the wheel alignment set to that specified in the "Settings" dialog.

For further details on using a [ground based vertical datum](#).

For further details on using a [chassis based vertical datum](#).

Resetting vehicle static ride height.

Following the initial calculations, you may decide that the vehicle static ride height as originally specified is no longer appropriate, and you wish to determine the effect on the wheel alignment and other suspension settings of changing the ride height.

This may be particularly appropriate when you have measured a vehicle in its road "ride height" condition, and wish to see the effect of lowering it for track use, or raising it for off-road use.

Enter the new ride heights.

In Geometry | Configuration, choose the appropriate wheel location and alignment option.

When the “Top and bottom A-arms + steering” option is specified, this means that the resultant wheel alignment will be the new values calculated. This corresponds to raising or lowering the vehicle without making any adjustments to the A-arm dimensions or toe. Track, wheelbase and axle cl to datum dimensions will be calculated. Static wheel alignment camber, [caster](#) and toe settings will be set to the new values calculated.

When the “Top and bottom A-arms + wheel toe” option is specified, this means that the resultant wheel camber and [caster](#) will be the new values calculated. This corresponds to raising or lowering the vehicle without making any adjustments to the A-arm dimensions, but resetting the toe. Track, wheelbase and axle cl to datum dimensions will be calculated. Static wheel alignment camber and [caster](#) settings will be set to the new values calculated.

When any other option is specified, this means that the resultant wheel alignment will be maintained at that specified in Geometry | Alignment. Depending on which links are specified, the various wheel alignment settings, datum dimensions, track and wheelbase will be calculated as noted above.

For the complete vehicle, repeat the calculation for both front and rear suspensions.

5.5 Vehicle mass and centre of gravity

From the Vehicle, Rates or Dynamic tab, select Mass.

Mass

The unsprung corner mass are for the upright, tyre and wheel assembly. For a live axle, each rear corner will include half the mass of the axle.

The vehicle corner mass are the mass of each corner as measured by each individual corner scale. This includes both the sprung and unsprung mass.

The sprung corner mass and all the percentage distributions will be calculated.

For the Spring and Anti-roll bar rates calculations, only the sprung mass (total, for the appropriate end of the vehicle under design) is used.

For the Dynamic calculations, the sprung and unsprung masses for both ends must be entered.

Centre of Gravity

Although there are three sets of CofG locations shown, only the Vehicle CofG height can be entered. All other dimensions will be calculated.

Enter the height of the centre of gravity. This is the height from the ground of the complete vehicle. See [Centre of Gravity calculation](#).

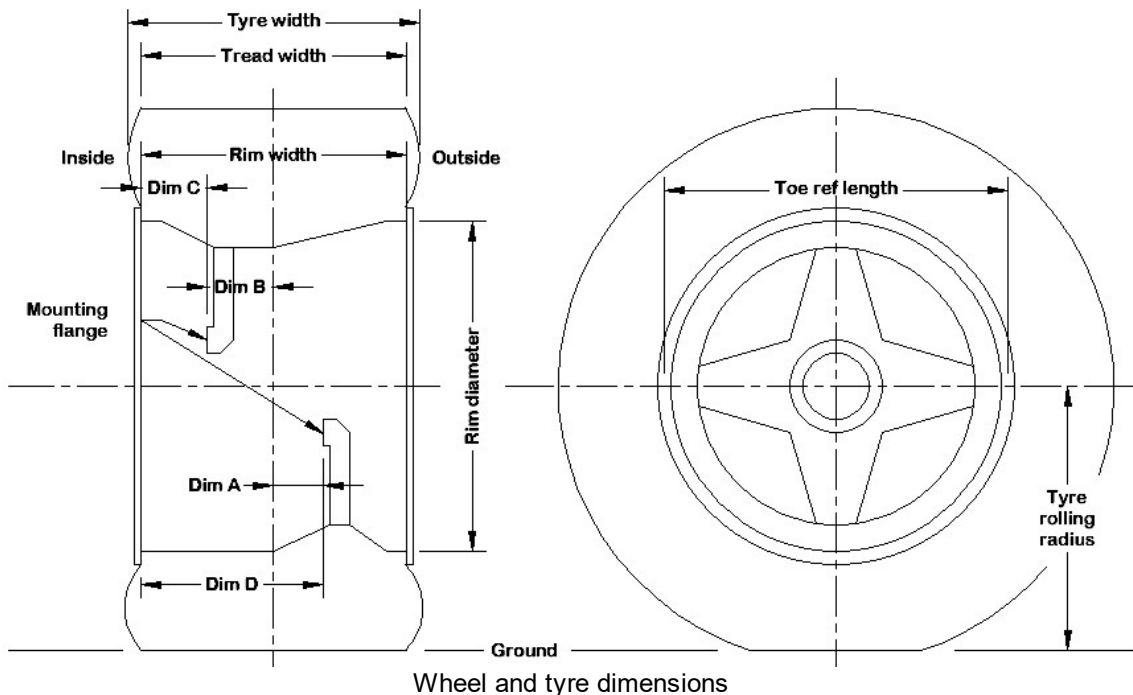
After calculating, the location of the centre of gravity of the sprung mass (ie the chassis) will be shown.

Both the vehicle and chassis centre of gravity are referenced in the same way. The horizontal dimension is from the vehicle centreline, the vertical dimension is from the ground upwards (and is always positive), and the longitudinal dimension is from the front axle centreline (and is always positive).

Also shown is the CofG location of the chassis referenced to the chassis datums.

Once all the values have been entered the mass totals and distributions, and the centre of gravity locations can be calculated with the Apply button.

5.6 Wheel and tyre



From the Vehicle tab, select All Wheels, Front Wheels or Rear Wheels.

If you select “All Wheels”, the initial data shown will be for the wheel located on the car end and car side currently specified in Geometry.

If this data is not valid (ie the rim diameter, tyre rolling radius and tyre diameter are not valid dimensions) then another wheel will be used.

When you “Apply” or “OK”, then all four wheel and tyres will be set to the values specified.

If you select “Front Wheels”, the initial data shown will be for the the front wheel located on the car side currently specified in Geometry.

If this data is not valid (ie the rim diameter, tyre rolling radius and tyre diameter are not valid dimensions) then the other side wheel will be used.

When you “Apply” or “OK”, then both front wheel and tyres will be set to the values specified.

If you select “Rear Wheels”, the initial data shown will be for the rear wheel located on the car side currently specified in Geometry.

If this data is not valid (ie the rim diameter, tyre rolling radius and tyre diameter are not valid dimensions) then the other side wheel will be used.

When you “Apply” or “OK”, then both rear wheel and tyres will be set to the values specified.

Generally production vehicles will have all four wheels the same. Even if there are variations, it may still be more convenient to initially specify all wheels identically, then update the individual wheel(s) that differs.

Wheel dimensions:

- rim diameter.
- rim width.
- mounting offset dimension and type. See [wheel coordinates](#).

Tyre dimensions:

- tyre tread width
- tyre section width (ie the overall width of the tyre across the sidewalls)

- tyre rolling radius. This is usually somewhat less than half the diameter due to the loaded deflection of the tyre.
- tyre diameter. This is the overall diameter of the inflated tyre. It will always be greater than twice the rolling radius.
- tyre spring rate. Enter the rate in either N/mm or lb/in using the related input box.

Tyre parameters:

- three sets of data points for the tyre contact patch offset and effective tyre radius at camber. See [tyre camber parameters](#).

Wheel fitment and alignment:

- spacer thickness. If there is a spacer between the hub face and the wheel face.
- toe reference length. This specifically required when specifying the wheel alignment toe as a distance. If specifying wheel alignment toe as an angle, then this dimension is not required, but it is suggested that it should be set to the rim diameter.

If Designer is in metric mode, then the edit boxes will display the metric dimensions, and additional inch dimensions will be shown. Dimensions can be entered in either mm or inches. Specify which by selecting the appropriate button. Wheel and tyre sizes are traditionally measured in inches, and this saves converting to mm.

If Designer is in imperial mode, then only inch dimensions will be shown and can be entered.

For the Geometry calculations only the rim diameter, tyre deflected radius (ie the rolling radius) and wheel offset are needed. If specifying the wheel alignment toe as a distance then toe reference length is needed. All other dimensions can remain at zero.

For the Spring calculations the tyre rate is needed.

For the Dynamic calculations both the tyre deflected radius and the tyre rate are needed.

Note that if the tyre rate is zero, then this is assumed to be an "infinitely stiff" tyre with no deflection under load.

All other values are for display only, are not used by SusProg3D calculations and can remain at zero.

For the wheel and tyre to display correctly, all dimensions should be input.

There is space for a 79-character comment (for example, the tyre make and size).

5.7 Undertray

To assist with the visual confirmation of the vehicle attitude, a basic undertray can be specified.

The undertray is broken down into three sections; front, centre and rear. Each section has four reference points which define a flat plane.

It is suggested that the front section corresponds to the section in front of the front axle or front wheels. This could be the front splitter or the front wing.

For a single seat racing car, the centre section could be the flat bottom or chassis undertray. For a sedan or touring car, the plane of the sidesills might be appropriate.

The sections can overlap.

5.8 Data

See [Print the data](#) for details.

5.9 Graphic

See [Print the graphic](#) for details.

5.10 VCalc

Recalculates the complete vehicle; front and rear, for the selected modules.

The dialog is similar to, and operates in the same way, as the [ECalc](#) dialog.
The difference is that ECalc does one end of the vehicle, VCalc does both ends.

6 Geometry

Defines the basic suspension characteristics in the static (normal ride height) position.

Config	Specify the suspension calculation options
Chassis	Specify the chassis mounting points (where the suspension linkages attach to the chassis, usually ball joints or rubber bushes)
Upright ¹	Specify the upright dimensions
Trailing arm ¹	Specify the trailing arm dimensions
Strut ¹	Specify the strut dimensions
Axle ¹	Specify the axle (axle housing plus pinion), brackets (suspension linkage attachment points), plus any "built-in" camber and toe settings.
Watts ²	Specify the Watts linkage dimensions
Mumford ²	Specify the Mumford linkage dimensions
Instant centres	Specify the linkage instant centres
Track	Show the track
Wheel and tyre	Specify the wheel and tyre dimensions
Alignment	Specify the wheel alignment (camber, caster and toe) and location
Turn ³	Specify the angle to turn the front wheels
Travel Limits	Specify the maximum bump and droop travel
Calc	Calculate the basic suspension
Results	Display the complete basic suspension data
ECalc	Specify the modules and calculate

1. Depending on the specified suspension type, only one of these will be shown.

2. Depending on the specified suspension type, only one of these will be shown.

3. Only for front suspension and specific config types

6.1 Configuration

The suspension geometry type is specified in [Vehicle Configure](#).

The suspension geometry calculation options are specified here.

From the Geometry tab, select Config.

Instant centre location.

There are two alternative ways to specify the swing axle lengths and instant centres. These alternatives will vary according to the suspension type.

Wheel location and alignment.

There are several alternative ways to specify the wheel location and alignment. These alternatives will vary according to the suspension type.

If working on an existing vehicle, and it is difficult to accurately measure the A-arm link lengths, then use the vehicle track and distance of the axle centreline to the datum, as these can usually be measured very accurately. Specify the Geometry configuration as “Wheel location and alignment”, and enter the camber, [caster](#), toe, wheel centreline to the horizontal and longitudinal datums as measured on the vehicle.

This option is generally more useful in the initial design stages, where the establishment of chassis pickup pivot point axes, roll centre location and camber change characteristics are more important than actual A-arm lengths, and the wheel location is determined by the required track.

Ensure that the distance of the axle centreline from the longitudinal datum (refer Geometry | Alignment or Vehicle | Datum) and the horizontal datum (refer Geometry | Alignment) are both specified. Note that the “half track” is required, as this allows for asymmetric track vehicles.

Geometry | Calculation will then establish the correct link lengths.

The other options are generally more useful once the required suspension characteristics have been established, and it is required to see the effect on changing wheel settings while maintaining certain fixed suspension linkages. This may also be used where there are design constraints which require specific suspension elements to be used.

Subsequent calculations can be done with the required links fixed to vary the other links, track and axle centreline datum distance as appropriate.

If you choose a configuration option that does not allow any link lengths to be specified, then the upright/strut/axle will be positioned on the vehicle centreline at the distance from the longitudinal datum as specified in the Datum or Alignment settings.

If you choose a configuration option that does require one or more link lengths, then the upright/strut/axle will be located in the appropriate position.

Track/Wheelbase reference point

Specify if the wheel location point is “On ground” (ie the centreline of the wheel and tyre on the ground) or “Wheel centre / axle” (ie the centreline of the wheel and tyre on the axle). See [Track](#) and [Wheelbase](#) for details.

6.1.1 Double A-arm, toe link

Instant centre location.

There are two alternative ways to specify the swing axle lengths and instant centres,

- “Suspension link chassis mounting points”.
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.
- “Swing axle lengths and roll/pitch centre heights”.
The swing axle lengths and roll centre heights must be entered in Geometry | ICs.

All chassis pivot point horizontal and longitudinal dimensions must be entered in the Chassis Design.

Geometry | Calculate will use the specified swing axle lengths, roll centre heights and chassis pivot horizontal and longitudinal values to calculate the chassis pivot vertical values.

Wheel location and alignment.

For the front suspension, the toe link is the steering linkage tie-rod.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

In all cases, if the instant centre location is determined by "Suspension link chassis mounting points" then all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified, and if the instant centre location is determined by "Swing axle lengths and roll/pitch centre heights" then the A-arm chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified.

- Wheel location + alignment.
The upper and lower A-arm chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- Upper A-arm + wheel alignment.
The upper and lower A-arm chassis mountings, upper A-arm link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and lower A-arm link lengths will be calculated.
- Lower A-arm + wheel alignment.
The upper and lower A-arm chassis mountings, lower A-arm link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper A-arm link lengths will be calculated.
- Upper and lower A-arms + wheel toe.
The upper and lower A-arm chassis mountings and link lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose one of the following geometry configuration options.

If the wheel camber is adjusted by means of an "[upright camber shim](#)" then use one of these options to see the effect of changing the camber shim thickness.

- Front: Upper and lower A-arms + steering linkage.
Rear: Upper and lower A-arms + toe link.
It is recommended that the Steering is dimensioned and calculated before this option is used.
The upper and lower A-arm chassis mountings and link lengths, and chassis rack end (or equivalent) and upright steering arm balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.
- Front: Upper and lower A-arms + steering linkage + turn.
Using the "+ turn" config option.
The upper and lower A-arm chassis mountings and link lengths, and chassis rack and upright steering arm balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.2 Upper "virtual A-arm", lower A-arm, toe link

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

For the front suspension, the toe link is the steering linkage tie-rod.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment.
The lower A-arm and upper link chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- Upper links + wheel alignment.
The upper links chassis mountings and lengths, lower A-arm chassis mountings, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and lower A-arm link lengths will be calculated.
- Lower A-arm + wheel alignment.
The lower A-arm and upper link chassis mountings, lower A-arm link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper link lengths will be calculated.
- Upper links + lower A-arm + wheel toe.
The upper link chassis mountings and link lengths, and lower A-arm chassis mountings and link lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose one of the following geometry configuration options

- Front: Upper links + lower A-arm + steering linkage
Rear: Upper links + lower A-arm + toe link
The upper link chassis mountings and link lengths, and lower A-arm chassis mountings and link lengths, and toe link length must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber, [caster](#) and toe will be calculated.
- Front: Upper links + lower A-arm + steering linkage + turn
Using the "+ turn" config option.
The upper link chassis mountings and link lengths, lower A-arm chassis mountings and link lengths, and toe control chassis mounting and link length must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.3 Upper parallel links, trailing link, lower A-arm

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.
All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- **Wheel location + alignment.**
The upper links and lower A-arm chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- **Lower A-arm + wheel alignment.**
The lower A-arm and upper link chassis mountings, lower A-arm link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose one of the following geometry configuration options

- **Upper lateral links + trailing link + lower A-arm.**
The upper link chassis mountings and link lengths, lower A-arm chassis mountings and link lengths must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.4 Upper A-arm, lower "virtual A-arm", toe link

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

For the front suspension, the toe link is the steering linkage tie-rod.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.
All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- **Wheel location + alignment.**
The upper A-arm and lower link chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- **Upper A-arm + wheel alignment.**
The upper A-arm chassis mountings and link lengths, lower link chassis mountings, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and lower link lengths will be calculated.
- **Lower links + wheel alignment.**
The lower links chassis mountings and lengths, upper A-arm chassis mountings, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper A-arm link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option

- **Upper A-arm + lower links + wheel toe.**
The upper A-arm and lower links chassis mountings and link lengths, and wheel alignment toe setting must be specified.

The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.

- Front: All links + steering linkage.
Rear: All links + toe link.
The upper A-arm and lower links chassis mountings and link lengths, and toe link mountings and length must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber, [caster](#) and toe will be calculated.
- Front: All links + steering linkage + turn.
Using the "+ turn" config option.
The upper A-arm and lower links chassis mountings and link lengths, and chassis rack and upright steering arm balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.5 Upper A-arm, lower trailing and two lateral links

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment.
The upper A-arm and lower link chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- Upper A-arm + wheel alignment.
The upper A-arm chassis mountings and link lengths, lower link chassis mountings, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and lower link lengths will be calculated.
- Lower front link + trailing link + wheel alignment.
The lower front link and trailing link chassis mountings and lengths, upper A-arm chassis mountings, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper A-arm link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option

- Upper A-arm + lower front link + trailing link + wheel toe.
The upper A-arm and lower front link and trailing link chassis mountings and link lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.
- All links
The upper A-arm, trailing and lateral links chassis mountings and link lengths, and upright toe control balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.6 Upper and lower lateral links, twin trailing links, toe link

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options. All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment.
All link chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- Upper trailing and lateral links + wheel alignment.
The upper trailing and lateral link chassis mountings and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and lower lateral and trailing link lengths will be calculated.
- Lower trailing and lateral links + wheel alignment.
The lower trailing and lateral link chassis mountings and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper lateral and trailing link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option

- All upper and lower links + wheel toe.
All link chassis mountings and upper and lower trailing and lateral link lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.
- All links
All link chassis mountings and link lengths, and upright toe control balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.7 Upper and lower "virtual A-arms", toe link

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

For the front suspension, the toe link is the steering linkage tie-rod.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options. All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment.
All link chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.

- Upper links + wheel alignment.
The upper link chassis mountings and link lengths, and wheel alignment must be specified. The track, distance of the axle centreline from the Z datum, and lower link lengths will be calculated.
- Lower links + wheel alignment.
The lower link chassis mountings and link lengths, and wheel alignment must be specified. The track, distance of the axle centreline from the Z datum, and upper link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option

- Upper and lower links + wheel toe.
All upper and lower link chassis mountings and link lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.
- Front: Upper and lower links + steering linkage.
Rear: Upper and lower links + toe link.
All upper and lower link chassis mountings and link lengths, and upright toe control balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.
- Front: Upper and lower links + steering linkage + turn.
Using the "+ turn" config option.
The upper and lower link chassis mountings and link lengths, and chassis rack and upright steering arm balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.8 Upper transverse leaf spring, lower reversed A-arm and trailing link

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified. Note that the leaf spring mounting point on the chassis is input in the spring section.

All upright mounting points horizontal, vertical and longitudinal dimensions must be specified. Note that the leaf spring mounting point on the upright is input in the spring section.

To maintain the static wheel alignment settings (and calculate the link dimensions), choose the following geometry configuration option.

- Leaf spring + wheel alignment.
The transverse leaf spring chassis mounting and main leaf length length, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and bottom link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option.

All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Leaf spring + all links
The transverse leaf spring chassis mounting and main leaf length length, and A-arm and

trailing link lengths must be specified.

The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.9 Upper lateral link, lower reversed A-arm, twin trailing links

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment.
All link chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- Upper links + wheel alignment.
The upper trailing and lateral link chassis mountings and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and lower link lengths will be calculated.
- Lower trailing link + front A-arm link + wheel alignment.
The lower trailing link and reverse A-arm chassis mountings and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option

- Trailing links + upper lateral link + front A-arm link + wheel toe.
All link chassis mountings and trailing, upper lateral and front reverse A-arm link lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.
- All links
All link chassis mountings and link lengths, and upright toe control balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.10 Upper reversed A-arm, lower lateral link, twin trailing links

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment.
All link chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- Upper trailing link + front A-arm link + wheel alignment.
The upper trailing and front A-arm link chassis mountings and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and lower link lengths will be calculated.
- Lower links + wheel alignment.
The lower trailing link and reverse A-arm chassis mountings and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option

- Trailing links + lower lateral link + front A-arm link + wheel toe.
All link chassis mountings and trailing, lower lateral and front reverse A-arm link lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.
- All links
All link chassis mountings and link lengths, and upright toe control balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.11 Upper lateral link, parallel lower links, twin trailing links

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment.
All link chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- Upper links + wheel alignment.
The upper trailing and lateral link chassis mountings and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and lower link lengths will be calculated.
- Lower trailing link + lower front lateral link + wheel alignment.
The lower trailing and front lateral link chassis mountings and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option

- Trailing links + upper lateral link + lower front lateral link + wheel toe.
All link chassis mountings and trailing, upper lateral and lower front lateral link lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.
- All links
All link chassis mountings and link lengths, and upright toe control balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.12 Aarm Caster Link

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment
The chassis mounting points, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The control arm and all link dimensions will be calculated.
- Lower control arm + wheel alignment
The chassis mounting points and the control arm dimensions must be specified.
The track, wheelbase, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option

- Upper link + lower control arm + caster link + wheel toe.
The chassis mounting points, the control arm dimensions and upper and caster link lengths must be specified.
The track, wheelbase, distance of the axle centreline from the Z datum, toe link length and wheel alignment camber and [caster](#) will be calculated.
- Upper link + lower control arm + caster link + toe link.
The chassis mounting points, the control arm dimensions and upper, caster and toe link lengths must be specified.
The track, wheelbase, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.13 Ford Twin I-Beam

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.
All chassis mounting points horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment
The chassis mounting points, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The I-beam and radius rod dimensions will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose one of the following geometry configuration options.

- I-Beam and radius rod + wheel toe.
The I-Beam and radius rod chassis mountings and link lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.
- I-Beam and radius rod + steering linkage.
The I-Beam and radius rod chassis mountings and link lengths, and steering gear and linkage and upright steering arm balljoints must be specified.
It is recommended that the Steering is dimensioned and calculated before this option is used.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.
- I-Beam and radius rod + steering linkage + turn.
Using the "+ turn" config option.
The I-Beam and radius rod chassis mountings and link lengths, and steering gear and linkage and upright steering arm balljoints must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

Note that the I-Beam and radius rod lengths are not the actual lengths of those items. They are the lengths as measured from the centre of the stub axle ball joints (or from the ends of the kingpin) to the centre of the appropriate chassis mounting bush.

See [link lengths](#).

6.1.14 Volkswagen twin trailing links

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment

To maintain the static wheel alignment settings (and calculate the link dimensions), choose one of the following geometry configuration options.

In all cases all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment.
The upper and lower trailing link chassis mountings, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The link lengths will be calculated.
- Upper trailing link + wheel alignment.
The upper and lower trailing link chassis mountings, upper trailing link lengths, and wheel alignment must be specified.

The track, distance of the axle centreline from the Z datum, and lower trailing link lengths will be calculated.

- Lower trailing link + wheel alignment.
The upper and lower trailing link chassis mountings, lower trailing link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, and upper trailing link lengths will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose one of the following geometry configuration options.

- Upper and lower trailing links + wheel toe.
The upper and lower trailing link chassis mountings and lengths, and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.
- Upper and lower trailing links + steering linkage.
The upper and lower trailing link chassis mountings and lengths, and chassis rack and upright steering arm balljoints and tie rod link length must be specified.
It is recommended that the Steering is dimensioned and calculated before this option is used.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.
- Upper and lower trailing links + steering linkage + turn.
Using the "+ turn" config option.
The upper and lower trailing link chassis mountings and lengths, and chassis rack and upright steering arm balljoints and tie rod link length must be specified.
The track, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

When using any of the above options that require the trailing link length(s) to be specified, then in order to correctly calculate the lateral offset of the trailing link upright mounting, the reference length is that length from the trailing link upright mounting to a convenient point on the trailing link pivot axis. This is because, geometrically, the trailing links are equivalent to an A-arm pivoting on the trailing link pivot axis.

6.1.15 Jaguar IRS

Instant centre location.

There are two alternative ways to specify the swing axle lengths and instant centres

In all cases, if the instant centre location is determined by "Suspension link chassis mounting points" then all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified, and if the instant centre location is determined by "Swing axle lengths and roll/pitch centre heights" then all required chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.

The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

- “Swing axle lengths and roll/pitch centre heights”.
The swing axle lengths and roll centre heights must be entered in Geometry | ICs. All chassis pivot point X dimensions must be entered in the Chassis Design. Geometry | Calculate will use the specified swing axle lengths, roll centre heights and chassis pivot horizontal values to calculate the chassis pivot vertical values.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

- Wheel location + alignment.
The wheel horizontal and longitudinal position, and the wheel alignment must be specified. The link lengths will be calculated.
- I-link + wheel camber.
The I-link front and diagonal lengths (chassis pivot to upright pivot), upright offset, and the wheel camber must be specified.
The distance of the axle centreline from the Z datum, driveshaft lengths and wheel alignment [caster](#) and toe will be calculated.

To maintain the driveshaft UJ location and I-link chassis mountings and I-link lengths (and calculate the static wheel alignment), choose the following geometry configuration option.

- I-link + driveshaft.
The I-link front and diagonal lengths (chassis pivot to upright pivot), upright offset, and driveshaft length must be specified.
The distance of the axle centreline from the Z datum, and wheel alignment will be calculated.

6.1.16 H-arm + camber link

Instant centre location.

There are two alternative ways to specify the swing axle lengths and instant centres.

In all cases, if the instant centre location is determined by “Suspension link chassis mounting points” then all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified, and if the instant centre location is determined by “Swing axle lengths and roll/pitch centre heights” then all chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified.

- “Suspension link chassis mounting points”.
All chassis pivot points must be entered in the Chassis Design. Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.
- “Swing axle lengths and roll/pitch centre heights”.
The swing axle lengths and roll centre heights must be entered in Geometry | ICs. All chassis pivot point X dimensions must be entered in the Chassis Design. Geometry | Calculate will use the specified swing axle lengths, roll centre heights and chassis pivot horizontal values to calculate the chassis pivot vertical values.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

- **Wheel location + alignment.**
The wheel horizontal and longitudinal position, and the wheel alignment must be specified. The link lengths will be calculated.
- **H-arm + wheel alignment.**
The H-arm front and diagonal lengths (chassis pivot to upright pivot), upright offset, and the wheel alignment camber must be specified. The distance of the axle centreline from the Z datum, camber link length and wheel alignment [caster](#) and toe will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option.

- **H-arm + camber link.**
The H-arm front and diagonal lengths (chassis pivot to upright pivot), upright offset, and camber link length must be specified. The distance of the axle centreline from the Z datum, and wheel alignment will be calculated.

This can also be inverted, with an upper H-arm and lower camber control link.

6.1.17 Porsche 928

Instant centre location.

There are two alternative ways to specify the swing axle lengths and instant centres.

In all cases, if the instant centre location is determined by “Suspension link chassis mounting points” then all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified, and if the instant centre location is determined by “Swing axle lengths and roll/pitch centre heights” then all required chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified.

- **“Suspension link chassis mounting points”.**
All chassis pivot points must be entered in the Chassis Design. Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle. The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.
- **“Swing axle lengths and roll/pitch centre heights”.**
The swing axle lengths and roll centre heights must be entered in Geometry | ICs. All chassis pivot point X dimensions must be entered in the Chassis Design. Geometry | Calculate will use the specified swing axle lengths, roll centre heights and chassis pivot horizontal values to calculate the chassis pivot vertical values.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or chassis mounting dimensions), choose one of the following geometry configuration options.

- **Wheel location + alignment.**
The wheel horizontal and longitudinal position, and the wheel alignment must be specified. The link lengths will be calculated.

- Trailing link + wheel alignment.
The trailing link front and diagonal lengths (chassis pivot to upright pivot), upright offset, and the wheel alignment camber must be specified.
The distance of the axle centreline from the Z datum, camber link length and wheel alignment [caster](#) and toe will be calculated.

To maintain the chassis mountings and link lengths (and calculate the static wheel alignment), choose the following geometry configuration option.

- Trailing link + camber link.
The trailing link front and diagonal lengths (chassis pivot to upright pivot), upright offset, and camber link length must be specified.
The distance of the axle centreline from the Z datum, and wheel alignment will be calculated.

6.1.18 Semi-trailing arm (also includes trailing arm and swing axle)

Trailing arm sub-type.

- Trailing
This has the trailing arm pivot axis perpendicular (or very close to) to the vehicle centreline in plan view.
- Semi-trailing
This has the trailing arm pivot axis at an angle to a line perpendicular to the vehicle centreline in plan view.
- Swing axle
This has the trailing arm axis parallel (or very close to) the vehicle centreline in plan view.

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment

- Chassis mounts + wheel location and alignment
The chassis mounting points, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The semi-trailing arm dimensions will be calculated.
- Chassis mounts + trailing arm
The chassis mounting points and the semi-trailing arm dimensions must be specified.
The track, wheelbase, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.1.19 Trailing arm, camber control and toe control links.

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

- Chassis mounts + wheel location and alignment
The wheel horizontal and longitudinal position, and wheel alignment must be specified.
All trailing arm dimensions must be specified.
The chassis trailing arm mounting, camber link orientation, and camber and toe control link lengths will be calculated.
- Chassis mounts + trailing arm + camber and toe links
The trailing arm chassis mounting, the camber control link orientation, mounting and length, and the toe control link mounting and length must be specified.

All trailing arm dimensions must be specified.

The track, distance of the axle centreline from the Z datum, wheel alignment camber, [caster](#) and toe will be calculated.

Camber link orientation.

Specify if the camber control link hangs down from the chassis (ie the camber control arm is below the chassis mounting point. This is the production car orientation.) or the camber control link stands up from the chassis (ie the camber control arm is above the chassis mounting point).

6.1.20 Trailing arm, upper and lower lateral links

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

- Chassis mounts + trailing arm + wheel alignment.
To calculate the wheel location and link lengths.
The wheel alignment (camber and toe) must be specified.
All chassis mounting points must be specified.
All trailing arm dimensions must be specified.
The trailing arm will be positioned on the chassis mounting point and the track, distance of the axle centreline from the longitudinal datum, wheel alignment [caster](#) and lateral link lengths will be calculated.
- Chassis mounts + trailing arm + lateral links.
To calculate the static wheel alignment settings.
All chassis trailing arm mounting and the lateral link chassis mountings and lengths must be specified.
All trailing arm dimensions must be specified.
The trailing arm will be positioned on the chassis mounting point and the track, distance of the axle centreline from the longitudinal datum, wheel alignment camber, [caster](#) and toe will be calculated.

6.1.21 Trailing arm, upper and lower lateral links, toe control link

Instant centre location.

The instant centre location is determined by the chassis pivot points.

Wheel location and alignment.

- Chassis mounts + trailing arm + wheel alignment.
To calculate the wheel location and link lengths.
The wheel alignment (camber and toe) must be specified.
All chassis mounting points must be specified.
All trailing arm dimensions must be specified.
The trailing arm will be positioned on the neutral chassis mounting point and the track, distance of the axle centreline from the horizontal datum, wheel alignment [caster](#) and lateral and toe control link lengths will be calculated.
- Chassis mounts + trailing arm + wheel location and alignment.
To calculate the wheel location and link lengths.
The wheel location (lateral location) and alignment (camber) must be specified.
All chassis mounting points must be specified.
All trailing arm dimensions must be specified.
The trailing arm will be positioned on the neutral chassis mounting point and the distance of

the axle centreline from the horizontal datum, wheel alignment [caster](#) and toe and lateral and toe control link lengths will be calculated.

- Chassis mounts + trailing arm + lateral and toe links
To calculate the static wheel alignment.
The chassis trailing arm mounting and the lateral link chassis mountings and lengths must be specified.
All trailing arm dimensions must be specified.
The trailing arm will be positioned on the chassis mounting axis and the track, distance of the axle centreline from the horizontal datum, compliance and wheel alignment camber, [caster](#) and toe will be calculated.

Because the trailing arm toe is controlled by the toe link, the trailing arm chassis mount has lateral compliance. This requires that the chassis mount is defined with two points which form an axis to provide lateral movement of the trailing arm. The neutral trailing arm chassis mounting point will be mid way between the two chassis points. If there is a difference between the neutral point and the calculated chassis trailing arm mounting point this will be noted as Compliance. A negative value means that the actual trailing arm mounting point is inwards from the neutral chassis trailing arm mounting; a positive value is outwards.

6.1.22 Strut, lower A-arm, toe link

Instant centre location.

There are two alternative ways to specify the swing axle lengths and instant centres.

In all cases, if the instant centre location is determined by "Suspension link chassis mounting points" then all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified, and if the instant centre location is determined by "Swing axle lengths and roll/pitch centre heights" then the lower A-arm chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.
- "Swing axle lengths and roll/pitch centre heights".
The swing axle lengths and roll centre heights must be entered in Geometry | ICs.
All chassis pivot point horizontal dimensions must be entered in the Chassis Design.
Geometry | Calculate will use the specified swing axle lengths, roll centre heights and chassis pivot horizontal values to calculate the chassis pivot vertical values.

Wheel location and alignment.

For the front suspension, the toe link is the steering linkage tie-rod.

Specifying an adjustable upper mounting horizontal value is equivalent to the usual practice of slotting the upper ball joint housing holes to provide horizontal adjustment and corresponding wheel camber change, and similarly specifying an adjustable upper mounting longitudinal value is equivalent to moving the upper ball joint housing fore and aft to provide castor change.

To maintain the static wheel alignment settings (and calculate the link and/or strut upper mounting dimensions), choose one of the following geometry configuration options.

- Wheel location + alignment.
The wheel horizontal and longitudinal position, and wheel alignment must be specified.
The strut upper mounting and link lengths will be calculated.
- Strut mounting + wheel alignment.
The strut upper mounting and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum and link lengths will be calculated.
- Lower A-arm + wheel alignment.
The strut upper mounting is adjustable in both the horizontal direction to provide camber adjustment and longitudinal direction to provide castor adjustment.
The lower A-arm mounting points and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum and strut upper mounting will be calculated.

To maintain the upper mounting point and the static wheel alignment, choose one of the following geometry configuration options. The strut dimensions will be adjusted to achieve the specified camber. For strut type A, the strut rod upper horizontal dimension will be calculated, for strut type B, the strut axis angle will be calculated, for strut type C, the strut adjustment angle will be calculated, and for strut type D, the strut axis angle will be calculated. For fixed struts, the adjustment point is effectively the strut tube lower point, and for adjustable struts it is the knuckle mounting point A.

- [Strut mounting + wheel location + alignment].
The strut upper mounting, track and wheel alignment settings are fixed.
The lower A-arm chassis mountings, strut upper mounting, track and wheel alignment settings must be specified.
The lower A-arm link lengths, strut-knuckle adjustment angle, and distance of the axle centreline from the Z datum will be calculated.
- [Strut mounting + lower A-arm + wheel alignment].
The strut upper mounting, lower A-arm and wheel camber and toe settings are fixed.
The lower A-arm chassis mountings and link lengths, strut upper mounting, and wheel alignment settings must be specified.
The track, [caster](#) and distance of the axle centreline from the Z datum will be calculated.
- Front: [Strut mounting + lower A-arm + steering linkage + wheel camber].
Rear: [Strut mounting + lower A-arm + toe link + wheel camber].
The strut upper mounting and the lower A-arm chassis mounting and link lengths, including steering tierod, are fixed.
The lower A-arm chassis mountings and link lengths, strut upper mounting, chassis rack and strut steering arm balljoints and wheel camber must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment [caster](#) and toe will be calculated.

To maintain the link lengths and upper mounting point (and calculate the static wheel alignment), choose one of the following geometry configuration options

- Strut mounting + lower A-arm + wheel toe.
The strut upper mounting and the lower A-arm chassis mounting and link lengths are fixed.
The lower A-arm chassis mountings and link lengths, strut upper mounting and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and [caster](#) will be calculated.
- Front: Strut mounting + lower A-arm + steering linkage.
Rear: Strut mounting + lower A-arm + toe link.
The strut upper mounting and the lower A-arm chassis mounting and link lengths, including steering tierod, are fixed.
The lower A-arm chassis mountings and link lengths, strut upper mounting, chassis rack

and strut steering arm balljoints must be specified.

The track, distance of the axle centreline from the Z datum, wheel alignment camber, [caster](#) and toe will be calculated.

- Front: Strut mounting + lower A-arm + steering linkage + turn.
Using the "+ turn" config option.
The strut upper mounting and the lower A-arm chassis mounting and link lengths, including steering tierod, are fixed.
The lower A-arm chassis mountings and link lengths, strut upper mounting, chassis rack and strut steering arm balljoints must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber, [caster](#) and toe will be calculated.

6.1.23 Strut, lower 'virtual A-arm' , toe link

Instant centre location.

There are two alternative ways to specify the swing axle lengths and instant centres.

In all cases, if the instant centre location is determined by "Suspension link chassis mounting points" then all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified, and if the instant centre location is determined by "Swing axle lengths and roll/pitch centre heights" then the lower A-arm chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.
- "Swing axle lengths and roll/pitch centre heights".
The swing axle lengths and roll centre heights must be entered in Geometry | ICs.
All chassis pivot point horizontal dimensions must be entered in the Chassis Design.
Geometry | Calculate will use the specified swing axle lengths, roll centre heights and chassis pivot horizontal values to calculate the chassis pivot vertical values.

Wheel location and alignment.

For the front suspension, the toe link is the steering linkage tie-rod.

Specifying an adjustable upper mounting horizontal value is equivalent to the usual practice of slotting the upper ball joint housing holes to provide horizontal adjustment and corresponding wheel camber change, and similarly specifying an adjustable upper mounting longitudinal value is equivalent to moving the upper ball joint housing fore and aft to provide castor change.

To maintain the static wheel alignment settings (and calculate the link and/or strut upper mounting dimensions), choose one of the following geometry configuration options.

- Wheel location + alignment.
The wheel horizontal and longitudinal position, and wheel alignment must be specified.
The strut upper mounting and link lengths will be calculated.
- Strut mounting + wheel alignment.
The strut upper mounting and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum and link lengths will be calculated.

- Lower links + wheel alignment.
The strut upper mounting is adjustable in both the horizontal direction to provide camber adjustment and longitudinal direction to provide castor adjustment.
The lower link mounting points and link lengths, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum and strut upper mounting will be calculated.

To maintain the upper mounting point and the static wheel alignment, choose one of the following geometry configuration options. The strut dimensions will be adjusted to achieve the specified camber. For strut type A, the strut rod upper horizontal dimension will be calculated, for strut type B, the strut axis angle will be calculated, for strut type C, the strut adjustment angle will be calculated, and for strut type D, the strut axis angle will be calculated. For fixed struts, the adjustment point is effectively the strut tube lower point, and for adjustable struts it is the knuckle mounting point A.

- [Strut mounting + wheel location + alignment].
The strut upper mounting, track and wheel alignment settings are fixed.
The lower link chassis mountings, strut upper mounting, track and wheel alignment settings must be specified.
The lower link lengths, strut-knuckle adjustment angle, and distance of the axle centreline from the Z datum will be calculated.
- [Strut mounting + lower links + wheel alignment].
The strut upper mounting, lower link and wheel camber and toe settings are fixed.
The lower link chassis mountings and link lengths, strut upper mounting, and wheel alignment settings must be specified.
The track, caster and distance of the axle centreline from the Z datum will be calculated.
- Front: [Strut mounting + lower links + steering linkage + wheel camber].
Rear: [Strut mounting + lower links + toe link + wheel camber].
The strut upper mounting and the lower link chassis mounting and link lengths, including steering tierod, are fixed.
The lower link chassis mountings and link lengths, strut upper mounting, chassis rack and strut steering arm balljoints and wheel camber must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment caster and toe will be calculated.

To maintain the link lengths and upper mounting point (and calculate the static wheel alignment), choose one of the following geometry configuration options

- Strut mounting + lower links + wheel toe.
The strut upper mounting and the lower A-arm chassis mounting and link lengths are fixed.
The lower A-arm chassis mountings and link lengths, strut upper mounting and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and caster will be calculated.
- Front: Strut mounting + lower links + steering linkage.
Rear: Strut mounting + lower links + toe link.
The strut upper mounting and the lower link chassis mounting and link lengths, including steering tierod, are fixed.
The lower link chassis mountings and link lengths, strut upper mounting, chassis rack and strut steering arm balljoints must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber, caster and toe will be calculated.
- Front: Strut mounting + lower links + steering linkage + turn.
Using the "+ turn" config option.
The strut upper mounting and the lower link chassis mounting and link lengths, including steering tierod, are fixed.

The lower link chassis mountings and link lengths, strut upper mounting, chassis rack and strut steering arm balljoints must be specified.

The track, distance of the axle centreline from the Z datum, wheel alignment camber, caster and toe will be calculated.

6.1.24 Strut tri-link

Instant centre location.

There are two alternative ways to specify the swing axle lengths and instant centres.

In all cases, if the instant centre location is determined by “Suspension link chassis mounting points” then all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified, and if the instant centre location is determined by “Swing axle lengths and roll/pitch centre heights” then the lower link chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified.

- “Suspension link chassis mounting points”.
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.
- “Swing axle lengths and roll/pitch centre heights”.
The swing axle lengths and roll centre heights must be entered in Geometry | ICs.
All chassis pivot point horizontal dimensions must be entered in the Chassis Design.
Geometry | Calculate will use the specified swing axle lengths, roll centre heights and chassis pivot horizontal values to calculate the chassis pivot vertical values.

Wheel location and alignment.

Specifying an adjustable top mounting horizontal value is equivalent to the usual practice of slotting the top ball joint housing holes to provide horizontal adjustment and corresponding wheel camber change, and similarly specifying an adjustable top mounting longitudinal value is equivalent to moving the top ball joint housing fore and aft to provide castor change.

To maintain the static wheel alignment settings (and calculate the link and/or strut top mounting dimensions), choose one of the following geometry configuration options.

- Wheel location + alignment.
The wheel horizontal and longitudinal position, and wheel alignment must be specified.
The strut top mounting and link lengths will be calculated.
- Strut mounting + wheel alignment.
The strut top mounting and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum and link lengths will be calculated.
- Trailing link + fr lateral link + wheel alignment.
The strut top mounting is adjustable in both the horizontal direction to provide camber adjustment and longitudinal direction to provide castor adjustment.
The trailing link mounting points and length, front lateral link mounting points and length, and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum, strut top mounting, and rear lateral link length will be calculated.

To maintain the top mounting point and the static wheel alignment, choose one of the following geometry configuration options. The strut dimensions will be adjusted to achieve the specified

camber. For strut type A, the strut rod top horizontal dimension will be calculated, for strut type B, the strut axis angle will be calculated, for strut type C, the strut adjustment angle will be calculated, and for strut type D, the strut axis angle will be calculated. For fixed struts, the adjustment point is effectively the strut tube lower point, and for adjustable struts it is the knuckle mounting point A.

- [Strut mounting + track + wheel alignment].
The strut top mounting, track and wheel alignment settings are fixed.
The trailing and lateral link mounting points, strut top mounting, track and wheel alignment settings must be specified.
The trailing and lateral link lengths, strut-knuckle adjustment angle, and distance of the axle centreline from the Z datum will be calculated.
- [Strut mounting + all links + wheel alignment].
The strut top mounting, trailing and lateral link mounting points and lengths and wheel camber settings are fixed.
The trailing and lateral link mounting points and lengths, strut top mounting, and wheel camber settings must be specified.
The track, strut-knuckle adjustment angle, [caster](#) and toe, and distance of the axle centreline from the Z datum will be calculated.

To maintain the link lengths and top mounting point (and calculate the static wheel alignment), choose the following geometry configuration options

- Strut mounting + all links.
The strut top mounting and the link chassis mounting and lengths are fixed.
The lower lateral and trailing link chassis mountings and lengths, and strut top mounting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber, [caster](#) and toe will be calculated.

6.1.25 Chapman strut

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Specifying an adjustable upper mounting horizontal value is equivalent to the usual practice of slotting the upper ball joint housing holes to provide horizontal adjustment and corresponding wheel camber change, and similarly specifying an adjustable upper mounting longitudinal value is equivalent to moving the upper ball joint housing fore and aft to provide castor change.

To maintain the static wheel alignment settings (and calculate the link and/or strut upper mounting dimensions), choose one of the following geometry configuration options.
In all cases all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

- Wheel location + alignment.
The wheel horizontal and longitudinal position, and wheel alignment must be specified.
The strut upper mounting and link lengths will be calculated.

- Strut mounting + wheel alignment.
The strut upper mounting and wheel alignment must be specified.
The track, distance of the axle centreline from the Z datum and all link lengths will be calculated.

To maintain the link lengths and upper mounting point (and calculate the static wheel alignment), choose the following geometry configuration option

- Strut mounting + all links.
The strut upper mounting and all link chassis mounting and lengths are fixed.
The trailing link chassis mountings and lengths, strut upper mounting and the driveshaft universal joint centres must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber, [caster](#) and toe will be calculated.

6.1.26 Dual-axis strut

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

To maintain the static wheel alignment settings (and calculate the link and/or strut upper mounting dimensions), choose one of the following geometry configuration options.

- Wheel location + alignment.
The wheel horizontal and longitudinal position, and wheel alignment must be specified.
The strut upper mounting and link lengths will be calculated.

To maintain the link lengths and upper mounting point (and calculate the static wheel alignment), choose one of the following geometry configuration options

- Strut mounting + lower A-arm + wheel toe.
The strut upper mounting and the lower A-arm chassis mounting and link lengths are fixed.
The lower A-arm chassis mountings and link lengths, strut upper mounting and wheel alignment toe setting must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber and caster will be calculated.
- Strut mounting + lower A-arm + steering linkage.
The strut upper mounting and the lower A-arm chassis mounting and link lengths, including steering tierod, are fixed.
The lower A-arm chassis mountings and link lengths, strut upper mounting, chassis rack and strut steering arm balljoints must be specified.
The track, distance of the axle centreline from the Z datum, wheel alignment camber, caster and toe will be calculated.
- Strut mounting + lower A-arm + steering linkage + turn.
Using the "+ turn" config option.
The strut upper mounting and the lower A-arm chassis mounting and link lengths, including steering tierod, are fixed.
The lower A-arm chassis mountings and link lengths, strut upper mounting, chassis rack and strut steering arm balljoints must be specified.

The track, distance of the axle centreline from the Z datum, wheel alignment camber, caster and toe will be calculated.

6.1.27 Live axle (torque arm) - 4 trailing links and birdcage + Panhard rod

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Panhard rod mounting

Specify the Panhard rod orientation and axle or birdcage mounted.

Instant centre location.

- “Suspension link chassis mounting points”.
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle (including torque arm) dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

- Axle alignment.
Specify the nominal centreline of the axle from the longitudinal datum.
The axle offset and wheel lead will be zero.
The pinion angle can be specified.
All torque arm and Panhard rod chassis and axle mounting points must be specified.
The axle will be positioned appropriately and the trailing link lengths, torque arm link length and Panhard link length will be calculated.

To maintain the torque arm chassis mounting and axle dimensions, trailing link mountings and lengths, torque arm link and Panhard rod chassis mounting and length, choose the following geometry configuration option

- Torque arm + all links + Panhard rod.
All torque arm, trailing link and Panhard rod chassis and axle mounting points must be specified.
Trailing link, torque arm link and Panhard rod lengths must be specified.
The birdcage will be rotated to connect with the upper and lower trailing links, and will then locate the axle longitudinally.

6.1.28 Live axle (torque arm) - 4 trailing links and birdcage + Watts linkage

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Watts pivot.

Specify where the Watts lever pivot is located, either on the chassis or on the axle.

Instant centre location.

- “Suspension link chassis mounting points”.
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle (including torque arm) dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

- Axle alignment.
The axle offset and wheel lead will be zero.
Specify the nominal centreline of the axle from the longitudinal datum.
The pinion angle can be specified.
All torque arm and Watts link chassis and axle mounting points must be specified.
The axle will be positioned appropriately and the trailing link lengths, torque arm link length and Watts link lengths will be calculated.

To maintain the torque arm chassis mounting and axle dimensions, trailing link mountings and lengths, torque arm link and Watts link chassis mounting and length, choose the following geometry configuration option

- Torque arm + all links + Watts linkage.
All torque arm, trailing link and Watts link chassis and axle mounting points must be specified.
Trailing link, torque arm link and Watts link lengths must be specified.
The birdcage will be rotated to connect with the upper and lower trailing links, and will then locate the axle longitudinally.

6.1.29 Live axle (torque arm slider) - 2 trailing links + Panhard rod

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Panhard rod chassis mounting

Specify which end of the Panhard rod is the mounted to the chassis.

Instant centre location.

- “Suspension link chassis mounting points”.
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle (including torque arm) dimensions and all required chassis mounting point

horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

- Torque arm slider + axle alignment.

Specify the nominal centreline of the axle from the longitudinal datum.

All torque arm and Panhard rod chassis and axle mounting points must be specified.

The axle will be positioned appropriately (the torque arm slider will be located on the chassis mounting point) and the wheel location, trailing link lengths and Panhard link length will be calculated.

If the torque arm is compliant, then the axle alignment will be as specified, and there will be an initial torque arm compliance.

If the trailing links are compliant, then the axle toe will be determined by the torque arm mounting.

To maintain the torque arm chassis mounting and axle dimensions, trailing link mountings and lengths and Panhard rod chassis mounting and length, choose the following geometry configuration option

- Torque arm slider + trailing links + Panhard rod.

All torque tube, trailing link and Panhard rod chassis and axle mounting points must be specified.

Trailing link and Panhard rod lengths must be specified.

The axle will be positioned appropriately.

Compliance location.

The torque arm slider is always positioned through the centre of the chassis mounting. The torque arm slider is free to move longitudinally, and also can also pivot, but is restrained in the vertical direction. Similarly, the Panhard rod is considered “rigid” and the length between mounting points is constant. Because of these constraints, the axle assembly will generally move sideways in bump and droop (primarily as a consequence of the Panhard rod arc). The torque arm is considered to be “rigid” in the vertical plane.

Choose one of the following compliance options.

- Trailing link compliance

In this mode, the torque arm slider is constrained in both horizontal and vertical directions.

The torque arm is also “rigid” in the horizontal plane. The primary constraints are the torque arm slider mounting (both horizontally and vertically), and the Panhard rod. Because of these constraints, as the axle assembly moves sideways in bump and droop (primarily as a consequence of the Panhard rod arc), it will also bump steer (controlled by the torque arm slider mounting). In turn, this requires slight compliance in the trailing link mountings. This mode should be used when the trailing links have rubber bushes.

- Torque arm compliance

In this mode, the torque arm slider is free to move laterally within the chassis mounting bearing, and/or the torque arm itself can deflect horizontally. The trailing links are considered “rigid” and the length between mounting points is constant. The primary constraints are the torque arm slider mounting (vertically), the trailing links, and the Panhard rod. Because of these constraints, as the axle assembly moves sideways in bump and droop (primarily as a consequence of the Panhard rod arc) and the axle bump steer is controlled by the trailing links, this requires horizontal compliance in the torque arm and/or the torque arm slider mounting.

This mode should be used when the trailing links have Heim joints.

6.1.30 Live axle (torque arm slider) - 2 trailing links + Watts linkage

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Watts pivot.

Specify where the Watts lever pivot is located, either on the chassis or on the axle.

Instant centre location.

- “Suspension link chassis mounting points”.
All chassis pivot points must be entered in the Chassis Design. Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle (including torque arm) dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

- Torque arm slider + axle alignment.
Specify the nominal centreline of the axle from the longitudinal datum.
All torque arm and Watts linkage chassis and axle mounting points must be specified.
The axle will be positioned appropriately (the torque arm slider will be located on the chassis mounting point) and the trailing link lengths and Watts link length will be calculated.
If the torque arm is compliant, then the axle alignment will be as specified, and there will be an initial torque arm compliance.
If the trailing links are compliant, then the axle toe will be determined by the torque arm mounting.

To maintain the torque arm chassis mounting and axle dimensions, trailing link mountings and lengths and Watts linkage mounting and length, choose the following geometry configuration option

- Torque arm slider + trailing links + Watts linkage.
All torque tube, trailing link and Watts linkage chassis and axle mounting points must be specified.
Trailing link and Watts link lengths must be specified.
The axle will be positioned appropriately.

Compliance location.

The torque arm slider is always positioned through the centre of the chassis mounting. The torque arm slider is free to move longitudinally, and also can also pivot, but is restrained in the vertical direction. Similarly, the Watts linkage is considered “infinitely stiff” and the length between mounting points is constant. Because of these constraints, the axle assembly will generally have no movement sideways in bump and droop.
The torque arm is considered to be “rigid” in the vertical plane.

Choose one of the following compliance options.

- Trailing link compliance
In this mode, the torque arm slider is constrained in both horizontal and vertical directions.
The torque arm is also “rigid” in the horizontal plane. The primary constraints are the torque

arm slider mounting (both horizontally and vertically), and the Watts linkage. This mode should be used when the trailing links have rubber bushes.

- Torque arm compliance

In this mode, the torque arm slider is free to move laterally within the chassis mounting bearing, and/or the torque arm itself can deflect horizontally. The trailing links are considered “rigid” and the length between mounting points is constant. The primary constraints are the torque arm slider mounting (vertically), the trailing links, and the Watts linkage. This mode should be used when the trailing links have Heim joints.

6.1.31 Live axle (torque tube) + Panhard rod

Panhard rod chassis mounting

Specify which end of the Panhard rod is the mounted to the chassis.

Instant centre location.

- “Suspension link chassis mounting points”.
All chassis pivot points must be entered in the Chassis Design. Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle (including torque tube) dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

- Torque tube + axle alignment.
All torque tube and Panhard rod chassis and axle mounting points must be specified. The axle will be positioned appropriately (the torque tube ball joint will be located on the chassis mounting point) and the Panhard rod length will be calculated.

To maintain the torque tube chassis mounting and axle dimensions, and Panhard rod chassis mounting and length, choose the following geometry configuration option

- Torque tube + Panhard rod.
All torque tube and panhard rod chassis and axle mounting points must be specified. Panhard rod length must be specified.
The axle will be positioned appropriately.

6.1.32 Live axle (torque tube) + Watts linkage

Watts pivot.

Specify where the Watts lever pivot is located, either on the chassis or on the axle.

Instant centre location.

- “Suspension link chassis mounting points”.
All chassis pivot points must be entered in the Chassis Design. Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.

The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle (including torque tube) dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment be specified.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

- Torque tube + axle alignment.
All torque tube and Watts linkage chassis and axle mounting points must be specified.
The axle will be positioned appropriately (the torque tube ball joint will be located on the chassis mounting point) and the Watts link length will be calculated.

To maintain the torque tube chassis mounting and axle dimensions, and Watts linkage mounting and length, choose the following geometry configuration option

- Torque tube + Watts linkage.
All torque tube and Watts linkage chassis and axle mounting points must be specified.
Watts link length must be specified.
The axle will be positioned appropriately.

6.1.33 Winters: 4 trailing links, 2 birdcages + Jacobs ladder

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Jacobs ladder

Specify on which side of the vehicle is the Jacobs ladder. Currently this must be on the right hand side.

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle (including torque tube) dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

- Torque tube + axle alignment.
All axle torque tube and birdcage dimensions must be specified.
All suspension links and torque tube ball chassis mounting points must be specified.
The axle will be positioned with the torque tube ball joint located on the chassis mounting point (with no torque tube alignment error), with the axle "straight across" the frame.
The birdcages will be positioned vertically.
All longitudinal link lengths and Jacobs ladder dimensions will be calculated.

To maintain the torque tube chassis mounting and axle dimensions, the longitudinal link lengths and Jacobs ladder dimensions, choose the following geometry configuration option

- All longitudinal links + Jacobs ladder.
All torque tube axle mounting points must be specified.
All chassis mounting points must be specified.
All longitudinal link and Jacobs ladder lengths must be specified.
The axle will be positioned appropriately. Note that this may result in a torque tube alignment error.

6.1.34 Live axle or deDion - 2 trailing arms + Mumford linkage

The choice between "live axle" and "de Dion" is specified in Vehicle Config.

Rear suspension is configured with two trailing arms; front suspension is configured with two leading arms.

Mumford linkage location.

Specify where the Mumford bellcrank is positioned, either on the left or right side.

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points, and the Mumford bellcrank angle and lever length, must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle. The lateral links will be calculated.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

The wheel toe can be specified for the front suspension only.

In all cases the wheel alignment - camber, [caster](#) and toe – and location will be calculated.

In all cases the the Mumford intermediate link length will be calculated.

- Front: Axle alignment + wheel toe
Rear: Axle alignment
All trailing arm and Mumford linkage chassis and axle mounting points must be specified.
The longitudinal wheel location must be specified.
The axle will be positioned appropriately and all link lengths will be calculated.

To maintain the trailing arm chassis mountings and lengths, and Mumford linkage chassis mountings, bellcrank dimensions and link lengths, choose the following geometry configuration options

- Front: Both lower arms + Mumford linkage + wheel toe
Rear: Both lower arms + Mumford linkage.
All trailing arm and Mumford linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately.
- Front: Both lower arms + Mumford linkage + steering linkage
All trailing arm and Mumford linkage chassis and axle mounting points must be specified.

All link lengths must be specified.

The axle will be positioned appropriately and wheel alignment calculated.

- Front: Both lower arms + Mumford linkage + steering linkage + turn.
Using the "+ turn" config option.
All trailing arm and Mumford linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.

6.1.35 Live axle or deDion - 2 trailing arms + Panhard rod

The choice between "live axle" and "de Dion" is specified in Vehicle Config.

Rear suspension is configured with two trailing arms; front suspension is configured with two leading arms.

Panhard rod chassis mounting

Specify which end of the Panhard rod is the mounted to the chassis.

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

The wheel toe can be specified for the front suspension only.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

The wheel toe can be specified for the front suspension only.

- Front: Axle alignment + wheel toe
Rear: Axle alignment
All trailing / leading arm and Panhard rod chassis and axle mounting points must be specified.
The longitudinal wheel location must be specified.
The axle offset and wheel lead will usually be zero.
The axle will be positioned appropriately and all link lengths will be calculated.

To maintain the trailing arm chassis mountings and lengths, and Mumford linkage chassis mountings, bellcrank dimensions and link lengths, choose the following geometry configuration options

- Front: Both lower arms + Panhard rod + wheel toe
Rear: Both lower arms + Panhard rod
All trailing arm and Panhard rod chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately.
- Front: Both lower arms + Panhard rod + steering linkage
All trailing arm and Panhard rod chassis and axle mounting points must be specified.

All link lengths must be specified.

The axle will be positioned appropriately and wheel alignment calculated.

- Front: Both lower arms + Panhard rod + steering linkage + turn.
Using the "+ turn" config option.
All trailing arm and Panhard rod chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.

6.1.36 Live axle or deDion - 2 trailing arms + Watts linkage

The choice between "live axle" and "de Dion" is specified in Vehicle Config.

Rear suspension is configured with two trailing arms; front suspension is configured with two leading arms.

Watts pivot.

Specify where the Watts lever pivot is located, either on the chassis or on the axle.

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

The wheel toe can be specified for the front suspension only.

In all cases the wheel alignment - camber, [caster](#) and toe – and location will be calculated.

In all cases the the Watts intermediate link length will be calculated.

- Front: Axle alignment + wheel toe
Rear: Axle alignment
All trailing arm and Watts linkage chassis and axle mounting points must be specified.
The longitudinal wheel location must be specified.
The axle will be positioned appropriately and all link lengths will be calculated.

To maintain the trailing arm chassis mountings and lengths, and Watts linkage chassis mountings, bellcrank dimensions and link lengths, choose the following geometry configuration options

- Front: Both lower arms + Watts linkage + wheel toe
Rear: Both lower arms + Watts linkage.
All trailing arm and Watts linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately.
- Front: Both lower arms + Watts linkage + steering linkage
All trailing arm and Watts linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.

- Front: Both lower arms + Watts linkage + steering linkage + turn.
Using the "+ turn" config option.
All trailing arm and Watts linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.

6.1.37 Live axle or deDion - 3 or 4 link + Mumford linkage

The choice between "live axle" and "de Dion" is specified in Vehicle Config.

Longitudinal links.

Specify the number of longitudinal links; 4 link, 4 link (LH birdcage), 4 link (RH birdcage), 3 link (no top LH link), 3 link (no top RH link).

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Mumford links.

The Mumford linkage can be either chassis mounted bellcrank and lever, or axle mounted bellcrank and lever; and the Mumford bellcrank positioned on the left or right side (of the vehicle).

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points, and the Mumford bellcrank angle and lever length, must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle. The lateral links will be calculated.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

The wheel toe can be specified for the front suspension only.

In all cases the wheel alignment - camber, [caster](#) and toe – and location will be calculated.

In all cases the Mumford intermediate link length will be calculated.

Some options are not applicable if a Birdcage is specified.

- Front: Axle alignment + wheel toe
Rear: Axle alignment
All trailing link and Mumford linkage chassis and axle mounting points must be specified.
The longitudinal wheel location must be specified (either in Wheel Alignment or Axle Static Alignment)
The axle will be positioned centrally and all link lengths will be calculated.

To maintain the trailing arm chassis mountings and lengths, and Mumford linkage chassis mountings, bellcrank dimensions and link lengths, choose the following geometry configuration options

- Front: All longitudinal links + Mumford linkage + wheel toe
Rear: All longitudinal links + Mumford linkage.
All longitudinal links and Mumford linkage chassis and axle mounting points must be specified.

All link lengths must be specified.
The axle will be positioned appropriately.

- Front: All longitudinal links + Mumford linkage + steering linkage
All longitudinal links and Mumford linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.
- Front: All longitudinal links + Mumford linkage + steering linkage + turn.
Using the "+ turn" config option.
All longitudinal links and Mumford linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.

6.1.38 Live axle or deDion - 3 or 4 link + Panhard rod

The choice between "live axle" and "de Dion" is specified in Vehicle Config.

Longitudinal links.

Specify the number of longitudinal links; 4 link, 4 link (LH birdcage), 4 link (RH birdcage), 3 link (no top LH link), 3 link (no top RH link).

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Panhard rod mounting

Specify which end of the Panhard rod is the mounted to the chassis.

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

The wheel toe can be specified for the front suspension only.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

The wheel toe can be specified for the front suspension only.

Some options are not applicable if a Birdcage is specified.

- Front: Axle alignment + wheel toe
Rear: Axle alignment
All trailing / leading link and panhard rod chassis and axle mounting points must be specified.
The longitudinal wheel location must be specified (in Axle Static Alignment)
The axle offset and wheel lead will be zero.
The axle will be positioned centrally and all link lengths will be calculated.

To maintain the longitudinal chassis mountings and lengths, and Panhard rod chassis mountings and link lengths, choose the following geometry configuration options

- Front: All longitudinal links + Panhard rod + wheel toe
Rear: All longitudinal links + Panhard rod.
All longitudinal links and Panhard rod chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately.
- Front: All longitudinal links + Panhard rod + steering linkage
All longitudinal links and Panhard rod chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.
- Front: All longitudinal links + Panhard rod + steering linkage + turn.
Using the "+ turn" config option.
All longitudinal links and Panhard rod chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.

6.1.39 Live axle or deDion - 3 or 4 link + Watts linkage

The choice between "live axle" and "de Dion" is specified in Vehicle Config.

Longitudinal links.

Specify the number of longitudinal links; 4 link, 4 link (LH birdcage), 4 link (RH birdcage), 3 link (no top LH link), 3 link (no top RH link).

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Watts pivot.

Specify where the Watts lever pivot is located, either on the chassis or on the axle.

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

The wheel toe can be specified for the front suspension only.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

Some options are not applicable if a Birdcage is specified.

- Front: Axle alignment + wheel toe
Rear: Axle alignment
All trailing link and Watts linkage chassis and axle mounting points must be specified.
The longitudinal wheel location must be specified (either in Wheel Alignment or Axle Static

Alignment)

The axle will be positioned centrally and all link lengths will be calculated.

To maintain the trailing arm chassis mountings and lengths, and Watts linkage chassis mountings, bellcrank dimensions and link lengths, choose the following geometry configuration options

- Front: All longitudinal links + Watts linkage + wheel toe
Rear: All longitudinal links + Watts linkage.
All longitudinal links and Watts linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately.
- Front: All longitudinal links + Watts linkage + steering linkage
All longitudinal links and Watts linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.
- Front: All longitudinal links + Watts linkage + steering linkage + turn.
Using the "+ turn" config option.
All longitudinal links and Watts linkage chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.

6.1.40 Live axle or deDion - 3 or 4 link + Woblink

The choice between "live axle" and "de Dion" is specified in Vehicle Config.

Longitudinal links.

Specify the number of longitudinal links; 4 link, 4 link (LH birdcage), 4 link (RH birdcage), 3 link (no top LH link), 3 link (no top RH link).

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Woblink.

The Woblink linkage can be either chassis or axle mounted, and the links positioned on the left or right side (of the vehicle).

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points, and the Woblink lever length, must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle. The lateral links will be calculated.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

The wheel toe can be specified for the front suspension only.

In all cases the wheel alignment - camber, [caster](#) and toe – and location will be calculated. Some options are not applicable if a Birdcage is specified.

- Front: Axle alignment + wheel toe
Rear: Axle alignment
All trailing link and Woblink chassis and axle mounting points must be specified.
The longitudinal wheel location must be specified (either in Wheel Alignment or Axle Static Alignment)
The axle will be positioned centrally and all link lengths will be calculated.

To maintain the trailing arm chassis mountings and lengths, and Woblink chassis mountings, bellcrank dimensions and link lengths, choose the following geometry configuration options

- Front: All longitudinal links + Woblink + wheel toe
Rear: All longitudinal links + Woblink.
All longitudinal links and Woblink chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately.
- Front: All longitudinal links + Woblink + steering linkage
All longitudinal links and Woblink chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.
- Front: All longitudinal links + Woblink + steering linkage + turn.
Using the "+ turn" config option.
All longitudinal links and Woblink chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.

6.1.41 Live axle or deDion - 4 links

The choice between "live axle" and "de Dion" is specified in Vehicle Config.

Usually one pair of links are arranged to converge on the axle to provide the lateral control.

Longitudinal link orientation.

Conventionally, rear suspension is configured with trailing links; front suspension is configured with leading links.

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

Choose one of the following geometry configuration options.

In all cases the axle dimensions and all required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified.

In some cases, the axle static alignment can be specified.

The wheel toe can be specified for the front suspension only.

In all cases the wheel alignment - camber, [caster](#) and toe - and location will be calculated.

- Front: Axle alignment + wheel toe
Rear: Axle alignment

All longitudinal link chassis and axle mounting points must be specified.
The longitudinal wheel location must be specified (in Axle Static Alignment)
The axle offset and wheel lead will be zero.
The axle will be positioned centrally and all link lengths will be calculated.

To maintain the longitudinal link chassis mountings and lengths, choose the following geometry configuration options

- Front: All longitudinal links + wheel toe
Rear: All longitudinal links
All longitudinal link chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately.
- Front: All longitudinal links + steering linkage
All longitudinal link chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.
- Front: All longitudinal links + steering linkage + turn.
Using the "+ turn" config option.
All longitudinal link chassis and axle mounting points must be specified.
All link lengths must be specified.
The axle will be positioned appropriately and wheel alignment calculated.

6.1.42 Mono wheel - trailing arm

Trailing arm.

- Double sided
Wheel mounts in the centre of the arms.
- Single side LH
The arm is on the LH side of the wheel, and the wheel mounts from the RH side.
- Single side RH
The arm is on the RH side of the wheel, and the wheel mounts from the LH side.

Instant centre location.

- "Suspension link chassis mounting points".
All chassis pivot points must be entered in the Chassis Design.
Geometry | Calculate will use the specified chassis pivot values to calculate the front view swing axle length and roll centre height and the side view swing axle length, side view instant centre height and the anti-dive/squat angle.
The Instant Centre dialog will show the calculated swing axle lengths and instant centre locations.

Wheel location and alignment.

- Chassis mounts + wheel location and alignment
The chassis mounting points, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The trailing arm dimensions will be calculated.
- Trailing arm + wheel location and alignment
The trailing arm dimensions, wheel horizontal and longitudinal position, and wheel alignment must be specified.
The chassis mounting points will be calculated.
- Chassis mounts + trailing arm
The chassis mounting points and the trailing arm dimensions must be specified.

The track, wheelbase, distance of the axle centreline from the Z datum, and wheel alignment camber, [caster](#) and toe will be calculated.

6.2 Car end and car side

The [Front] or [Rear] tab choice will indicate the currently selected vehicle end.

The [LH] or [RH] tab choice will indicate the currently selected vehicle side.

These tabs acts as a toggle, and selecting this tab will switch between each of two.

Depending on the suspension geometry configuration, some menu bar items may not be available.

When a dialog box is opened, the title will include the currently selected car end and car side. If the car side is not shown, then the dialog box applies to both sides. If the car end is not shown, then the dialog box applies to both ends.

6.3 Chassis

From the Geometry tab, select Chassis.

Chassis mounting points:

Note that horizontal values are from the chassis centreline, vertical values are from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are from the chosen chassis longitudinal datum.

6.3.1 Double A-arm

If the configuration option "Swing axle lengths and roll/pitch centre heights" is specified, the chassis mounting vertical dimensions cannot be input, and will be calculated. The swing axle lengths and roll centre height must be specified.

Enter the values for the top A-arm front & rear pivot points.

Enter the values for the bottom A-arm front & rear pivot points.

The longitudinal values need not be entered, and if left at 0.00, they will be set to default values such that the A-arm base length is approximately equal to the tyre rolling radius.

If the configuration does not include the steering linkage, the toe control mounting values are not required, and the Roll & Bump calculations will assume that there is no toe change in bump and droop.

6.3.2 Lower A-arm, upper "virtual A-arm", toe link

Enter the values for the top front & rear links pivot points.

Enter the values for the bottom A-arm front & rear pivot points.

The longitudinal values for the A-arm and the top links need not be entered, and if left at 0.00, they will be set to default values such that the A-arm base length and distance between the top link chassis mountings is approximately equal to the tyre rolling radius.

If the configuration does not include the toe linkage, the toe control mounting values are not required, and the Roll & Bump calculations will assume that there is no toe change in bump and droop.

6.3.3 Lower A-arm, upper parallel links, trailing link

Enter the values for the top lateral links pivot points.

Enter the values for the bottom A-arm front & rear pivot points.

Enter the horizontal and vertical values for the trailing link pivot points.

The longitudinal values for the A-arm and the lateral links need not be entered, and if left at 0.00, they will be set to default values such that the A-arm base length and distance between the lateral link chassis mountings is approximately equal to the tyre rolling radius.

6.3.4 Upper A-arm, lower "virtual A-arm", toe link

Enter the values for the top A-arm front & rear pivot points.

Enter the values for the bottom links pivot points.

The longitudinal values for the A-arm and the lateral links need not be entered, and if left at 0.00, they will be set to default values such that the A-arm base length and distance between the lateral link chassis mountings is approximately equal to the tyre rolling radius.

If the configuration does not include the toe linkage, the toe control mounting values are not required, and the Roll & Bump calculations will assume that there is no toe change in bump and droop.

6.3.5 Upper A-arm, lower trailing and lateral links, toe link

Enter the values for the top A-arm front & rear pivot points.

Enter the values for the bottom lateral and trailing links pivot points.

The longitudinal values for the A-arm and the lateral links need not be entered, and if left at 0.00, they will be set to default values such that the A-arm base length and distance between the lateral link chassis mountings is approximately equal to the tyre rolling radius.

6.3.6 Upper and lower lateral links, twin trailing links, toe link

Enter the values for the top trailing and lateral links pivot points.

Enter the values for the bottom trailing and lateral links pivot points.

Enter the values for the toe control pivot points.

If the configuration does not include the toe linkage, the toe control mounting values are not required, and the Roll & Bump calculations will assume that there is no toe change in bump and droop.

6.3.7 Upper and lower "virtual A-arms", toe link

Enter the values for the top links pivot points.

Enter the values for the bottom links pivot points.

Enter the values for the toe control pivot points.

If the configuration does not include the toe linkage, the toe control mounting values are not required, and the Roll & Bump calculations will assume that there is no toe change in bump and droop.

6.3.8 Upper transverse leaf spring, lower reversed A-arm and trailing link

Enter the values for the bottom trailing link and reverse A-arm apex pivot points.

The transverse leaf spring is also a suspension member.

The [spring mounting point on the chassis](#), together with the [basic spring dimensions](#), must also be specified.

There are some additional [implementation notes](#).

6.3.9 Upper lateral link, lower reversed A-arm, twin trailing links

Enter the values for the top trailing and lateral links pivot points.

Enter the values for the bottom trailing link and reverse A-arm apex pivot points.

6.3.10 Lower lateral link, upper reversed A-arm, twin trailing links

Enter the values for the top trailing link and reverse A-arm apex pivot points.

Enter the values for the bottom trailing link and lateral link pivot points.

6.3.11 Upper lateral link, lower parallel links, twin trailing links

Enter the values for the top trailing and lateral links pivot points.

Enter the values for the bottom lateral links and trailing link pivot points.

6.3.12 Aarm Caster Link

Enter the values for the top control link pivot point.

Enter the values for the bottom control arm and toe control link pivot points.

6.3.13 Ford Twin I-Beam

Enter the values for the I-Beam and radius rod chassis pivot points.

6.3.14 Volkswagen twin trailing links

Enter the values for the top trailing link pivot point and the top torsion bar pivot mounting.

Enter the values for the bottom trailing link pivot point and the bottom torsion bar pivot mounting.

With a conventional suspension, the torsion bar pivot mounting is any convenient point along the line between the trailing link chassis mounting point and the trailing link chassis mounting point on the opposite side.

For the Porsche 718 K suspension, the torsion bar pivot mounting is usually on the vehicle centreline, and lower down, resulting in an inclined pivot axis in front view.

If the configuration does not include the steering linkage, the toe control mounting values are not required, and the Roll & Bump calculations will assume that there is no toe change in bump and droop.

6.3.15 Jaguar/H-arm + camber link/Porsche928

If the configuration option “Swing axle lengths and roll/pitch centre heights” is specified, the chassis mounting vertical dimensions cannot be input, and will be calculated. The swing axle lengths and roll centre height must be specified.

For the Jaguar, the top pivot points correspond to the driveshaft universal joint centres.

Enter the values for the top pivot point.

Enter the values for the bottom A-arm front & rear pivot points.

The longitudinal values need not be entered, and if left at 0.00, they will be set to default values such that the A-arm base length is approximately equal to the tyre rolling radius.

If the configuration does not include the steering linkage, the toe control mounting values are not required, and the Roll & Bump calculations will assume that there is no toe change in bump and droop.

The H-arm and camber link can also be inverted, with an upper H-arm and lower camber control link.

6.3.16 Semi-trailing arm (also includes trailing arm and swing axle)

Depending on the Geometry configuration selected, not all values can be input. If the values are “read only”, they will be calculated.

Enter the horizontal, vertical and longitudinal values for the two chassis pivot points.

For a semi-trailing arm or trailing arm, the two pivot points are called ‘Outer’ and ‘Inner’.

For a swing axle, the two pivot points are called ‘Front’ and ‘Rear’.

It is common in this configuration to use a single jointed half shaft as one of the suspension links.

6.3.17 Semi-trailing arm (fixed outer pivot, suspended inner pivot), toe link.

Enter the chassis trailing arm mounting (if required), toe control link mounting, and toe link mounting.

6.3.18 Trailing arm, upper and lower lateral links

Depending on the Geometry configuration selected, not all values need be input. Conversely, some input values may be recalculated.

Enter the chassis top and bottom lateral link mountings, and, if required, the chassis trailing arm mounting.

6.3.19 Trailing arm, upper and lower lateral links, toe control link

Depending on the Geometry configuration selected, not all values need be input. Conversely, some input values may be recalculated.

Enter the chassis upper and lower lateral link mountings, toe control link mounting, and, if required, the chassis trailing arm mounting.

6.3.20 Strut

Depending on the Geometry configuration selected, not all values need be input. Conversely, some input values may be recalculated.

Enter the chassis top strut mounting pivot point values.

Value	Comment
-------	---------

Horizontal	If the 'strut top mounting' option is selected, this will fix the strut top mounting horizontal value, otherwise it will be calculated.
------------	---

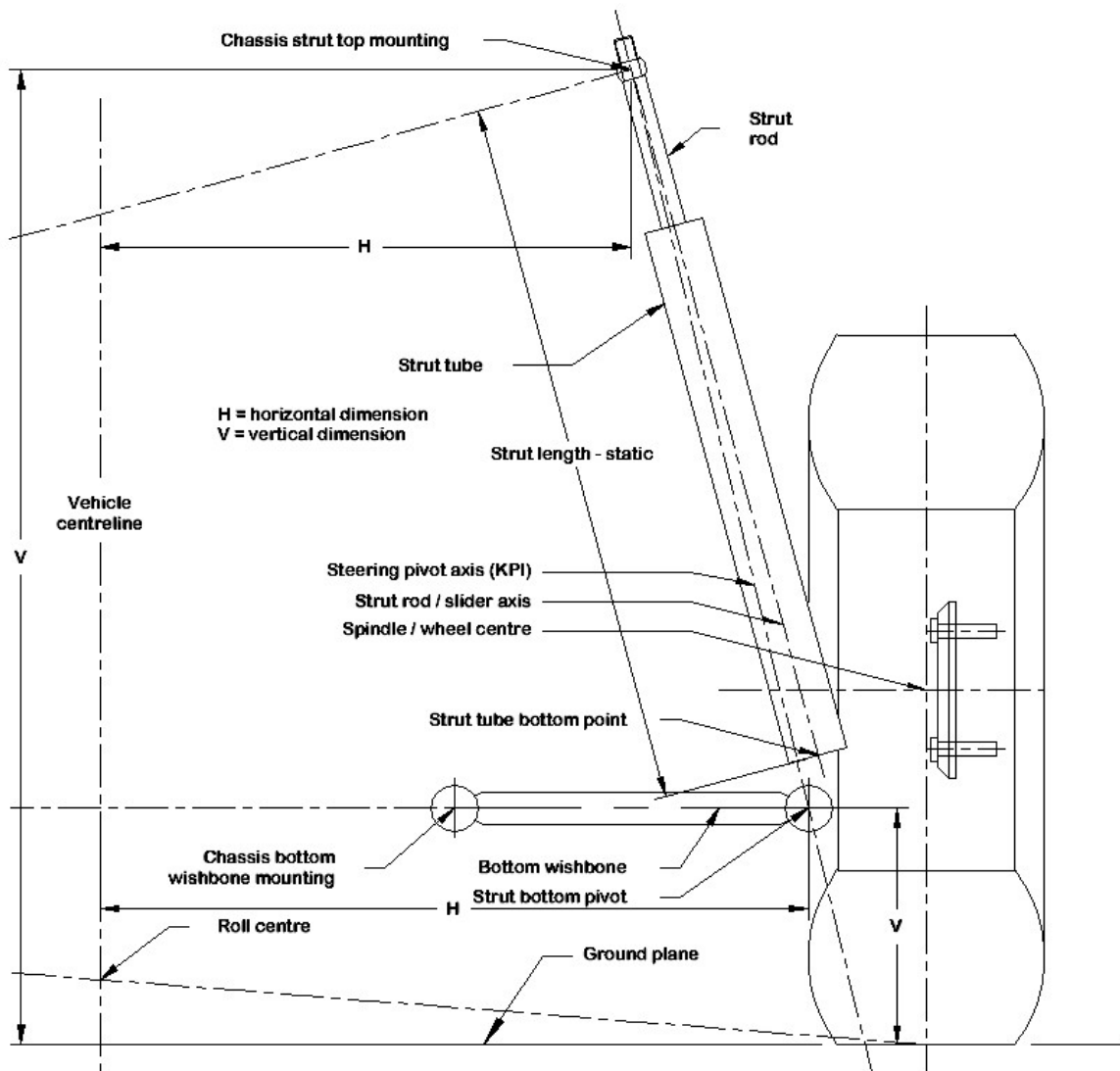
Vertical	If input, will be as specified. If the input value is zero, the vertical dimension will be calculated to put the chassis mounting point on the same point as the strut rod top pivot point.
----------	---

Longitudinal	If the 'strut top mounting, Z' option is selected, this will fix the strut top mounting longitudinal value, otherwise it will be calculated.
--------------	--

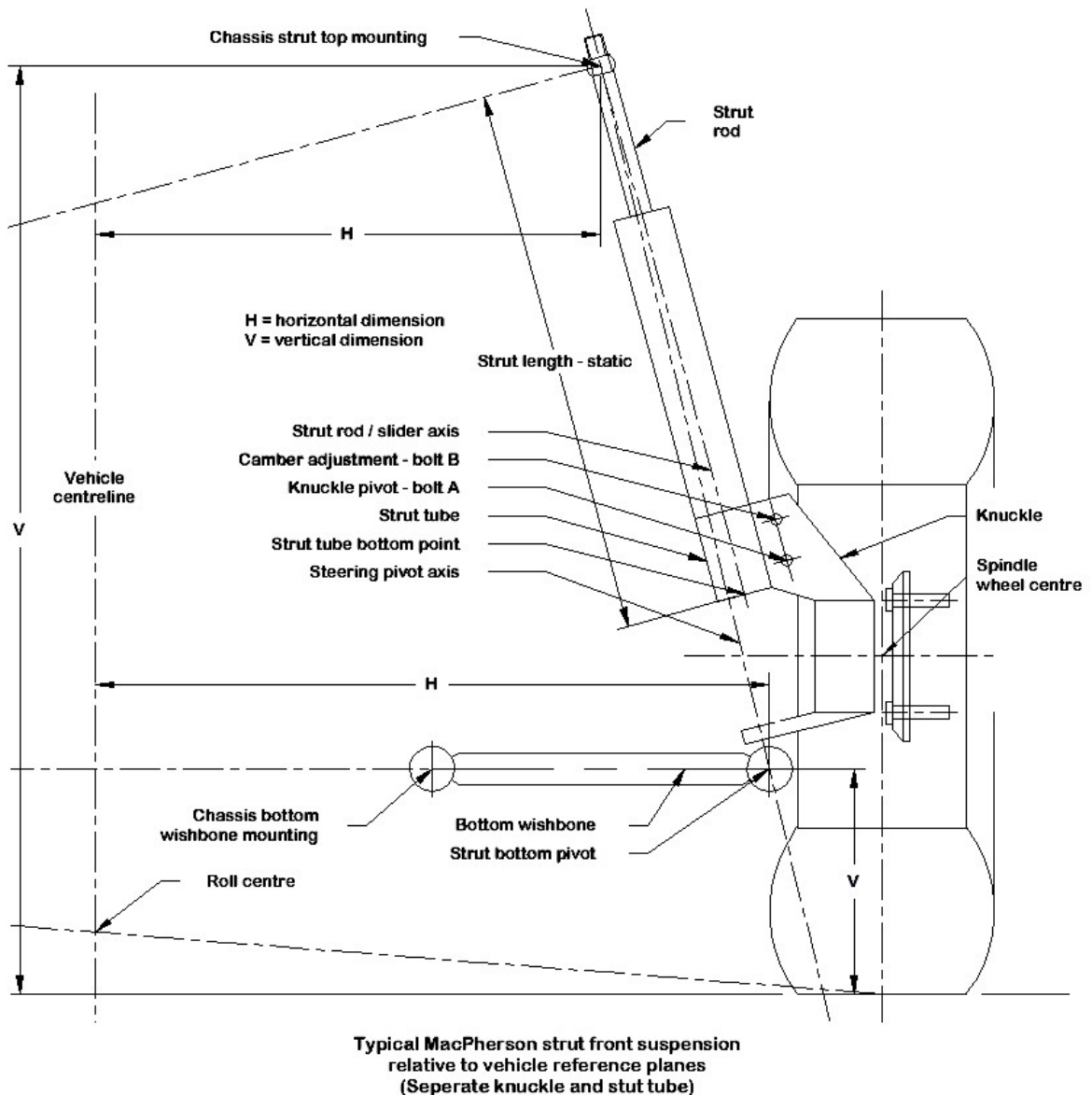
Enter the values for the bottom link front & rear pivot points.

The longitudinal values need not be entered, and if left at 0.00, they will be set to default values such that the A-arm base length is approximately equal to the tyre rolling radius.

If the configuration does not include the steering linkage, the toe control mounting values are not required, and the Roll & Bump calculations will assume that there is no toe change in bump and droop.



Typical MacPherson strut front suspension relative to vehicle reference planes (Integral knuckle and strut tube)



6.3.21 Live axle (torque arm) - 4 trailing links with birdcage + Panhard rod

Enter the horizontal, vertical and longitudinal values for the trailing links and Panhard rod chassis mounting point.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

Enter the horizontal, vertical and longitudinal values for the torque arm link chassis pivot point.

Usually, the torque arm is offset to one side of the chassis centreline (in plan view) to clear the driveline. The horizontal dimension will be either positive (if offset along the positive horizontal axis) or negative (if offset along the negative horizontal axis).

6.3.22 Live axle (torque arm) - 4 trailing links with birdcage + Watts linkage

Enter the horizontal, vertical and longitudinal values for the trailing link chassis mounting points.

Depending on the chosen configuration, enter the horizontal, vertical and longitudinal values for either the Watts axis pivot points, or the Watts links.

Except for the chassis mounted Watts linkage reference point P2, note that horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

If the Watts linkage is chassis mounted, then P1 is the actual chassis pivot point, and the horizontal value will be zero. P2 is a point along the pivot axis and is referenced relative to P1. If the axis is parallel to both the the chassis horizontal and vertical datum, then the horizontal dimension will be 0, the vertical dimension will be 0.0 and the longitudinal dimension will be some convenient value, say 100mm.

Enter the horizontal, vertical and longitudinal values for the torque arm link chassis pivot point.

Usually, the torque arm is offset to one side of the chassis centreline (in plan view) to clear the driveline. The horizontal dimension will be either positive (if offset along the positive horizontal axis) or negative (if offset along the negative horizontal axis).

6.3.23 Live axle (torque arm) - 2 trailing links and torque arm slider + Panhard rod

Enter the horizontal, vertical and longitudinal values for the torque arm slider chassis pivot point, trailing link chassis mounting points and Panhard rod chassis mounting point.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

Usually, the torque arm is offset to one side of the chassis centreline (in plan view) to clear the driveline. The horizontal dimension will be either positive (if offset along the positive horizontal axis) or negative (if offset along the negative horizontal axis).

6.3.24 Live axle (torque arm) - 2 trailing links and torque arm slider + Watts linkage

Enter the horizontal, vertical and longitudinal values for the torque arm slider chassis pivot point and trailing link chassis mounting points.

Depending on the chosen configuration, enter the horizontal, vertical and longitudinal values for either the Watts axis pivot points, or the Watts links.

Except for the chassis mounted Watts linkage reference point P2, note that horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

If the Watts linkage is chassis mounted, then P1 is the actual chassis pivot point, and the horizontal value will be zero. P2 is a point along the pivot axis and is referenced relative to P1. If the axis is parallel to both the the chassis horizontal and vertical datum, then the horizontal dimension will be 0, the vertical dimension will be 0.0 and the longitudinal dimension will be some convenient value, say 100mm.

Usually, the torque arm is offset to one side of the chassis centreline (in plan view) to clear the driveline. The horizontal dimension will be either positive (if offset along the positive horizontal axis) or negative (if offset along the negative horizontal axis).

6.3.25 Live axle (torque tube) + Panhard rod

Enter the horizontal, vertical and longitudinal values for the torque tube ball joint chassis pivot point and Panhard rod chassis mounting point.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

Usually, the torque tube ball joint is on the chassis centreline (in plan view) and the horizontal value will be zero. If, however, it is offset, then the horizontal dimension will be either positive (if offset along the positive horizontal axis) or negative (if offset along the negative horizontal axis).

6.3.26 Live axle (torque tube) + Watts linkage

Enter the horizontal, vertical and longitudinal values for the torque tube ball joint chassis pivot point.

Depending on the chosen configuration, enter the horizontal, vertical and longitudinal values for either the Watts axis pivot points, or the Watts links.

Except for the chassis mounted Watts linkage reference point P2, note that horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

If the Watts linkage is chassis mounted, then P1 is the actual chassis pivot point, and the horizontal value will be zero. P2 is a point along the pivot axis and is referenced relative to P1. If the axis is parallel to both the the chassis horizontal and vertical datum, then the horizontal dimension will be 0, the vertical dimension will be 0.0 and the longitudinal dimension will be some convenient value, say 100mm.

Usually, the torque tube ball joint is on the chassis centreline (in plan view) and the horizontal value will be zero. If, however, it is offset, then the horizontal dimension will be either positive (if offset along the positive horizontal axis) or negative (if offset along the negative horizontal axis).

6.3.27 Winters: 4 trailing links, 2 birdcages + Jacobs ladder

Longitudinal links that attach to the chassis in front of the axle are trailing links; longitudinal links that attach to the chassis behind the axle are leading links. But all links are referred to as trailing links.

The longitudinal links can be arranged with all four links in the same direction (either trailing or leading) or with the links in a "Z" configuration, usually with the top link trailing and the bottom link leading, similar to a Watts linkage.

Enter the horizontal, vertical and longitudinal values for the trailing link chassis mounting points, torque tube ball joint chassis pivot point and Jacobs ladder chassis mounting point.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or

[chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

Usually, the torque tube ball joint is on the chassis centreline (in plan view) and the horizontal value will be zero. If, however, it is offset, then the horizontal dimension will be either positive (if offset along the positive horizontal axis) or negative (if offset along the negative horizontal axis).

6.3.28 Live axle/deDion - twin trailing arms + Mumford linkage

Enter the horizontal, vertical and longitudinal values for the trailing link chassis pivot points, LH and RH, Mumford bellcrank axis pivot points, and the Mumford lever pivot point and all arm and link lengths.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, vertical values are measured from the chassis vertical datum, and longitudinal values from the chassis longitudinal datum.

Except for the Mumford bellcrank reference point P2, note that horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

The Mumford bellcrank axis P2 is a point along the pivot axis and is referenced relative to P1. If the axis is parallel to both the the chassis horizontal and vertical datum, then the horizontal dimension will be 0, the vertical dimension will be 0.0 and the longitudinal dimension will be some convenient value, say 100mm.

The Mumford lever axis is always parallel to the bellcrank axis.

6.3.29 Live axle/deDion - twin trailing arms + Panhard rod

Rear suspension is configured with trailing arms; front suspension is configured with leading arms.

Enter the horizontal, vertical and longitudinal values for the trailing / leading arm chassis pivot points, LH and RH and Panhard rod chassis mounting point.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

6.3.30 Live axle/deDion - twin trailing arms + Watts linkage

Enter the horizontal, vertical and longitudinal values for the trailing link chassis pivot points, LH and RH.

Depending on the chosen configuration, enter the horizontal, vertical and longitudinal values for either the Watts axis pivot points, or the Watts links.

Except for the chassis mounted Watts linkage reference point P2, note that horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

If the Watts linkage is chassis mounted, then P1 is the actual chassis pivot point, and the horizontal value will be zero. P2 is a point along the pivot axis and is referenced relative to P1. If the axis is parallel to both the the chassis horizontal and vertical datum, then the horizontal dimension will be 0,

the vertical dimension will be 0.0 and the longitudinal dimension will be some convenient value, say 100mm.

6.3.31 Live axle/deDion - 3 or 4 link + Mumford linkage

Enter the horizontal, vertical and longitudinal values for the trailing link chassis pivot points, LH top, LH bottom, RH top, RH bottom (as required), Mumford bellcrank axis pivot points, and the Mumford lever pivot point and all arm and link lengths.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, vertical values are measured from the chassis vertical datum, and longitudinal values from the chassis longitudinal datum.

Except for the Mumford bellcrank reference point P2, note that horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

The Mumford bellcrank axis P2 is a point along the pivot axis and is referenced relative to P1. If the axis is parallel to both the the chassis horizontal and vertical datum, then the horizontal dimension will be 0, the vertical dimension will be 0.0 and the longitudinal dimension will be some convenient value, say 100mm.

The Mumford lever axis is always parallel to the bellcrank axis.

6.3.32 Live axle/deDion - 3 or 4 link + Panhard rod

Usually the rear suspension is configured with trailing links; front suspension is configured with leading links.

Enter the horizontal, vertical and longitudinal values for the trailing / leading link chassis pivot points, LH top, LH bottom, RH top, RH bottom (as required) and Panhard rod chassis mounting point.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

6.3.33 Live axle/deDion - 3 or 4 link + Watts linkage

Enter the horizontal, vertical and longitudinal values for the trailing link chassis pivot points, LH top, LH bottom, RH top, RH bottom (as required).

Depending on the chosen configuration, enter the horizontal, vertical and longitudinal values for either the Watts axis pivot points, or the Watts links.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, vertical values are measured from the chassis vertical datum, and longitudinal values from the chassis longitudinal datum.

Except for the chassis mounted Watts linkage reference point P2, note that horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

If the Watts linkage is chassis mounted, then P1 is the actual chassis pivot point, and the horizontal value will be zero. P2 is a point along the pivot axis and is referenced relative to P1. If the axis is

parallel to both the the chassis horizontal and vertical datum, then the horizontal dimension will be 0, the vertical dimension will be 0.0 and the longitudinal dimension will be some convenient value, say 100mm.

6.3.34 Live axle/deDion - 3 or 4 link + Woblink

Enter the horizontal, vertical and longitudinal values for the trailing link chassis pivot points, LH top, LH bottom, RH top, RH bottom (as required).

Depending on the chosen configuration, enter the horizontal, vertical and longitudinal values for either the Woblink axis pivot points, or the Woblink links.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, vertical values are measured from the chassis vertical datum, and longitudinal values from the chassis longitudinal datum.

Except for the chassis mounted Woblink reference point P2, note that horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

If the Woblink is chassis mounted, then P1 is the actual chassis pivot point, and the horizontal value will be zero. P2 is a point along the pivot axis and is referenced relative to P1. If the axis is parallel to both the the chassis horizontal and vertical datum, then the horizontal dimension will be 0, the vertical dimension will be 0.0 and the longitudinal dimension will be some convenient value, say 100mm.

6.3.35 Live axle/deDion - 4 link

Enter the horizontal, vertical and longitudinal values for the trailing link chassis pivot points, LH top, LH bottom, RH top, RH bottom.

The horizontal values for both RH and LH points are positive and are measured from the vehicle centreline outwards, horizontally from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

6.3.36 Mono wheel - trailing arm

Depending on the Geometry configuration selected, not all values can be input. If the values are “read only”, they will be calculated.

Enter the horizontal, vertical and longitudinal values for the two chassis pivot points, LH and RH.

The horizontal dimension of the trailing arm pivot points are positive measuring out from the chassis centreline, regardless of the direction of the positive horizontal axis.

6.4 Upright/Trailing Arm/Strut/Axle

From the Geometry tab, select Upright, Strut, Trailing arm, or Axle.

6.4.1 Upright

Upright coordinates are vehicle independent and are represented with horizontal, vertical and longitudinal values. The datums for the upright are the wheel mounting flange and the axle (or hub) centreline.

Again, imagine the upright viewed from the front of the vehicle. Horizontal values are axial dimensions (along the axle or spindle) from the wheel mounting flange, vertical and longitudinal values are radial dimensions from the axle centreline.

All upright measurements are measured with the upright at zero camber, [castor](#) and toe position.

The horizontal dimension of points inboard of the wheel mounting flange are always positive, regardless of the direction of the positive horizontal axis.

For the usual design of upright, the top pivot point(s) is above the axle centreline, and the bottom pivot point(s) is below the axle centreline. If the vertical axis is positive upward, then the top pivot vertical dimension will be positive and the bottom pivot vertical dimension will be negative; if the vertical axis is positive downward, then the top pivot vertical dimension will be negative and the bottom pivot vertical dimension will be positive.

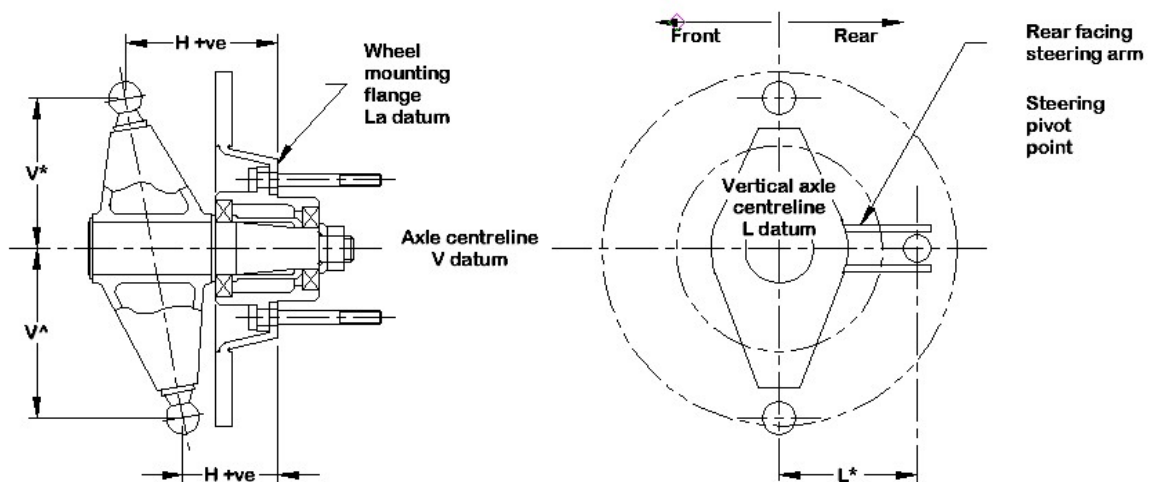
Longitudinal values are measured radially from the axle centreline in side view, and will be positive to the rear, negative to the front (if the longitudinal axis is specified as +ve rear); or will be positive to the front, negative to the rear (if the longitudinal axis is specified as +ve front).

If you have been provided with upright mounting points in vehicle coordinates, use the [CAD2SusProg](#) tool to convert back to upright coordinates.

Depending on the particular geometry type, there will be 3, 4 or 5 pivot mounting points.

Enter the required values for the upright top and bottom pivot points.

If the wheel camber is adjusted by means of an "[upright camber shim](#)" then use one of these options to see the effect of changing the camber shim thickness.



Upright dimensions

For most A-arm Geometry calculations the toe control mounting values are not required as the wheel alignment toe is specified, and in this case the Roll & Bump calculations will assume that there is no toe change in bump and droop. If all links and steering are fixed, then the Roll & Bump calculations will calculate the toe change in bump and droop.

For all other suspension types, the toe control mounting values are required. The Roll & Bump calculations will calculate the toe change in bump and droop.

The spindle reference point is a “user defined” point and can be at any location along the axle (or spindle). The position is measured axially from the wheel mounting flange. It is positive if inboard from the wheel mounting flange.

The spindle centre point is located on the axle centreline, in the plane of the wheel and tyre centre. There is no user input for this point.

After Geometry | Calculate, the vehicle coordinate values for these points will be shown in the Result window.

6.4.1.1 Uprights with trunnions or kingpins

For a front suspension with upper and lower A-arms, some upright designs do not use a ball joint, but instead use a kingpin swivel (sometimes called a trunnion). The kingpin swivel is arranged such that it can only rotate about the kingpin axis, usually on some kind of bush or bearing. Some uprights use a thread.

Type 1: The Triumph family, Spitfire, Vitesse, TR4, TR6 and many of the 60's and 70's race cars used the Alford & Alder vertical link, with a top ball joint and a bottom trunnion.

Type 2: The later Skyline also use a top kingpin swivel with a lower ball joint.

Type 3: The MG family, TD, TF, MGA and MGB use a long kingpin with top and bottom trunnions.

Type 4: Early production cars, typically US models in the 40's, 50's and even into the 60's used a vertical link which combined a short kingpin and upper and lower A-arm mounts in a single component, the upright knuckle.

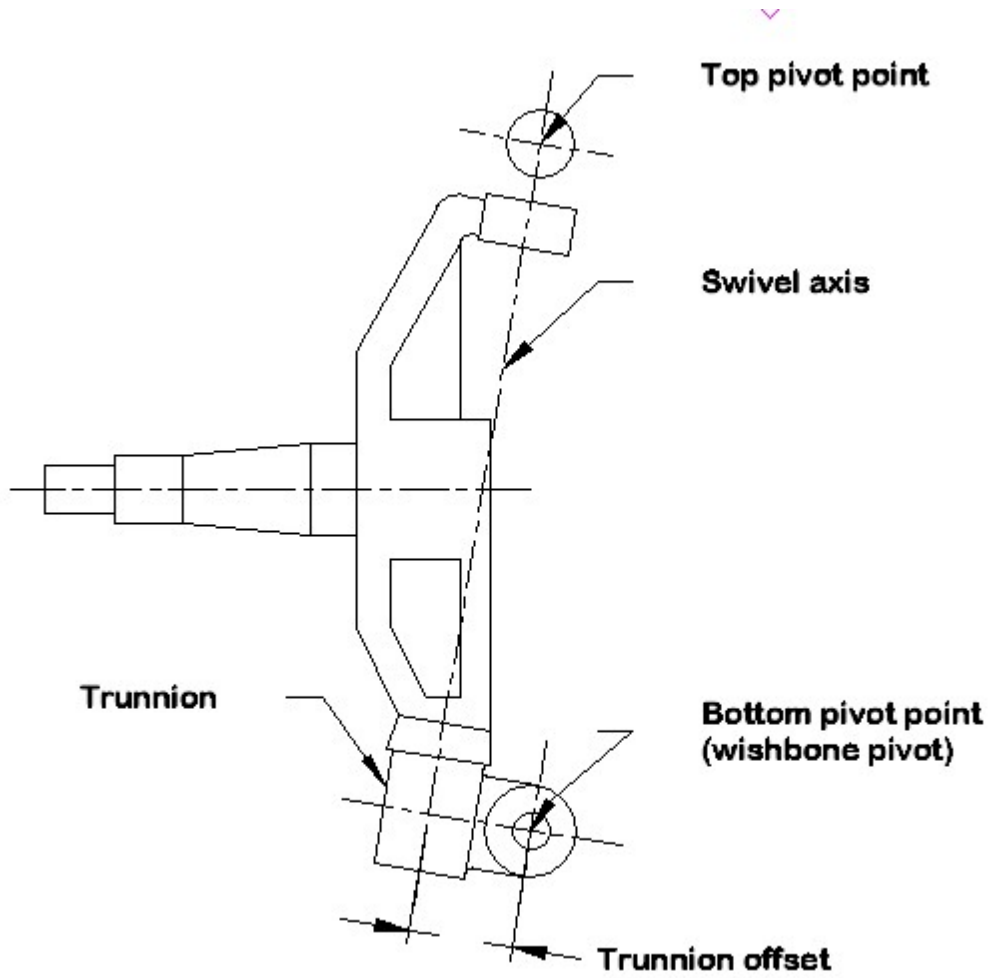
For Type 1 and 2, the ball joint and the trunnion end of the kingpin are dimensioned from the hub mounting face and the axle centreline.

For Type 3 and 4, the upper and lower ends of the kingpin are dimensioned from the hub mounting face and the axle centreline.

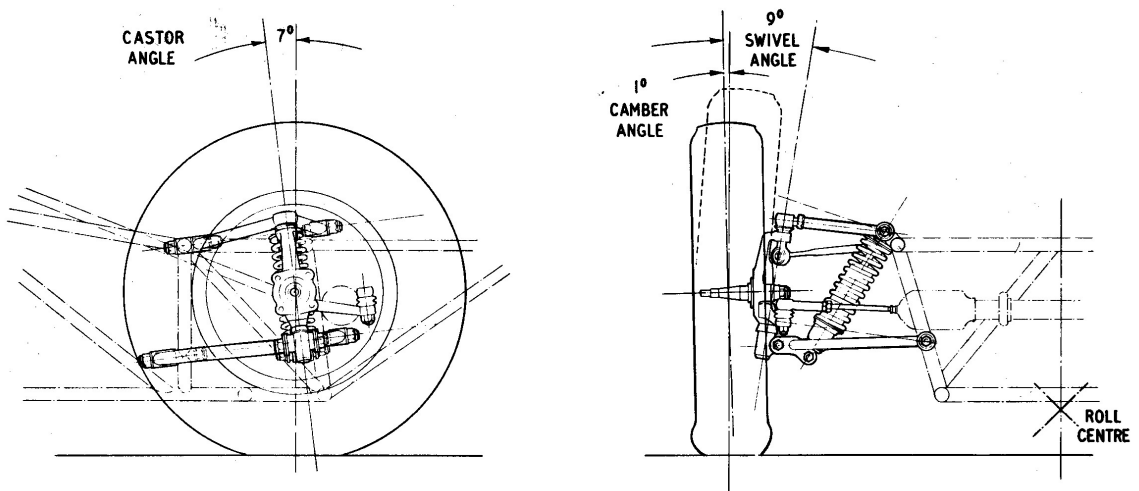
For all types, the A-arm pivot is then dimensioned from the kingpin point. The swivel offset is the distance from the horizontal A-arm pivot normal to the kingpin swivel axis. If the a-arm pivot is further out from the kingpin swivel axis (as the Triumph Spitfire bottom trunnion) this dimension is positive. If the a-arm pivot is back toward the the hub face datum from the kingpin swivel axis (as the MGB top trunnion) this dimension is negative.

The kingpin swivel can also have a vertical offset. This offset is measured along the kingpin axis. If the a-arm pivot is above the kingpin point, then this dimension will be positive.

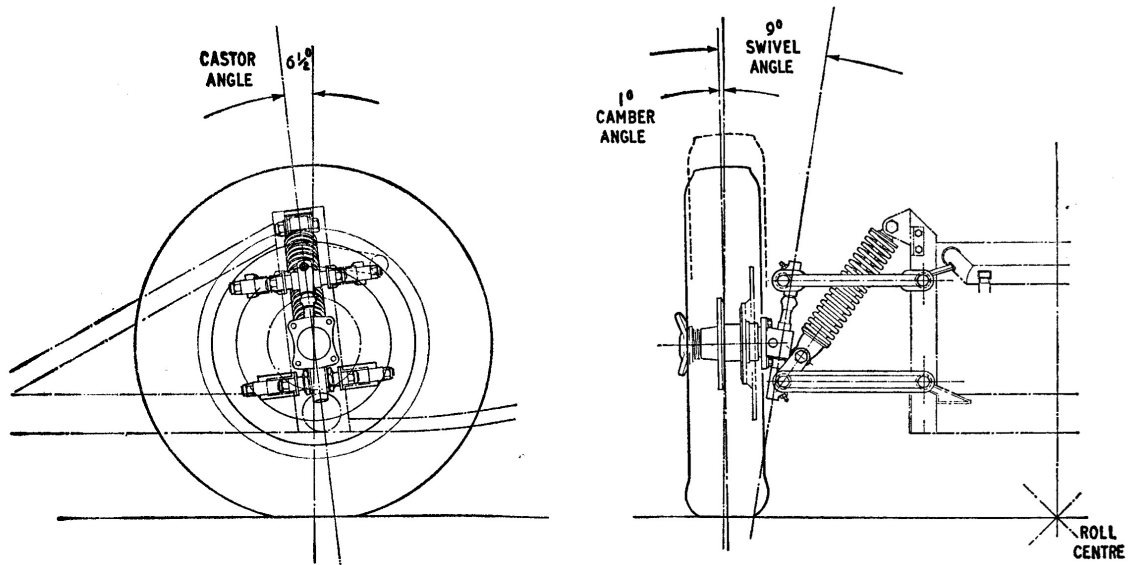
When the suspension geometry is calculated, the kingpin swivel is rotated around the kingpin axis such that the a-arm pivot (in the swivel) is parallel to the a-arm chassis pivot axis (in plan view). The kingpin swivel will always be kept in alignment with the kingpin axis. If there is any misalignment in side view (usually because the a-arm chassis pivot axis isn't at right angles to the kingpin axis) then this will be reported. In the ideal world, the a-arm pivot (in the swivel) would always be parallel to the a-arm chassis pivot axis. If there is any misalignment then this will eventually lead to wear and unwanted movement in the a-arm swivel bearing or the kingpin swivel bearing.



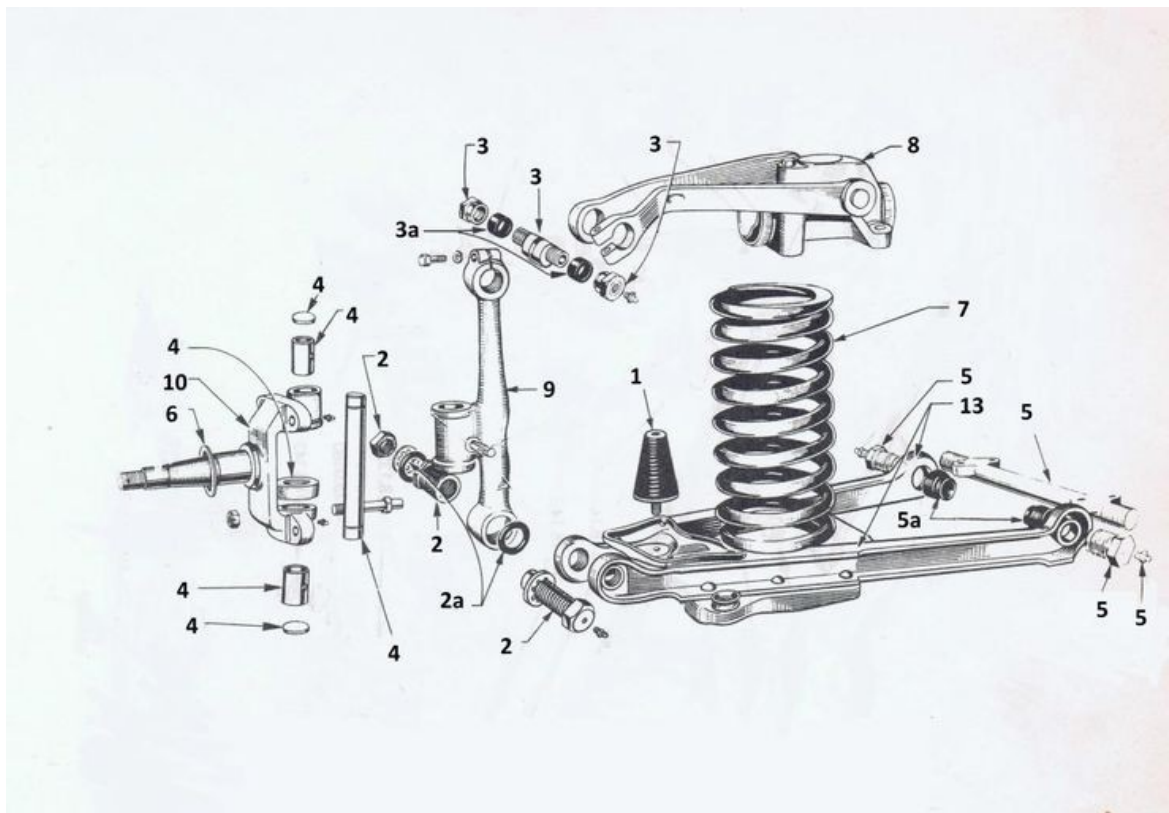
Type 1: Triumph Spitfire front upright



Type 1: Typical 60's race car with Triumph type front upright. Note how the A-arms are both inclined in side view to match the caster angle.



Type 3: 1957 Lister Jaguar using what appear to be MGA uprights. Note how the A-arms are both inclined in side view to match the caster angle.



Type 4: The knuckle, 10, is dimensioned from the hub face and axle centreline. The A-arm mounting points 2 and 3 on the upright 9 are dimensioned from the kingpin 4. Note that there is provision for both camber (item 3) and caster (item 2) adjustment. The actual degree of caster adjustment was relatively small, and any consequent misalignment of the A-arm swivel pivot axis with the A-arm chassis pivot axis is absorbed by the A-arms twisting. The consequence was that the pivots required frequent lubrication.

6.4.1.2 Upright camber shims

For double A-arm configurations, there is provision for specifying an “upright camber shim”. This shim is fitted between the upright body and the upright pivot bracket. The upright pivot bracket is often extended to include the toe control pivot, in which case adjusting camber has little or no effect on toe settings. It also is a way of decoupling camber and [KPI](#), so that each may be adjusted independently of the other.

Currently, there are five upright camber shim styles available:

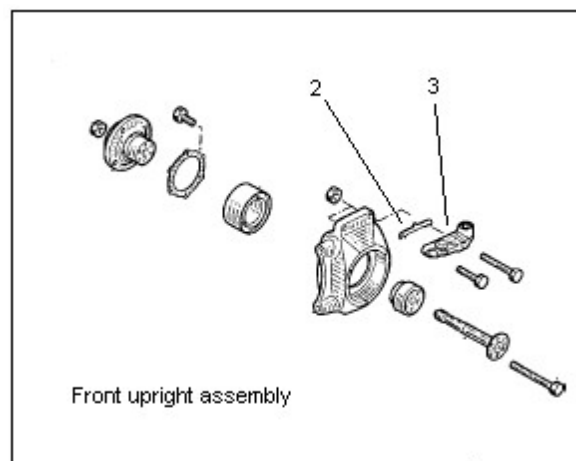
None	The design of the upright does not incorporate camber shims.
Top pivot only	The camber shim adjusts the top upright pivot only. Adding shims will increase positive camber; and for a front steer car, usually increase toe-in.
Top pivot and toe control	The camber shim adjusts both the top upright pivot and the toe control point by the same amount. Adding shims will increase positive camber; toe is unchanged.
Bottom pivot only	The camber shim adjusts the bottom upright pivot only. Adding shims will increase negative camber; and for a front steer car, usually increase toe-in.
Bottom pivot and toe control	The camber shim adjusts both the bottom upright pivot and the toe control point by the same amount. Adding shims will increase negative camber; toe is unchanged.

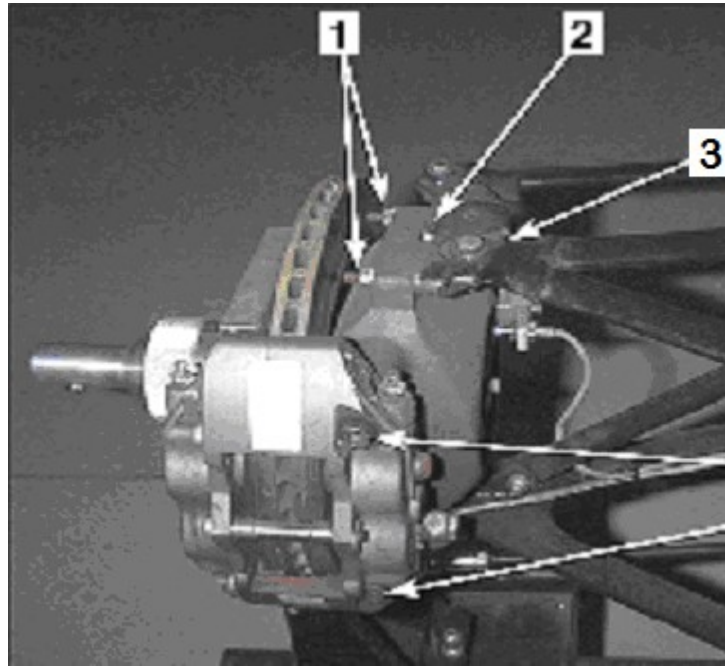
Specify the pivot point horizontal dimensions **without** shims.

Specify the shim thickness - this is the thickness of one shim.

Specify the number of shims.

For maximum adjustability, specify a shim pack half the maximum number with the camber at the design setting. This will allow for maximum camber adjustment from the design setting.

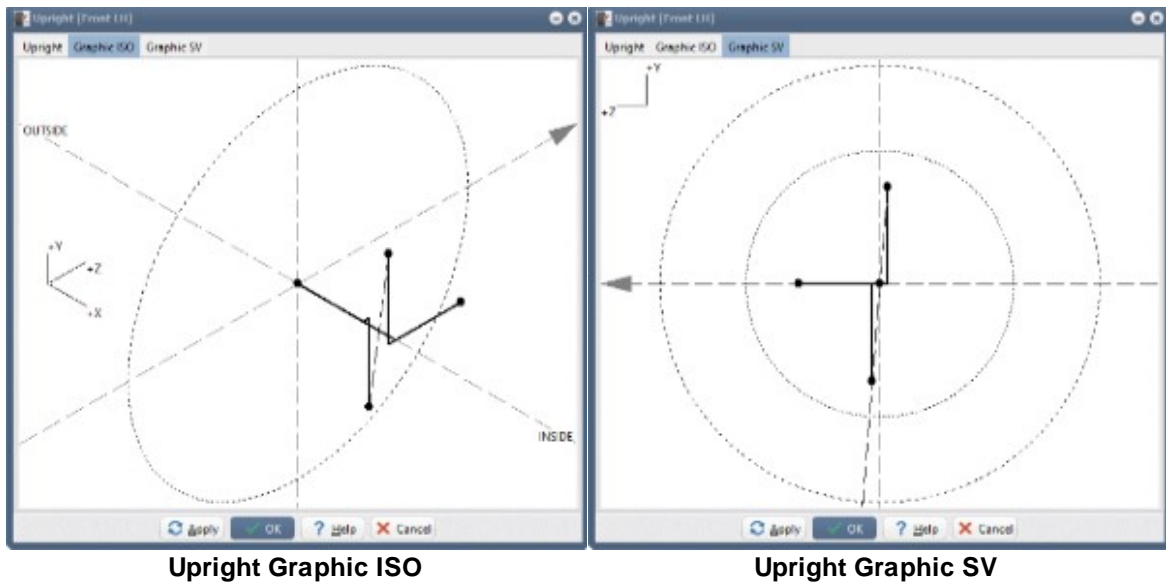




Typical front suspension assembly showing upright camber shim [2]. In this example, the bracket [3] combines the top A-arm mounting and the steering arm. The camber shim adjusts both the top upright pivot and the steering arm by the same amount.

6.4.1.3 Graphic

After entering the required dimensional data, click on either the "Graphic ISO" tab to display a 3D isometric representation of the upright, or the "Graphic SV" tab to display a 2D side view.



Upright Graphic ISO

Upright Graphic SV

It will show the A-arm mounting points, steering arm and [kingpin axis](#) as appropriate.

It is intended that this graphic will provide a basic visual confirmation that all the elements are in the expected position and orientation.

A reference axis is shown.

If you hover the mouse over a pivot point or line, a hint will show with the identification and coordinates of that point.

For the front suspension, a dashed line indicates the kingpin axis. The nominal kingpin axis is drawn from top to bottom ball joints.

If either (or both) ball joint is a "double ball joint" then the actual kingpin axis point will be determined by the link geometry. For this graphic, the kingpin axis line will be drawn to the mid point of the two ball joints.

- Graphic ISO The elliptical dotted line represents the centre of the tyre.
 The axis labeled "INSIDE" – "OUTSIDE" is the spindle or axle centreline and the axis with the arrow points to the front of the vehicle.
 The upright is viewed as though you were standing on the opposite side of the vehicle, looking at the inside of the wheel.
 All pivot points are drawn with a line starting at the datum intersection, along the horizontal axis, then backwards or forwards parallel to the longitudinal axis, and finally up or down parallel to the vertical axis.
- Graphic SV The outer circle represents the tyre diameter, and the inner circle the wheel diameter.
 The axis with the arrow points to the front of the vehicle.
 All pivot points are drawn with a line starting at the datum intersection, backwards or forwards along the horizontal axis, and finally up or down parallel to the vertical axis.

6.4.2 Trailing arm (independent suspension)

Trailing arms come in two basic configurations: double pivot and single pivot. The single pivot types will have additional lateral control links.

They are usually large castings or fabrications which comprise a hub carrier (which houses the hub shaft bearings and hub shaft) extended with one or two 'legs' terminating in bushes which then attach to the chassis.

Measuring hints.

When measuring a trailing arm it is probably easiest to set up the trailing arm on a flat surface, with the axle and bearings in place. The axle will usually have small machining location centres in each end which can be used as location points.

Draw two lines on the surface at right angles. These will be the horizontal and longitudinal datum lines.

Since the axle and the pivot axis may not be co-planar, it may be easiest to use the axle ends and one mounting bush to define the vertical datum plane.

You will need packing blocks and shims to place under the hub section, and under each of the mounting points. Adjust the blocks so that the axle is horizontal and that the centre of one of the mounting bushes (probably the outer (or front) one) is at the same height as the axle centre. Call this mounting bush 'A'. Make sure that the centreline of the axle is directly above the longitudinal datum line, and that the face of the wheel hub is on the horizontal datum line. This will now have the axle and one mounting point in a plane parallel to the vertical datum plane, and some distance above it. Note this dimension 'B'.

Now measure the horizontal and longitudinal dimensions of the two mounting points (as close to the bush centre as possible) from the horizontal and longitudinal datum lines.

The vertical dimension of mounting point 'A' will be zero. Measure the height of the other mounting point (as close to the centre as possible). The vertical dimension of this mounting point will be the measured dimension less the 'B' dimension.

This same technique can be used to locate the spring, shockabsorber and anti-roll bar linkage mounting points.

If you are unable to remove or disassemble the trailing arm, then reasonable dimensions can be made by placing a straight edge across the wheel mounting flange and measuring the mounting

offsets. For the initial calculations you can assume that the axle and pivot axis are co-planar, and that both mounting points have zero vertical dimensions.

6.4.2.1 Semi-trailing arm (includes trailing arm and swing axle)

The chassis mounting points are all dimensioned relative to the wheel mounting flange, the axle centreline and a horizontal plane through the axle centreline (in side view).

Note that the semi-trailing arm datums are the same as when the semi-trailing arm is positioned with zero camber, zero inclination and zero toe. Zero inclination (in side view) means that the axle centre and the chassis mounting are horizontal. This is also the same as zero [caster](#).

It is easiest to measure the semi-trailing arm removed from the vehicle. If this is not possible then take care to ensure that the correct reference datums are used to establish these dimensions.

If you have been provided with semi-trailing arm mounting points in vehicle coordinates, use the [CAD2SusProg](#) tool to convert back to trailing arm coordinates.

In this type of semi-trailing arm, the arm and the hub and spindle assembly are rigidly fixed together.

The spindle reference point is a "user defined" point and can be at any location along the axle (or spindle). The position is measured axially from the wheel mounting flange. It is positive if inboard from the wheel mounting flange.

The spindle centre point is located on the axle centreline, in the plane of the wheel and tyre centre. There is no user input for this point.

For a semi-trailing arm or trailing arm, the two pivot points are called 'Outer' and 'Inner'.

For a swing axle, the two pivot points are called 'Front' and 'Rear'.

It is common in this configuration to use a drive shaft with a single universal joint as one of the suspension links. In this case, the vertical and longitudinal dimensions of the "drive shaft" link must be zero, because the drive shaft must be at right angles to the plane of the wheel. Also, if the "drive shaft" link is the rear link, then either the trailing arm dimensions, or the chassis mounting points, should be adjusted to minimise the "mounting error" because the calculations are using the front mount point as the reference point. As long as the "mounting error" is small the error will be insignificant.

See above for [measuring hints](#).

Calculation note.

If the semi-trailing arm mounting points on the chassis and the dimensions of the semi-trailing arm are both specified, it is possible that there is a small difference in the calculated distance between the two chassis mounting points and the two semi-trailing arm mounting points. When the arm is fitted to the vehicle, there is often enough flexibility (especially if rubber bushes are used), free play in the bolt holes, or shim washers to allow for this.

For SusProg3D calculation purposes, the semi-trailing arm outer (or front) mounting will always be coincident with the corresponding chassis mounting point. The semi-trailing arm inner (or rear) mounting will be located along the pivot axis (as defined by the two mounting points), but may not be coincident with the chassis mounting point. This offset will be noted as 'Mounting error' and will be positive if the span of the semi-trailing arm mountings is greater than the span of the chassis mountings.

6.4.2.2 Trailing arm

The horizontal link mounting points and the chassis mounting point are all dimensioned relative to the wheel mounting flange, the axle centreline and a horizontal plane through the axle centreline (in side view).

Note that the trailing arm datums are the same as when the trailing arm is positioned with zero camber, zero inclination and zero toe. Zero inclination (in side view) means that the axle centre and the chassis mounting are horizontal. This is also the same as zero [caster](#).

It is easiest to measure the trailing arm removed from the vehicle. If this is not possible then take care to ensure that the correct reference datums are used to establish these dimensions.

If you have been provided with trailing arm mounting points in vehicle coordinates, use the [CAD2SusProg](#) tool to convert back to trailing arm coordinates.

In this type of trailing arm, the arm and the hub and spindle assembly are rigidly fixed together.

The spindle reference point is a "user defined" point and can be at any location along the axle (or spindle). The position is measured axially from the wheel mounting flange. It is positive if inboard from the wheel mounting flange.

The spindle centre point is located on the axle centreline, in the plane of the wheel and tyre centre. There is no user input for this point.

See above for [measuring hints](#).

6.4.2.3 Mono wheel - trailing arm

The chassis mounting points are all dimensioned relative to the wheel mounting flange, the axle centreline and a horizontal plane through the axle centreline (in side view).

Note that the trailing arm datums are the same as when the trailing arm is positioned with zero camber, zero inclination and zero toe. Zero inclination (in side view) means that the axle centre and the chassis mounting are horizontal. This is also the same as zero [caster](#).

The horizontal dimension of the trailing arm pivot points are always positive measuring out from the wheel mounting flange, regardless of the direction of the positive horizontal axis.

It is easiest to measure the trailing arm removed from the vehicle. If this is not possible then take care to ensure that the correct reference datums are used to establish these dimensions.

If you have been provided with trailing arm mounting points in vehicle coordinates, use the [CAD2SusProg](#) tool to convert back to trailing arm coordinates.

In this type of trailing arm, the arm and the hub and spindle assembly are rigidly fixed together.

The spindle reference point is a "user defined" point and can be at any location along the axle (or spindle). The position is measured axially from the wheel mounting flange. It is positive if inboard from the wheel mounting flange.

The spindle centre point is located on the axle centreline, in the plane of the wheel and tyre centre. There is no user input for this point.

The two pivot points are called 'LH' and 'RH'.

See above for [measuring hints](#).

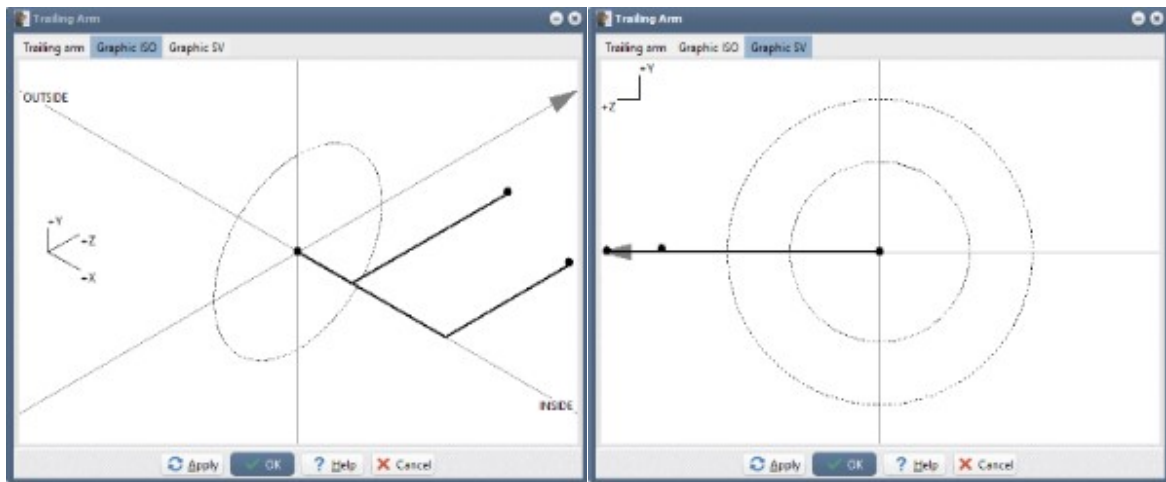
Calculation note.

If the trailing arm mounting points on the chassis and the dimensions of the trailing arm are both specified, it is possible that there is a small difference in the calculated distance between the two chassis mounting points and the two trailing arm mounting points. When the arm is fitted to the vehicle, there are often shim washers to allow for this.

For SusProg3D calculation purposes, the trailing arm will be laterally located with any mounting error equal on each mounting. This offset will be noted as 'Mounting error' and will be positive if the span of the semi-trailing arm mountings is greater than the span of the chassis mountings.

6.4.2.4 Graphic

After entering the required dimensional data, click on either the "Graphic ISO" tab to display a 3D isometric representation of the upright, or the "Graphic SV" tab to display a 2D side view.



Trailing Arm Graphic ISO ISO

Trailing Arm Graphic SV

It will show the trailing arm mounting points as appropriate.

It is intended that this graphic will provide a basic visual confirmation that all the elements are in the expected position and orientation.

A reference axis is shown.

If you hover the mouse over a pivot point or line, a hint will show with the identification and coordinates of that point.

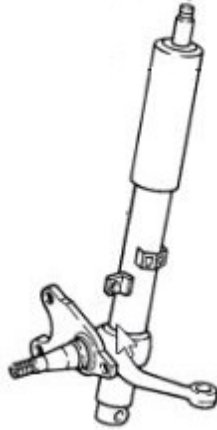
The trailing arm is drawn with a dotted line indicating the centre of the tyre.

Graphic ISO The elliptical dotted line represents the centre of the tyre.
 The axis labeled "INSIDE" – "OUTSIDE" is the spindle or axle centreline and the axis with the arrow points to the front of the vehicle.
 The trailing arm is viewed as though you were standing on the opposite side of the vehicle, looking at the inside of the wheel.
 All pivot points are drawn with a line starting at the datum intersection, along the horizontal axis, then backwards or forwards parallel to the longitudinal axis, and finally up or down parallel to the vertical axis.

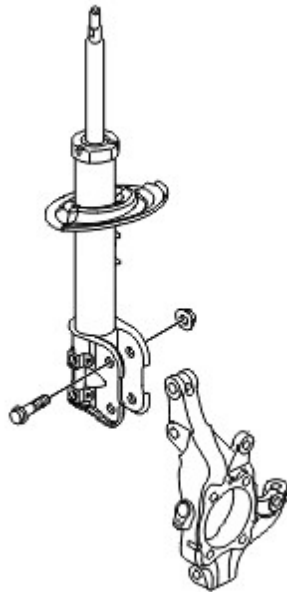
Graphic SV The outer circle represents the tyre diameter, and the inner circle the wheel diameter.
 The axis with the arrow points to the front of the vehicle.
 All pivot points are drawn with a line starting at the datum intersection, backwards or forwards along the horizontal axis, and finally up or down parallel to the vertical axis.

6.4.3 Strut

Depending on the type of strut (integral knuckle or separate knuckle) there are various alternative dimension points which define the basic strut configuration.



- for [integral strut tube and knuckle](#) type - strut & knuckle (fixed). Data input A or B.



- for [separate strut tube and knuckle](#) type - strut & knuckle (adjustable). Data input C or D.

The bottom A-arm ball joint pivot(s) position and the CV joint position are both dimensioned relative to the wheel mounting flange, the axle centreline and a vertical line through the axle centreline parallel to the strut rod axis with the strut rod vertical (in side view).

Note that the knuckle datums are the same as the strut position with zero camber and zero toe. If the axle centreline is on the strut rod axis (in side view), then this is also the same as zero [caster](#).

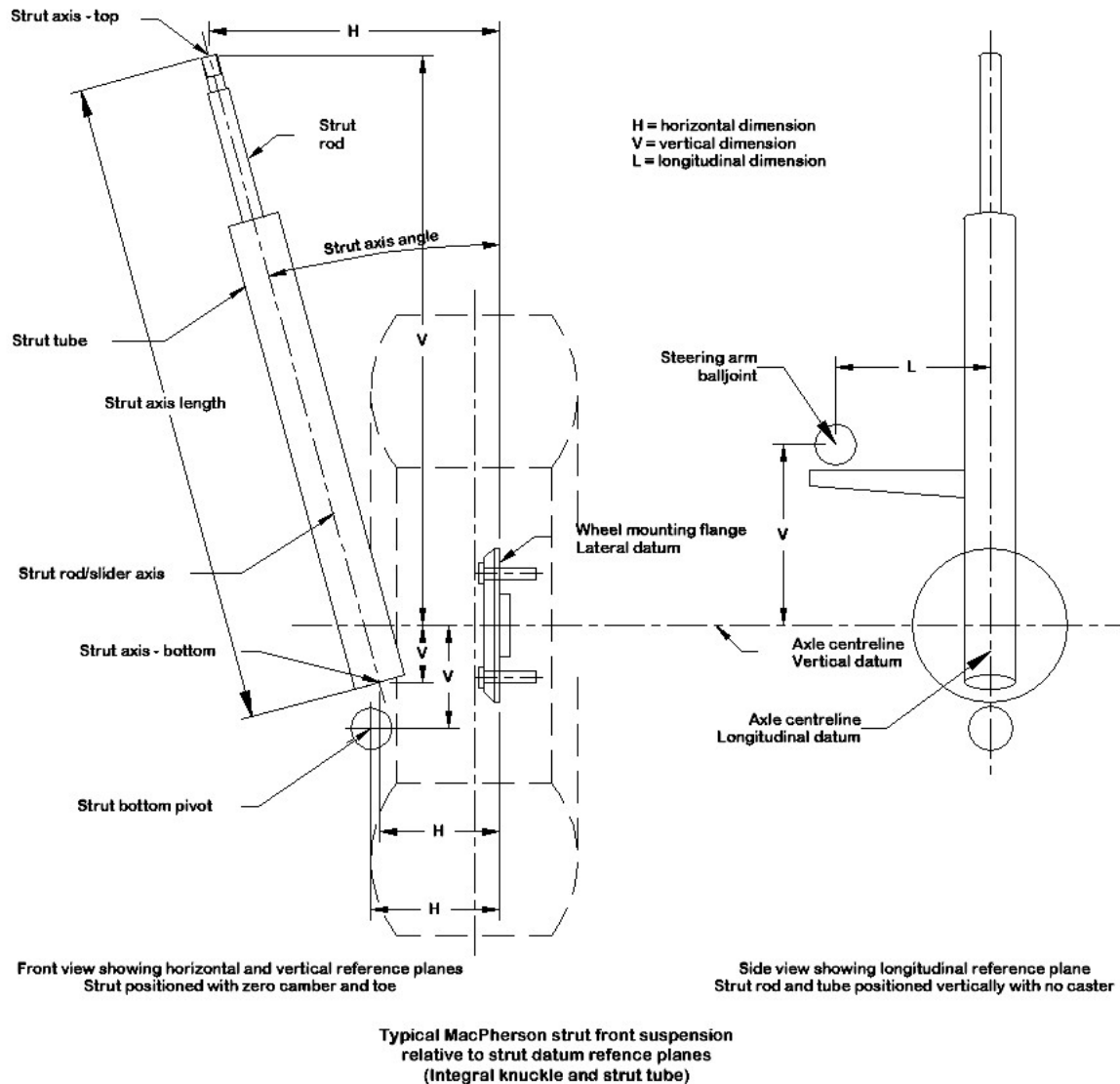
It is easiest to measure the strut removed from the vehicle. If this is not possible then take care to ensure that the correct reference datums are used to establish these dimensions.

If you have been provided with strut points in vehicle coordinates, use the [CAD2SusProg](#) tool to convert back to strut coordinates.

The spindle reference point is a “user defined” point and can be at any location along the axle (or spindle). The position is measured axially from the wheel mounting flange. It is positive if inboard from the wheel mounting flange.

The spindle centre point is located on the axle centreline, in the plane of the wheel and tyre centre. There is no user input for this point.

6.4.3.1 Integral strut tube and knuckle



In this type of strut, the strut tube & knuckle are rigidly fixed together.

- Strut data input style 'A'.

This is specified with the strut rod top and strut tube bottom dimensions, referenced to the wheel mounting flange, the axle centreline and a vertical line through the axle centreline parallel to the strut rod axis with the strut rod vertical (in side view). The “strut axis – top” dimension is to the top of the strut rod in the fully extended position, and the “strut axis – bottom” measurement is to the bottom of the strut tube. Both points are on the centreline of the strut rod and/or tube. If the vertical axis is positive upward, then if the strut tube bottom point is below the stub axle centreline then the vertical value must be negative; if the vertical axis is positive downward, then if the strut tube bottom point is below the stub axle centreline then the vertical value must be positive. You can measure to the end of the strut rod with the

rod in any position (although fully extended is probably best). This allows both the stub axle centreline and the bottom ball joint to be offset from the strut rod axis.

The strut axis length and strut axis angle will be calculated. The “strut axis – bottom” point is also used to define the strut length.

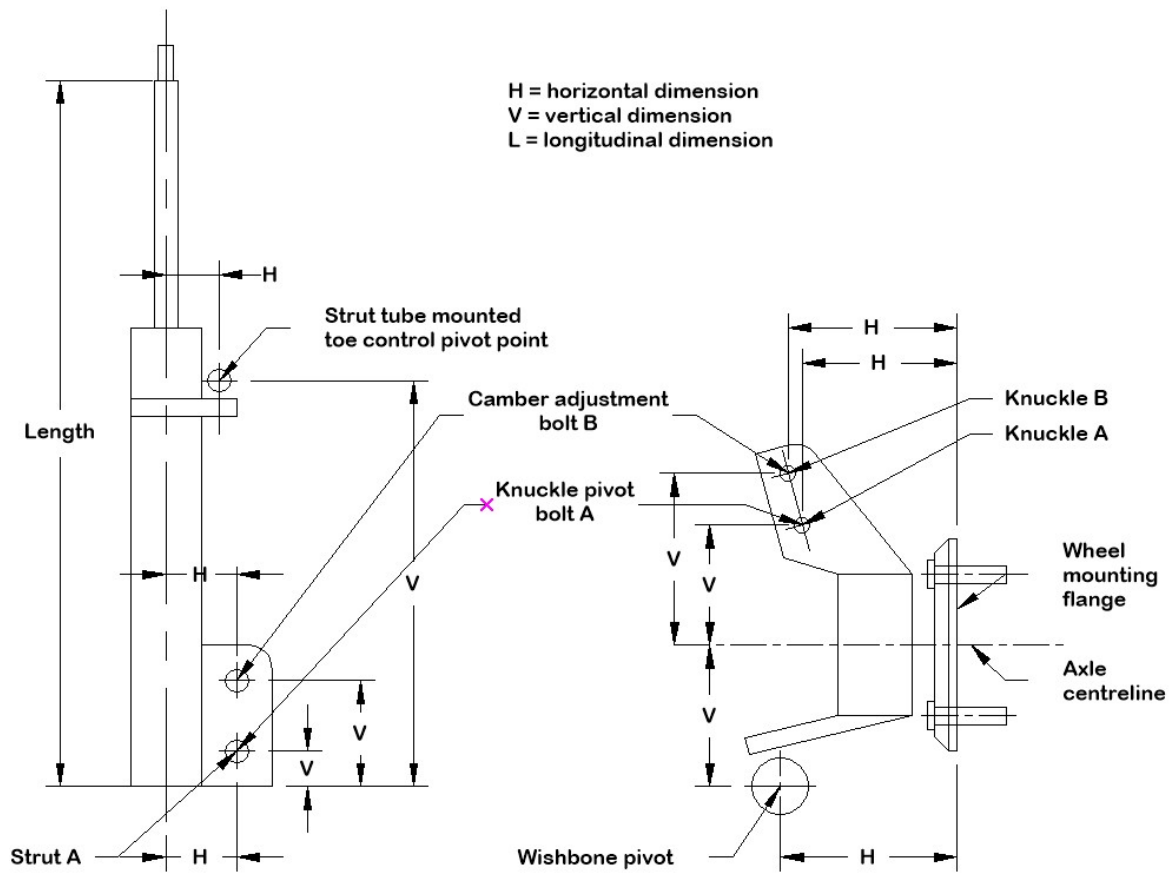
- Strut data input style 'B'.

This is specified with the strut tube bottom dimensions, the strut axis angle, and the strut axis length (optional, will default to tyre diameter if left at zero), all referenced to the wheel mounting flange, the axle centreline and a vertical line through the axle centreline parallel to the strut rod axis with the strut rod vertical (in side view). The “strut axis – bottom” measurement is to the bottom of the strut tube. Both points are on the centreline of the strut rod and/or tube. If the vertical axis is positive upward, then if the strut tube bottom point is below the stub axle centreline then the vertical value must be negative; if the vertical axis is positive downward, then if the strut tube bottom point is below the stub axle centreline then the vertical value must be positive. You can measure to the length of the strut with the rod in any position (although fully extended is probably best).

The “strut axis – top” point will be calculated. The “strut axis – bottom” point is also used to define the strut length.

Although the steering arm can be attached to the knuckle or strut tube, the steering ball joint is measured relative to the wheel mounting flange, the axle centreline and a vertical line through the axle centreline parallel to the strut rod axis with the strut rod vertical (in side view). The steering arm location is only used to display an appropriately positioned steering arm.

6.4.3.2 Separate strut tube and knuckle



Typical MacPherson strut tube assembly
and bolt-on knuckle
relative to strut datum reference planes

In this type of strut, the upright or knuckle is bolted to brackets welded to the strut tube, with a limited amount of adjustability.

- The strut data input style is 'C'.
This is specified with the knuckle mounting holes on the strut tube (Strut A & B, referenced to the strut tube bottom and strut axis), the strut axis length (optional, will default to tyre diameter if left at zero), the strut mounting holes on the knuckle (Knuckle A & B, referenced to the wheel mounting flange, the axle centreline and a vertical line through the axle centreline), and the knuckle/strut adjustment angle (which can be left as zero. Typically this angle is in the range of + or - 2 degree).
The "strut axis – top" and "strut axis – bottom" points, strut axis length and strut axis angle will be calculated. The "strut axis – bottom" point is also used to define the strut length.
- The strut data input style is 'D'.
This is specified with the bottom knuckle mounting holes on the strut tube (Strut A, referenced to the strut tube bottom and strut axis), the strut axis length (optional, will default to tyre diameter if left at zero), the bottom strut mounting holes on the knuckle (Knuckle A, referenced to the wheel mounting flange, the axle centreline and a vertical line through the axle centreline), and the strut axis angle.
The "strut axis – top" and "strut axis – bottom" points, strut axis length and strut axis angle will be calculated. The "strut axis – bottom" point is also used to define the strut length.

The strut/knuckle mounting adjustment bolt (bolt B) can be above the pivot bolt (bolt A) as shown in the above diagram; or they can be reversed with the adjustment bolt (bolt B) below the pivot bolt (bolt A).

In vehicle side view, the strut tube mountings are symmetrical about the strut tube axis. Both Strut A & B longitudinal dimensions will default to zero.

In vehicle side view, if the strut tube axis is offset from the axle centreline, then Knuckle A & B longitudinal dimensions should reflect this offset. Both Knuckle A & B longitudinal dimensions must be the same.

If necessary, rotate the knuckle (in side view) so that the knuckle mounting points A and B are in the same vertical line. Then measure all knuckle dimensions in this position.

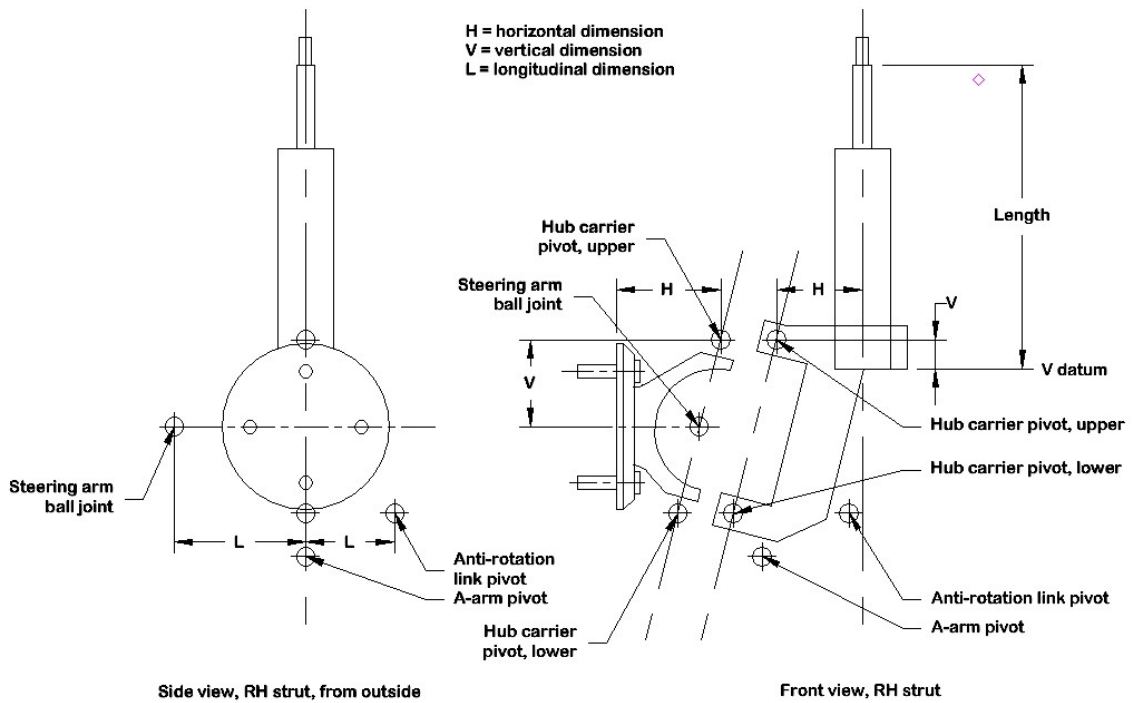
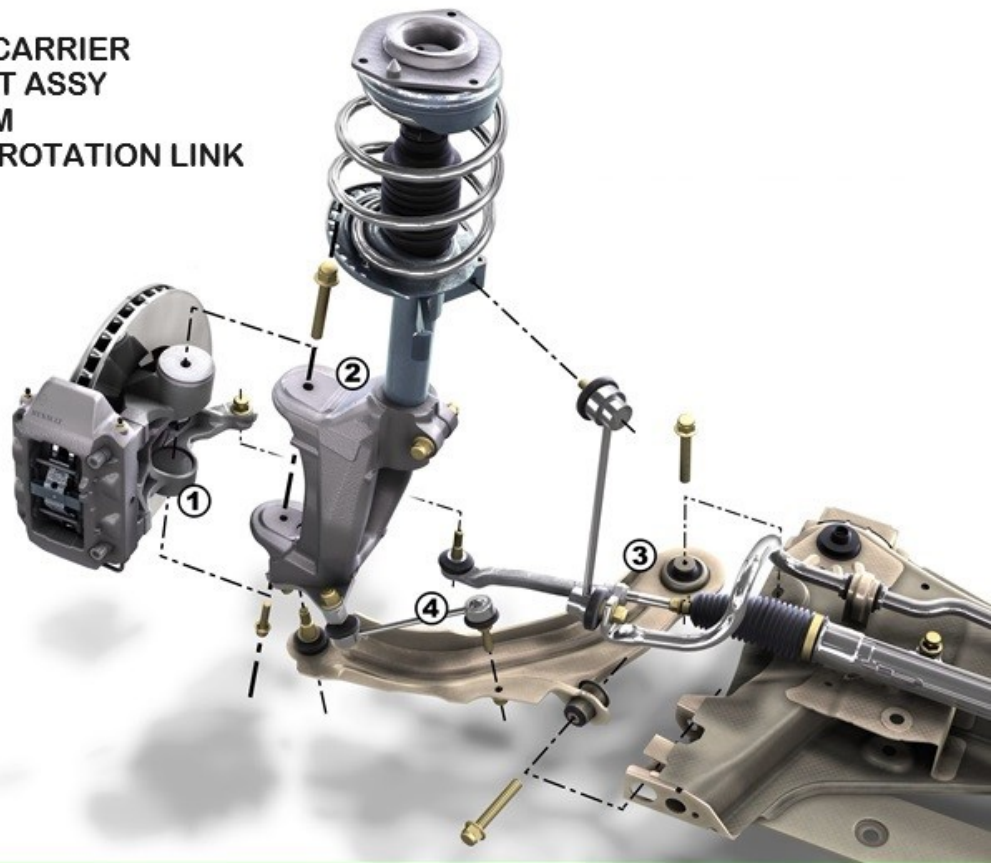
As an alternative method of adjusting the strut axis angle, especially as a method of adjusting wheel camber settings, some strut and knuckle combinations (for example, the Holden Harrop front strut) allow the knuckle mounting B point horizontal dimension to be adjusted (usually by a vernier adjustment). This can be simulated by changing the knuckle mounting B point horizontal dimension.

The steering arm can be attached to the knuckle or strut tube.

- If attached to the knuckle, the steering ball joint is measured relative to the wheel mounting flange, the axle centreline and a vertical line through the axle centreline parallel to the strut rod axis with the strut rod vertical (in side view). Specify the steering arm location as 'knuckle' and enter the dimensions in the 'steering arm balljoint (knuckle)'.
- If attached to the strut tube, the steering ball joint is measured relative to the strut tube bottom and strut axis. Note that if the ball joint is offset in the horizontal direction towards the outside of the vehicle, then the horizontal dimension is positive. Specify the steering arm location as 'strut tube' and enter the dimensions in the 'steering arm balljoint (strut tube)'. The ball joint dimensions relative to the knuckle will be calculated.

6.4.3.3 Dual-axis strut

- 1 HUB CARRIER
- 2 STRUT ASSY
- 3 A-ARM
- 4 ANTI-ROTATION LINK



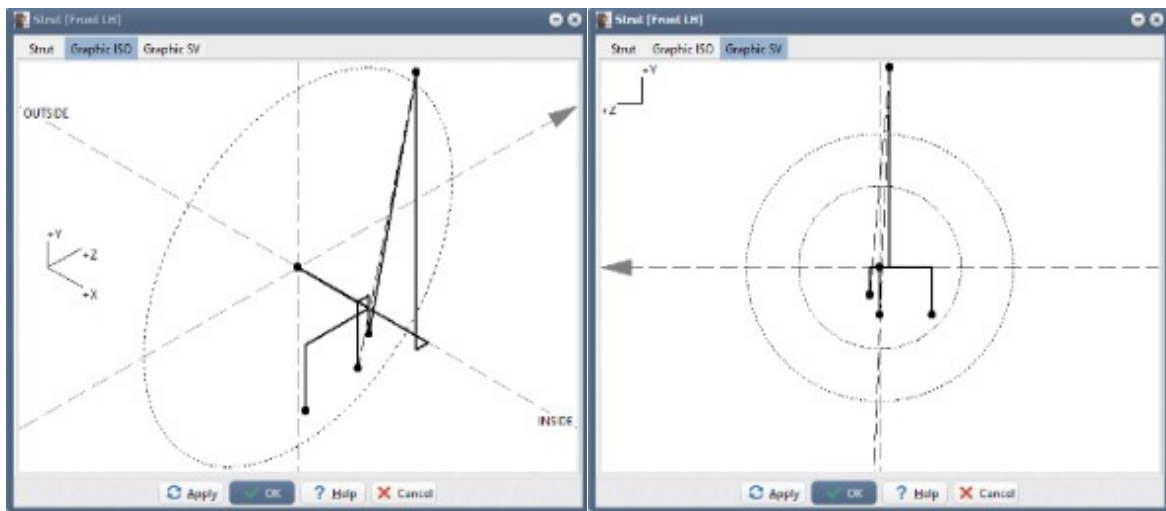
In this type of strut, the strut and the hub carrier are separate items.

- **Strut.**
The strut has four mounting points. All are referenced to the strut rod axis and the bottom of the strut.
The strut length dimension is to the top of the strut rod in the fully extended position.
The four mounting points (hub carrier upper and lower, A-arm pivot and anti-rotation link mounting) are all dimensioned from the strut rod centreline (with positive H dimensions towards the outside of the vehicle) and negative V dimensions for those below the bottom of the strut.
- **Hub carrier.**
The hub carrier has three mounting points (hub carrier upper and lower, and steering tierod mounting) all referenced to the wheel mounting flange (with positive H dimensions towards the inside of the vehicle), the axle centreline and a vertical line through the axle centreline.

The distance between the upper and lower hub carrier mounts on both strut and hub carrier should be identical. But if there is any difference then the hub carrier will be attached to the strut with the upper mounts coincident, and the hub carrier lower mount aligned along the strut hub carrier mount axis. Effectively the kingpin axis. Any difference will be noted as "carrier pivot error".

6.4.3.4 Graphic

After entering the required dimensional data, click on either the "Graphic ISO" tab to display a 3D isometric representation of the upright, or the "Graphic SV" tab to display a 2D side view.



Strut Graphic ISO

Strut Graphic SV

It will show the A-arm mounting points, steering arm, strut tube and kingpin axis as appropriate.

It is intended that this graphic will provide a basic visual confirmation that all the elements are in the expected position and orientation.

A reference axis is shown.

If you hover the mouse over a pivot point or line, a hint will show with the identification and coordinates of that point.

For the front suspension, a dashed line indicating the kingpin axis. The nominal kingpin axis is drawn from the strut rod top to the bottom ball joint. When the strut geometry is calculated, the kingpin axis will be drawn from the actual strut rod chassis top mount point.

If the ball joint is a "double ball joint" then the actual kingpin axis point will be determined by the link geometry. For this graphic, the kingpin axis line will be drawn to the mid point of the ball joints.

If the steering arm is "strut mounted" then the steering arm pivot point will be shown in the correct (ie using the strut tube as the local datum) but the coordinates are shown relative to the hub mounting plane and the axle centreline.

The upright is drawn with a dotted line indicating the centre of the tyre.

- Graphic ISO The elliptical dotted line represents the centre of the tyre.
The axis labeled "INSIDE" – "OUTSIDE" is the spindle or axle centreline and the axis with the arrow points to the front of the vehicle.
The strut is viewed as though you were standing on the opposite side of the vehicle, looking at the inside of the wheel.
All pivot points are drawn with a line starting at the datum intersection, along the horizontal axis, then backwards or forwards parallel to the longitudinal axis, and finally up or down parallel to the vertical axis.
- Graphic SV The outer circle represents the tyre diameter, and the inner circle the wheel diameter.
The axis with the arrow points to the front of the vehicle.
All pivot points are drawn with a line starting at the datum intersection, backwards or forwards along the horizontal axis, and finally up or down parallel to the vertical axis.

6.4.4 Axle (conventional)

This is the conventional axle and diff centre section with enclosed axle shafts. It can be non-floating, semi-floating or full floating.

There are three sets of axle dimensions

- Housing, diff and hubs
- Mounting brackets
- Static alignment.

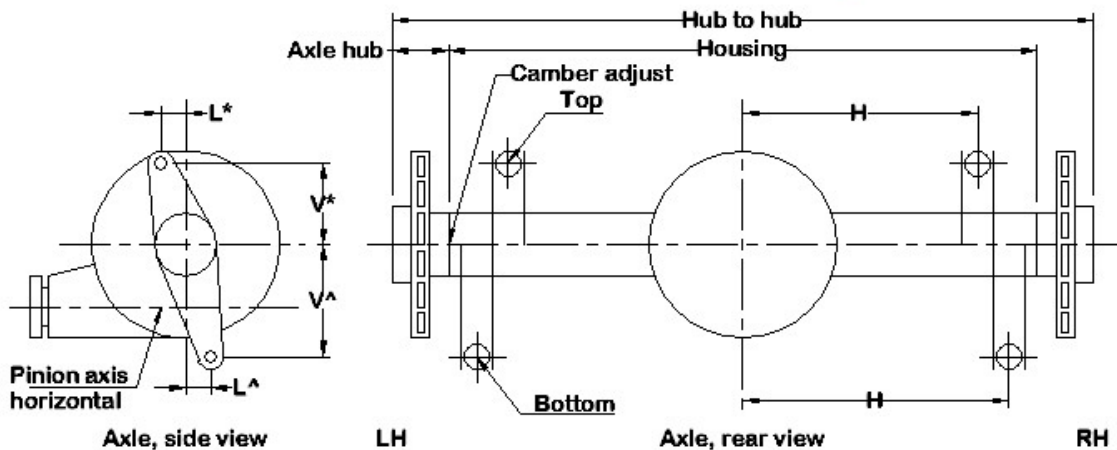
Plus

- Graphic

6.4.4.1 Housing, diff and hubs

If the axle housing is a typical production car item and has no adjustment for camber and toe, then the axle housing length will be specified as the distance over the axle wheel mounting flanges, and the axle hub length will be zero. The overall hub to hub length will be the same as the axle housing length. All dimensions for LH and RH hub alignment should be set to zero.

If the axle is a deDion, then the axle hub length is then the length from the outboard universal joint mounting flange to the wheel mounting flange, the axle housing length will be the distance between the mounting flanges of the left and right outboard universal joints, and the overall hub to hub length will be distance across the left and right wheel mounting flanges.



If the axle housing is a typical Australian V8 Supercar item and has adjustable "hub carriers", then the axle housing length is the fixed centre section. The axle hub length is then the length of the "hub carrier" from the axle centre section mounting face to the wheel mounting flange. The nominal hub to hub length will be the width of the centre section plus the length of both hub carriers. This will vary slightly with camber and toe.

The spindle reference point is a "user defined" point and can be at any location along the axle (or spindle). The position is measured axially from the wheel mounting flange. It is positive if inboard from the wheel mounting flange.

The spindle centre point is located on the axle centreline, in the plane of the wheel and tyre centre. There is no user input for this point.

For live axle, all points are specified relative to the axle centrelines, with the pinion horizontal.

The pinion horizontal location is specified relative to the centre of the axle housing. If the pinion is offset in the direction of the positive horizontal axis, then the horizontal value will be positive, if offset in the direction of the negative horizontal axis, then the horizontal value will be negative.

The pinion vertical offset is specified as the distance from the pinion shaft centreline to the axle centre. Note that this dimension is always normal to the pinion shaft centreline, so be careful if the pinion angle is non-zero. If the vertical axis is positive upwards, then a negative dimension means the pinion is below the axle centreline.

The pinion length is the distance from the face of the pinion flange to the axle centreline.

For a torque tube axle, the torque tube length is measured to the centre of the torque tube ball joint.

The hub alignment is the "built-in" axle alignment. Again it is measured for each hub, with the both the axle centre section and pinion horizontal.

Note that there are no "wheel alignment" settings for rear live axle. The wheel camber and toe settings are controlled by the axle hub alignment onto the housing, and the subsequent alignment of the entire axle assembly by the locating links.

For a front live axle, there are additional inputs.

The hub alignment includes caster and kingpin inclination (KPI) angles.

Caster is the inclination of the steering axis (the kingpin) in side view. It is measured from the vertical, and is positive if the top of the kingpin is rearward, and the bottom of the king pin is forward. Note that this is relative to the horizontal axle datum. If the axle is tilted when installed in the vehicle, then the wheel alignment caster will be different to this axle caster. Caster is typically between 0 and 10 degrees.

KPI is the angle of the steering axis (the kingpin) in front view. It is measured from the vertical, and is positive if the top of the kingpin is inclined towards the centre of the vehicle, and the bottom of the

kingpin is inclined outwards. KPI is typically between 5 and 10 degrees.
In the usual driven front axle, the steering axis intersects the drive axle universal.

The steering arms are also specified. There are two steering arms (one LH and one RH) that connect to the tie rod, which connect the two wheels. There is a third steering arm that connects to the drag link, which connects to the steering box (the pitman arm).

Note that the steering arm balljoint is dimensioned from the hub mounting face (not the axle centre).
See [upright](#).

6.4.4.2 Mounting brackets

Rear suspension is configured with trailing links; front suspension is configured with leading links.

Enter the horizontal, vertical and longitudinal values for the trailing / leading link axle pivot points, LH top, LH bottom, RH top, RH bottom (as required).

The torque tube axle mounting point is the torque tube ball joint..

The torque arm slider axle has two points which define the torque arm slider, P1 and P2. P1 is one end of the slider, and is dimensioned from the axle datums. Typically the horizontal value will be zero (if the slider mounting is on the vehicle centreline), the vertical value will be below the axle (when the torque arm is below the propshaft) and the longitudinal value will be the length of the torque arm. P2 is defined relative to P1. If the slider axis is parallel to the vehicle centreline (in plan view) then the horizontal dimension will be zero; if the slider axis is horizontal then the vertical dimension will be 0.0; and the longitudinal dimension will be the slider length. Generally the slider will be positioned longitudinally in the centre of the chassis mounting bearing.

Depending on the chosen configuration, enter the horizontal, vertical and longitudinal values for the Panhard rod axle mounting point, or the Mumford lever pivot axis points, or the Watts lever pivot axis points, or the two Watts links.

For live axle, all mounting points are specified relative to the axle centrelines, usually with the pinion horizontal.

If it is more convenient to measure the mounting points relative to a horizontal datum which is not parallel to the axle pinion (in side view) then the pinion angle must be specified (in the housing, diff and hubs section).

For deDion, all mounting points are specified relative to the axle hub centrelines, and not the deDion tube.

For a rigid (non driving) axle, all mounting points are specified relative to the central axle tube.

The horizontal values for RH and LH points are both positive and are measured from the centre of the axle housing outwards.

Lateral values for single points (that are usually on or close to the vehicle centreline in plan view) are either positive (if along the positive horizontal axis) or negative (if along the negative horizontal axis).

For all points, vertical values are measured vertically from the axle housing centreline, and longitudinal values horizontally from the axle housing centreline. If the vertical axis is positive upwards, a positive value for the pivot point means it is above the axle centreline, a negative value for the pivot point means it is below the axle centreline; if the vertical axis is positive downwards, a negative value for the pivot point means it is above the axle centreline, a positive value for the pivot point means it is below the axle centreline. If the longitudinal axis is positive rearward, a positive value means the pivot point is to the rear, a negative value means the pivot point is to the front; if the longitudinal axis is positive forward, a negative value means the pivot point is to the rear, a positive value means the pivot point is to the front.

For the twin trailing arm style, the vertical dimension (in side view) is the distance from the centreline of the axle to the centreline of the trailing arm (ie normal to the centreline of the trailing arm). The "sign" of the dimension will determine whether the trailing arm is mounted above or below the axle.

If the Watts linkage is axle mounted, then P1 is the actual axle pivot point, and the horizontal value will be zero. P2 is a point along the pivot axis and is referenced relative to P1. If the axis is horizontal, then the horizontal dimension will be 0.0, the vertical dimension will be 0.0 and the longitudinal dimension will be some convenient value, say 100mm (4.0").

6.4.4.3 Birdcage

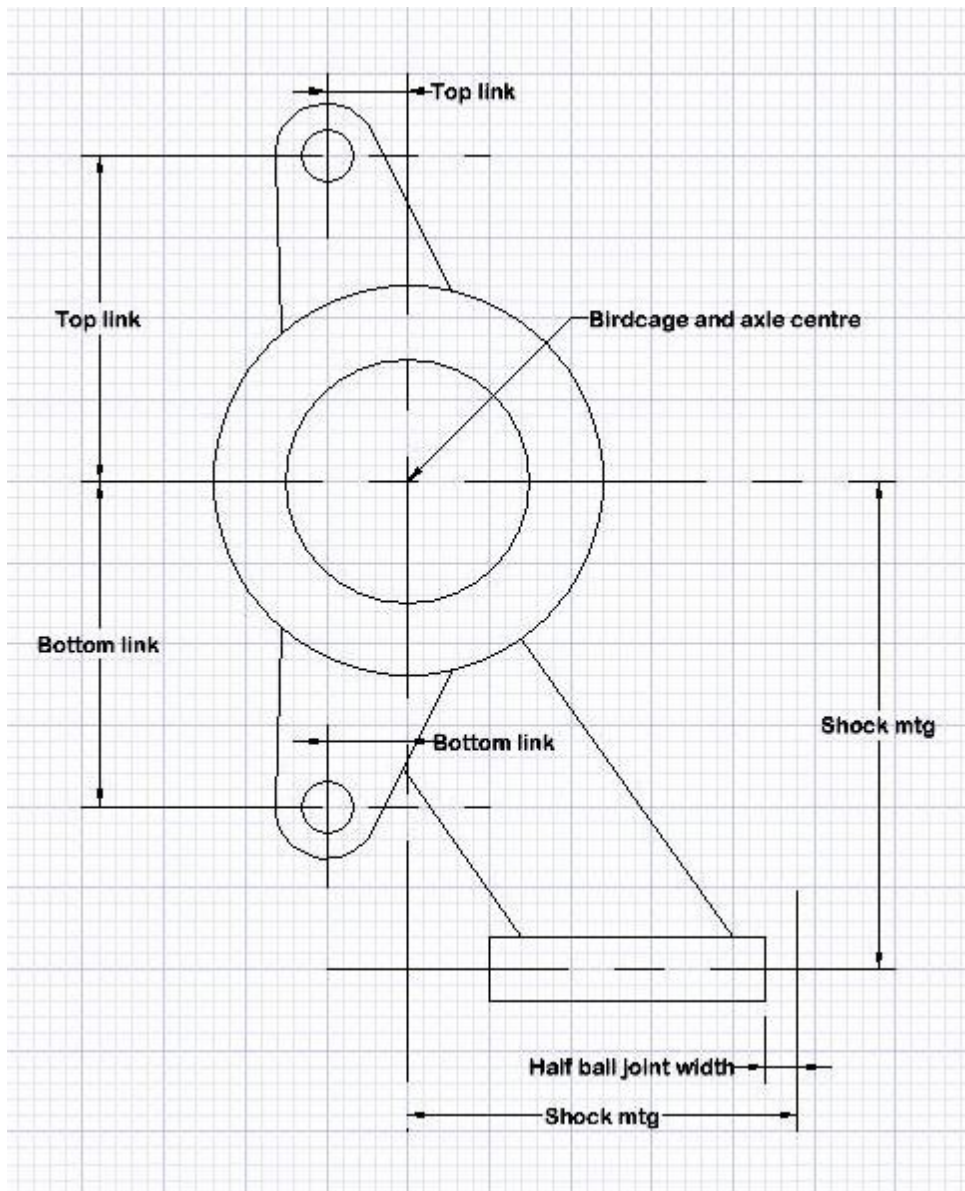
The typical birdcage is located on the axle, is axially restrained, but has radial freedom. It is used with a pair (the upper and lower links) of trailing links.

With a torque arm axle the usual configuration is with 4 trailing links (with each upper and lower pair connected to the birdcage) with a Panhard or Watts linkage (connected to the axle) providing lateral location. The torque arm locates the axle and take the torque reaction.

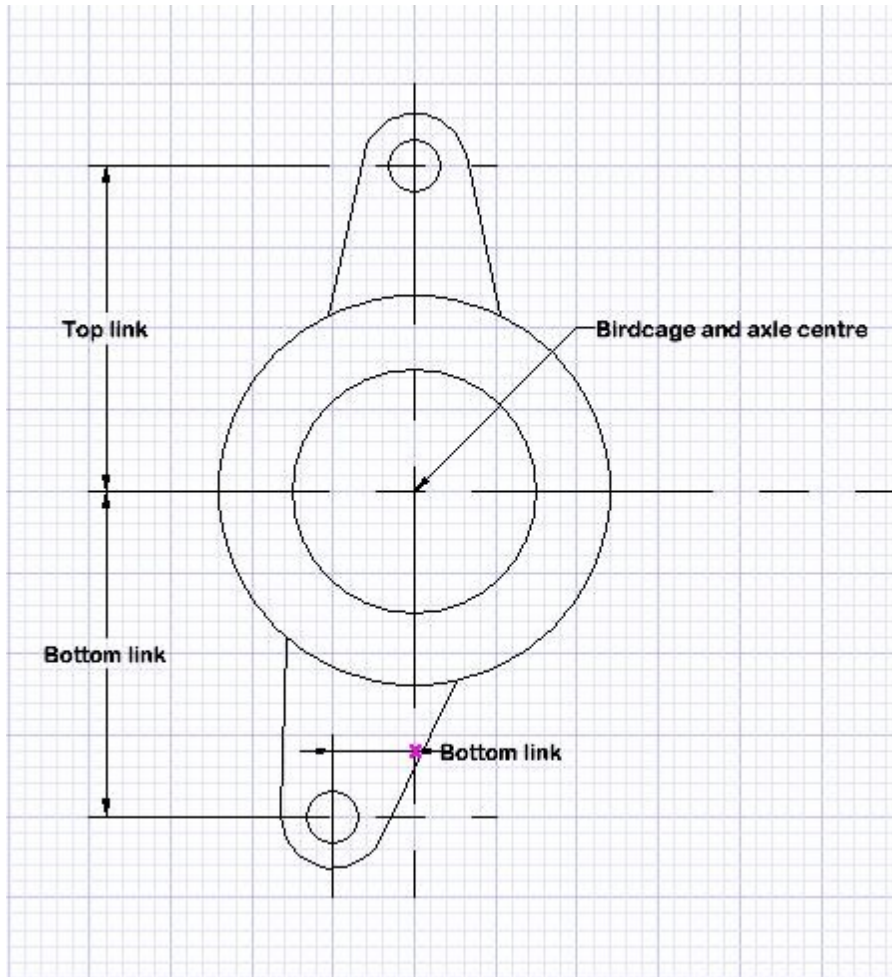
With a four link live axle, one pair of links is attached to brackets on the axle and the other pair of links is attached to the birdcage. This allows the axle to rotate in bump and droop and removes any twisting of the axle. Lateral location is provided by a Panhard or Watts linkage (connected to the axle).



If the birdcage includes the shock mount, then measure it with the shock mount horizontal.



If the birdcage has only the upper and lower trailing link mounts, then measure it with the upper link mount on the vertical axis through the bearing centre.



The horizontal dimensions (width) for all points are measured from the axle centre.

6.4.4.4 Static alignment

Enter the longitudinal datum to axle centreline. This is the distance that the centre of the axle (as defined above) is from the longitudinal datum.

This value can be entered in Vehicle Datum, and Geometry Alignment

The pinion angle is specified relative to the ground plane. If the vertical axis is positive upwards, then a positive angle is “pinion nose up” and a negative angle is “pinion nose down”; if the vertical axis is positive downwards, then a positive angle is “pinion nose down” and a negative angle is “pinion nose up”.

Most production cars run 3 or 4 degrees of pinion nose down, as this helps to dampen the prop shaft oscillations.

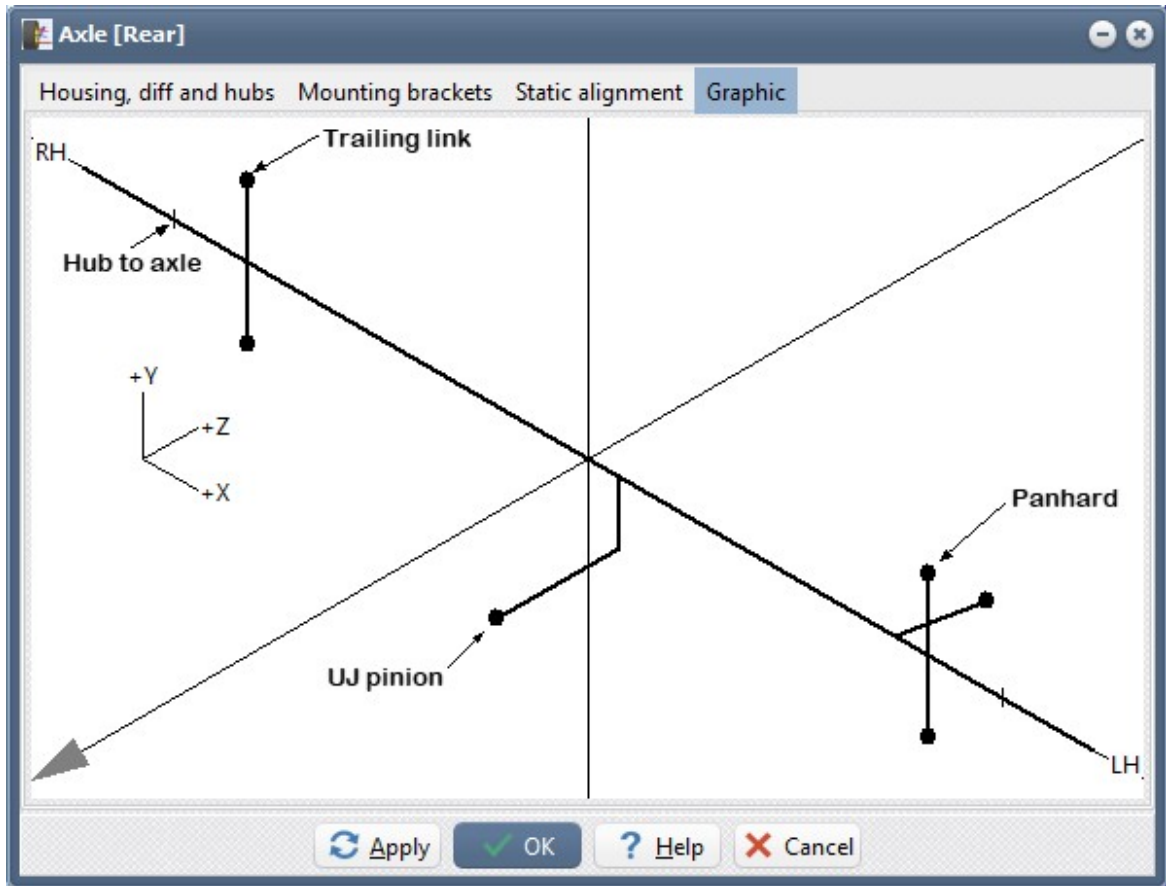
The axle offset is the sideways offset of the axle in the static position. The centre of the axle is the mid point between the LH and RH wheel reference points (either the wheel centres on ground, or the wheel centres at hub height). The offset is the distance this “axle mid point” is from the horizontal datum. For most vehicles it will be zero.

The wheel lead is the distance that one wheel is “ahead” (in a longitudinal sense) of the other. For most vehicles it will be zero.

The individual wheel longitudinal positions can also be entered in Geometry Alignment.

6.4.4.5 Graphic

After entering the required dimensional data, click on the “Graphic” tab. This will display an isometric front view representation of the axle.



It will show the axle housing centreline and the two hubs, the axle pinion, the link brackets, and the steering arms and kingpin axis as appropriate.

It is intended that this graphic will provide a basic visual confirmation that all the elements are in the expected position and orientation.

The axis labelled “LH - RH” is the axle centreline (the vertical datum axis), the axis with the arrow points to the front of the vehicle (the longitudinal datum axis), the vertical axis is the horizontal datum axis.

The axle is viewed as though you were standing on the LH side of the vehicle, looking towards the front of the axle ie looking rearwards.

The plane of the longitudinal and vertical axes centred on the axle centre.

If you hover the mouse over a pivot point, a hint will show with the identification and coordinates of that point.

A reference axis is shown.

Note that all horizontal coordinates are signed appropriately, even though the data input may not require signing. For example, the LH and RH link mounting brackets will both be entered as positive numbers, but in the graphic one of them (depending on the axis direction) will be negative.

6.4.5 Axle (speedway)

This is the speedway style axle assembly.

The wheels or hubs are splined to the axle and both the centre section and the locating links rotate on the axle.

Winters and Halibrand are examples.

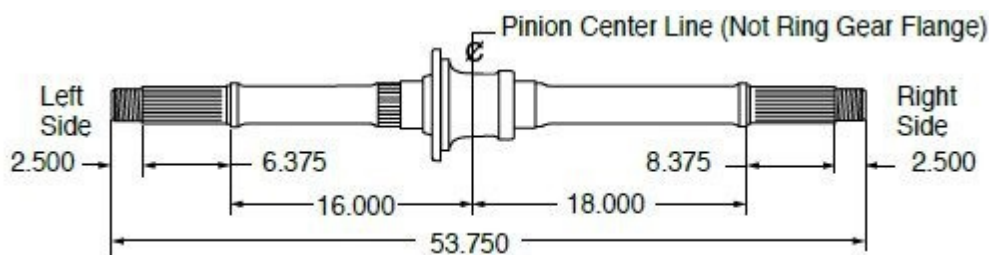
There are three sets of axle dimensions

- Axle and centre
- Mounting brackets
- Static alignment.

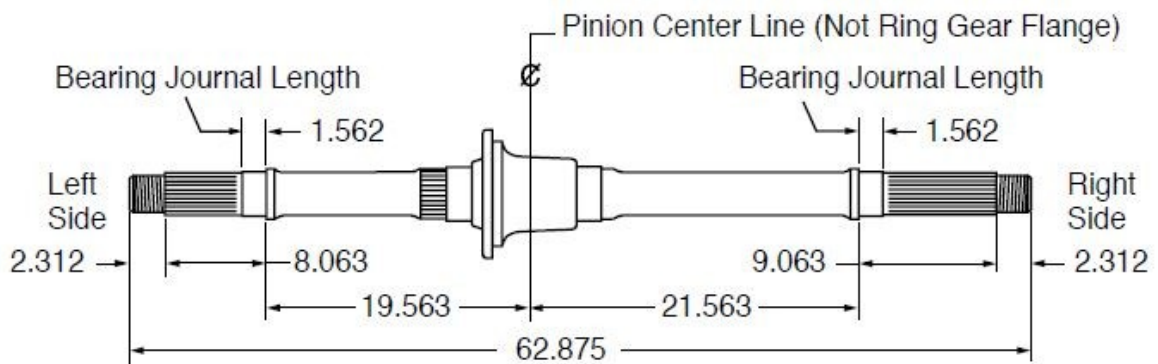
Plus

- Graphic

6.4.5.1 Axle and centre section



Winters 44-1 Midget axle



Winters 52-1 Sprint axle

Axle shaft length is the distance from the pinion centreline to the axle flange.

Axle hub length is the distance from the axle flange to the end of the axle splines.

Axle thread length is the length of the wheel nut thread.

The overall length is the sum of the above, and should match the overall length of the axle.

Gear centre is the distance between the pinion and coupler shaft. Typically 3" (76.20mm).

Coupler is the length, in side view, from the axle centreline to the centre of the spline in the coupler. It is not the length of the coupler shaft.

Torque tube length is the length, in side view, from the axle centreline, to the centre of the torque tube ball joint. Usually there is some provision for torque tube slip so this measurement should be the nominal length.

Note that for this release the axle centreline is the midpoint between the axle splined ends. For the 44-1 axle the axle centreline is 2" to the right from the pinion centreline.

This will be changed in a future release and the pinion centre will be used as the axle centre.

Also, for the wheels, for this release the wheel spacer thickness equals the width of the spacers between the axle flange and the birdcage plus the width of the birdcage bearing plus the total width any spacers outboard from the birdcage.

This will be changed in a future release and the wheel spacer thickness will only be the width of any spacers outboard from the birdcage.

6.4.5.2 Mounting brackets

Longitudinal links that attach to the chassis in front of the axle are trailing links; longitudinal links that attach to the chassis behind the axle are leading links. But all links are referred to as trailing links.

All links, including the Jacobs ladder, are "fixed" to the axle via [birdcages](#). Measure the birdcage link points with the birdcage in the vertical position.

Enter the horizontal, vertical and longitudinal values for the longitudinal link axle pivot points, LH top, LH bottom, RH top, RH bottom.

Enter the horizontal, vertical and longitudinal values for the Jacobs ladder birdcage mounting point.

The horizontal values for RH and LH points are both positive and are measured from the axle centreline outwards.

Note that this release uses the axle centreline (not the pinion centreline) as the datum for the horizontal values. For the typical speedway axle this means that the axle centre is offset from the pinion centre.

This will be changed in a future release and all horizontal dimensions will be referenced from the pinion centre.

For all points, vertical values are measured vertically from the axle housing centreline, and longitudinal values horizontally from the axle housing centreline. If the vertical axis is positive upwards, a positive value for the pivot point means it is above the axle centreline, a negative value for the pivot point means it is below the axle centreline; if the vertical axis is positive downwards, a negative value for the pivot point means it is above the axle centreline, a positive value for the pivot point means it is below the axle centreline. If the longitudinal axis is positive rearward, a positive value means the pivot point is to the rear, a negative value means the pivot point is to the front; if the longitudinal axis is positive forward, a negative value means the pivot point is to the rear, a positive value means the pivot point is to the front.

6.4.5.3 Static alignment

The static alignment will be calculated.

The axle offset is the sideways offset of the axle in the static position. The centre of the axle is the mid point between the LH and RH wheel reference points (either the wheel centres on ground, or the

wheel centres at hub height). The offset is the distance this "axle mid point" is from the horizontal datum. For most vehicles it will be zero.

Note that this release uses the axle centreline (not the pinion centreline) to determine axle offset.

This will be changed in a future release and the axle offset will be referenced to the pinion centre.

The longitudinal datum to axle centreline is the distance that the centre of the axle (as defined above) is from the longitudinal datum.

If the Wheel location and alignment option is "Torque tube axle" then this value is derived from the position of the torque tube ball joint housing on the chassis, and the length of the torque tube. Together these determine the position of the axle. Note that this option will always position the torque tube ball exactly at the chassis torque tube ball joint housing with zero alignment error.

If the Wheel location and alignment option is "All top and bottom links + Jacobs ladder" then this value is derived from the lengths of the longitudinal links. Together with the Jacobs ladder dimensions, these will determine the position of the axle. Note that this may result in a torque tube alignment error.

The wheel lead is the distance that one wheel is "ahead" (in a longitudinal sense) of the other. For most vehicles it will be zero.

The individual wheel longitudinal positions can also be entered in Geometry Alignment.

6.4.6 Stub axle

Stub axle coordinates are vehicle independent and are represented with horizontal, vertical and longitudinal values. The datums for the upright are the wheel mounting flange and the stub axle centreline.

Again, imagine the stub axle viewed from the front of the vehicle. Lateral values are axial dimensions (along the axle or spindle) from the wheel mounting flange, vertical and longitudinal values are radial dimensions from the stub axle centreline.

All stub axle measurements are measured with the stub axle at zero camber, [castor](#) and toe position.

The horizontal dimension of points inboard of the wheel mounting flange are always positive, regardless of the direction of the positive horizontal axis.

For the usual design of the stub axle, the top pivot point(s) is above the axle centreline, and the bottom pivot point(s) is below the axle centreline. If the vertical axis is positive upward, then the top pivot vertical dimension will be positive and the bottom pivot vertical dimension will be negative; if the vertical axis is positive downward, then the top pivot vertical dimension will be negative and the bottom pivot vertical dimension will be positive.

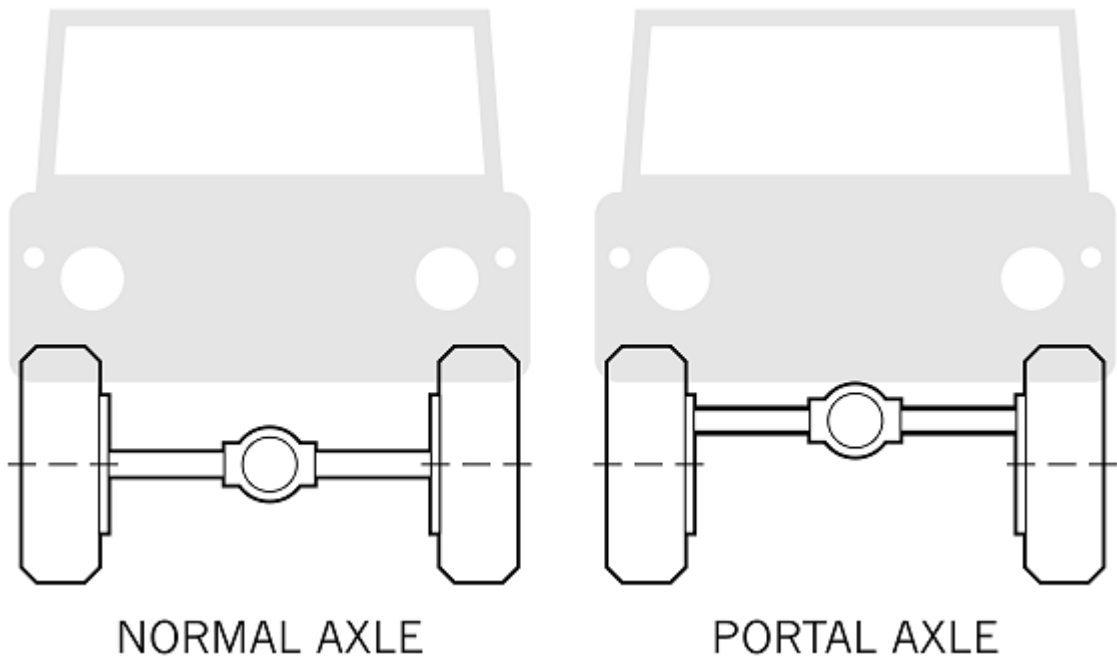
Longitudinal values are measured radially from the stub axle centreline in side view, and will be positive to the rear, negative to the front (if the longitudinal axis is specified as +ve rear); or will be positive to the front, negative to the rear (if the longitudinal axis is specified as +ve front).

If you have been provided with stub axle mounting points in vehicle coordinates, use the [CAD2SusProg](#) tool to convert back to stub axle coordinates.

Enter the required values for the stub axle top and bottom pivot points.

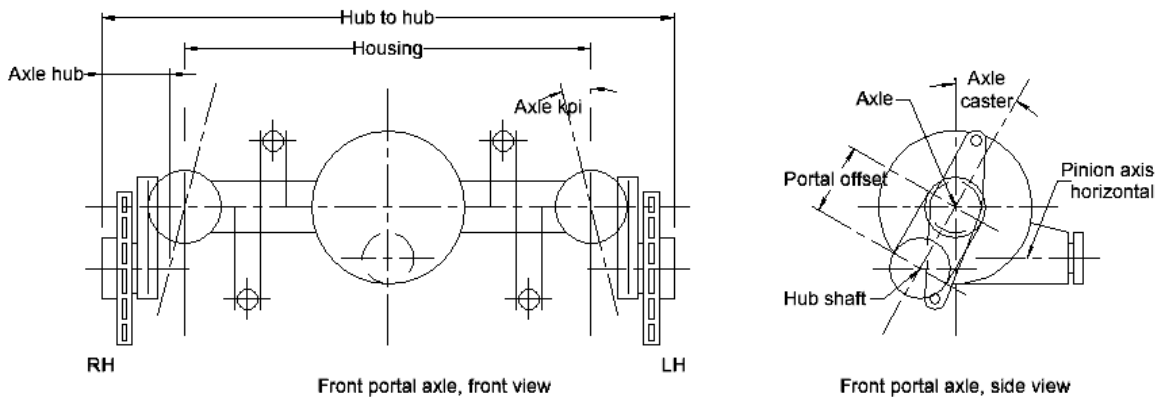
For the early models, the reference points are the centre of the top and bottom ends of the kingpin. For the later models, the reference points are the centre of the top and bottom ball joints.

6.4.7 Portal axle



Currently the only linkage styles supported are the 3 or 4 trailing / leading links and the twin trailing / leading arms together with a Panhard rod, Watts linkage or Mumford linkage.

Front portal axle dimensions



As drawn, this example has about 10° kpi and 30° positive [caster](#).

Axle [caster](#) will be the same as the portal angle. Axle [caster](#) must be the same for both LH and RH. Axle [camber](#) must be the same for both LH and RH.

With zero toe, the hub shafts are parallel to the axle in plan view.

The portal offset is the centre distance between the axle shaft and the hub shaft gears. In side view, with the axle assembly sitting with the axle level and the pinion horizontal, the portal offset will be aligned along the kingpin axis line.

Note that the kingpin line (axle [caster](#)) is dimensioned with the pinion horizontal. When the axle is fitted to the vehicle and the pinion is tilted up or down, then this will change the actual [caster](#).

The axle housing length is the distance between the intersection of the centreline of axles and the kingpin axis line.

The hub shaft length is the distance between the intersection of the centreline of the hub shaft gear and the kingpin axis line.

The overall axle length is across the wheel mounting faces.

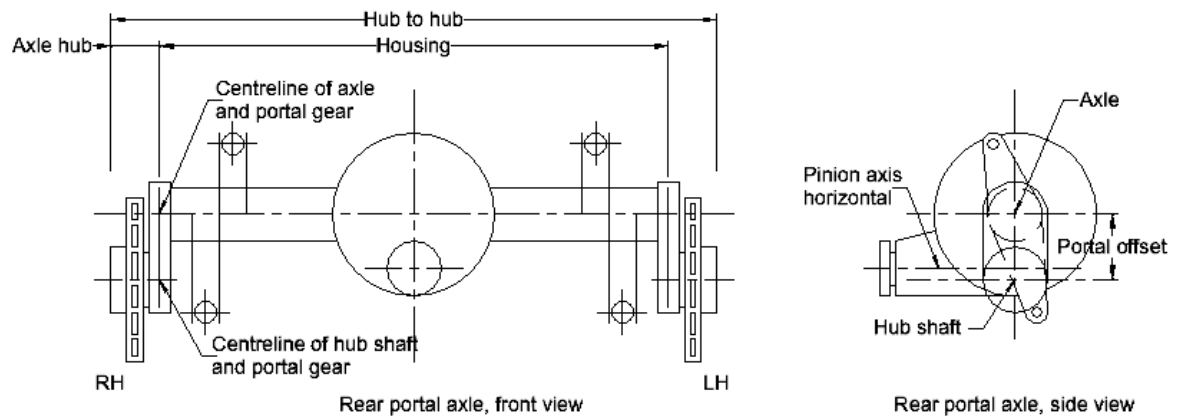
The axle housing and hub shaft lengths should be exact as those dimensions determine the steering calculations.

After calculating, check that the overall (hub to hub) width is correct.

Axle mounting brackets are dimensioned the same as the normal axle, referenced from the axle centreline with the pinion horizontal.

Steering arms are dimensioned the same as the normal axle, referenced from the hub mounting face and the hub axle centreline with the kingpin axis vertical in side view.

Rear portal axle dimensions



As drawn, this example has 0° [caster](#).

There is no provision for toe or camber. The hub shafts are parallel to the axle in both plan and front view.

The portal offset is the centre distance between the axle shaft and the hub shaft gears. Similarly to the front axle, the portal can be rotated in side view. With the axle assembly sitting with the axle level and the pinion horizontal, if the portal hub shaft is leading, then this is +ve portal angle.

The axle housing length is the distance between the centres of the axle shaft gears.

The hub shaft length is the distance between the centre of the hub shaft gear and the wheel mounting face.

The overall axle length is across the wheel mounting faces.

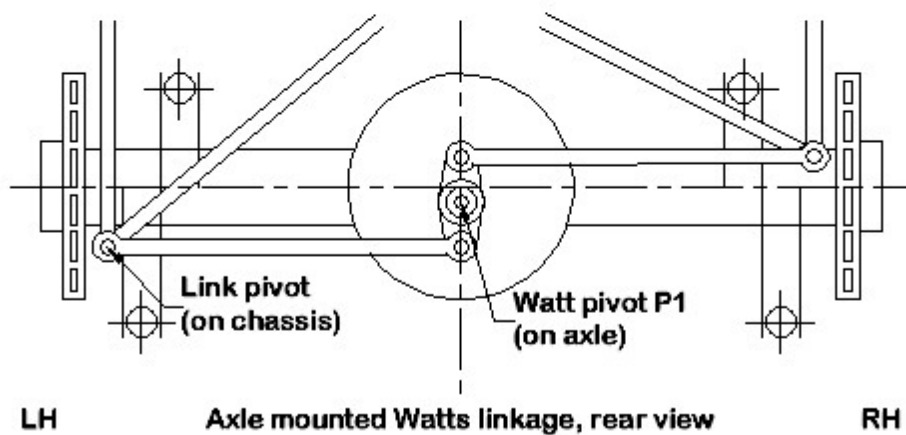
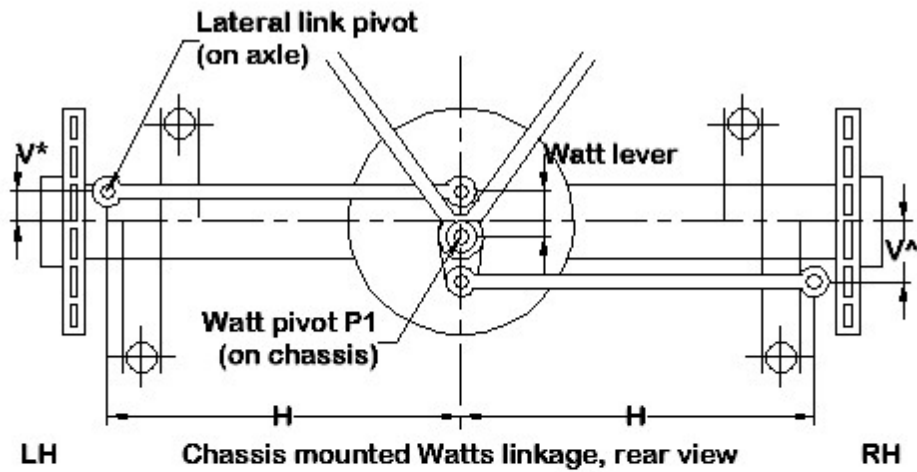
It doesn't matter if the axle housing and hub shaft lengths are not exact, as long as the overall (hub to hub) width is correct.

Axle mounting brackets are dimensioned the same as the normal axle, referenced from the axle centreline with the pinion horizontal.

6.5 Watts

From the Geometry tab, select Watts

Specify the length of the Watts lever from the pivot point to the rod mounting point.



It is not essential for the upper and lower arms of the Watts lever to be equal length.

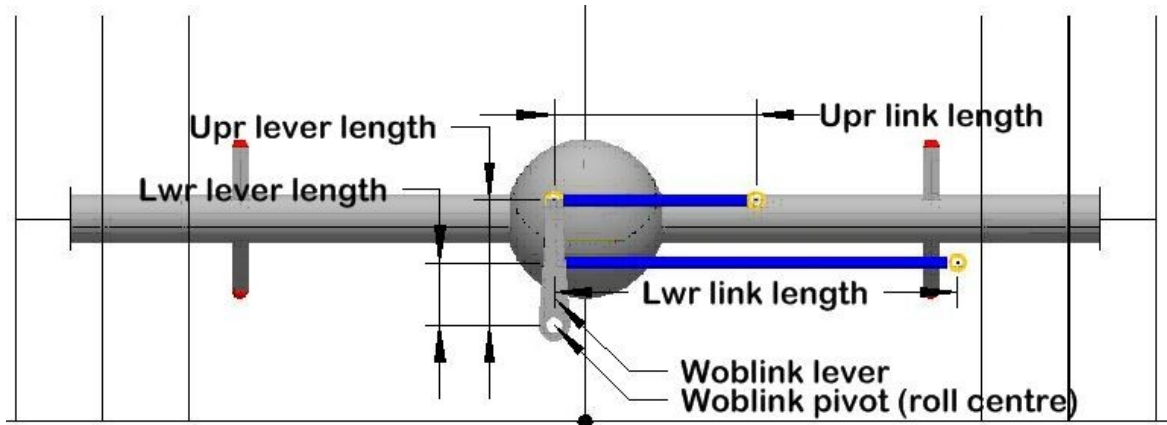
To optimally compensate for errors, the ratio of the upper and lower arms and the ratio of the link lengths should be the same, with the shortest arm connecting to the longest link.

6.6 Woblink

From the Geometry tab, select Woblink

Specify the length of the Woblink lever from the pivot point to the upper and the lower link mounting points.

If the Geometry Config is specified as "All top and bottom links + Woblink" then the upper and lower link lengths must be specified in Geometry -> Links. For all other Geometry Config options the link lengths will be calculated.



$$\frac{UprLeverLength}{LwrLeverLength} = \frac{LwrLinkLength}{UprLinkLength}$$

Note that optimally $\frac{UprLeverLength}{LwrLeverLength} = \frac{LwrLinkLength}{UprLinkLength}$

6.7 Mumford

From the geometry tab, select Mumford.

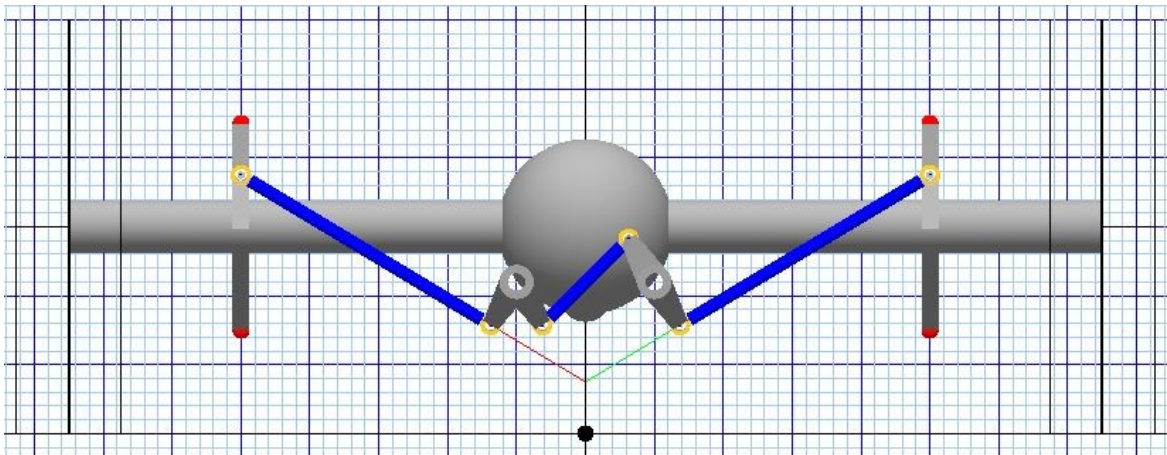
The instant centre location is specified as "Suspension link chassis mounting points".

The roll centre is the projected intersection of the two lateral links. The position of the link points is a combination of the link and lever lengths; and this requires that the lateral and intermediate link lengths, Mumford chassis pivot points, and bellcrank and lever dimensions must be specified.

The bellcrank angle must be between 0° and 180°, and is typically between 60° and 120°.

The lever can be straight (180°) or slightly bent (typically between 120° and 180°).

If the initial Geometry Calculation fails, usually with a message "Excessive travel. Mumford links will not connect", then use the [Mumford](#) tool to calculate a starting set of linkages.



Note that the bellcrank and lever pivot axis coordinates and the lateral link mounting coordinates are specified in the [chassis](#) and [axle](#) input dialogs.

6.8 Jacobs ladder

The Jacobs ladder consists of a triangular body section, and a pair of straps.

The apex of the body connects to the axle, and the straps connect the ladder to the chassis.

The instant centre is the intersection of the line of the straps, the roll centre is where the line connecting the apex of the ladder and the instant centre crosses the vehicle centreline.

The equivalent length Panhard rod is not the distance from the instant centre to the ladder apex, but the locus of the path described by the ladder apex.

In fact, a well designed Jacobs ladder will closely approximate a Roberts linkage, an early form of straight line motion linkage.

With a well designed Jacobs ladder the equivalent Panhard rod length would be at least twice the track.

For an ideal linkage the ladder sides and straps should be the same length as the distance between the the two link chassis mounts, and the ladder base length half the distance between the the two link chassis mounts.

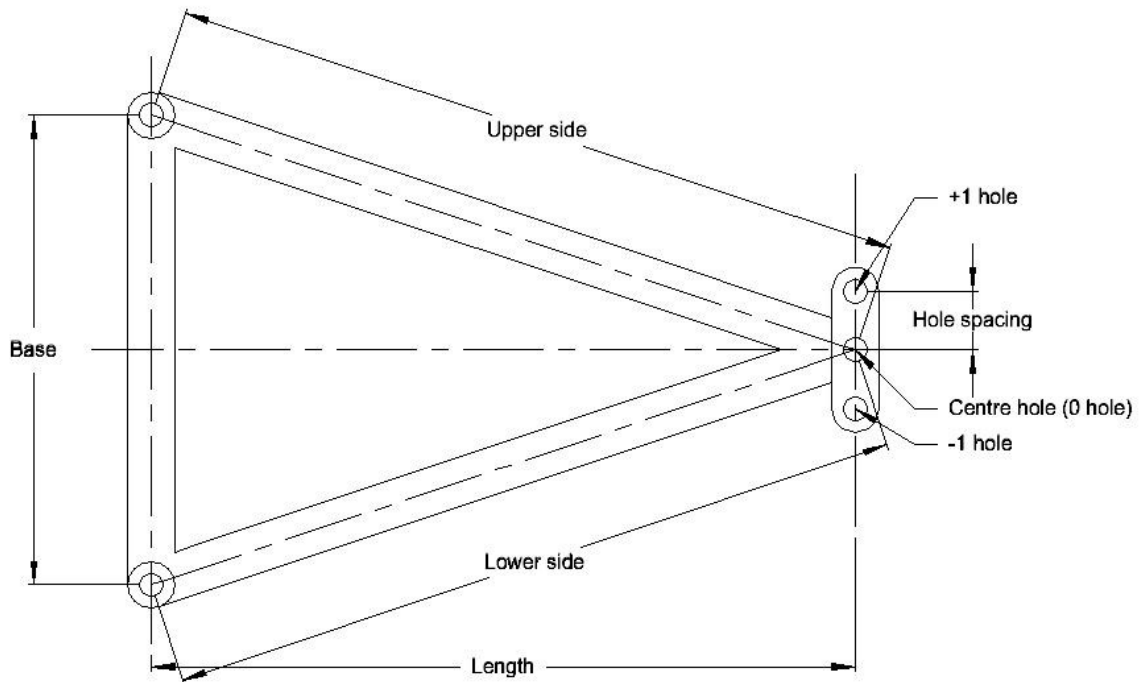
If the Geometry calculation option is "Torque tube axle", the Jacobs ladder dimensions will be calculated using the distance between the strap chassis mounts, making the strap lengths and ladder base length half that distance, and the ladder length calculated so that the ladder will connect to the axle birdcage. Both sides of the triangle will be equal.



Single hole Jacob's ladder



Adjustable 3-hole Jacob's ladder



Jacob Ladder Dimensions

Roberts linkage is named after Richard Roberts (1789–1864)

https://en.wikipedia.org/wiki/Roberts_Mechanism

6.9 Instant Centres

From the Geometry tab, select ICs to specify or check the roll centre, swing axle length, side view instant centre and swing axle dimensions.

Depending on the geometry, there may be two alternative ways to specify the swing axle lengths and instant centres,

From the Geometry tab, select Configure and choose either "Suspension link chassis mounting points" or "Swing axle lengths and roll/pitch centre heights".

If the instant centre location is "Suspension link chassis mounting points", then all the instant centre dimensions will be calculated.

Swing axle and roll centre (front view)

The front view swing axle and roll centre is referenced in the front view plane of the axle.

The swing axle length will usually be a positive value, generally in the range of 1 to 3 times the track.

Note that a negative swing axle length means that the linkage instant centre is outboard on the same side of the vehicle, rather than the opposite side of the vehicle.

The roll centre height is the intersection of the lines from each tyre contact centreline to the instant centre of the suspension linkages.

The roll centre height can be positive (above ground), zero (on ground) or negative (below ground).

If the roll centre offset is non-zero, then it is offset in the same direction as the positive horizontal axis (ie if positive, it is offset in the same direction as the positive horizontal axis; if negative it is offset in the same direction as the negative horizontal axis).

Anti-dive / anti-squat (side view)

The Anti-dive / anti-squat instant centre and effective angle are referenced in the side view plane of the tyre.

Front axle: For a positive anti-dive effect, the intersection point will be behind the front axle and will be a positive dimension; for a negative (or pro-dive) effect, the intersection point will be ahead of the front axle and will be a negative dimension.

Rear axle: For a positive anti-squat effect, the intersection point will be ahead of the rear axle and will be a positive dimension; for a negative (or pro-squat) effect, the intersection point will be behind the rear axle and will be a negative dimension.

The instant centre height is the intersection of the lines from each tyre contact centreline to the instant centre of the suspension linkages.

The instant centre height can be positive (above ground), zero (on ground) or negative (below ground).

If the suspension linkages are parallel (in side view) there is no intersection point, but they can be angled to achieve the same result.

The swing axle and the side view instant centre apply to both sides of the vehicle, so there are LH and RH values.

If the vehicle is symmetrical, then only one side need be input, and the other side will be set to the same values. If the vehicle is not symmetrical, or the symmetrical checkbox is cleared, then values for both sides will need to be input.

The location of the instant centres can be quite sensitive to small variations in the actual link lengths and chassis pivot point heights. This often shows as a small difference between the specified and the calculated swing arm lengths and instant centre heights. If the Geometry calculation is set to calculate the link lengths and/or the chassis pivot mount heights (ie the swing axle length and roll centre height is specified) then the calculation is always done twice. The first calculation will calculate the link lengths and chassis pivot points, then both the link lengths and chassis pivot point coordinates are rounded to the appropriate number of decimal places (0.01 for mm, 0.001 for inches) and a second calculation done with these fixed dimensions. Depending on the arrangement of the links, this can then result in a small difference between the requested and calculated instant centre dimensions.

6.9.1 Suspension link chassis mounting points

If the instant centre location is "Suspension link chassis mounting points", then the instant centre dimensions will be calculated.

Swing axle and roll centre (front view)

The front view swing axle length is the distance (measured horizontally) from the tyre contact cl to the instant centre of the suspension linkages.

The roll centre height is the intersection of the lines from each tyre contact centreline to the instant centre of the suspension linkages.

The roll centre offset is the distance that the roll centre is offset from the vehicle centreline.

Anti-dive / anti-squat (side view)

Front axle: For a positive anti-dive effect, the intersection point will be behind the front axle and will be a positive dimension; for a negative (or pro-dive) effect, the intersection point will

be ahead of the front axle and will be a negative dimension. If the linkages are parallel, and there is no intersection point, a positive angle is equivalent to a positive anti-dive effect.

Rear axle: For a positive anti-squat effect, the intersection point will be ahead of the rear axle and will be a positive dimension; for a negative (or pro-squat) effect, the intersection point will be behind the rear axle and will be a negative dimension. If the linkages are parallel, and there is no intersection point, a positive angle is equivalent to a positive anti-squat effect.

Geometry | Calculate will use the specified chassis dimensions to calculate the swing axle lengths and instant centres.

The swing axle and the side view instant centre apply to both sides of the vehicle, so there are LH and RH values.

6.9.2 Swing axle lengths and roll/pitch centre heights

If the instant centre location is "Swing axle lengths and roll/pitch centre heights", then the instant centre dimensions must be entered.

The swing axle and the side view instant centre apply to both sides of the vehicle, so there are LH and RH values.

If the vehicle is symmetrical, then only one side need be input, and the other side will be set to the same values. If the vehicle is not symmetrical, or the symmetrical checkbox is cleared, then values for both sides will need to be input.

Swing axle and roll centre (front view)

- The front view swing axle length is the distance (measured horizontally) from the tyre contact cl to the instant centre of the suspension linkages.
This dimension will be positive if the instant centre is inboard from the wheel centreline.
- The roll centre height is the intersection of the lines from each tyre contact centreline to the instant centre of the suspension linkages.
This dimension will be positive if the roll centre is above ground.
- The roll centre offset is the distance that the roll centre is offset from the vehicle centreline.
This dimension will be positive in the direction of the positive horizontal axis.

The swing axle length will usually be a positive value, generally in the range of 1 to 3 times the track.

The roll centre height can be positive, zero or negative.

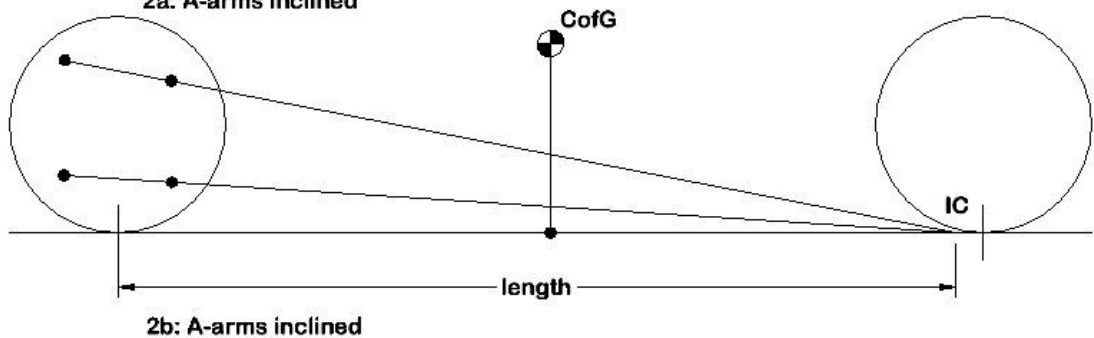
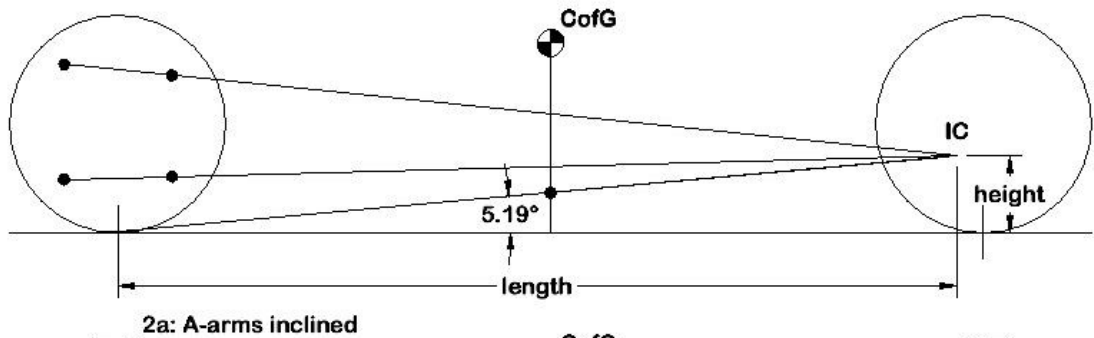
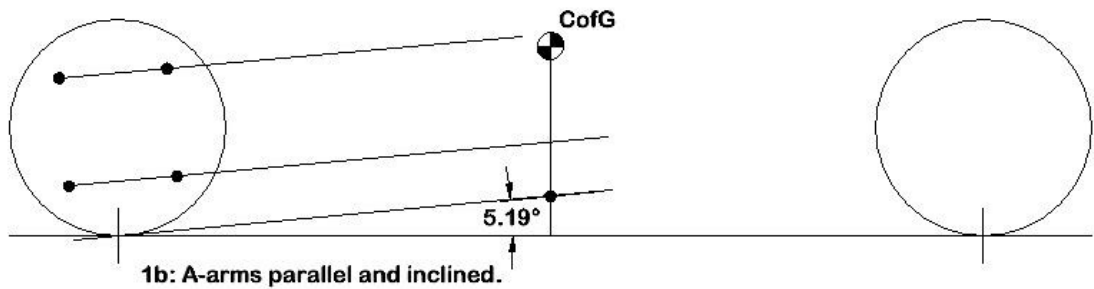
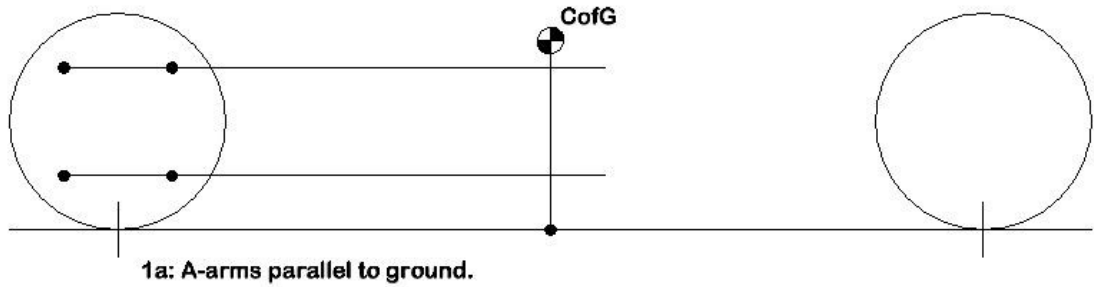
Anti-dive / anti-squat (side view)

Either

- Enter the side view swing axle length and instant centre height (which can be positive, zero or negative) and select the Height radio button,

or

- Enter the side view swing axle length and anti-dive/squat angle and select the Angle radio button. If the angle is zero, then both A-arm pivot axis will be parallel to the ground (in side view).



- Option 1a A-arms parallel to the ground with the side view instant centre on the ground. No anti-dive.
Specify the length, height and angle all zero. "Calculate using" not used.
- Option 1b Upper and lower A-arms parallel, and inclined with respect to the ground.
Specify the angle, with both length and height zero. :Calculate using" angle.
- Option 2a A-arms inclined with respect to each other.
Specify either
- the length, angle and "Calculate using" angle, or
- the length, height and "Calculate using" height.
- Option 2b A-arms inclined with respect to each other with the side view instant centre on the ground. No anti-dive.
Specify the length, and both height and angle zero. "Calculate using" not used.

The diagrams illustrate typical front suspension layouts where the side view swing arm instant centre is around the rear axle. As drawn, length, height and angle are all positive. If the IC is below ground then the height and angle will be negative.

For the rear suspension, where the side view swing arm intersection point is typically around the front axle. In this case length is considered positive if the IC is forward of the rear axle, height and angle are both positive if the IC is above ground.

Geometry | Calculate will use the specified dimensions to calculate the front & rear A-arm chassis pivot vertical values, maintaining the specified horizontal and longitudinal values (as entered in Geometry | Chassis).

6.9.3 Swing axle lengths and roll/pitch centre heights - Strut

The geometry instant centres and swing arm lengths are defined by the intersection of two planes. The strut rod slider axis and the chassis top mounting point together define one of the planes, and the three pivot points of the bottom links define the other. The two instant centres are the roll centre (in front view) and the pitch centre (in side view).

The front view instant centre, roll centre and swing arm length are calculated from the strut slider axis and the linkage pivot points, in the plane of the axle.

The side view instant centre and swing arm length are calculated from the strut slider axis and the linkage pivot points, in the plane of the wheel.

From the Geometry tab, select Configure and choose either "Suspension link chassis mounting points" or "Swing axle lengths and roll/pitch centre heights".

The strut rod slider axis and the chassis top mounting point together define one of the projection planes which determine the instant centre locations. If the anti-squat is specified as "Strut" then the anti-squat will be calculated from the strut rod inclination and a horizontal bottom A-arm.

If the instant centre location is determined by "Suspension link chassis mounting points" then the instant centres will be calculated. All required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified. The instant centre values shown in Geometry | ICs will all be "read only".

If the instant centre location is determined by "Swing axle lengths and roll/pitch centre heights" then the bottom A-arm chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified in Geometry | ICs

- either the front view swing axle length or roll centre height can be specified (but not both), and
- either the side view swing axle length or the side view instant centre height or the anti angle can be specified (but not more than one of them).

This option will calculate the bottom A-arm chassis mounting vertical dimensions.

6.10 Link lengths

From the Geometry tab, select Link Lengths.

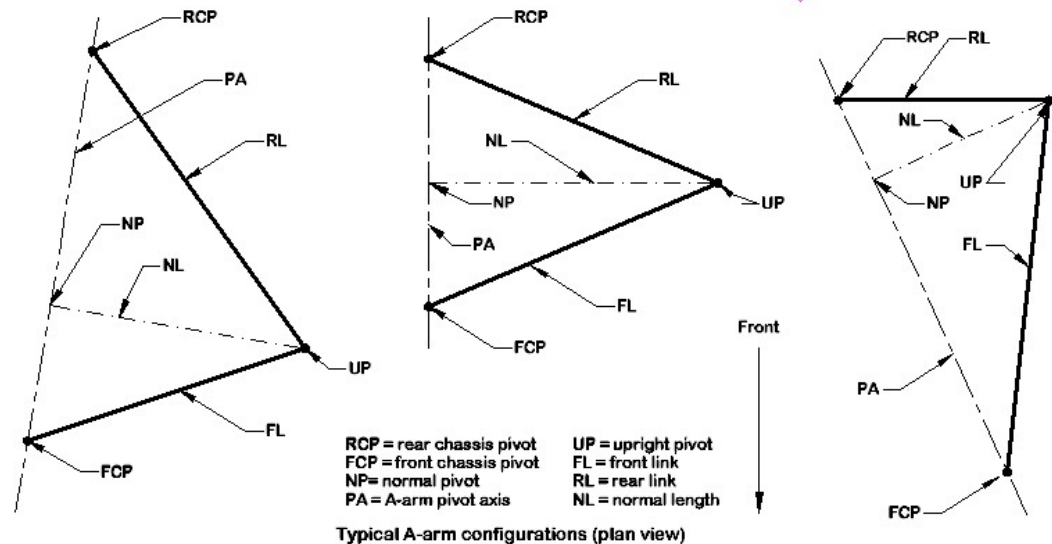
All link lengths are measured between the two pivot points. There is no allowance made for any offsets in the link, or for A-arms where the links do not joint at the apex.

6.10.1 Link lengths

A-arms have five dimensions.

The front and rear link lengths are the actual link pivot to pivot lengths, as is the base length. The normal length is a calculated length.

The normal length is the distance from the normal point to the apex. The normal point is the point on the A-arm pivot axis where a line drawn from the apex to the pivot axis intersects at 90 degrees.



The normal lengths will always be calculated. Depending on the geometry configuration, the front and rear links lengths will also be calculated.

Semi-trailing arm link lengths are measured the same as an A-arm, except that the apex is on the axle at the wheel mounting face, and length dimensions are taken from that point. There is no option to specify link lengths, they will be calculated.

The chosen geometry configuration option will determine if any of the link lengths can be altered.

For the rear suspension, it is important that the links and pivot points that control the basic upright location and the upright toe control are correctly identified, especially as in some designs a single chassis pivot point has several functions.

6.10.2 Ford Twin I-Beam

Note that the I-Beam and radius rod lengths are not the actual lengths of those items. They are the lengths as measured from the centre of the stub axle ball joints (or from the ends of the kingpin) to the centre of the appropriate chassis mounting bush.

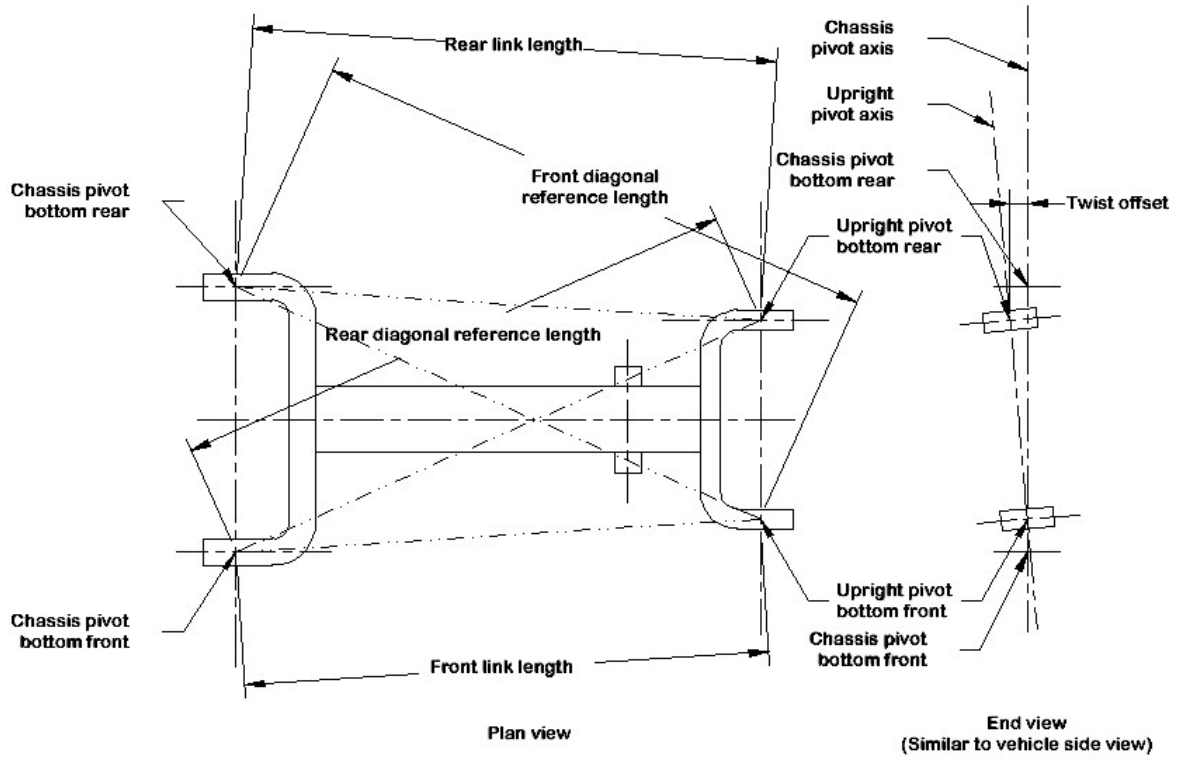
6.10.3 Volkswagen twin trailing links

Geometrically, each trailing link is equivalent to an A-arm pivoting on the torsion bar.

The trailing link actual length is the distance from the centre of the boss on the end of the torsion bar (the chassis mounting point) to the centre of the upright ball joint.

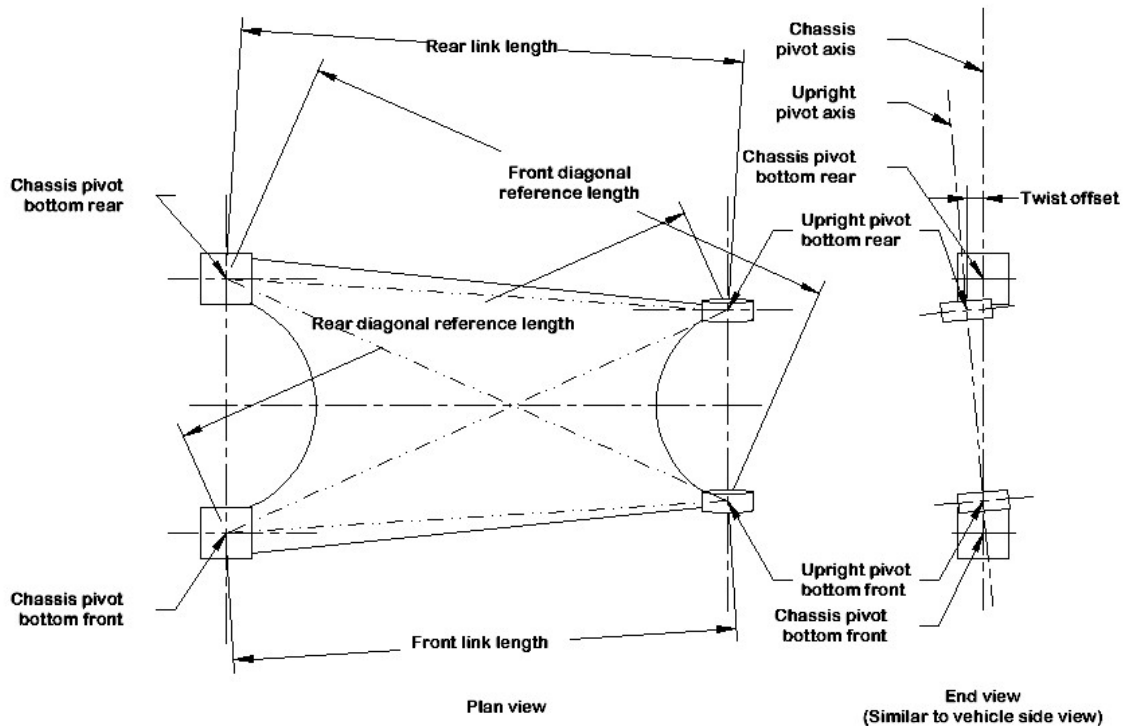
The trailing link reference length is the distance from the torsion bar inner mounting point (on the chassis) to the centre of the upright ball joint.

6.10.4 Control arm (Jaguar)



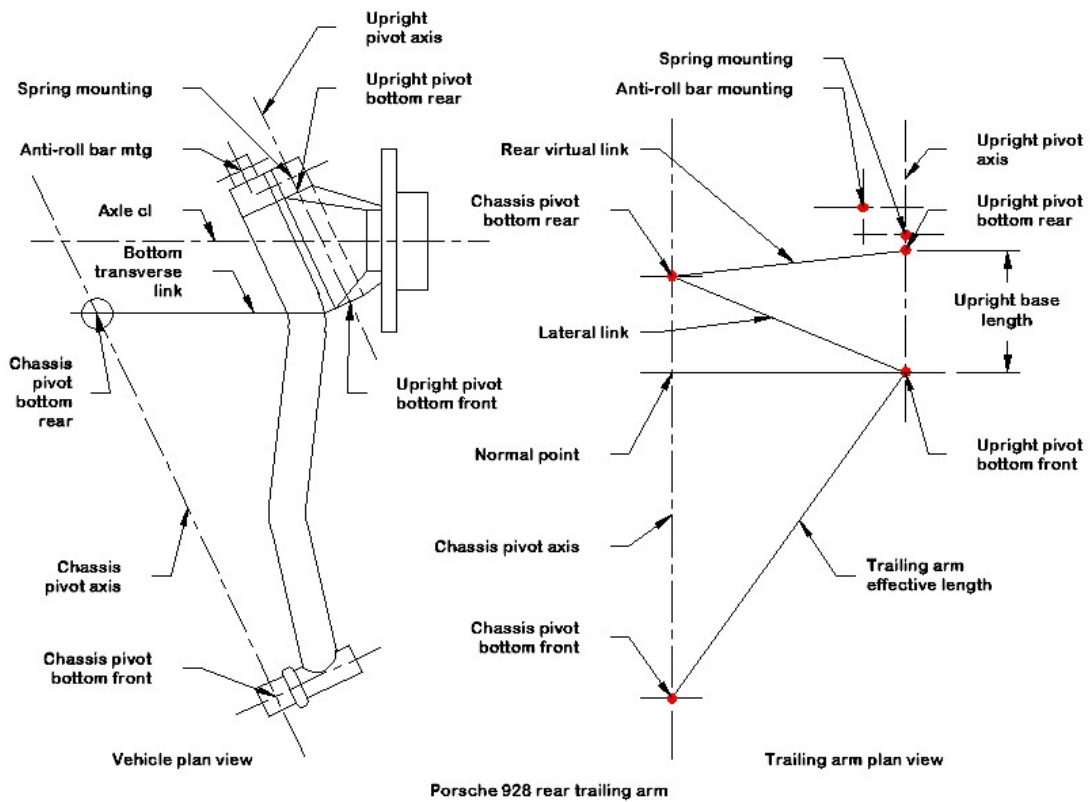
Jaguar rear control arm

6.10.5 Control arm (H-arm)



Typical H-arm control arm

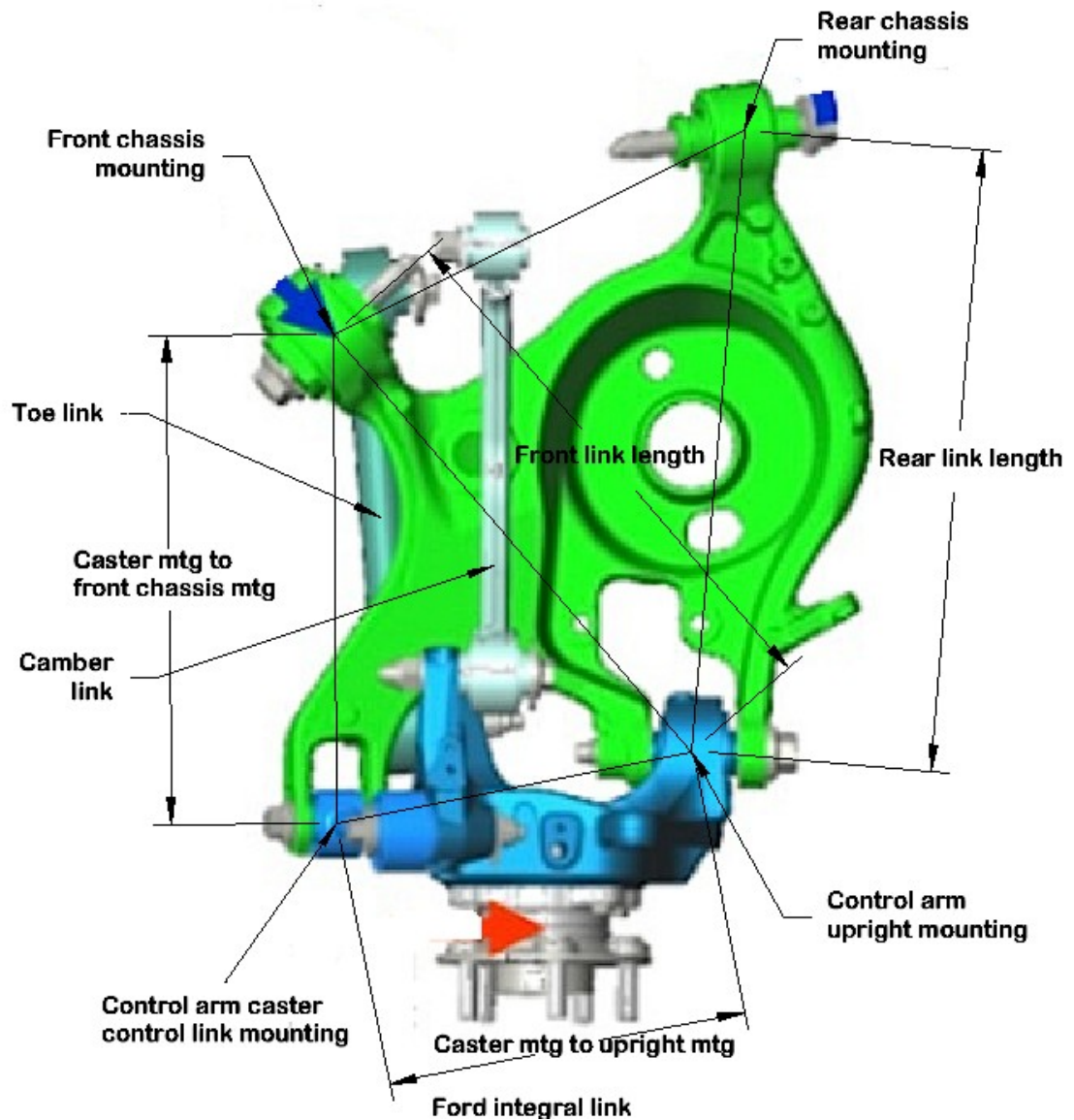
6.10.6 Control arm (Porsche 928)



Porsche 928 rear trailing arm

6.10.7 Control arm (A-arm Caster Link)

For the bottom control arm, the front link length is the length from the front chassis pivot to the upright pivot, and the rear link length is the length from the rear chassis pivot to the upright pivot. The [caster](#) control mounting is dimensioned from the front chassis mounting, and from the upright mounting. The control arm plane is defined by the two chassis pivot points and the single upright pivot point. If the control arm [caster](#) control link pivot is not in the plane of the control arm, then there will be a twist offset.



6.11 A-arm

This tool enables the calculation of the adjustable elements of the A-arm.

Style 0 is the basic A-arm.
There are no A-arm components.

Currently there are 4 available A-arm styles

The Geometry Config setting will determine if the A-arm effective lengths can be calculated from the A-arm component dimensions, and if the A-arm component dimensions can be calculated from the A-arm effective lengths.

If the Geometry Config is "Wheel location and alignment" then the A-arm effective lengths are calculated (by the Geometry Calculation). The A-arm component dimensions can be calculated. Specifically, once all the fixed dimensions have been input, the adjustable dimensions will be calculated.

If the Geometry Config includes "Top A-arm" or "Upper A-arm" or "Bottom A-arm" or "Lower A-arm" then the A-arm effective lengths are required for the Geometry Calculation. If all the A-arm component dimensions are specified, including the adjustment actual dimensions) then the effective lengths can be calculated. Specify "Effective link dimensions" and calculate.

Usually, all A-arm component dimensions will be positive. Exceptions are noted in the individual style pages.

But the adjustment dimensions are always positive. Adjustments are provide by means of shims or screwing ball joints in or out.

Each link adjustment has a minimum and maximum value.

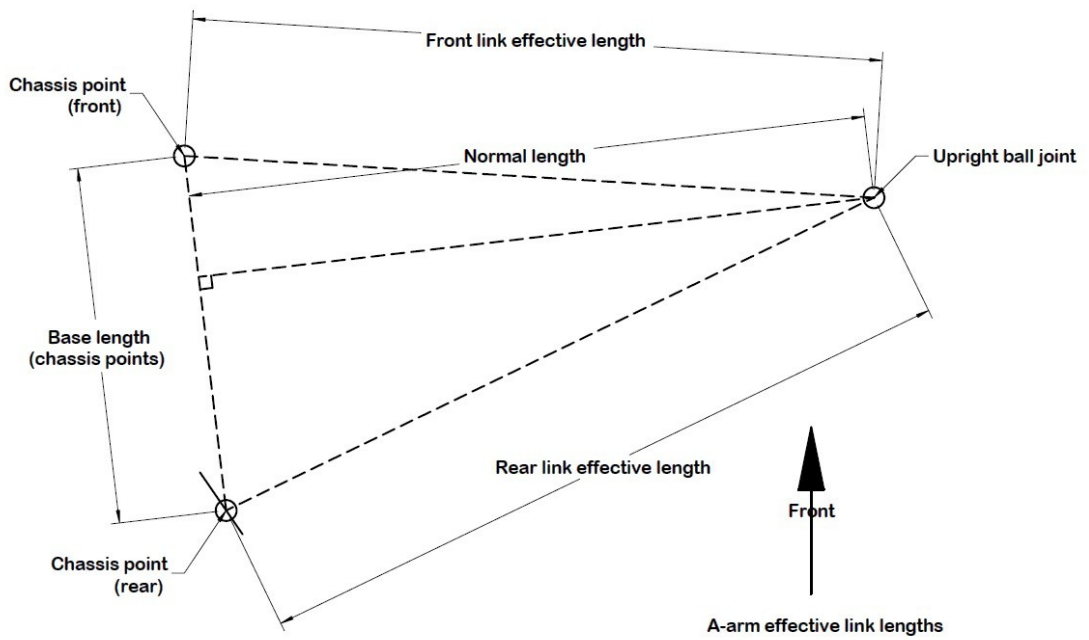
In the case of shims, then the minimum would be zero (ie no shims fitted) and the maximum the thickness of the total shim pack.

With a ball joint or Heim joint, the minimum would be the measurement from the centre of the ball to the end of the link with the ball joint screwed in all the way. The maximum would be with the ball joint screwed out as far as possible while still retaining an adequate thread length engaged.

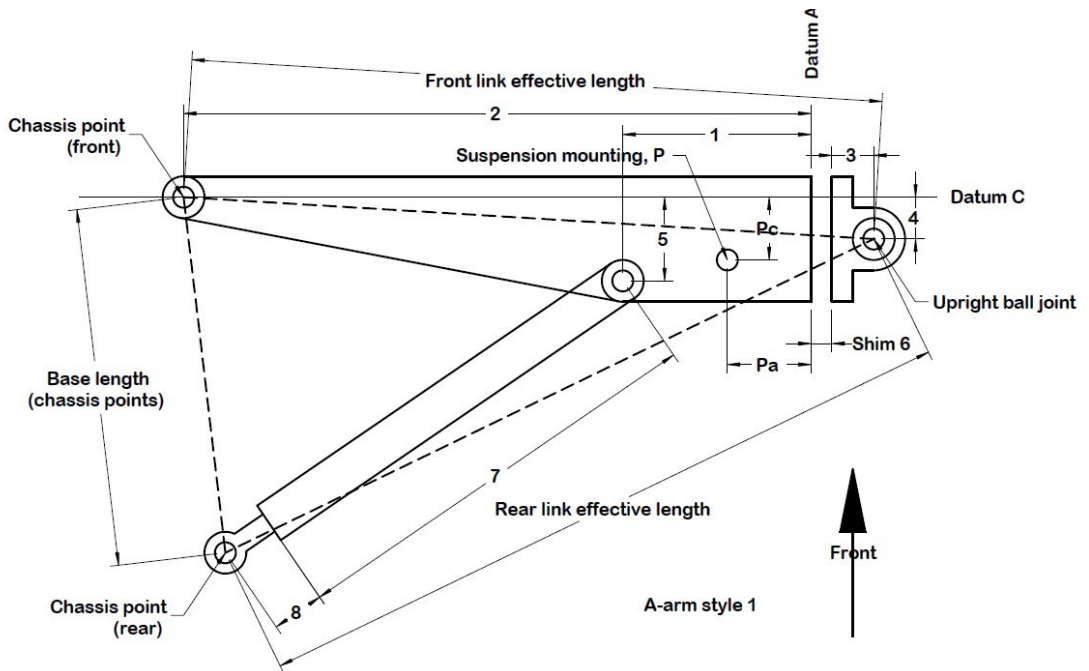
If a link has no adjustment, then the link length would be to the centre of the mounting, with both minimum and maximum set to zero.

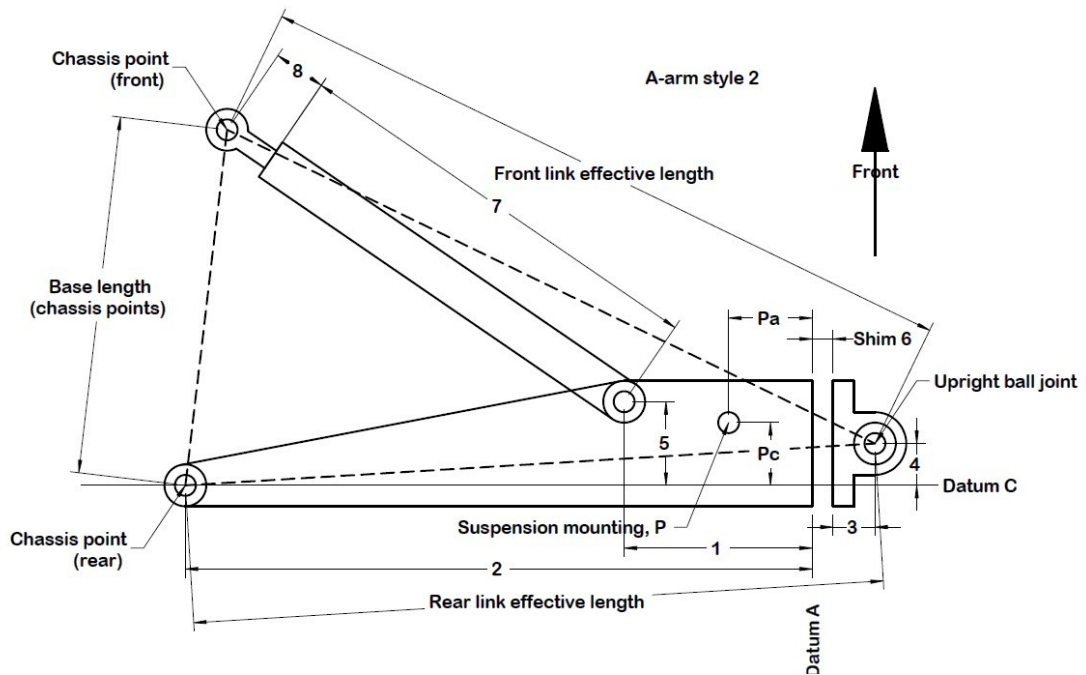
If the A-arm effective lengths are calculated (by the Geometry Calculation) and then the A-arm component dimensions calculated, it is possible that an adjustment dimension is negative. In this case it means that the physical A-arm link is too long, and will need to be shortened.

6.11.1 Basic A-arm



6.11.2 A-arm styles 1 & 2





A-arm styles 1 and 2 are similar, with opposite orientation.

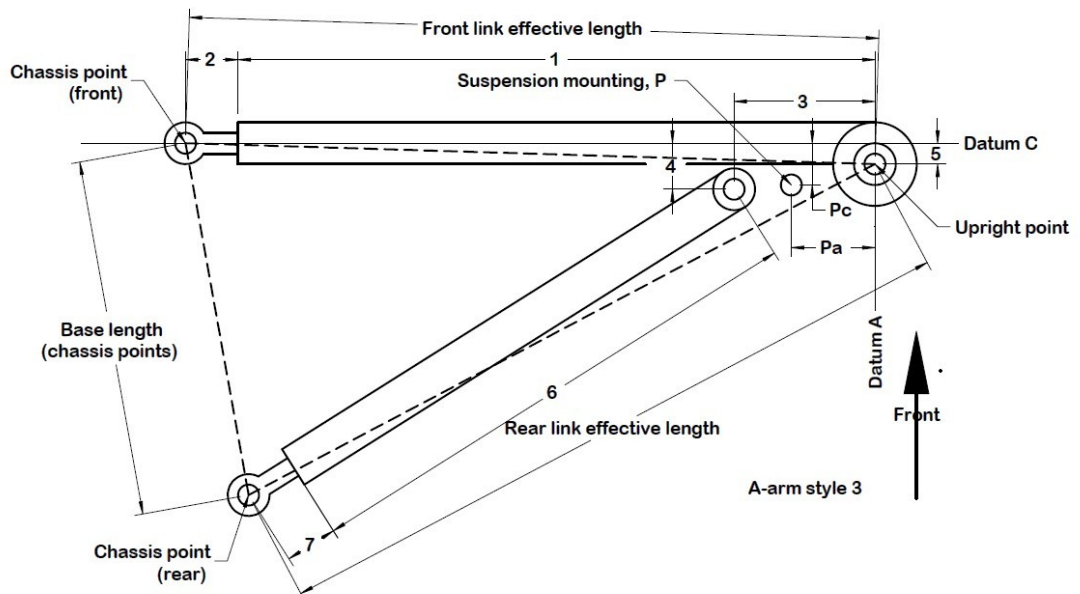
All dimensions are positive, except for offsets 4 and 5 which are negative if the offset is to the opposite side of the datum.

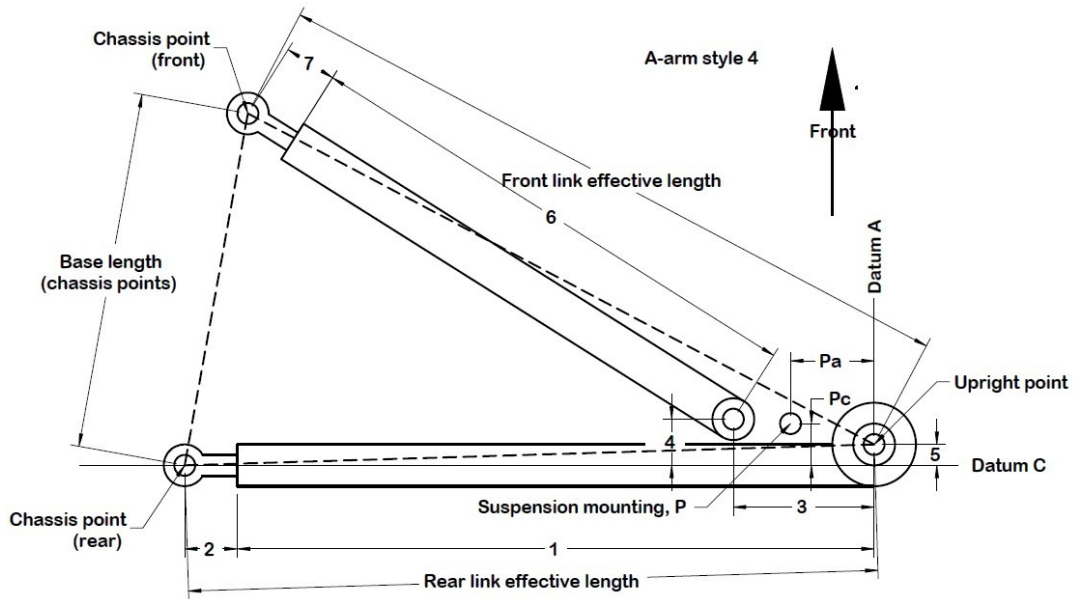
Dimensions 6 and 8 are adjustable.

Suspension mounting P is where a shock absorber, anti-roll bar link, pushrod or pullrod or spring is attached to the A-arm.

Dimension Pa is always positive, dimension Pc is positive (as drawn) or is negative if on the opposite side of datum C. Dimension Pb is positive if P is above the plane of the A-arm, and negative if below.

6.11.3 A-arm styles 3 & 4





A-arm styles 3 and 4 are similar, with opposite orientation.

All dimensions are positive, except for offsets 4 and 5 which are negative if the offset is to the opposite side of the datum.

Dimensions 2 and 7 are adjustable.

Suspension mounting P is where a shock absorber, anti-roll bar link, pushrod or pullrod or spring is attached to the A-arm.

Dimension Pa is always positive, dimension Pc is positive (as drawn) or is negative if on the opposite side of datum C. Dimension Pb is positive if P is above the plane of the A-arm, and negative if below.

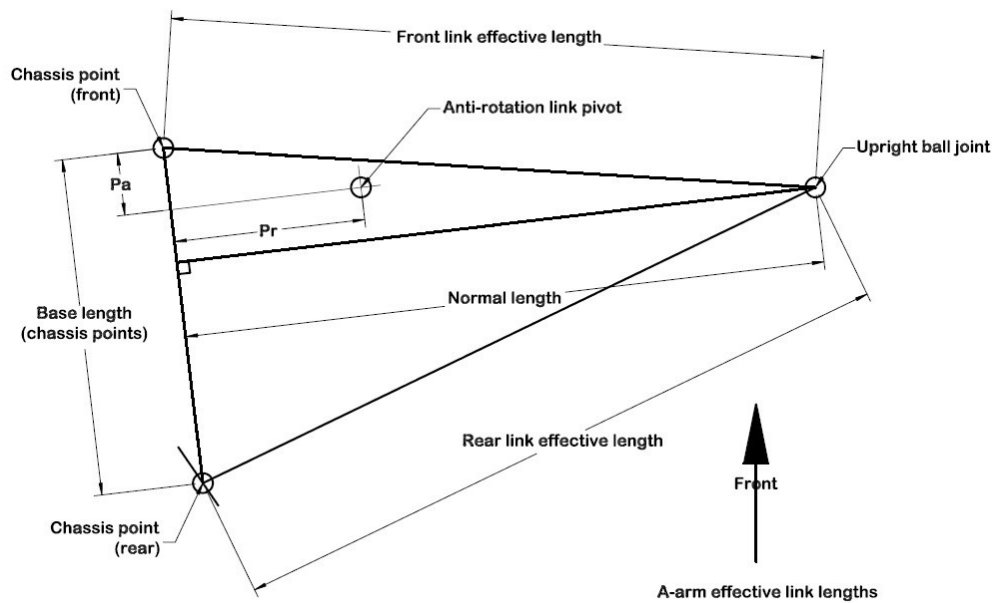
A typical example of this style is the Brabham BT30 front upper A-arm.



This is a style 3, with the centreline of the lateral link tube as the datum, with both the upright ball joint and the attachment of the leading link offset from the tube centreline (dimensions 4 and 5).

A more common application is the lower A-arm for a strut suspension where a lateral link is combined with a [caster](#) link, often using the anti-roll bar. Generally the upright ball joint and the [caster](#) link attaching point are on the lateral link centreline, with dimensions 4 and 5 both zero.

6.11.4 A-arm dual axis strut



The A-arm dual axis strut is the same as the [basic A-arm](#) with the addition of the anti-rotation link mount, P.

The actuation point is measured relative to the A-arm datums. These datums are the A-arm pivot axis (the base line joining the chassis front & rear pivot points), the line joining the upright pivot point to the normal pivot point (the A-arm normal link length) and the plane of the three pivot points.

The horizontal dimension, P_r , is specified from the A-arm pivot axis, is the distance from the A-arm pivot axis along a line normal to the A-arm pivot axis. Positive dimensions are in the outboard direction (toward the upright).

The vertical value is the distance above or below the plane of the A-arm. If the vertical axis is positive upward, then a positive dimension is above the A-arm plane and a negative dimension is below the A-arm plane; if the vertical axis is positive downward, then a positive dimension is below the A-arm plane and a negative dimension is above the A-arm plane.

The longitudinal value, P_a , is the distance along the A-arm pivot axis to where the normal from P intersects the A-arm pivot axis, measured from the front chassis pivot point. If the longitudinal axis is positive rearward, then a positive dimension positions P towards the rear chassis point; if the longitudinal axis is positive forward, then a positive dimension positions P forward of the front chassis pivot point.

6.12 Track

6.12.1 Independent suspensions

From the Geometry tab, select Track.

If the [wheel location point](#) is specified as "Wheel centre / axle" then the track will be shown with two sets of dimensions, one will be the "on ground" dimension and the other will be the "Wheel centre / axle" dimension.

If the wheel location point is specified as "On ground" then the track is measured on the ground between the tyre contact patch centrelines with the specified camber, castor and toe.

If the wheel location point is specified as "Wheel centre / axle" then the track is measured between then wheel centres at hub height, with the specified camber, castor and toe.

The axle offset is the horizontal distance from the vehicle centreline to the centre of the track.

NASCAR specify that track is measured at hub height at the tyre centre (width) with the wheels in the straight ahead position.

For example, if both wheels have negative camber, then the NASCAR track will be narrower than the "on ground" track measurement.

In practice, it is the average of two measurements, one at the front of the tyre and the other at the rear of the tyre, across the outside of the tyre tread minus the tread width, taken at hub height.

This is "display only" and will be calculated from the specified A-arm link lengths, or the specified half track.

6.12.2 Live axle/deDion

From the Geometry tab, select Track.

If the [wheel location point](#) is specified as "Wheel centre / axle" then the track will be shown with two sets of dimensions, one will be the "on ground" dimension and the other will be the "Wheel centre / axle" dimension.

If the wheel location point is specified as "On ground" then the track is measured on the ground between the tyre contact patch centrelines with the specified camber, castor and toe.

If the wheel location point is specified as "Wheel centre / axle" then the track is measured between then wheel centres at hub height, with the specified camber, castor and toe.

The axle offset is the horizontal distance from the vehicle centreline to the centre of the track.

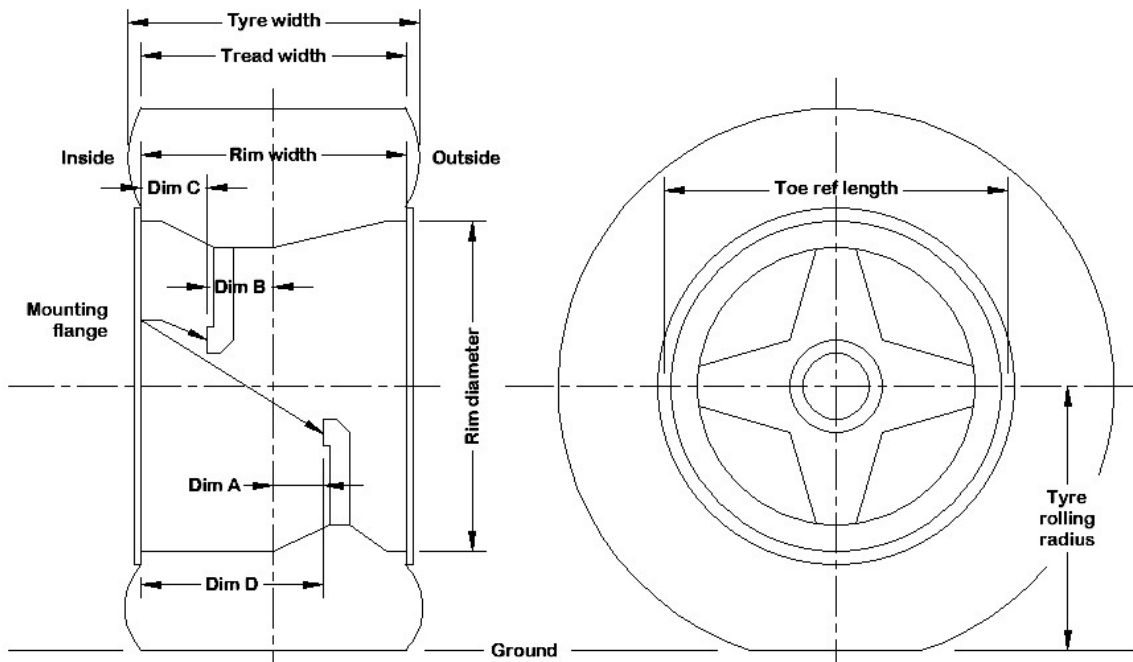
NASCAR specify that track is measured at hub height at the tyre centre (width) with the wheels in the straight ahead position.

For example, if both wheels have negative camber, then the NASCAR track will be narrower than the "on ground" track measurement.

In practice, it is the average of two measurements, one at the front of the tyre and the other at the rear of the tyre, across the outside of the tyre tread minus the tread width, taken at hub height.

This is "display only" and will be calculated from the specified axle dimensions and alignment, wheel sizes and alignment settings.

6.13 Wheel and tyre



From the Geometry tab, select Wheel.

The data shown will be for the wheel referenced in the dialog title. This is the car end and car side currently specified. When you “Apply” or “OK”, and the “Symmetric” box is ticked, then both wheel and tyres (for that car end) will be set to the values specified. When you “Apply” or “OK”, and the “Symmetric” box is not ticked, then only the wheel referenced in the dialog title will be set to the values specified.

Generally production vehicles will have all four wheels the same. Even if there are variations, it may still be more convenient to initially specify all wheels identically, then update the individual wheel(s) that differs.

See [Vehicle | All Wheels](#).

Wheel dimensions:

- rim diameter.
- rim width.
- rim mounting offset / ET. See [wheel coordinates](#).

Tyre dimensions:

- tyre tread width
- tyre section width (ie the overall width of the tyre across the sidewalls)
- tyre rolling radius. This is usually somewhat less than half the diameter due to the loaded deflection of the tyre.
- tyre diameter. This is the overall diameter of the inflated tyre. It will always be greater than twice the rolling radius.
- tyre spring rate. Enter the rate in either N/mm or lb/in using the related input box.

Tyre parameters:

- three sets of data points for the tyre contact patch offset and effective tyre radius at camber. See [tyre camber parameters](#).

Wheel fitment and alignment:

- spacer thickness. If there is a spacer between the hub face and the wheel face.
- toe reference length. This specifically required when specifying the wheel alignment toe as a distance. If specifying wheel alignment toe as an angle, then this dimension is not required, but it is suggested that it should be set to the rim diameter.

All dimensions can be input as either mm or inches. Specify which by selecting the appropriate button.

If Designer is in metric mode, the default will be mm for all dimensions, except rim width and rim diameter which are more commonly measured in inches.

If Designer is in imperial mode, the default will be inch for all dimensions.

For the Geometry calculations only the rim diameter, tyre deflected radius (ie the rolling radius) and wheel offset are needed. If specifying the wheel alignment toe as a distance then toe reference length is needed. All other dimensions can remain at zero.

For the Spring calculations the tyre rate is needed.

For the Dynamic calculations both the tyre deflected radius and the tyre rate are needed.

Note that if the tyre rate is zero, then this is assumed to be an "infinitely stiff" tyre with no deflection under load.

All other values are for display only, are not used by SusProg3D calculations and can remain at zero.

For the wheel and tyre to display correctly, all dimensions should be input.

There is space for a 79-character comment (for example, the tyre make and size).

6.14 Wheel alignment

From the Geometry tab, select Alignment.

6.14.1 Wheel alignment

Depending on the chosen Geometry calculation configuration, some wheel alignment settings will be determined by the geometry and will be calculated.

If there is the option to use Caster or Inclination, specify either Caster or Inclination.

Enter the required static wheel camber in degrees.

Enter the required static wheel castor or inclination, both in degrees.

Enter the required static wheel toe, in degrees, mm or inches (as appropriate).

Toe-in is always positive; toe-out is always negative.

If the toe is non-zero and is either mm or inches, the toe reference length must also be specified.

This is usually the rim diameter. Some laser wheel alignment equipment defaults to 1000mm for the reference length.

If required, enter distance from the vehicle centreline (ie the horizontal datum), horizontally, to the wheel location point.

If the wheel location point is "On ground", then this is measured horizontally on the ground datum from the tyre contact patch centreline to the vertical plane of the horizontal datum with the wheel at the specified camber, castor and toe.

If the wheel location point is "Wheel centre /axle", then this is measured horizontally from the wheel centre on the axle (or spindle) to the vertical plane of the horizontal datum with the wheel at the

specified camber, castor and toe.

For symmetrical vehicles, with the horizontal datum on the vehicle centreline, this will be half the actual track dimension.

For asymmetric vehicles (where the axle is "offset" to one side) then the LH and RH dimensions will be different.

This dimension is always positive.

If required, enter distance from the longitudinal datum reference point, horizontally, to the wheel location point.

If the wheel location point is "On ground", then this is measured horizontally on the ground datum from the tyre contact patch centreline to the vertical plane of the longitudinal datum reference point with the wheel at the specified camber, castor and toe. If there is zero toe, then this is the same as the actual axle centreline to longitudinal datum.

If the wheel location point is "Wheel centre /axle", then this is measured horizontally from the wheel centre on the axle (or spindle) to the vertical plane of the longitudinal datum reference point with the wheel at the specified camber, castor and toe. If there is zero toe, then this is the same as the actual axle centreline to longitudinal datum.

For asymmetric vehicles (where the axle is "offset" to one side) then the LH and RH dimensions will be different.

If incorporated in the upright design, the wheel camber can also be adjusted by means of an "[upright camber shim](#)".

For all front suspensions, and rear suspensions using Caster, after the Geometry | Calculation, the [upright pivot inclination \(kingpin axis inclination \(KPI\) or steering axis inclination \(SAI\)\)](#), scrub radius and trail will be shown.

The scrub radius is the distance in front view between the kingpin axis and the center of the contact patch of the wheel, where both would theoretically touch the road.

The [kingpin](#) axis is the line between the upper and lower ball joints of the hub. On a MacPherson strut, the top pivot point is the strut bearing, and the bottom point is the lower ball joint. The inclination of the steering axis is measured as the angle between the steering axis and a vertical line from center contact area of the tire.

With multi-link suspensions, in particular those designs with "virtual A-arms", the location of the "virtual pivot point" can be quite sensitive to small variations in the actual link lengths. This often shows as a small difference between the specified and the calculated [caster](#). If the Geometry calculation is set to use calculated the link lengths (ie the wheel location and alignment is specified) then the calculation is always done twice. The first calculation will calculate the link lengths, then the link lengths are rounded to the appropriate number of decimal places (0.01 for mm, 0.001 for inches) and a second calculation done with these fixed link lengths. Depending on the arrangement of the links, this can then result in a small difference in the position of the "virtual pivot" and hence a small difference in [caster](#).

6.14.2 Jaguar IRS/H-arm + camber link/Porsche 928

For the typical Jaguar and H-arm IRS where the chassis pivot points are parallel to both the ground (in side view) and the vehicle centreline (in plan view), and there is no "twist" in the bottom A-arm itself (that is, the chassis pivot axis and upright pivot axis are coincident in side view, and the vertical offset is 0.0) then set both [inclination](#) and toe to zero and specify a configuration option that does not require that the bottom link offset be specified.

6.14.3 Semi-trailing arm

Enter the camber and toe values.

In the bump and droop display the value of inclination is indicative of the angular movement of the semi-trailing arm in side view.

6.14.4 Mono wheel - trailing arm

Enter the camber and toe values.

In the bump and droop display the value of inclination is indicative of the angular movement of the semi-trailing arm in side view.

Camber and toe are typically zero.

Track is always zero, but it is possible to have a small centreline offset.

6.14.5 Trailing arm, upper and lower lateral links

Enter the camber, inclination and toe values.

In the bump and droop display the value of inclination is indicative of the angular movement of the trailing arm in side view.

6.14.6 Live axle/deDion

For the front axle

- The wheel alignment camber, [caster](#) and KPI settings are calculated from the axle configuration (by adjusting the hub camber, [caster](#) and KPI settings) and the axle location (as determined by the locating links).
- The wheel alignment toe setting can be specified.
- In the bump and droop results the value of "pinion" is indicative of the angular movement of the axle in side view, and "[caster](#)" is the actual wheel alignment [caster](#).

For the rear axle

- The wheel alignment settings are calculated from the axle configuration (by adjusting the hub camber and toe settings) and the axle location (as determined by the locating links).
- In the bump and droop results the value of "pinion" is indicative of the angular movement of the axle in side view.

6.15 Turn

For the front suspension only, and if the Geometry | Configuration option includes "+ Turn" option.

Using the "+ turn" config option.

From the Geometry tab, select Turn.

Enter the vehicle turn direction, the initial wheel alignment toe setting, the required turn angle in degrees and if the turn angle is the wheel toe or the steering wheel rotation.

If using the wheel toe this is the angle through which the outer wheel is turned, from the initial toe setting position.

If using the steering wheel this is the angle the steering wheel is rotated from the straight ahead position, and turns the outside wheel from the initial toe setting.

The initial wheel alignment toe setting for both wheels is that for the “straight ahead” position. The turn angle of the inner wheel will be determined by the steering geometry.

After doing calculations with a turn angle specified, all the static alignment settings will be those with the wheels now turned to the specified angle. This will mean that, for example, the static toe setting will now include the turn angle.

Subsequent calculations always start from the “straight ahead” wheel alignment.

To reset the calculations back to the “straight ahead” alignment, specify a zero turn angle, and then calculate.

The turn direction and the roll direction are now decoupled. This makes it possible to see the effect of steering in the opposite direction. For example, an understeering car in a left hand turn will be rolling onto the right side, and will also have the wheels steered left. But an oversteering car in the same left hand turn, while rolling onto the right hand side, will have the wheels steered to the right.

Note that for both rack and pinion and recirculating ball type steering boxes the steering ratio is fixed.

6.16 Travel limits

From the Geometry tab, select Travel.

Enter the appropriate values. Note that both values are positive.

If the specified bump and droop is greater than is geometrically possible, an error message will display and require the appropriate action. Generally a reduction in wheel travel increment will be required.

If the maximum and minimum wheel travel is set by specifying the open and closed shock absorber lengths (See Rates | Travel), then this will be noted here, and the maximum and minimum wheel travel values cannot be changed here. If you do need to set the maximum and minimum wheel travel values then go to Rates | Travel and set them there, ensuring that “Limit by wheel travel” is checked.

6.17 Calculate

From the Geometry tab, select Calculate.

After all required dimensions have been input, SusProg3D will calculate all other dimensions.

The status bar will display a message ‘Calculating...’ followed by either ‘OK’ or an error message.

On fast processors, the ‘Calculating...’ message may not remain long enough to be visible.

6.18 Results

If some of the results are needed, then the appropriate Dialog box can be opened. For example, if it is required to check the roll centre height because of using fixed chassis pivot points, then Geometry | ICs will open the Dialog box and display the calculated values. (Use Cancel to close the Dialog box if no input values are changed).

From the Geometry tab, select Result.

This will display a window with all the calculated suspension values. If it is needed to change a value, it is necessary to close the result window first.

If this menu choice is made without first doing the calculation the result will be blank. Note that if you change a value and then select result without redoing the calculation, the displayed results may be inconsistent. It's always safest to do a calculate before a result.

SusProg3D SRD912.s3d Front Geometry			
Double A-arm, steering link			
Vehicle horizontal datum (X):	Vehicle centreline		
Vehicle vertical datum (Y):	Ground		
Vehicle longitudinal datum (Z):			
Chassis pivot points (from vehicle X, Y, Z datum)			
- top A-arm chassis pivot (front/rear)	- X	300.00	300.00
	- Y	383.20	373.28
	- Z	-132.50	132.50
- bottom A-arm chassis pivot (front/rear)	- X	250.00	250.00
	- Y	165.84	165.85
	- Z	-132.50	132.50
- tie rod	- X	256.89	
	- Y	277.21	
	- Z	-99.17	
Upright pivot points (from vehicle X, Y, Z datum)			
- top A-arm upright pivot	- X	546.72	
	- Y	379.05	
	- Z	10.89	
- bottom A-arm upright pivot	- X	598.74	
	- Y	140.41	
	- Z	-10.13	
- tie rod (steering arm)	- X	547.36	
	- Y	268.21	
	- Z	-99.17	
- spindle reference point	- X	697.72	
	- Y	260.82	
	- Z	0.01	
- spindle / wheel cl point	- X	697.72	
	- Y	260.82	
	- Z	0.01	
Instant centres			
Front view swing axle length (at IC point)		3173.79	
Front view swing axle height (at IC point)		364.50	
Roll centre height		80.39	
Roll centre offset		0.00	
Side view IC length (at IC point)		6717.63	
Side view IC height (at IC point)		141.43	
Side view IC height (at rear axle centreline)		48.13	
Side view IC angle (from tyre contact patch centre)		1.21	
Suspension roll axis		-2.1%	
Brake force split 60% front 40% rear			
Brake anti-dive %		9.5%	
Track (wheel centreline on ground)		1400.00	
Top A-arm link lengths (front/rear)		285.39	275.12
Top A-arm (normal length)		246.72	
Top A-arm (base length)		265.19	
Bottom A-arm link lengths (front/rear)		370.46	377.64
Bottom A-arm (normal length)		349.67	
Bottom A-arm (base length)		265.00	
Steering tie rod length		290.61	
Tyre centreline on ground from Z datum		0.00	
Tyre centreline on ground from vehicle centreline		700.00	

Tyre rolling radius (nominal)		260.83	
Tyre diameter (overall)		542.53	
Rim diameter		330.20	
Rim width		203.20	
Rim mounting offset		0.00	
Wheel mounting spacer		0.00	
Wheel alignment in straight ahead position			
Camber angle		-0.50	
Top king pin point (actual)	- X	546.72	
	- Y	379.05	
	- Z	10.89	
Bottom king pin point (actual)	- X	598.74	
	- Y	140.41	
	- Z	-10.13	
Upright pivot inclination (kpi)		12.31	
Upright pivot scrub radius (tyre cl on ground)		70.58	
Caster angle and trail		5.00	22.72
Steering offset		74.15	
Spindle offset from kingpin axis (side/front view)		0.00	122.36
Static toe (degree) toein		0.17	
Ride height ref point (from vehicle X, Y, Z datum)			
Rear LH	Rear RH	Front LH	Front RH
Front LH: Bottom A-arm, front mounting			
Rear LH: Bottom A-arm, rear mounting			
		- X	250.00 -250.00
275.00	-275.00		
Ride height (ref point to ground)			
164.81	164.81	- Y	165.84 165.84
		- Z	-132.50 -132.50
2423.50	2423.50		
Datum reference dimensions			
Chassis horizontal datum (X): Chassis centreline			
Chassis vertical datum (Y):			
Chassis longitudinal datum (Z):			
Ride height ref point (from chassis X, Y, Z datum)			
Rear LH			
Front LH: Bottom A-arm, front mounting			
Rear LH: Bottom A-arm, rear mounting			
		- X	250.00
275.00			
		- Y	165.84
164.81			
		- Z	-132.50
2423.50			
Chassis pivot points (from chassis X, Y, Z datum)			
- top A-arm (front/rear)	- X	300.00	300.00
	- Y	383.20	373.28
	- Z	-132.50	132.50
- bottom A-arm (front/rear)	- X	250.00	250.00
	- Y	165.84	165.85
	- Z	-132.50	132.50
- tie rod	- X	256.89	
	- Y	277.21	

	- Z	-99.17
Upright pivot points (from upright X, Y, Z datum)		
- top A-arm	- X	150.00
	- Y	120.00
	- Z	0.00
- bottom A-arm	- X	100.00
	- Y	-120.00
	- Z	0.00
- tie rod (steering arm)	- X	150.00
	- Y	0.00
	- Z	-100.00
- spindle reference point	- X	0.00
Upright pivot points (from chassis X, Y, Z datum)		
- top A-arm	- X	546.72
	- Y	379.05
	- Z	10.89
- bottom A-arm	- X	598.74
	- Y	140.41
	- Z	-10.13
- tie rod (steering arm)	- X	547.36
	- Y	268.21
	- Z	-99.17
- spindle reference point	- X	697.72
	- Y	260.82
	- Z	0.01

6.19 ECalc

Allows several modules to be calculated from one point.

For example, if a chassis mounting point is changed, you can recalculate all modules with one click.

See [ECalc](#)

7 Roll and bump the chassis

Note that Geometry | Calculate must complete without error before this operation can be done.

7.1 Configure

Specify the bump and roll increments and the roll axis.

From the Roll Bump tab, select Configure, and then choose "Bump and droop increments", "Roll increments" and "Roll centre and axis".

Note that any changes to the bump and droop increments or limits; the roll increments or limits, will clear all calculated data and all calculations will need to be redone.

7.1.1 Bump and droop increments

Enter the wheel bump and droop maximum travel. Note that both values are positive.

If the maximum and minimum wheel travel is set by specifying the open and closed shock absorber lengths (See Rates | Travel), then this will be noted here, and the maximum and minimum wheel travel values cannot be changed here. If you do need to set the maximum and minimum wheel travel values then go to Rates | Travel and set them there, ensuring that "Limit by wheel travel" is checked.

The default values for maximum travel increment are 100mm (4.0") for both bump and droop.

Enter the wheel bump and droop increments. Note that both values are positive.

The default values for wheel travel increment are 20mm (0.75") for both bump and droop.

If the specified bump and droop is greater than is geometrically possible, an error message will display and require the appropriate action. Generally a reduction in maximum wheel travel will be required.

It is permissible to set the wheel droop to zero, but the wheel bump must be greater than zero.

Bump calculations are done for as many positions as required.

For example, if wheel travel increment is 10mm, maximum bump is 85mm, and maximum droop is 75mm, the bump and droop calculations will be done at the 85, 80, 70, 60, 50, 40, 30, 20, 10, static, -10, -20, -30, -40, -50, -60, -70 and -75mm positions for a total of 18 calculations, 9 bump + static + 8 droop.

7.1.2 Roll increments

Enter the maximum roll (in degrees). Note that this value is positive.

Enter the required values for the chassis roll calculation & display increments, and the starting position for the roll calculations.

The roll calculation interval specifies the steps taken in internal calculations as the chassis is rolled. Starting from the initial roll centre, the chassis is rolled by the calculation interval and the resultant roll centre found. The chassis is then rolled by the calculation interval about this new roll centre and the resultant roll centre found. This process continues until the chassis has been rolled by the required amount (as specified by the display increment). This enables a degree of "dynamism" to the roll centre. Be aware that the smaller the calculation interval, the longer the calculation time.

The default values for chassis roll increments are 0.5 degree for display and 0.25 degree for calculate, and the starting position defaults to the static position.

The chassis roll increment can be set to zero.

Roll calculations are done for as many positions as required.

LH roll means that the chassis is rolling onto the left hand side; the left hand suspension is moving into bump, and the right hand side into droop. It is the equivalent of a right hand turn.

Similarly, RH roll means that the chassis is rolling onto the right hand side; the right hand suspension is moving into bump, and the left hand side into droop. It is the equivalent of a left hand turn.

For example, if the maximum roll is 5 degrees and the display interval is 1 degree, the roll calculations will be done at the 5° LH, 4° LH, 3° LH, 2° LH, 1° LH, 0°, 1° RH, 2° RH, 3° RH, 4°RH, 5° RH positions for a total of 11 calculations.

If a roll starting position other than Static is specified, then this position will be the 0° position for the chassis roll calculations.

For example, if wheel travel increment is 20mm, the maximum roll is 4 degrees and the chassis roll increment is 0.5°, and the initial bump position is 40mm, the chassis will be bumped 40mm, and then the chassis will be rolled through 0.5°, 1.0°, 1.5°, 2.0°, 2.5°, 3.0°, 3.5° and 4.0° both LH and RH

7.1.3 Roll centre and axis

Specify the chassis roll centre location and the roll axis.

If the chassis roll location is set to 'Fixed roll centre' then the chassis will be rolled about the initial roll centre regardless of the calculated roll centre position.

If the chassis roll location is set to 'SemiDynamic roll centre' then the chassis roll centre will be at the resultant roll centre height, but positioned on the vehicle centreline. Both [CRA94a] and [REIM96] suggest that the chassis always rolls about a point on (or very close to) the vehicle centreline.

If the chassis roll location is set to 'Dynamic roll centre' then the chassis roll centre will be the resultant roll centre (both in height and offset).

If the chassis roll axis is set to 'Horizontal' (the traditional and default method) then the vehicle end is rolled about the roll centre, with no account taken of the roll centre at the opposite end of the vehicle. [MILL95] suggests that inclined axis calculations are infrequently used.

If the chassis roll axis is set to 'Inclined' then the vehicle end is rolled about the inclined roll axis, where the roll axis is the line joining the roll centre (of the vehicle end being rolled) and the static roll centre at the opposite end of the vehicle. In order to use this option, make sure that both the roll centre (at the opposite end of the vehicle) and the wheelbase have been specified. These values are shown in the dialog panel for reference. Note that using this option when there are large amounts of sideways roll centre movement may lead to an undesirable 'diagonal pitching' condition.

7.2 Car end

The [Front] or [Rear] tab choice will indicate the currently selected vehicle end.

These tabs acts as a toggle, and selecting this tab will switch between each of two.

Depending on the vehicle configuration, some menu bar items may not be available.

When a dialog box is opened, the title will include the currently selected car. If the car end is not shown, then the dialog box applies to both ends.

7.3 Calculate

After all required dimensions have been entered, SusProg3D will calculate the suspension characteristics in chassis roll and wheel bump & droop.

Before the full range of bump and droop calculations can be calculated, Geometry | Calculate must complete without error.

From the Roll Bump tab, select Calculate.

This will do all Geometry and Roll Bump calculations.

The status bar will display a message 'Calculating...' followed by either 'OK' or an error message.

On fast processors, the 'Calculating...' message may not remain long enough to be visible.

For suspension designs where the roll centre migrates far from the original static position, small amounts of roll can produce large amounts of chassis movement. Setting either the roll centre location to 'Fixed roll centre' or the chassis roll increment to zero (or very small value) will allow Roll and Bump to execute.

7.4 Results

From the Roll Bump tab, select Result.

This will display a window with all the calculated suspension values. See Geometry | Result above.

Because of the amount of data, it may be necessary to increase the width of the window to display all data without text wrapping.

```
SusProg3D SRD912.s3d Front Roll and bump

Chassis roll values calculated every 1.00degrees
SemiDynamic roll centre, horizontal roll axis. Roll starts at Static.

LH wheel      camber  caster  caster  kpi  scrub
steering      wheel   axle    toe     roll centre
              angle  angle  trail  angle  radius
offset  scrub  tramp  degree  offset  height  fvsax
 4.00 roll LH  2.35  5.37  24.97  9.47  69.88
74.20  -0.75  0.91  0.16  -215.90  74.37  1977.32
 3.00 roll LH  1.69  5.28  24.41  10.13  70.03
74.16  -0.44  0.67  0.17  -164.08  76.93  2183.26
 2.00 roll LH  0.99  5.18  23.85  10.83  70.19
74.13  -0.20  0.45  0.17  -110.41  78.84  2435.13
 1.00 roll LH  0.26  5.09  23.28  11.55  70.38
74.13  -0.05  0.22  0.17  -55.52  80.00  2753.80
 0.00 roll    -0.50  5.00  22.72  12.31  70.58
74.15  0.00  0.00  0.17  0.00  80.39  3173.76
 1.00 roll RH -1.30  4.91  22.14  13.11  70.81
74.20  -0.06  -0.22  0.17  55.52  80.00  3759.86
 2.00 roll RH -2.13  4.82  21.57  13.93  71.07
74.27  -0.25  -0.45  0.17  110.41  78.84  4647.52
 3.00 roll RH -2.99  4.72  20.99  14.80  71.35
74.38  -0.57  -0.69  0.17  164.08  76.93  6174.78
 4.00 roll RH -3.90  4.63  20.40  15.70  71.67
74.52  -1.05  -0.94  0.18  215.90  74.37  9488.26

RH wheel      camber  caster  caster  kpi  scrub
steering      wheel   axle    toe     roll centre
```

offset	scrub	angle tramp	angle degree	trail offset	angle height	radius fvsax
4.00	roll LH	-3.90	4.63	20.40	15.70	71.67
74.52	-1.05	-0.94	0.18	-215.90	74.37	9488.26
3.00	roll LH	-2.99	4.72	20.99	14.80	71.35
74.38	-0.57	-0.69	0.17	-164.08	76.93	6174.78
2.00	roll LH	-2.13	4.82	21.57	13.93	71.07
74.27	-0.25	-0.45	0.17	-110.41	78.84	4647.52
1.00	roll LH	-1.30	4.91	22.14	13.11	70.81
74.20	-0.06	-0.22	0.17	-55.52	80.00	3759.86
0.00	roll	-0.50	5.00	22.72	12.31	70.58
74.15	0.00	0.00	0.17	0.00	80.39	3173.76
1.00	roll RH	0.26	5.09	23.28	11.55	70.38
74.13	-0.05	0.22	0.17	55.52	80.00	2753.80
2.00	roll RH	0.99	5.18	23.85	10.83	70.19
74.13	-0.20	0.45	0.17	110.41	78.84	2435.13
3.00	roll RH	1.69	5.28	24.41	10.13	70.03
74.16	-0.44	0.67	0.17	164.08	76.93	2183.26
4.00	roll RH	2.35	5.37	24.97	9.47	69.88
74.20	-0.75	0.91	0.16	215.90	74.37	1977.32
LH and RH wheel steering	camber wheel	caster axle	caster toe	caster rc	kpi roll centre	scrub height
offset	scrub	angle tramp	angle degree	trail offset	angle chassis	radius ground
fvsax						
100.00	bump	-3.42	5.92	26.20	15.25	71.40
76.05	0.98	1.93	0.06	0.00	37.07	-62.93
1392.14						
80.00	bump	-2.65	5.72	25.52	14.48	71.16
75.60	2.42	1.47	0.12	0.00	44.23	-35.77
1586.75						
60.00	bump	-1.98	5.53	24.83	13.80	70.97
75.19	3.06	1.06	0.15	0.00	52.18	-7.82
1825.45						
40.00	bump	-1.40	5.35	24.14	13.22	70.81
74.81	2.88	0.69	0.17	0.00	60.88	20.88
2131.33						
20.00	bump	-0.91	5.17	23.44	12.72	70.68
74.47	1.87	0.35	0.17	0.00	70.29	50.29
2548.70						
Static		-0.50	5.00	22.72	12.31	70.58
74.15	0.00	0.00	0.17	0.00	80.39	80.39
3173.76						
20.00	droop	-0.18	4.82	21.97	11.99	70.51
73.86	-2.75	-0.35	0.17	0.00	91.21	111.21
4261.74						
40.00	droop	0.04	4.64	21.19	11.77	70.47
73.59	-6.41	-0.72	0.17	0.00	102.78	142.78
6782.67						
60.00	droop	0.16	4.46	20.38	11.65	70.45
73.34	-11.02	-1.12	0.19	0.00	115.17	175.17
20745.91						
80.00	droop	0.15	4.28	19.52	11.65	70.47
73.13	-16.62	-1.57	0.22	0.00	128.45	208.45
14004.66						
100.00	droop	-0.02	4.08	18.60	11.82	70.53
72.94	-23.25	-2.11	0.29	0.00	142.71	242.71
4421.39						

Equivalent suspension travel due to chassis roll

	LH	RH
4.00 roll LH	48.64	-49.02
3.00 roll LH	36.53	-36.75
2.00 roll LH	24.38	-24.48
1.00 roll LH	12.20	-12.23
0.00 roll	0.00	0.00
1.00 roll RH	-12.23	12.20
2.00 roll RH	-24.48	24.38
3.00 roll RH	-36.75	36.53
4.00 roll RH	-49.02	48.64

Side view swing axle and instant centre

	IC length	IC height	axle height	angle
100.00 bump	6690.81	100.56	34.36	0.86
80.00 bump	6783.57	116.62	39.30	0.98
60.00 bump	6831.69	128.60	43.03	1.08
40.00 bump	6837.05	136.85	45.76	1.15
20.00 bump	6801.34	141.61	47.60	1.19
Static	6737.00	143.12	48.56	1.22
20.00 droop	6624.98	141.39	48.79	1.22
40.00 droop	6470.56	136.37	48.18	1.21
60.00 droop	6263.04	127.73	46.62	1.17
80.00 droop	5983.25	114.80	43.86	1.10
100.00 droop	5607.96	96.41	39.30	0.98

LH

	brake a-dive%	accel a-lift%
100.00 bump	6.8	0.0
80.00 bump	7.7	0.0
60.00 bump	8.5	0.0
40.00 bump	9.0	0.0
20.00 bump	9.4	0.0
Static	9.6	0.0
20.00 droop	9.6	0.0
40.00 droop	9.5	0.0
60.00 droop	9.2	0.0
80.00 droop	8.6	0.0
100.00 droop	7.7	0.0

Trailing arm mount lateral compliance

	LH	RH
100.000 bump	-7.212	-7.212
80.000 bump	-4.117	-4.117
60.000 bump	-1.840	-1.840
40.000 bump	-0.373	-0.373
20.000 bump	0.292	0.292
Static	0.148	0.148
20.000 droop	-0.820	-0.820
40.000 droop	-2.628	-2.628
60.000 droop	-5.222	-5.222
80.000 droop	-8.835	-8.835
100.000 droop	-13.415	-13.415
4.00 roll LH	-0.977	-3.199
3.00 roll LH	-0.278	-2.001
2.00 roll LH	0.144	-0.995

1.00	roll LH	0.286	-0.279
0.00	roll	0.000	0.000
1.00	roll RH	-0.279	0.286
2.00	roll RH	-0.995	0.144
3.00	roll RH	-2.001	-0.278
4.00	roll RH	-3.199	-0.977
		Link error	
		(Compliance)	
50.000	bump	0.000	
40.000	bump	0.000	
30.000	bump	0.000	
20.000	bump	0.000	
10.000	bump	0.000	
	Static	0.000	
10.000	droop	0.000	
20.000	droop	0.000	
30.000	droop	0.000	
40.000	droop	0.000	
50.000	droop	0.000	
4.00	roll LH	0.005	
3.00	roll LH	0.001	
2.00	roll LH	0.004	
1.00	roll LH	0.005	
0.00	roll	0.000	
1.00	roll RH	0.005	
2.00	roll RH	0.003	
3.00	roll RH	0.001	
4.00	roll RH	0.005	

Scrub is the distance the wheel cl moves laterally from the static position.

Positive scrub is the distance the wheel cl moves outwards, and negative scrub is the distance the wheel cl moves inwards.

Tramp is the distance the wheel contact cl moves backward and forward from the static position.

Positive tramp is movement in the direction of the positive longitudinal axis, and negative tramp is movement in the direction of the negative longitudinal axis.

Sax is the swing axle length, measured from the wheel contact cl to the instantaneous centre of the suspension links. A negative swing axle length means that the swing axle instant centre is outboard of the wheel.

Roll centre offset is the horizontal distance of the roll centre from the vehicle cl.

Positive roll centre offset is in the direction of the positive horizontal axis, and negative roll centre offset is in the direction of the negative horizontal axis.

Roll centre height is the vertical distance of the roll centre above the ground line.

Negative roll centre height is the distance of the roll centre below the ground line. "Chassis" roll centre heights are the distances from the static ground line with the chassis stationary and the wheel moving up (bump) and down (droop). This is analogous to a vehicle wheel moving up and down with a (nominally) stationary chassis. "Ground" roll centre heights are the distances from the ground line with the chassis moving down (wheel bump) and up (wheel droop). This is analogous to a vehicle chassis moving up and down on a stationary ground plane, for example under braking. Roll centre heights for the roll positions are also "ground" heights.

Toe-in is the amount of toe-in (in either mm or inches) at each bump and roll position.

A positive value is toe-in, a negative amount is toe-out.

For A-arm and strut suspensions, the toe control pivots are not used and the wheel toe is held at the static setting. As part of the Steering calculations, the Roll&Bump data is recalculated. If, after doing the Steering calculation, the Roll&Bump is displayed (note! Do not recalculate) the toe variation will

be incorporated into the roll and bump data.

For all other suspension types, the toe control pivot points are specified and the wheel toe will vary accordingly.

Trailing arm mount lateral compliance

For a multi-link trailing arm suspension (for example, Honda Integra and the Kia Carnival) where there is an extra toe control link and the trailing arm chassis mount bush has lateral flexibility, then this data shows the amount the trailing arm mount moves laterally. A positive dimension is an outwards movement; a negative value is an inwards movement.

Link error (Compliance)

For a non-independent axle located with 4 longitudinal links and additional lateral location (eg a Panhard rod or a Watts linkage) then there will be a small error in one of the link lengths as the chassis rolls. This usually taken up by using a rubber bush in one of the links. This error is also referred to as "Geometric Quarrel" by Arthur Mallock.

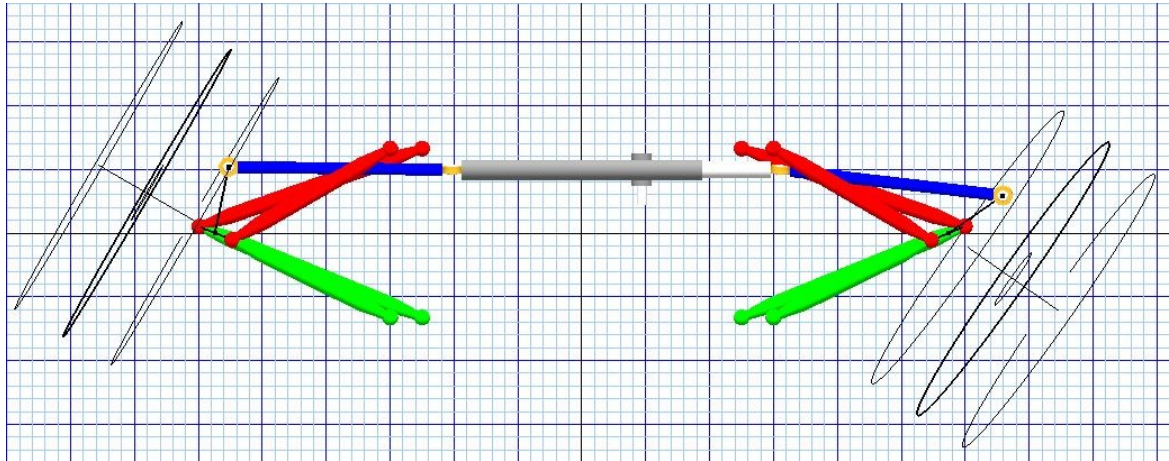
7.5 ECalc

Allows several modules to be calculated from one point.

For example, if the roll and bump increments are changed, you can recalculate all modules with one click.

See [ECalc](#)

8 Steering



Note that this module is equally applicable to the rear suspension for bump steer analysis, although the terminology is more appropriate for the front suspension.

The Ackermann and toe-out-in-turn calculations are not done for the rear suspension.

Also Roll&Bump | Calculate must successfully execute before this can be calculated.

8.1 Configure

From the Steering tab, select Configure.

For the front of the vehicle, there are a number of steering configuration options.

Steering type.	<p>For IFS, specify either 'Rack and pinion', 'Pitman arm, centre link, idler arm' or 'Pitman arm, intermediate rod, idler arm' or 'Pitman arm'.</p> <p>For Volkswagen trailing arm suspension, specify either 'Rack and pinion' or 'Pitman arm'.</p> <p>For live axle, specify either 'Lateral drag link' or 'Longitudinal drag link' or 'Rack and pinion (axle mounted)'</p>
C-factor	<p>For rack and pinion steering.</p> <p>This is the distance the rack moves for one complete turn (360 degrees) of the steering wheel, typically in the range 1-1/2" - 2" (38mm - 50mm).</p> <p>Together with the steering arms, this determines the steering ratio. For race cars this will range from 20:1 (slow) to less than 10:1 (very fast).</p> <p>Note that the steering ratio is fixed. Variable ratio racks are not supported.</p>
Steering box ratio	<p>For recirculating ball and drag link steering.</p> <p>This is the number of turns of the input shaft (the steering wheel) for one turn of the output shaft (the pitman arm).</p> <p>It is usually easier to measure the amount the pitman arm rotates (in degrees) for one turn of the input shaft. The the steering ratio is 360 / the pitman arm rotation degrees.</p> <p>Note that the steering ratio is fixed. Variable ration steering boxes are not supported. Ratios around 16:1 are typical.</p> <p>Note that this is not the overall steering ratio.</p>

Steering gearbox location.	Specify either left hand drive or right hand drive. Note that this is the location of the steering gearbox.
Steering arm and tie rod location.	Front steer has the steering arms projecting forward from the upright (or strut) and the steering tie rods are ahead of the front axle. Rear steer has the steering arms projecting rearward from the upright (or strut) and the steering tie rods are behind the front axle. This is specified by entering the appropriate longitudinal dimension for the steering arm balljoint. For a front live axle, this is the location of the steering tie rod(s).
Pitman arm rotation.	For both recirculating ball and lateral drag link configurations. Specify either opposed or synchronous. This is determined by the rotation of the pitman arm relative to the steering arm in plan view. For front live axle, the steering arm is the one to which the drag link connects. In an opposed configuration, the pitman arm rotates in the opposite direction to the steering arm. In a synchronous configuration, the pitman arm rotates in the same direction as the steering arm. For example, when turning left, the steering arm is rotated anti-clockwise (counter clockwise). If the pitman arm rotates clockwise, this is opposed. If the pitman arm rotates anti-clockwise (counter clockwise), then this is synchronous.
Tie rod connection	For the 'Pitman arm, intermediate rod, idler arm' configuration. In the 'Conventional' configuration, the tie rod connects the steering arm to the Pitman or idler arm on the same side of the vehicle. In the 'Crossed' configuration, the tie rod connects the steering arm to the Pitman or idler arm on the opposite side of the vehicle.
Pitman arm orientation	For longitudinal drag link configuration. In the straight ahead position, is the pitman arm 'upwards' or 'downwards'.
Rack and pinion configuration type.	Rack and pinion only. Specify the configuration type. Type 1 Tie rod joints connect to each end of the rack. The rack housing is central on the rack, and the pinion is at the left hand end of the housing (for left hand drive) or the right hand end of the housing (for right hand drive). The usual passenger and sports car configuration. Type 2 Tie rod joints connect to each end of the rack. The rack housing is central on the rack, and the pinion is in the centre of the housing. The typical "single-seater" configuration and some Porsche's. Type 3 The tie rod joints are close together in the centre of the rack, with the housing extending outwards in both directions. The pinion is at the left hand end of the housing (for left hand drive) or the right hand end of the housing (for right hand drive). Often used in conjunction with struts and high mounted steering arms.

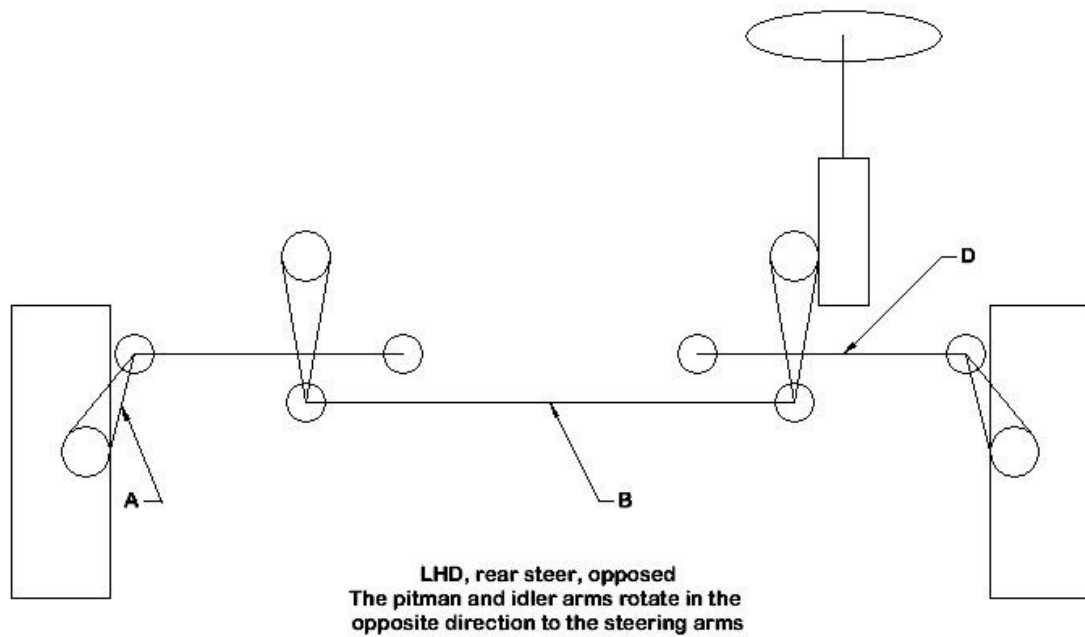
Type 4 The tie rod joints are close together, connecting to one end of the rack. The housing and pinion extend to either the left (for left hand drive) or the right (for right hand drive). Preferred by Audi and VW.

This is only used to draw a representative steering rack. It has no effect on the steering calculations.

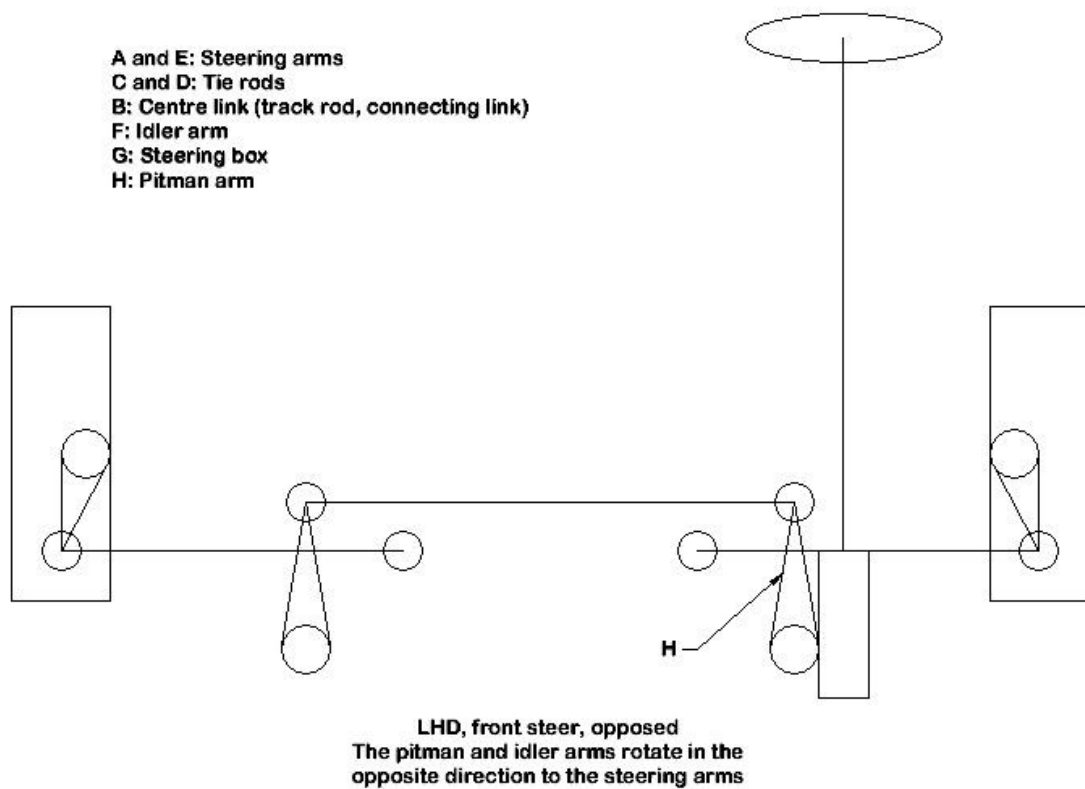
In all cases, the required dimensions are those for the centre of the tie rod ball joint where it attaches to the steering rack.

For the rear of the vehicle, the options are determined by the basic geometry configuration.

Geometry type	Toe link configuration
Double A-arm	Specify either a chassis mounted toe link, or an A-arm mounted toe link.
Strut (with a single lower A-arm)	In both cases the other end of the toe link attaches to the upright or strut. The upright or strut mounting point will be specified as part of the upright or strut. For the chassis mounted toe link, the chassis point will be specified as part of the chassis, and for the A-arm mounted toe link, the A-arm mounting point will be specified as part of the A-arm
All other geometry	The toe link will be either; a toe link, one end attached to the chassis, the other to the upright or strut, or combined with one of the suspension members. In either case, the chassis point will be specified as part of the chassis.



A and E: Steering arms
C and D: Tie rods
B: Centre link (track rod, connecting link)
F: Idler arm
G: Steering box
H: Pitman arm



8.2 Car end and car side

The [Front] or [Rear] tab choice will indicate the currently selected vehicle end.

The [LH] or [RH] tab choice will indicate the currently selected vehicle side.

These tabs acts as a toggle, and selecting this tab will switch between each of two.

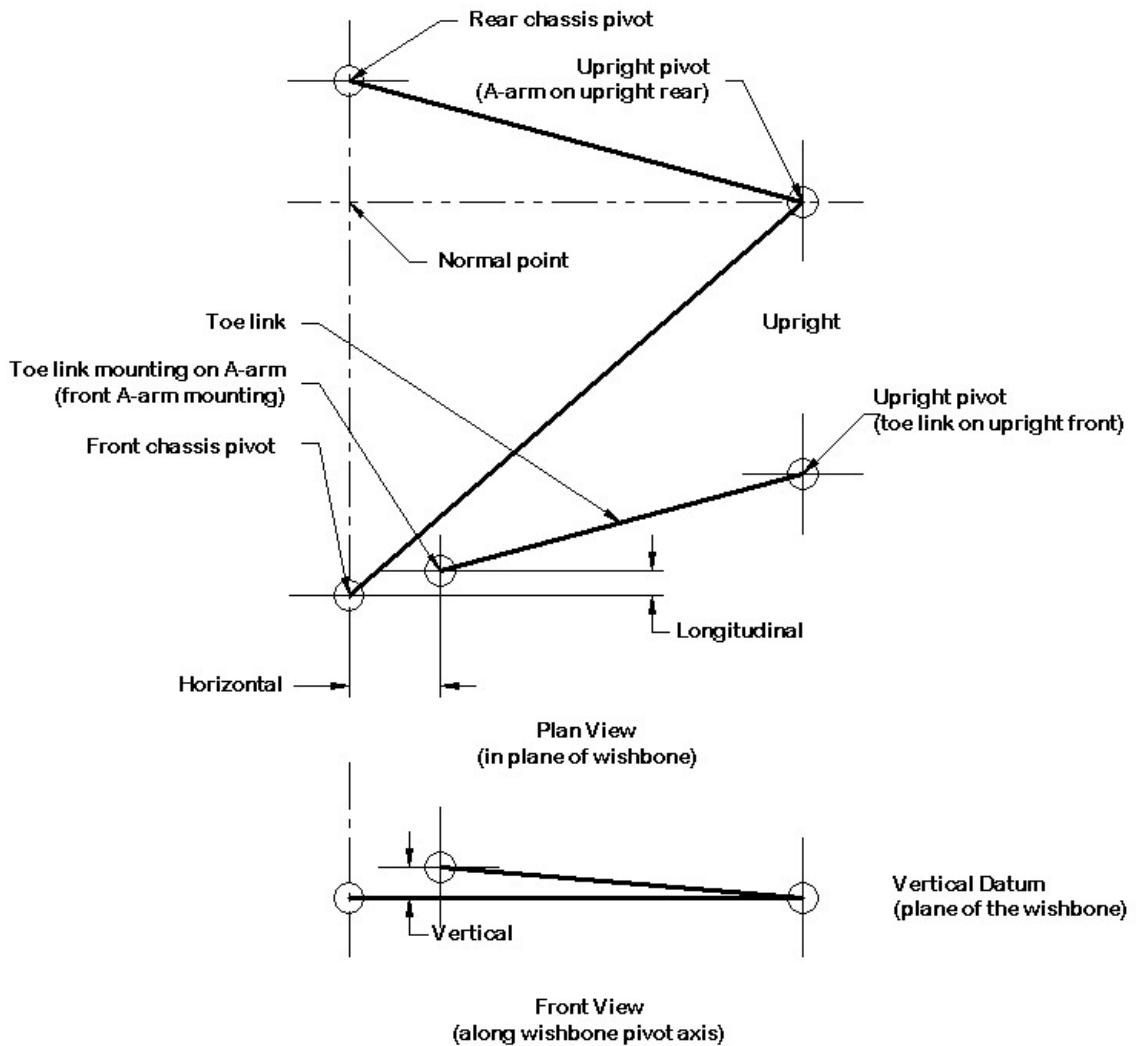
Depending on the vehicle configuration, some menu bar items may not be available.

When a dialog box is opened, the title will include the currently selected car end and car side. If the car side is not shown, then the dialog box applies to both sides. If the car end is not shown, then the dialog box applies to both ends.

8.3 A-arm (toe control link pickup point).

From the Steering tab, select A-arm.

Enter the values for the toe link ball joint pickup point.



In the above diagram, the toe link is referenced the front A-arm chassis pivot.

The horizontal dimension is positive, because the attaching point is outboard from the A-arm chassis pivot axis.

The vertical dimension will be positive (if the vertical axis is positive upwards), because the attaching point is above the plane of the A-arm.

The longitudinal dimension will be positive (if the longitudinal axis is positive in the rearward direction), because the attaching point is rearward from the A-arm front chassis mounting point.

A-arm mounting points:

Note that horizontal values are horizontal measurements from the A-arm chassis pivot axis, vertical

values are vertical measurements from the A-arm plane, and longitudinal values are horizontal measurements from the chosen A-arm chassis pivot.

Specify the A-arm (either upper or lower) and the A-arm chassis pivot point that the toe link mounting point is referenced from (either front or rear).

The plane of the A-arm is defined by the three A-arm points: the two chassis mounting points and the upright mounting point.

The A-arm is considered to be rigid and the appropriate A-arm link is restrained from any radial movement. To minimise any rotational tendencies, the A-arm mounting should be positioned so that the centre line of the toe link pivot is coincident with the appropriate A-arm chassis mounting pivot.

8.4 Rack location (toe control link chassis pickup point)

From the Steering tab, select Rack Location or Chassis.

Enter the values for the rack ball joint pickup point.

This is the same dialog box as the initial chassis design.

Chassis mounting points:

Note that horizontal values are horizontal measurements from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

If you specify the upright steering arm ball joint and want to calculate the rack location to minimise the amount of bump steer, skip this menu choice and see [Calculate the optimum rack position](#).

8.5 Steering gear (centre link)

From the Steering tab, select Steering Gear.

The various components of a recirculating ball steering mechanism with centre link are specified here.



Typical LHD recirculating ball steering gear.

This is the LH side with Pitman arm [1] and centre link [2].
The tie rod [4] connects the the centre link to the steering arm.
The steering configuration is LHD, front steer, opposed rotation.

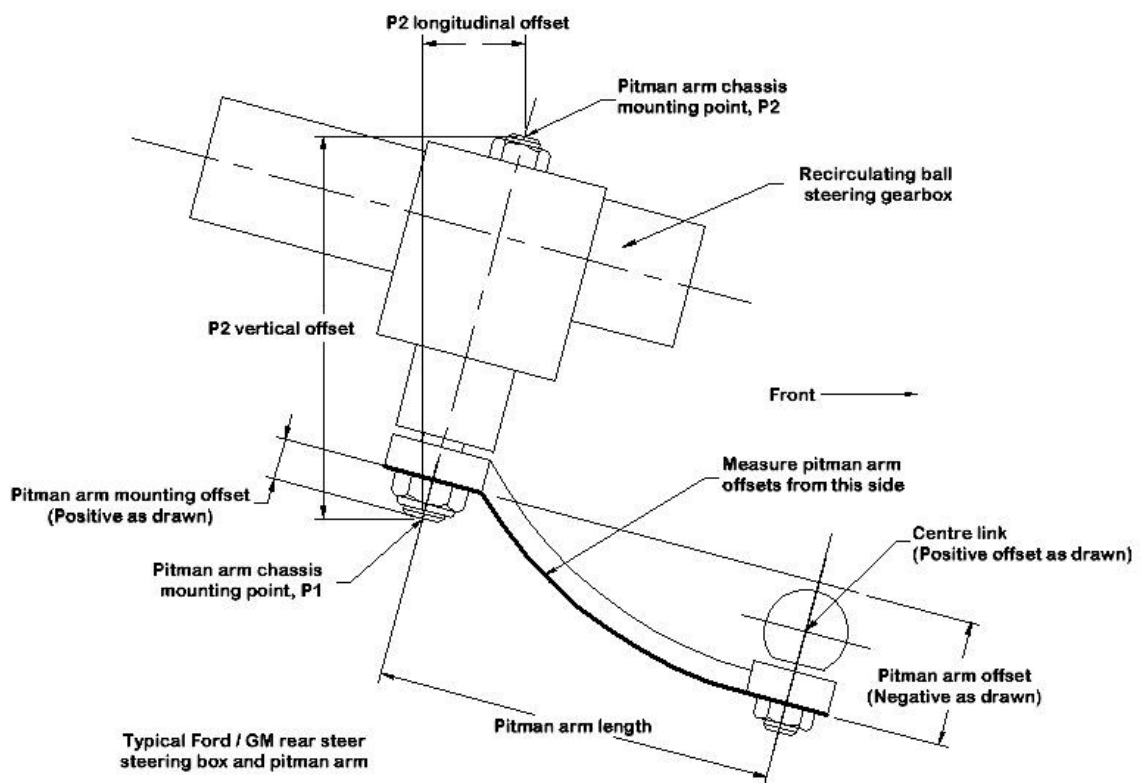
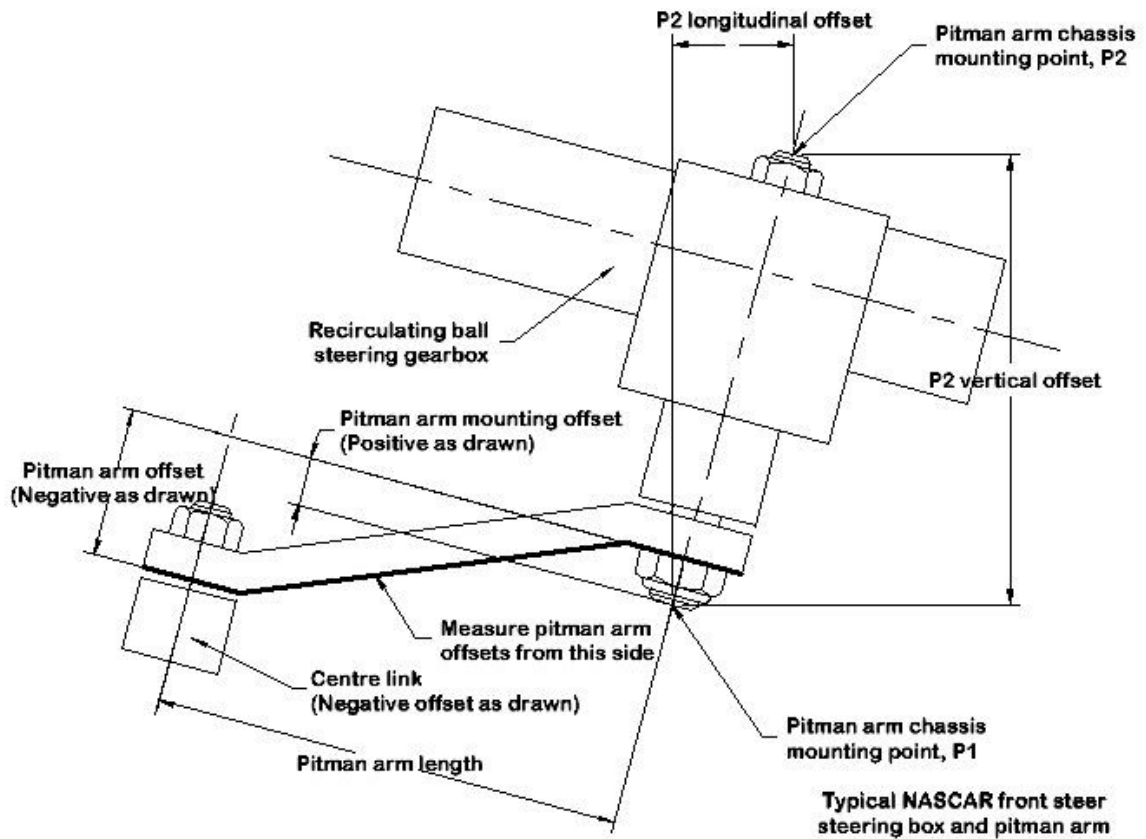


Typical LHD recirculating ball steering gear.
This is the RH side with centre link [2] and idler arm [3].
The tie rod [4] connects the the centre link to the steering arm.
The steering configuration is LHD, front steer, opposed rotation.

8.5.1 Pitman arm (centre link)

Enter the values for the pitman arm chassis mounting points, P1 and P2. These are two points on the steering gearbox sector shaft and define the pitman arm rotation axis. P1 is the primary location point (close to the pitman arm) and P2 is the secondary location point (on the top of the steering box).

Enter the length and offsets of the pitman arm.



Chassis mounting point P1:

Note that horizontal values are horizontal measurements from the chassis centreline, vertical values

are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

Chassis mounting point P2:

Note that these dimensions are relative to P1, and will be positive or negative in accordance with the specified axis system. They are measured in the chassis datum position, and P2 is always above P1.

Usually the P2 horizontal dimension will be zero, unless the steering gear is not mounted vertically (in front view). If P2 is outboard of P1 then the P2 horizontal dimension will be positive; if P2 is inboard of P1 then the P2 horizontal dimension will be negative.

If the vertical axis is positive upwards, then the P2 vertical dimension will be positive, otherwise the P2 vertical dimension will be negative. Note that this is a vertical dimension (relative to the vertical datum) and not the axial distance between P1 and P2.

Usually P2 will be "ahead" of P1, as this angles the steering box so that the worm shaft is aligned with the steering wheel shaft. If P2 is ahead of P1, and the longitudinal axis is "positive forward" then the P2 longitudinal dimension will be positive; if the longitudinal axis is "positive rearward" then the P2 longitudinal dimension will be negative.

Pitman arm length:

This is always positive.

Pitman arm datum surface:

This is the retaining nut contact surface of the pitman arm mounting boss on the steering gear shaft.

Pitman arm mounting offset:

This is measured axially from P1 to the pitman arm datum surface. If the pitman arm datum surface is offset towards P2 (the usual case) then this dimension will be positive.

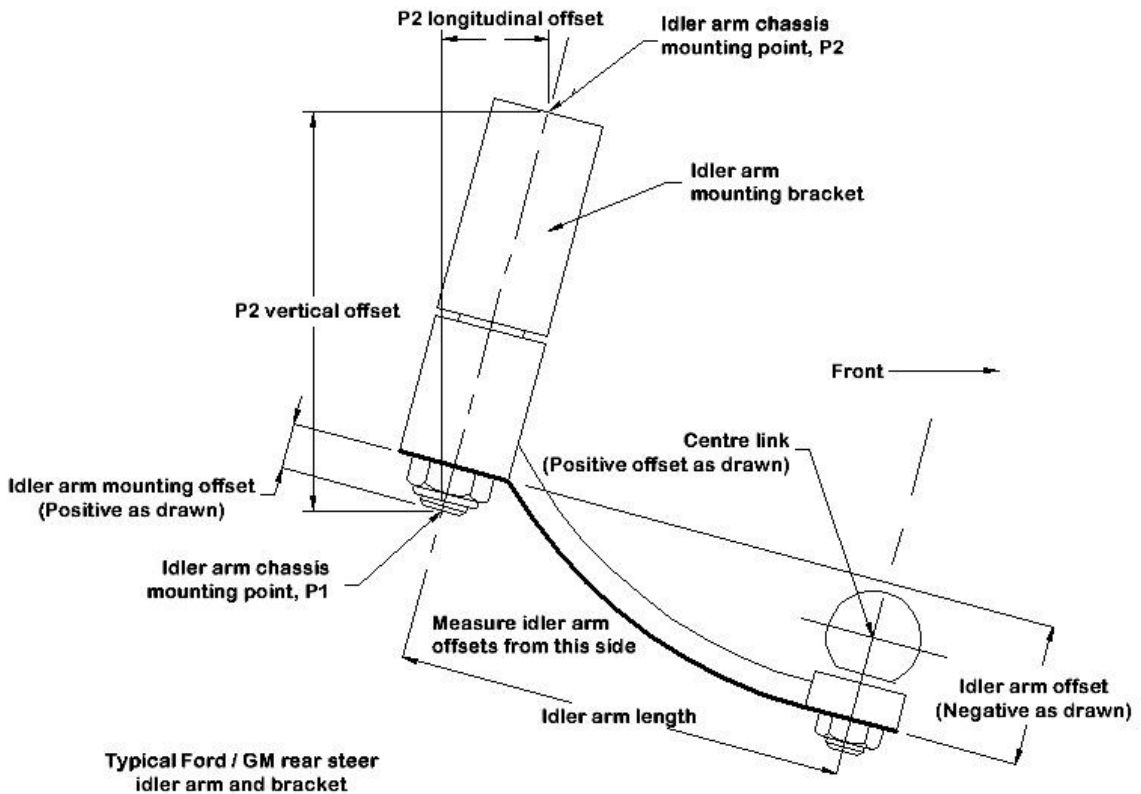
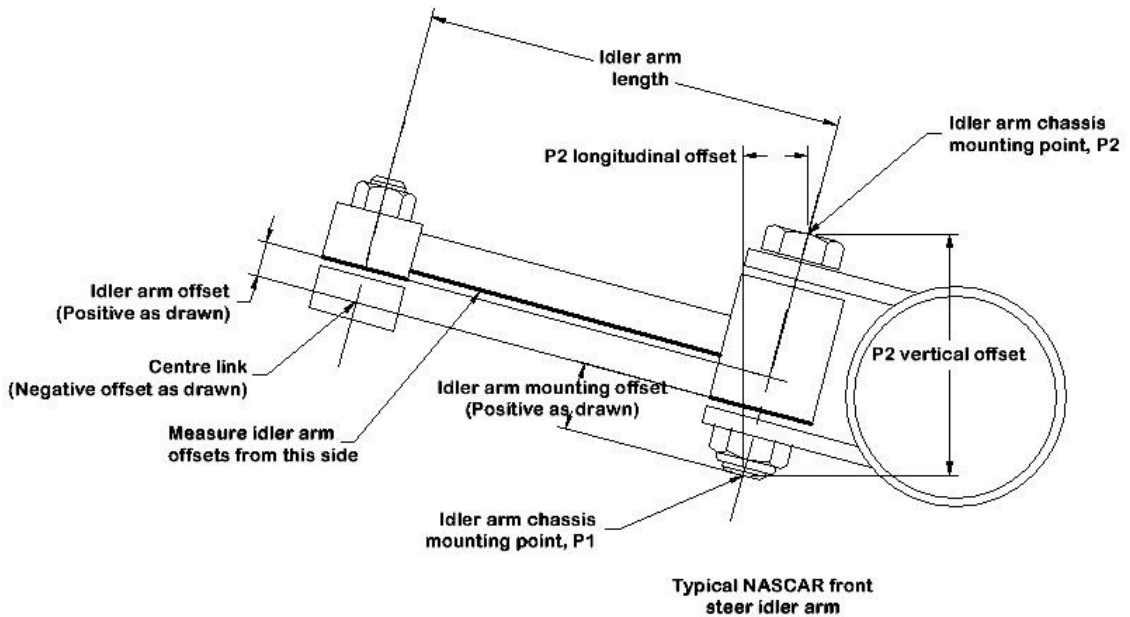
Pitman arm offset:

This is measured axially on the pitman arm datum surface, from the sector shaft mounting surface to the centre link mounting. If the pitman arm is cranked downwards (away from P2, the usual case) then this dimension will be negative.

8.5.2 Idler arm (centre link)

Enter the values for the idler arm chassis mounting points, P1 and P2. These are two points on the idler arm pivot shaft and define the idler arm rotation axis. P1 is the primary location point (usually on the underside of the idler arm) and P2 is the secondary location point (usually on the topside of the idler arm).

Enter the length and offsets of the idler arm.



Chassis mounting point P1:

Note that horizontal values are horizontal measurements from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

Chassis mounting point P2:

Note that these dimensions are relative to P1, and will be positive or negative in accordance with the specified axis system. They are measured in the chassis datum position, and P2 is always above P1.

Usually the P2 horizontal dimension will be zero, unless the steering gear is not mounted vertically

(in front view). If P2 is outboard of P1 then the P2 horizontal dimension will be positive; if P2 is inboard of P1 then the P2 horizontal dimension will be negative.

If the vertical axis is positive upwards, then the P2 vertical dimension will be positive, otherwise the P2 vertical dimension will be negative. Note that this is a vertical dimension (relative to the vertical datum) and not the axial distance between P1 and P2.

Usually P2 will be "ahead" of P1, so that the idler arm pivot axis is parallel to the steering gear sector shaft in side view. If P2 is ahead of P1, and the longitudinal axis is "positive forward" then the P2 longitudinal dimension will be positive; if the longitudinal axis is "positive rearward" then the P2 longitudinal dimension will be negative.

Idler arm length:

This is always positive.

Idler arm datum surface:

This is the face of the idler arm closest to the mounting point P1.

Idler arm mounting offset:

This is measured axially from P1 to the idler arm datum surface. If the idler arm datum surface is offset towards P2 (the usual case) then this dimension will be positive.

Idler arm offset:

This is measured axially on the idler arm datum surface, from the chassis pivot shaft mounting surface to the centre link mounting surface. If the idler arm is cranked downwards (away from P2, the usual case) then this dimension will be negative.

Idler arm mounting error:

After calculating, the idler arm mounting error will be shown in results data.

This is the amount that the idler mounting point P2 is out of parallel in side and front view.

Typically both idler and pitman arms rotation axis are parallel. Add the offset error to the idler arm chassis pivot P2 point if required.

8.5.3 Centre link

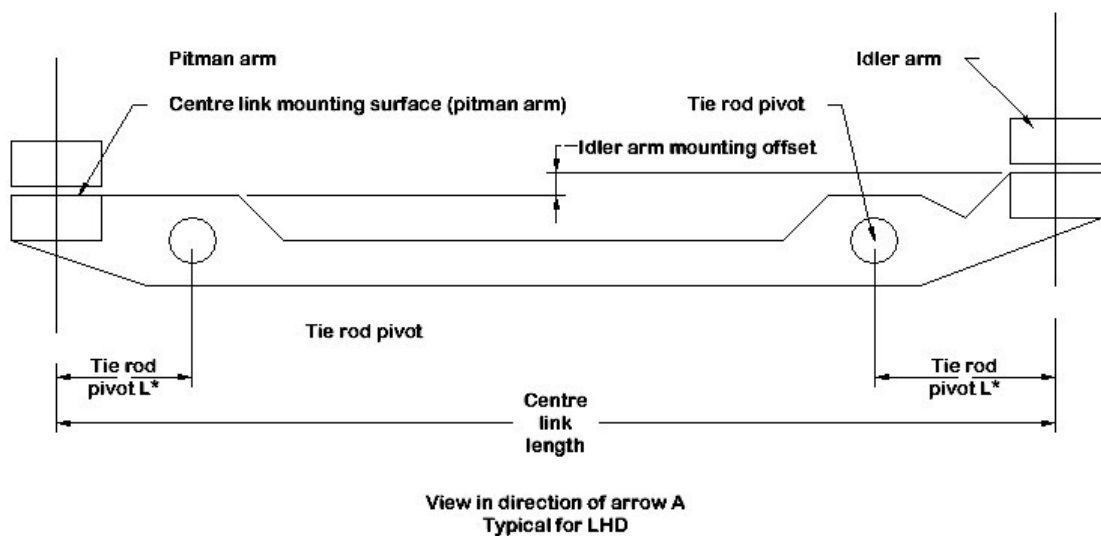
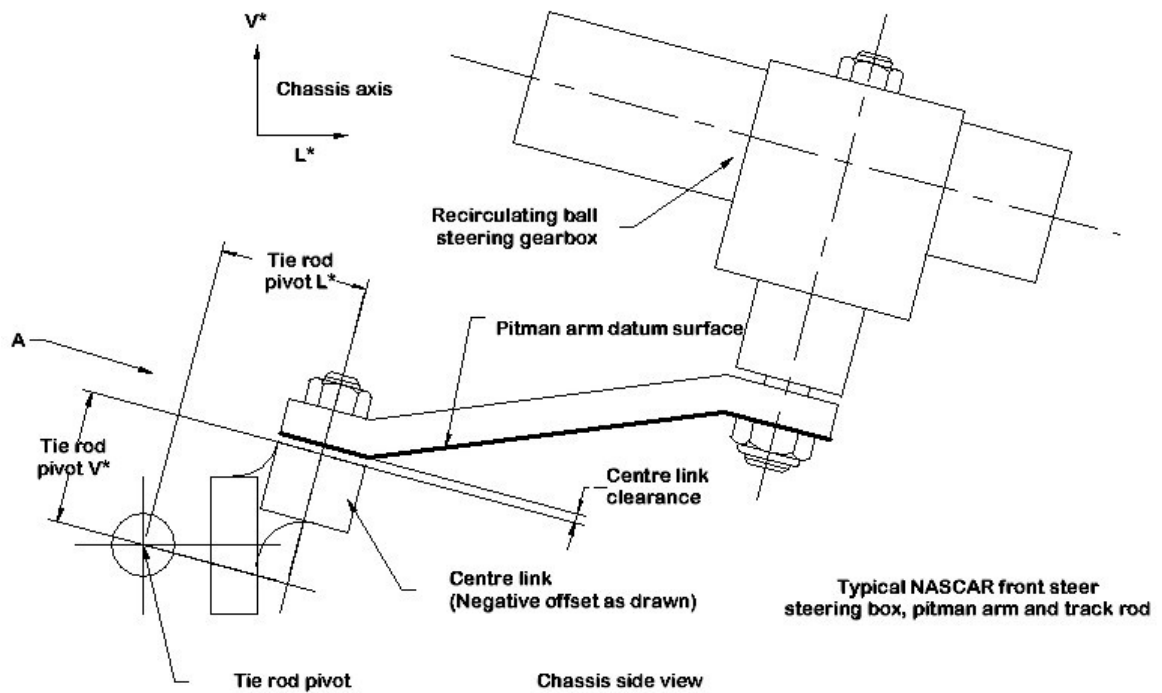
Enter the values for the tie rod pivot points on the centre link. The centre link is also known as "track rod" or "connecting link".

Enter the values for the centre link to pitman and idler arm clearances.

Specify if the centre link is mounted outside or inside the pitman / idler arm.

Enter the value for the centre link length (Pitman arm pivot to idler arm pivot)

Specify where the tie rods are relative to the centre link. The tie rods will be either in front, behind, above or below the centre link.



Centre link mounting surfaces:

These are the faces of the centre link adjacent to the pitman and idler arm. The pitman arm end is the primary centre link mounting surface. The idler arm end is the secondary centre link mounting surface.

Tie rod pivots:

These can be specified as offsets from the centre link pitman and idler arm pivots, or as chassis datum coordinates.

Centre link offsets.

Note that these dimensions are offsets relative to the centre link mounting faces and the pitman / idler arm pivots, and will be positive or negative in accordance with the specified axis system

Usually the tie rod pivots are inboard of the pitman / idler arm pivots. If the tie rod pivot is inboard of the pitman / idler arm pivot then horizontal dimension will be negative.

If the tie rod pivot is "above" the plane of the centre link mounting surface, and if the vertical axis is positive upwards, then the vertical dimension will be positive, otherwise the vertical dimension will be negative.

If the tie rod pivot is "behind" the pitman / idler arm pivot, and if the longitudinal axis is positive rearwards, then the longitudinal dimension will be positive, otherwise the longitudinal dimension will be negative.

Chassis datum coordinates.

Note that these dimensions are relative to the chassis datums, and will be positive or negative in accordance with the specified axis system.

Specify where the tie rods mount to centre link. Specify front, rear, above or below.

Specify the input dimensions as either "Centre link offsets" or "Chassis datum". When the calculation is done, the other dimensions will be calculated.

If you specify the steering calculation as [Fixed] or [Upright] then the tie rod pivot dimensions must be input. If you specify the steering calculation as [Chassis] then the tie rod pivot dimensions cannot be input, and will be calculated to minimise the amount of bump steer. See [Calculate the optimum rack position](#).

Centre link length:

This is always positive. It is the distance between the pitman and idler arm pivot points.

Centre link mounting clearance:

These clearances are always positive. They are the gap between the centre link mounting surface and the pitman / idler arm datum surfaces. In some production cars, this clearance is virtually zero and restrains the centre link radially.

Centre link idler arm mounting offset:

After calculating, the centre link idler arm mounting offset will be shown in results data. This is the amount that the idler mounting datum surface is out of the plane of the pitman mounting datum surface. In most cases, it is desired that both idler and pitman arms rotation axis are in the same plane. Adjust the idler arm offsets if required.

8.5.4 Alignment (centre link)

The direction of the Pitman and idler arms (either forward or rearward facing) will be determined by the direction of the steering arms, and whether the Pitman arm rotation is opposed or synchronous.

Pitman arm alignment.

This is defined as the horizontal offset of the centre link end of the Pitman arm from a position parallel to the vehicle centreline (in plan view).

If the Pitman arm is parallel to the vehicle centreline (in plan view) then this offset will be zero.

If the Pitman arm is angled outwards from the vehicle centreline (in plan view) then this offset will be positive.

If the Pitman arm is angled inwards from the vehicle centreline (in plan view) then this offset will be negative.

Generally, if the centre link length is the same as the Pitman arm pivot to idler arm pivot length, then both Pitman arm and idler arm will be parallel to the vehicle centreline (the offset will be zero); if the centre link length is less than the Pitman arm pivot to idler arm pivot length, then both Pitman arm and idler arm will incline inwards (the offset will be negative); and if the centre link length is greater than the Pitman arm pivot to idler arm pivot length, then both Pitman arm and idler arm will incline outwards (the offset will be positive).

The idler arm will be positioned according to the length of the centre link, and the idler arm offset will be calculated.

The idler arm offset is defined as the horizontal offset of the centre link end from a position parallel to the vehicle centreline (in plan view).

If the idler arm is parallel to the vehicle centreline (in plan view) then this offset will be zero.

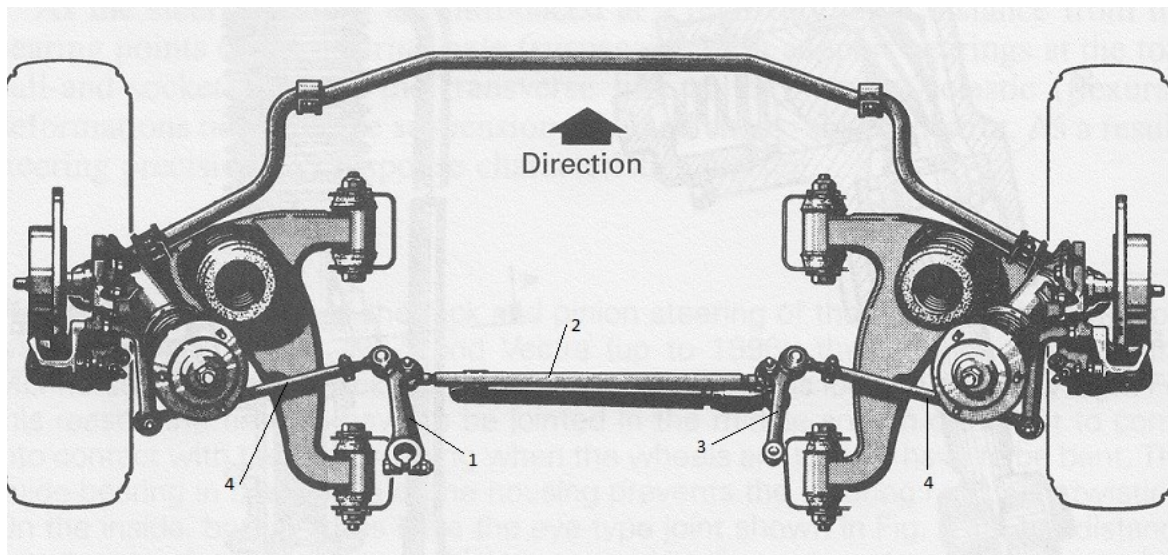
If the idler arm is angled outwards from the vehicle centreline (in plan view) then this offset will be positive.

If the idler arm is angled inwards from the vehicle centreline (in plan view) then this offset will be negative.

8.6 Steering gear (intermediate rod)

From the Steering tab, select Steering Gear.

The various components of a recirculating ball steering mechanism with intermediate rod are specified here.

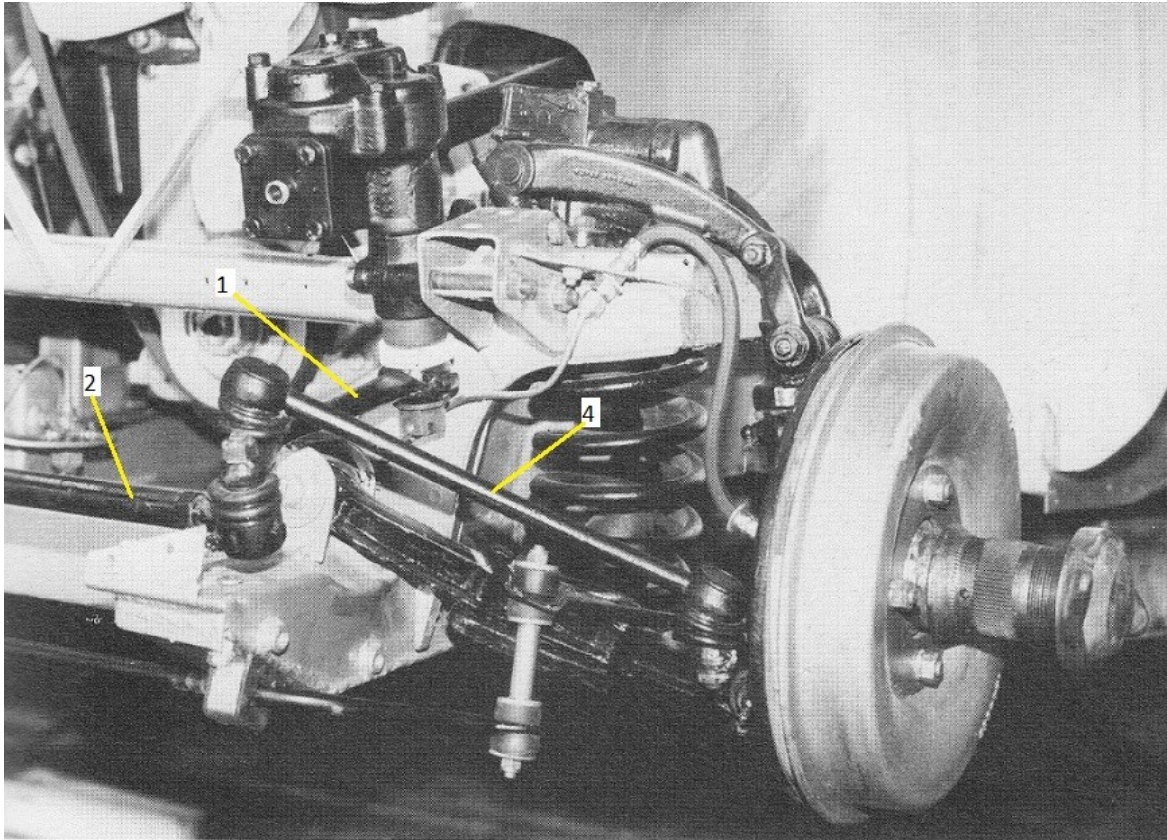


Typical LHD recirculating ball steering gear with Pitman arm [1], intermediate rod [2], and idler arm [3].

The tie rods [4] connect the the Pitman and idler arms to the steering arms.

The tie rod ball joints are on the top of the Pitman and idler arms; the intermediate rod ball joints are below the Pitman and idler arms.

The steering configuration is LHD, rear steer, opposed rotation.



Austin-Healy BN1/BN2 front suspension.

LHD recirculating ball steering gear with Pitman arm [1] and intermediate rod [2].

The tie rod [4] connects the the Pitman arm to the steering arm.

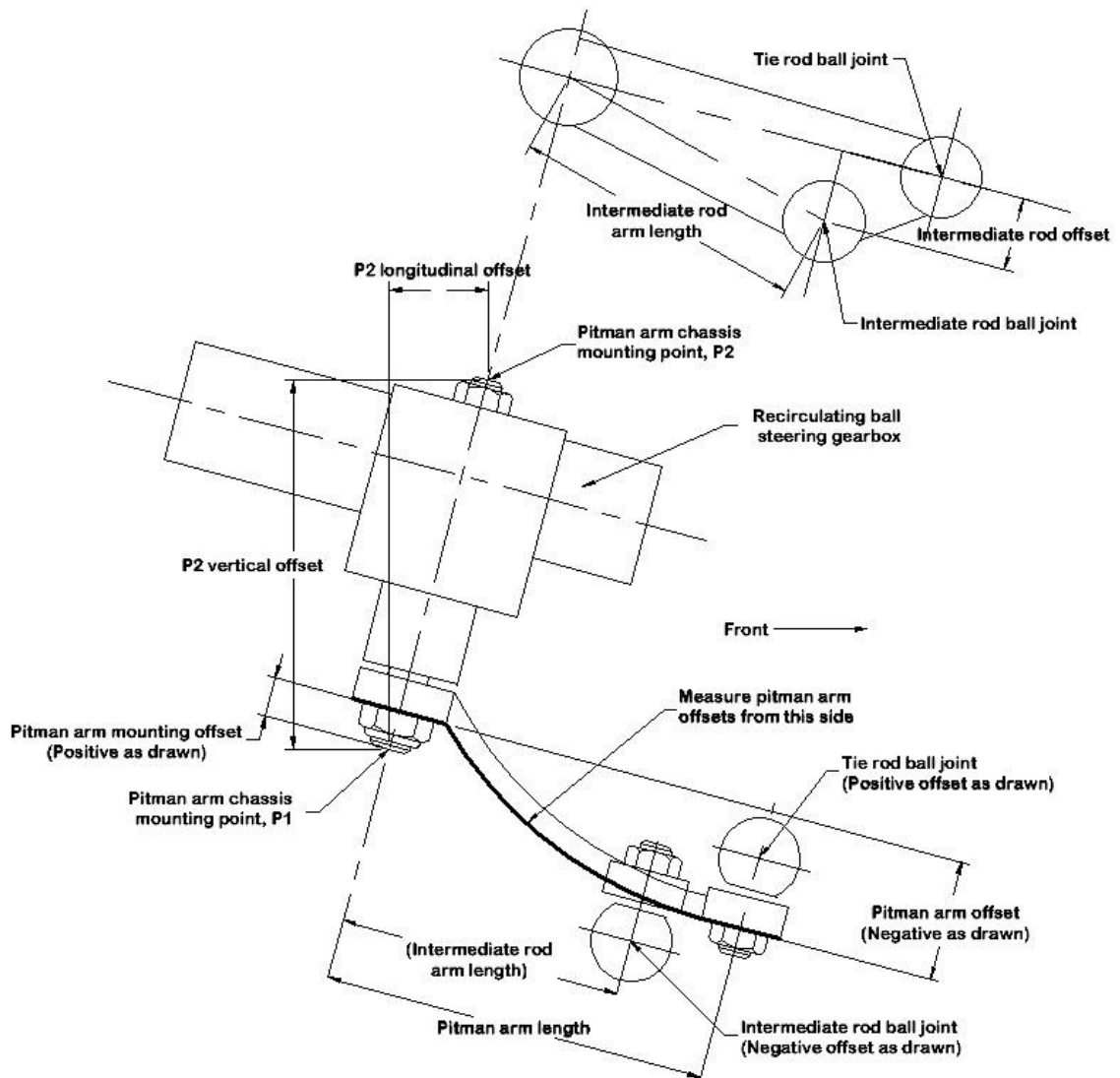
The tie rod ball joints are on the top of the Pitman arm; the intermediate rod ball joints are below the Pitman arm.

The steering configuration is LHD, front steer, synchronous rotation.

8.6.1 Pitman arm (intermediate rod)

Enter the values for the pitman arm chassis mounting points, P1 and P2. These are two points on the steering gearbox sector shaft and define the pitman arm rotation axis. P1 is the primary location point (close to the pitman arm) and P2 is the secondary location point (on the top of the steering box).

Enter the length and offsets of the pitman arm.



Steering box and pitman arm

Chassis mounting point P1:

Note that horizontal values are horizontal measurements from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

Chassis mounting point P2:

Note that these dimensions are relative to P1, and will be positive or negative in accordance with the specified axis system. They are measured in the chassis datum position, and P2 is always above P1.

Usually the P2 horizontal dimension will be zero, unless the steering gear is not mounted vertically (in front view). If P2 is outboard of P1 then the P2 horizontal dimension will be positive; if P2 is inboard of P1 then the P2 horizontal dimension will be negative.

If the vertical axis is positive upwards, then the P2 vertical dimension will be positive, otherwise the P2 vertical dimension will be negative. Note that this is a vertical dimension (relative to the vertical datum) and not the axial distance between P1 and P2.

Usually P2 will be "ahead" of P1, as this angles the steering box so that the worm shaft is aligned with the steering wheel shaft. If P2 is ahead of P1, and the longitudinal axis is "positive forward" then the P2 longitudinal dimension will be positive; if the longitudinal axis is "positive rearward" then the P2 longitudinal dimension will be negative.

There are two ball joints on the Pitman arm, the tie rod ball joint and the intermediate rod ball joint.

Pitman arm tie rod ball joint dimensions:

Arm datum surface:	This is the retaining nut contact surface of the pitman arm mounting boss on the steering gear shaft.
Arm length:	This is always positive.
Arm mounting offset:	This is measured axially from P1 to the pitman arm datum surface. If the pitman arm datum surface is offset towards P2 (the usual case) then this dimension will be positive.
Arm offset:	This is measured axially on the pitman arm datum surface, from the sector shaft mounting surface to the tie rod mounting surface. If the pitman arm is cranked downwards (away from P2, the usual case) then this dimension will be negative.
Ball joint offset:	This is measured axially from the pitman arm datum surface to the centre of the tie rod ball joint. If the ball joint is offset towards P2 then this dimension will be positive.

Pitman arm intermediate rod ball joint dimensions:

Arm datum surface:	This is the retaining nut contact surface of the pitman arm mounting boss on the steering gear shaft.
Arm length:	This is always positive.
Arm mounting offset:	This is measured axially from P1 to the pitman arm datum surface. If the pitman arm datum surface is offset towards P2 (the usual case) then this dimension will be positive.
Arm offset:	This is measured axially on the pitman arm datum surface, from the sector shaft mounting surface to the intermediate rod mounting surface. If the pitman arm is cranked downwards (away from P2, the usual case) then this dimension will be negative.
Ball joint offset:	This is measured axially from the pitman arm datum surface to the centre of the tie rod ball joint. If the ball joint is offset towards P2 then this dimension will be positive.
Intermediate rod offset:	This is the offset of the intermediate rod ball joint from the line of the Pitman arm axis and the tie rod ball joint in plan view. If the intermediate rod ball joint is closer to the vehicle centreline than the tie rod ball joint, this dimension is negative; if the intermediate rod ball joint is further from to the vehicle centreline than the tie rod ball joint, this dimension is positive.

8.6.2 Idler arm (intermediate rod)

The idler arm is dimensioned in the same way as the Pitman arm.

Because most vehicles with this type of steering are symmetrical, tick the "Idler arm symmetric with Pitman arm" box and the Pitman arm mounting points and dimensions will be copied when the "Apply" or "OK" button is clicked.

Even if the layout is not symmetrical, it may still be easier to tick the "Idler arm symmetric with Pitman arm" then "Apply" to copy the dimensions across. Then untick the "Idler arm symmetric with Pitman arm" and change the dimensions.

8.6.3 Intermediate rod

Enter the length of the intermediate rod.

If the steering is [Chassis] then the tie rod end positions will be calculated, the steering arms positioned accordingly, and the length of the intermediate rod calculated.

8.6.4 Alignment (intermediate rod)

The direction of the Pitman and idler arms (either forward or rearward facing) will be determined by the direction the of the steering arms, and whether the Pitman arm rotation is opposed or synchronous.

Pitman arm alignment.

This is defined as the horizontal offset of the tie rod end of the Pitman arm from a position parallel to the vehicle centreline (in plan view).

If the Pitman arm is parallel to the vehicle centreline (in plan view) then this offset will be zero.

If the Pitman arm is angled outwards from the vehicle centreline (in plan view) then this offset will be positive.

If the Pitman arm is angled inwards from the vehicle centreline (in plan view) then this offset will be negative.

Idler arm alignment.

The idler arm offset is defined as the horizontal offset of the tie rod end from a position parallel to the vehicle centreline (in plan view).

If the idler arm is parallel to the vehicle centreline (in plan view) then this offset will be zero.

If the idler arm is angled outwards from the vehicle centreline (in plan view) then this offset will be positive.

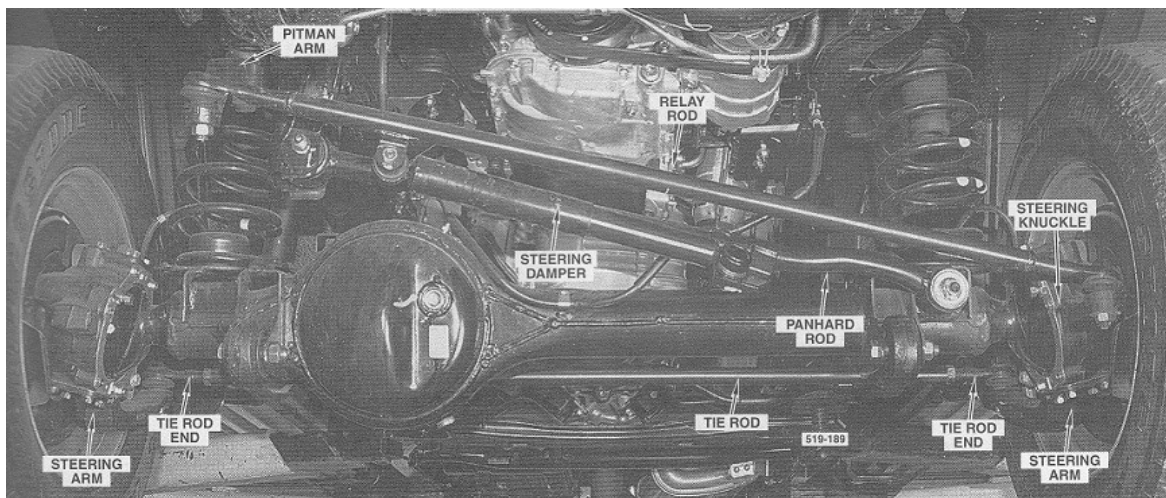
If the idler arm is angled inwards from the vehicle centreline (in plan view) then this offset will be negative.

8.7 Steering gear (drag link)

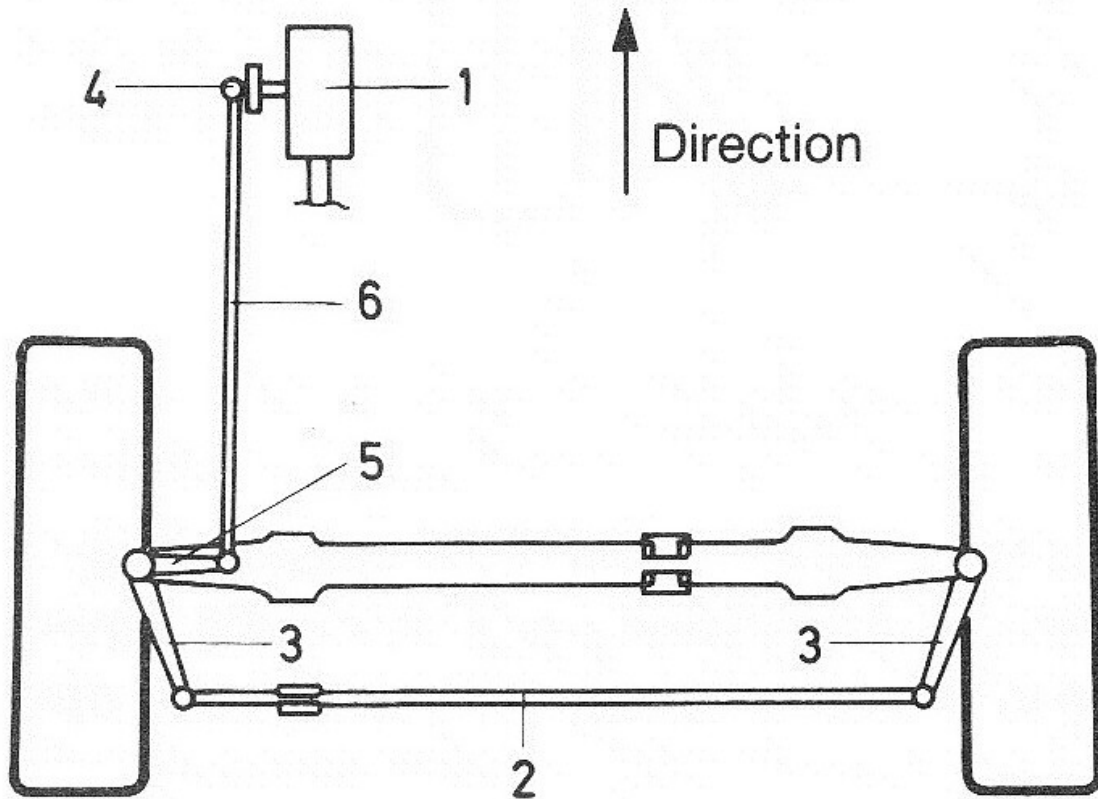
From the Steering tab, select Steering Gear.

The various components of a recirculating ball and drag link steering mechanism are specified here.

There are two configurations for the drag link steering: lateral drag link and longitudinal drag link.



Typical RHD recirculating ball steering gear with Pitman arm and lateral drag link (aka relay rod)
 The tie rod connects the steering arms.
 The steering configuration is lateral drag link, RHD, rear steer, synchronous rotation.

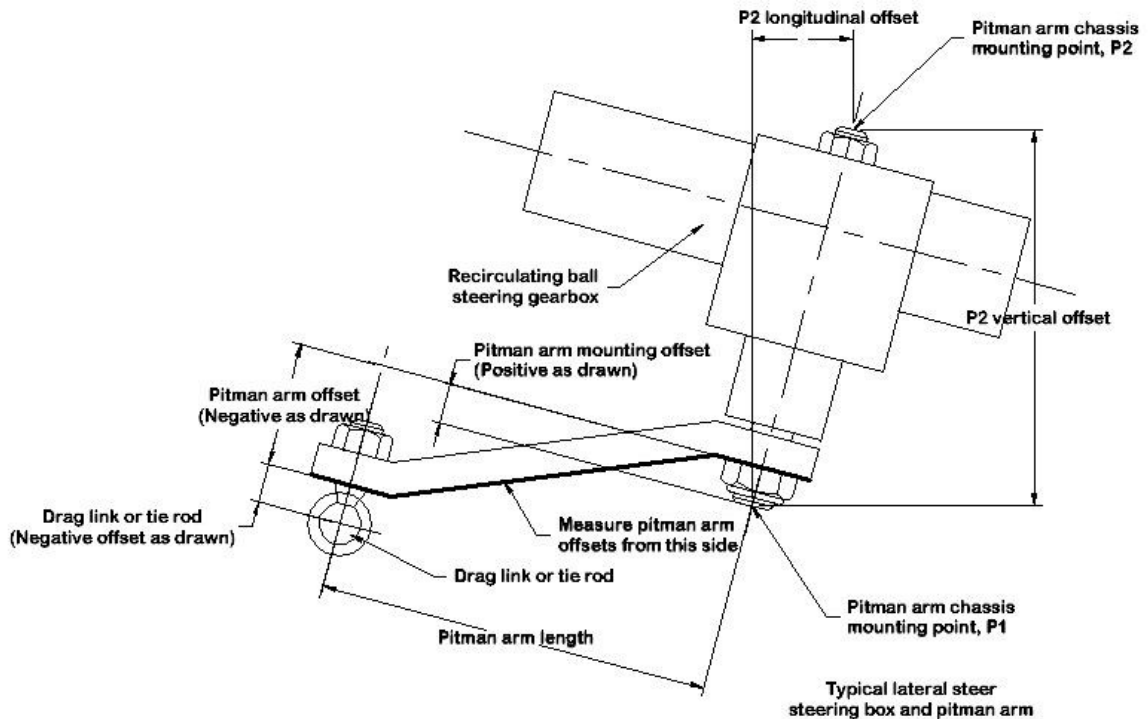


Typical LHD recirculating ball steering gear with Pitman arm [4] and longitudinal drag link [6]
 The tie rod [2] connects the steering arms [3].
 The steering configuration is longitudinal drag link, LHD, rear steer.

8.7.1 Pitman arm (lateral drag link)

Enter the values for the pitman arm chassis mounting points, P1 and P2. These are two points on the steering gearbox sector shaft and define the pitman arm rotation axis. P1 is the primary location point (close to the pitman arm) and P2 is the secondary location point (on the top of the steering box).

Enter the length and offsets of the pitman arm.



Chassis mounting point P1:

Note that horizontal values are horizontal measurements from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

Chassis mounting point P2:

Note that these dimensions are relative to P1, and will be positive or negative in accordance with the specified axis system. They are measured in the chassis datum position.

If the vertical axis is positive upwards, then the P2 vertical dimension will be positive, otherwise the P2 vertical dimension will be negative. Note that this is a vertical dimension (relative to the vertical datum) and not the axial distance between P1 and P2.

Pitman arm length:

This is always positive.

Pitman arm datum surface:

This is the retaining nut contact surface of the pitman arm mounting boss on the steering gear shaft.

Pitman arm mounting offset:

This is measured axially from P1 to the pitman arm datum surface. If the pitman arm datum surface is offset towards P2 (the usual case) then this dimension will be positive.

Pitman arm offset:

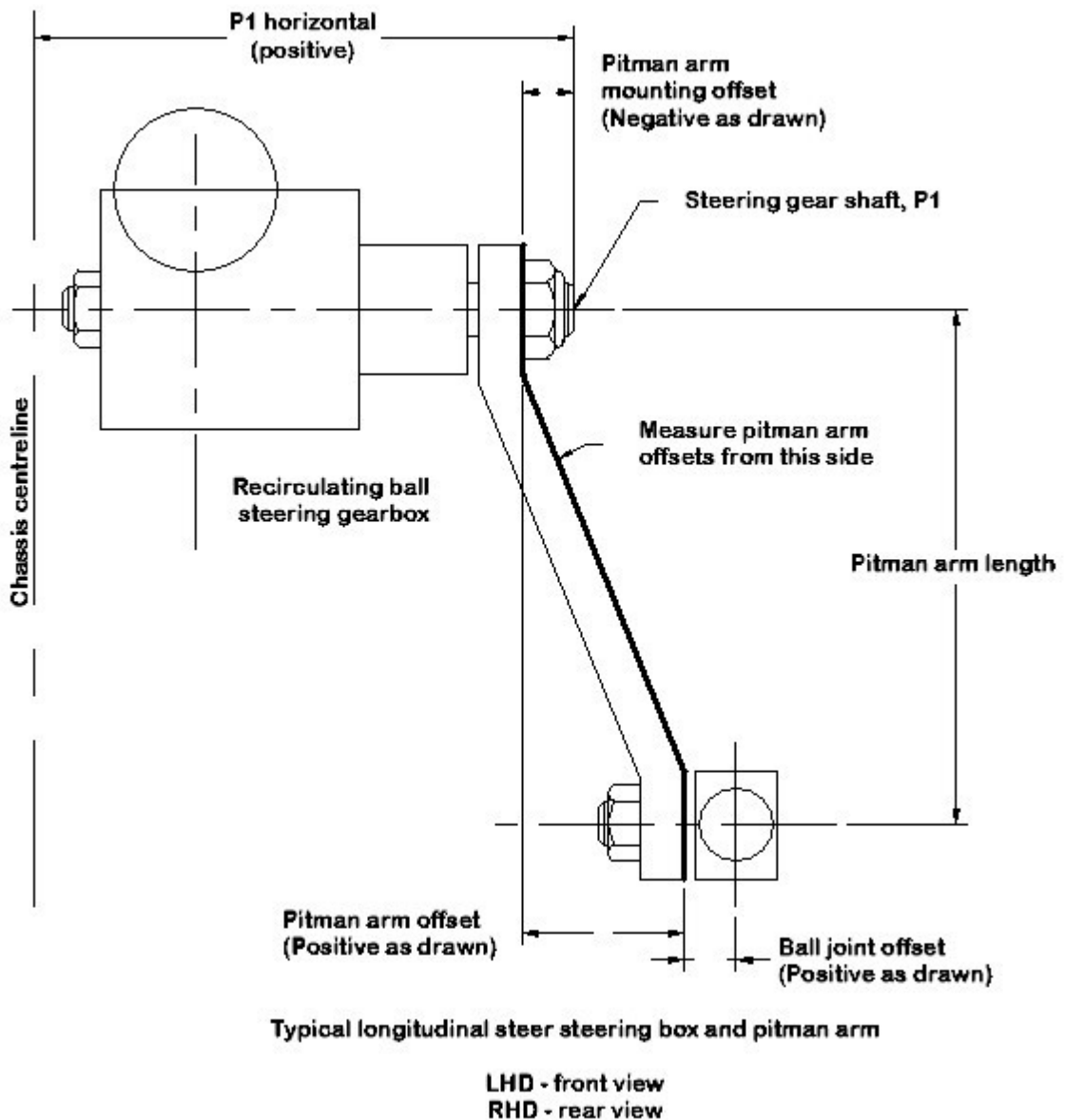
This is measured axially on the pitman arm datum surface, from the sector shaft mounting surface to the drag link mounting surface. If the pitman arm is cranked towards P2 then this dimension will be positive.

8.7.2 Pitman arm (longitudinal drag link)

In this configuration the steering box is mounted horizontally so that the sector shaft axis is "across" the vehicle and the Pitman arm rotates in a vertical plane parallel to the vehicle centreline.

Enter the value for the steering gear shaft, P1. This point is on the end of the steering gearbox sector shaft and defines the pitman arm rotation axis.

Enter the length and offsets of the pitman arm.



Chassis mounting point P1:

Note that the horizontal value is a positive horizontal measurement from the chassis centreline, vertical value is a vertical measurement from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and the longitudinal value is a horizontal measurement from the chosen chassis longitudinal datum.

Pitman arm length:

This is always positive.

Pitman arm datum surface:

This is the retaining nut contact surface of the pitman arm mounting boss on the steering gear shaft.

Pitman arm mounting offset:

This is measured axially from P1 to the pitman arm datum surface. If the pitman arm datum surface is offset inwards from P1 (the usual case) then this dimension will be negative.

Ball joint offset:

This is measured axially from the pitman arm datum surface. If the drag link is mounted on the outside of the pitman arm then this dimension will be positive.

8.7.3 Idler arm (drag link)

From the Steering tab, select Steering Arm.

Enter the values for the idler arm / drag link balljoint.

This is the same dialog box as the initial axle design.

8.7.4 Tie rod (drag link)

The length of the tie rod will be calculated using the specified wheel alignment, in the straight ahead position.

8.7.5 Drag link

Specify if the drag link is mounted outside or inside the pitman arm, and the distance from the pitman arm datum surface to the ball joint centre.

The length of the drag link will be calculated using the specified wheel alignment and pitman arm alignment, in the straight ahead position.

8.7.6 Alignment (drag link)

Pitman arm alignment in the straight ahead position.

Lateral drag link This is defined as the horizontal offset of the drag link end of the Pitman arm from a position parallel to the vehicle centreline (in plan view).

If the Pitman arm is parallel to the vehicle centreline (in plan view) then this offset will be zero.

If the Pitman arm is angled outwards from the vehicle centreline (in plan view) then this offset will be positive.

If the Pitman arm is angled inwards from the vehicle centreline (in plan view) then this offset will be negative.

Longitudinal drag link This is defined as the longitudinal offset of the drag link end of the Pitman arm from a vertical position (in vehicle side view).

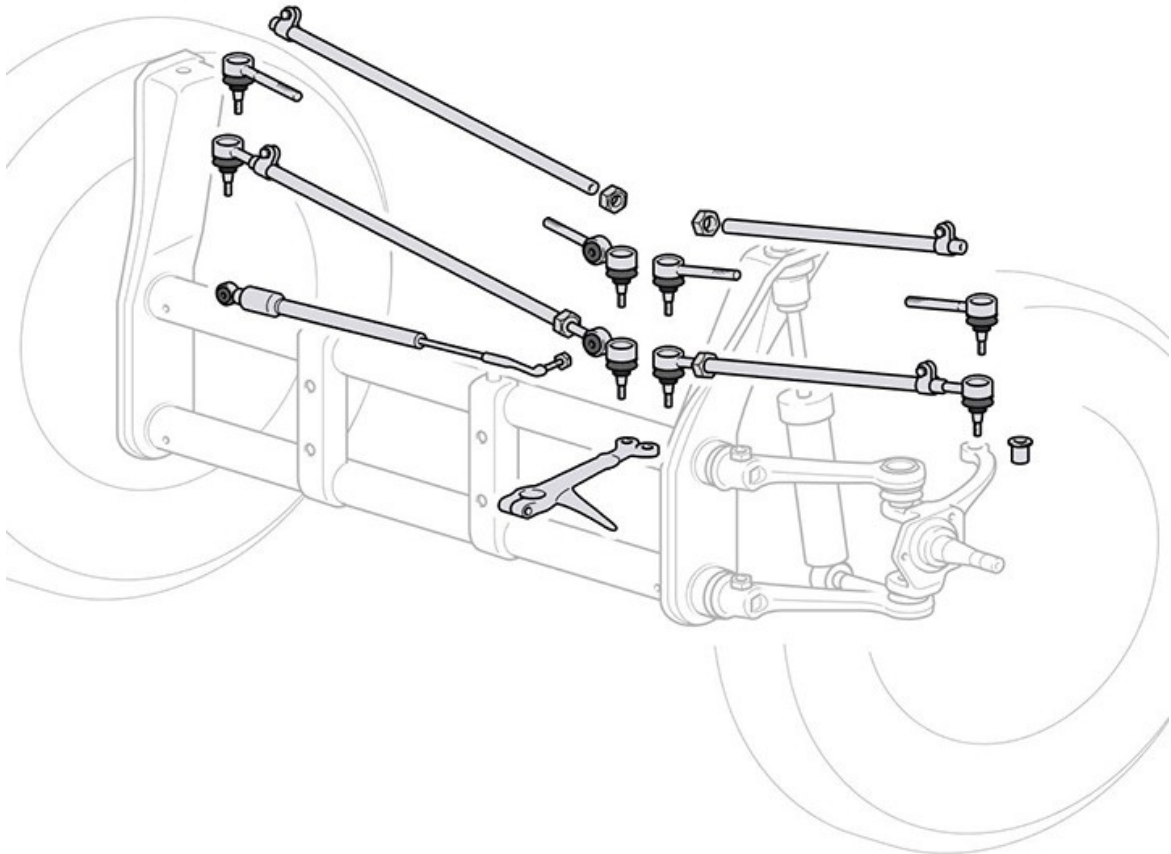
If the Pitman arm is vertical (in vehicle side view) then this offset will be zero.

If the Pitman arm is angled forwards from the vertical position (in vehicle side view) then this offset will be positive (if the longitudinal axis is positive in the forward direction) or negative (if the longitudinal axis is negative in the forward direction).

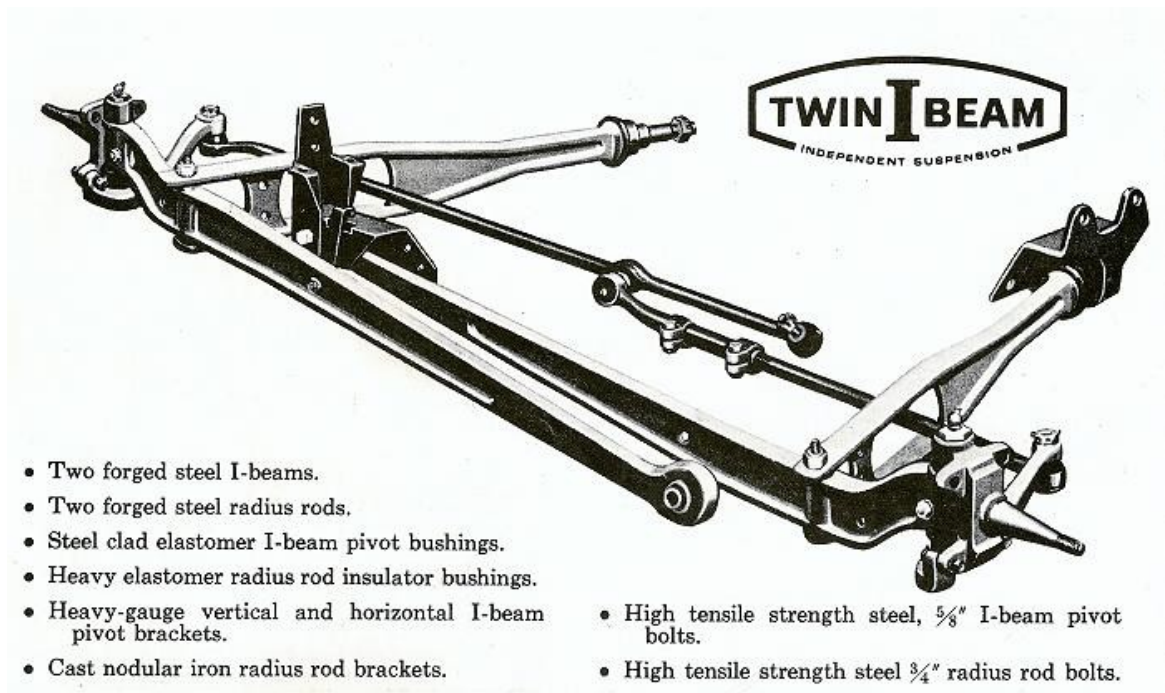
If the Pitman arm is angled backwards from the vertical position (in vehicle side view) then this offset will be negative (if the longitudinal axis is positive in the forward direction) or positive (if the longitudinal axis is negative in the forward direction).

8.8 Steering gear (direct)

These steering configurations use a steering box with a single Pitman arm.

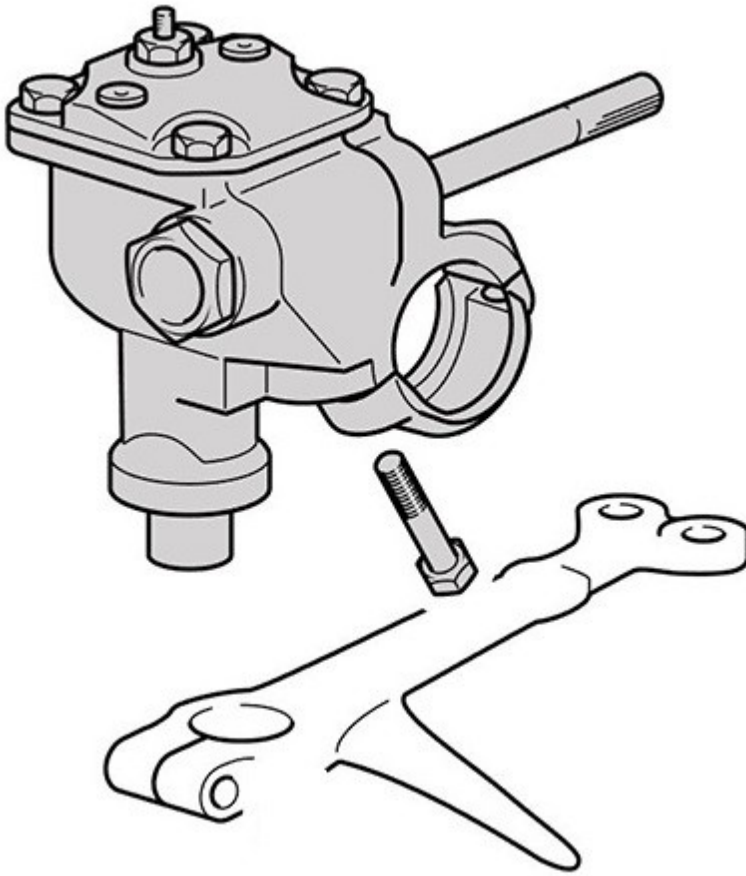


Typical Volkswagen Beetle steering, showing the two tie rods connected to a single Pitman arm.



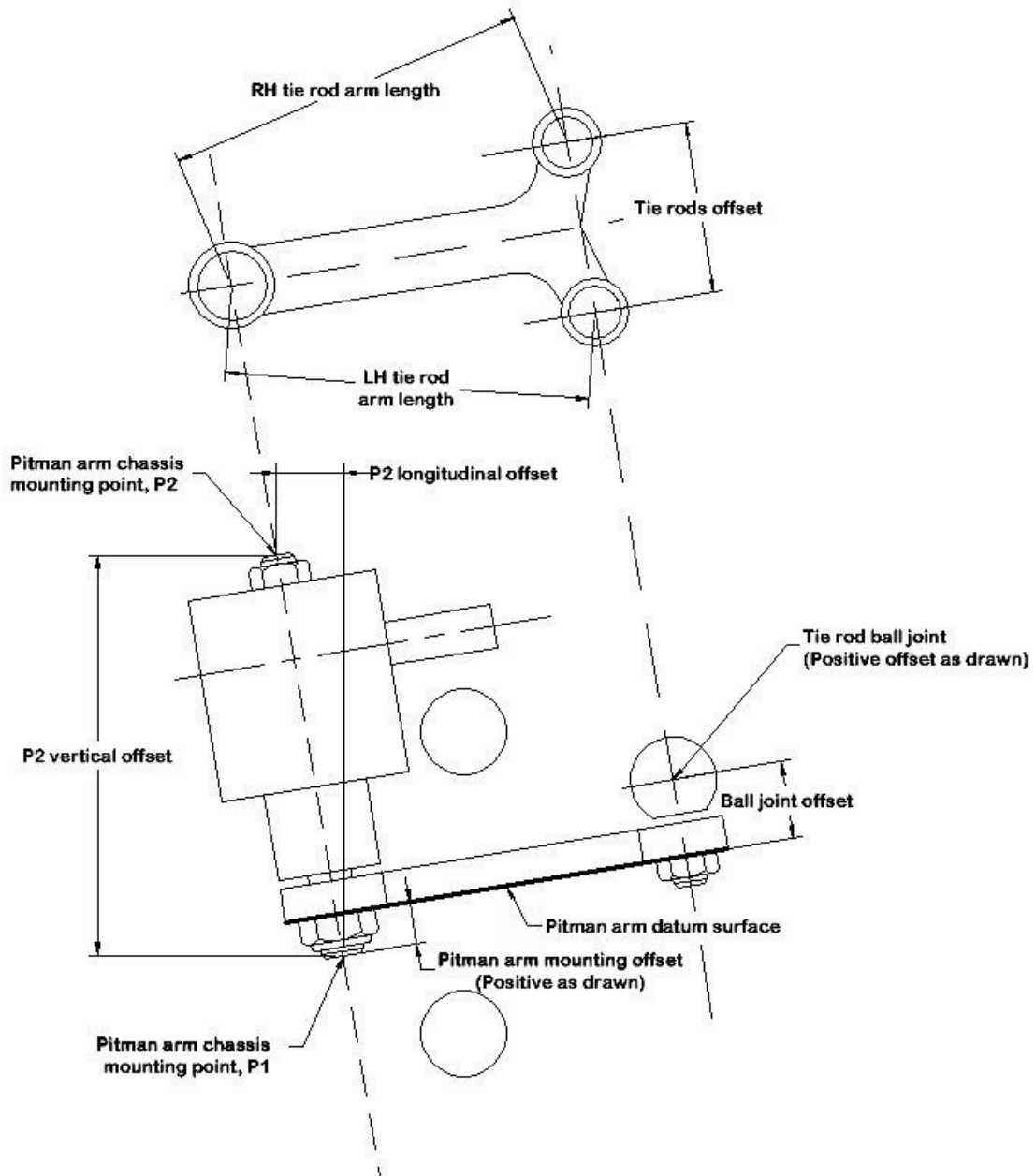
Typical Ford Twin I-Beam steering, showing the RH tie rod connecting to the Pitman arm (not shown) and RH front wheel, and the LH tie rod connecting to the RH tie rod and the LH front wheel.

8.8.1 Pitman arm (direct)



Enter the values for the pitman arm chassis mounting points, P1 and P2. These are two points on the steering gearbox sector shaft and define the pitman arm rotation axis. P1 is the primary location point (close to the pitman arm) and P2 is the secondary location point (on the top of the steering box).

Enter the length and offsets of the pitman arm.



Chassis mounting point P1:

Note that horizontal values are horizontal measurements from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

Chassis mounting point P2:

Note that these dimensions are relative to P1, and will be positive or negative in accordance with the specified axis system. They are measured in the chassis datum position, and P2 is always above P1.

Usually the P2 horizontal dimension will be zero, unless the steering gear is not mounted vertically (in front view). If P2 is outboard of P1 then the P2 horizontal dimension will be positive; if P2 is inboard of P1 then the P2 horizontal dimension will be negative.

If the vertical axis is positive upwards, then the P2 vertical dimension will be positive, otherwise the P2 vertical dimension will be negative. Note that this is a vertical dimension (relative to the vertical datum) and not the axial distance between P1 and P2.

Usually P2 will be "ahead" of P1, as this angles the steering box so that the worm shaft is aligned with the steering wheel shaft. If P2 is ahead of P1, and the longitudinal axis is "positive forward" then the P2 longitudinal dimension will be positive; if the longitudinal axis is "positive rearward" then the P2 longitudinal dimension will be negative.

There are two ball joints on the Pitman arm for the LH and RH tie rods.

Pitman arm LH and RH tie rod ball joint dimensions:

Arm datum surface:	This is the retaining nut contact surface of the pitman arm mounting boss on the steering gear shaft.
Arm length:	This is always positive.
Arm mounting offset:	This is measured axially from P1 to the pitman arm datum surface. If the pitman arm datum surface is offset towards P2 (the usual case) then this dimension will be positive.
Arm offset:	This is measured axially on the pitman arm datum surface, from the sector shaft mounting surface to the tie rod mounting surface. If the pitman arm is cranked downwards then this dimension will be negative.
Ball joint offset:	This is measured axially from the pitman arm datum surface to the centre of the tie rod ball joint. If the ball joint is offset towards P2 then this dimension will be positive.

Tie rod offset:

This is the offset between the LH and RH rod ball joints in plan view.

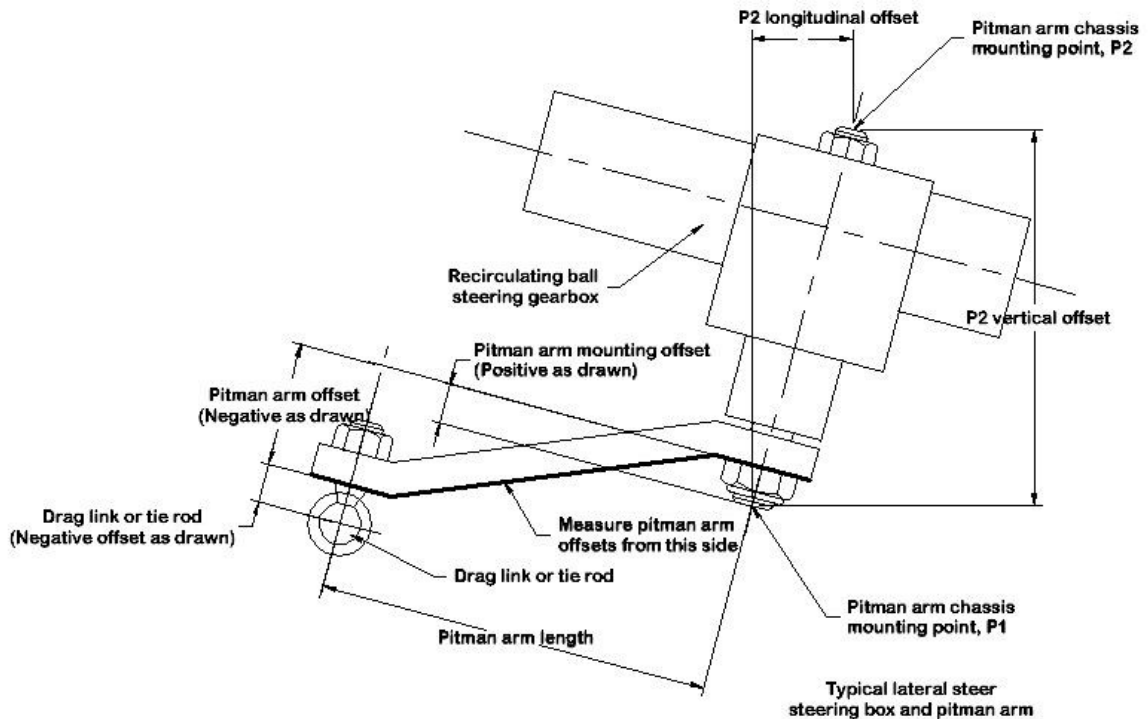
If positive, then the tie rod ball joints are offset towards the outside of the vehicle. If negative, then the tie rod ball joints are offset to the opposite side of the Pitman arm in a "crossed" arrangement.

The diagrams above are drawn with a positive tie rod offset.

8.8.2 Ford Twin I-Beam

Enter the values for the pitman arm chassis mounting points, P1 and P2. These are two points on the steering gearbox sector shaft and define the pitman arm rotation axis. P1 is the primary location point (close to the pitman arm) and P2 is the secondary location point (on the top of the steering box).

Enter the length and offsets of the pitman arm.



There are two tie rods.

One tie rod (the primary tie rod) connects from the pitman arm to the steering arm on the opposite side of the vehicle. For a LHD car, the steering gear is on the LH side, and the primary tie rod connects directly to the RH wheel.

The other tie rod (the secondary tie rod) connects to a point on the primary tie rod some distance from the point where the primary tie rod connects to the Pitman arm, and then to the wheel. For a LHD car, the secondary tie rod connects to the primary tie rod and to the LH wheel.

Note that the tie rod linkage isn't a dimensionally exact representation of the Ford linkage, but it is a reasonable approximation.

8.9 Steering arm (or toe control pickup point)

From the Steering tab, select Steering Arm.

Enter the values for the steering arm balljoint, or toe control pickup point.

This is the same dialog box as the initial upright / strut / axle design.

If you specify the rack location and want to calculate the upright steering arm ball joint to minimise the amount of bump steer, skip this menu choice and see [calculate optimum steering arm position](#).

The steering arm length may need to be entered.

If the longitudinal dimension for the steering arm ball joint is ahead of the kingpin axis, then this is front steer. If the longitudinal dimension for the steering arm ball joint is behind the kingpin axis, then this is rear steer.

8.10 Wheelbase

From the Steering tab, select Wheelbase.

The wheelbase is calculated in accordance with the specified A-arm link lengths, the wheel alignment settings and/or the datum to front axle and datum to rear axle dimensions.

If you are only designing the front suspension, you will need to enter the rear axle to datum distance so that the wheelbase can be calculated.

The wheelbase is also required to calculate the turning radius and curb-curb turning circle.

8.11 Calculate the optimum rack or steering arm position

From the Steering tab, select the button between Wheelbase Datum and Travel.

This is a toggle button, and will be Fixed, Chassis, one of Chassis X or Chassis Y or Chassis Z and Upright. Clicking the button will advance to the next available option. The available options will depend on the specific steering / toe control configuration.

The chassis pivot points depend on the specific steering / toe control configuration.

- Rack and pinion. The chassis points are the tie rod pivots on the end of the rack.
- Recirculating ball with centre link. The chassis points are the tie rod pivots on the centre link. The pitman and idler arms must be fully dimensioned, together with the centre link clearances and length.
- Recirculating ball with intermediate link. The chassis points are the tie rod pivots on the Pitman and idler arms. The pitman and idler arms must be fully dimensioned.
- Recirculating ball. The chassis points are the tie rod pivot(s) on the Pitman arm. The pitman arm must be fully dimensioned.
- Rear suspension with a separate toe control link, the chassis points are the toe control link pivots on the chassis.

Fixed Both the chassis location coordinates and the steering arm ball joint upright dimensions must be input.

Calculate the toe variation with specified chassis and steering arm ball joint positions.

Chassis The upright steering arm ball joint dimensions must be input.

Using the specified upright steering arm ball joint position, the ideal chassis pivot positions will be calculated to minimise the toe variation, and positioned in line with the upright points in plan view.

For recirculating ball with centre link steering this option will maintain the Pitman and idler arm mounting points and dimensions. It will change the tie rod mounting points on the centre link.

For Pitman arm steering (when used with a double A-arm or strut suspension) this will position the tie rods both laterally and vertically while maintaining the longitudinal location and changing the Pitman arm dimensions.

For other recirculating ball type steering this option will only calculate the optimum tie rod mounting positions. Both the ideal and the actual position will be noted in the results.

Chassis X	Only one of these will be available, and will be the same as the character used for the longitudinal axis.
Chassis Y	
Chassis Z	The calculation is similar to the Chassis calculation above, but allows for specifying the longitudinal position of the chassis pivot. For the Pitman arm steering, this option will be the same character as used for the horizontal axis. The calculation is similar to the Chassis calculation above, but will hold the specified horizontal position, ie it will not move the tie rod position laterally but will change the ball joint offset (equivalent to adding or subtracting spacers between the Pitman arm and the tie rod ball joint).
Upright	The chassis pivot point coordinates must be input. Calculate the upright steering arm ball joint position to minimise the toe variation using the specified chassis pivot point location. The upright steering arm ball joint points will be calculated to minimise the amount of bump steer. If the length of the steering arm is zero, the steering arm length will be calculated to position the steering arm ball joint in line with the chassis pivot point in plan view.

8.12 Toe-out in turn increment

From the Steering tab, select Toe turn.

Enter the maximum turn angle and the increment, in degrees and if the turn angle is the wheel toe or the steering wheel rotation.

The initial wheel alignment toe setting for both wheels is that for the "straight ahead" position. The turn angle of the inner wheel will be determined by the steering geometry.

If using the wheel toe this is the angle through which the outer wheel is turned, from the initial toe setting position.

The maximum turn angle is the angle through which the outside wheel is turned (from the straight ahead position).

The increment can be any value (not exceeding the maximum turn angle).

If using the steering wheel this is the angle the steering wheel is rotated, and turns the outside wheel from the initial toe setting.

The maximum turn angle is the angle through which the steering wheel is rotated (from the straight ahead position).

The increment can be any value (not exceeding the maximum turn angle).

The increment will determine the number of calculation points.

For example, if the maximum is 30 degrees, and the increment is 5 degrees, then there will be 6 calculations in each direction plus the straight ahead calculation; a total of 13 calculation points.

The outside wheel is turned through the specified increment (starting from the static alignment position) and the steering linkage is used to determine the resulting position of the inside wheel.

Depending on the steering configuration, when the outer wheel is turned the inner wheel may turn through a greater angle (typically when Ackermann geometry is employed) or a lesser angle (typically when anti-Ackermann geometry is employed). In either case, the calculation limit is reached when one wheel reaches a maximum turn angle of 57 degrees (1 radian). You will need to adjust the maximum turn angle if the calculation limit is reached.

Toe-out (or toe-in) in turn is the angle between the two front wheels.

If the rack travel or steering linkage determines the steering angle.

Often the steering turn angle is limited by the actual rack travel or the individual components of the steering linkage. To establish the maximum turn angle start with a reasonable value (say 20 degrees), and then do the steering calculation using the wheel toe option. Use the display and turn the wheels. Adjust the maximum turn angle and repeat until the required rack travel and/or turn angle is achieved. The maximum turn angle can be specified in decimal degrees.

Note that for both rack and pinion and recirculating ball type steering boxes the steering ratio is fixed.

8.13 Calculate

Before the steering calculations can be calculated, Roll Bump | Calculate must complete without error.

From the Steering tab, select Calculate.

This will do all Geometry, Roll Bump and Steering calculations.

The status bar will display a message 'Calculating...' followed by either 'OK' or an error message.

On fast processors, the 'Calculating...' message may not remain long enough to be visible.

8.14 Results

From the Steering tab, select Result.

This will open a result window with all the calculated steering values.

Because of the amount of data, it may be necessary to increase the width of the window to display all data without text wrapping.

```

SusProg3D SRD912.s3d Front Steering

RHD Rack and pinion, front steer

Vehicle horizontal datum (X): Vehicle centreline
Vehicle vertical datum (Y): Ground
Vehicle longitudinal datum (Z):

Steering pivot points (from vehicle X, Y, Z datum)
- tie rod (rack ball joint)           - X   256.89
                                       - Y   277.21
                                       - Z   -99.17
- tie rod (steering arm)             - X   547.36
                                       - Y   268.21
                                       - Z   -99.17

Steering tie rod length                290.61
Steering arm length (actual)           102.95
Steering arm length (effective)        99.84
Steering arm - tie rod angle (effective, degrees) 103.70

Rack c-factor                          50.00
Steering ratio - nominal (straight ahead) 12.46
Turning radius (tyre contact centre) LH/RH 4678.81
Turning circle (curb-to-curb) LH/RH   9594.09
Steering wheel turns, lock to lock     1.78

Bump steer          absolute degree      relative degree

```

100.00 bump	0.06	toe in	-0.11	toe out		
80.00 bump	0.12	toe in	-0.05	toe out		
60.00 bump	0.15	toe in	-0.02	toe out		
40.00 bump	0.17	toe in	0.00			
20.00 bump	0.17	toe in	0.00			
Static	0.17	toe in	0.00			
20.00 droop	0.17	toe in	0.00			
40.00 droop	0.17	toe in	0.00			
60.00 droop	0.19	toe in	0.02	toe in		
80.00 droop	0.22	toe in	0.05	toe in		
100.00 droop	0.29	toe in	0.12	toe in		
Steering	Toe out	Wheel toe angle	Rack	Steering Ratio:1		
Ackermann						
turn angle	in turn	LH	RH	travel	LH	RH
%						
30.00 LH	5.55	-24.62	30.17	44.55	13.01	8.70
-54.65						
25.00 LH	3.89	-21.28	25.17	38.51	13.07	9.66
-55.27						
20.00 LH	2.58	-17.59	20.17	31.81	13.08	10.49
-58.27						
15.00 LH	1.59	-13.58	15.17	24.52	13.02	11.21
-65.69						
10.00 LH	0.90	-9.27	10.17	16.73	12.89	11.81
-86.25						
5.00 LH	0.48	-4.69	5.17	8.53	12.64	12.29
192.06						-
Straight	0.34	0.17	0.17	0.00	12.46	12.46
0.00						
5.00 RH	0.48	5.17	-4.69	8.53	12.29	12.64
192.06						-
10.00 RH	0.90	10.17	-9.27	16.73	11.81	12.89
-86.25						
15.00 RH	1.59	15.17	-13.58	24.52	11.21	13.02
-65.69						
20.00 RH	2.58	20.17	-17.59	31.81	10.49	13.08
-58.27						
25.00 RH	3.89	25.17	-21.28	38.51	9.66	13.07
-55.27						
30.00 RH	5.55	30.17	-24.62	44.55	8.70	13.01
-54.65						
Steering	Camber (actual)	Camber (change)	Caster (actual)			
Caster (change)						
turn angle	LH	RH	LH	RH	LH	RH
LH	RH					
30.00 LH	2.67	-1.29	3.17	-0.79	9.81	-1.91
4.81	-6.91					
25.00 LH	2.12	-1.40	2.62	-0.90	9.25	-0.74
4.25	-5.74					
20.00 LH	1.56	-1.41	2.06	-0.91	8.59	0.43
3.59	-4.57					
15.00 LH	1.00	-1.33	1.50	-0.83	7.83	1.60
2.83	-3.40					
10.00 LH	0.45	-1.15	0.95	-0.65	6.99	2.75
1.99	-2.25					
5.00 LH	-0.05	-0.87	0.45	-0.37	6.04	3.89
1.04	-1.11					

Straight	-0.50	-0.50	0.00	0.00	5.00	5.00
0.00	0.00					
5.00 RH	-0.87	-0.05	-0.37	0.45	3.89	6.04
-1.11	1.04					
10.00 RH	-1.15	0.45	-0.65	0.95	2.75	6.99
-2.25	1.99					
15.00 RH	-1.33	1.00	-0.83	1.50	1.60	7.83
-3.40	2.83					
20.00 RH	-1.41	1.56	-0.91	2.06	0.43	8.59
-4.57	3.59					
25.00 RH	-1.40	2.12	-0.90	2.62	-0.74	9.25
-5.74	4.25					
30.00 RH	-1.29	2.67	-0.79	3.17	-1.91	9.81
-6.91	4.81					

Steering		Jacking effect		Caster trail		KPI Offset	
Steering offset							
turn angle		LH	RH	LH	RH	LH	RH
LH	RH						
30.00 LH		6.72	-1.80	46.06	-8.60	69.23	70.98
83.15	71.50						
25.00 LH		5.61	-2.05	43.19	-3.35	69.44	71.04
81.77	71.12						
20.00 LH		4.45	-2.08	39.89	1.92	69.66	71.05
80.28	71.07						
15.00 LH		3.27	-1.89	36.18	7.18	69.90	71.00
78.71	71.36						
10.00 LH		2.11	-1.47	32.08	12.42	70.14	70.91
77.13	71.99						
5.00 LH		1.00	-0.84	27.59	17.60	70.37	70.77
75.59	72.92						
Straight		0.00	0.00	22.72	22.72	70.58	70.58
74.15	74.15						
5.00 RH		-0.84	1.00	17.60	27.59	70.77	70.37
72.92	75.59						
10.00 RH		-1.47	2.11	12.42	32.08	70.91	70.14
71.99	77.13						
15.00 RH		-1.89	3.27	7.18	36.18	71.00	69.90
71.36	78.71						
20.00 RH		-2.08	4.45	1.92	39.89	71.05	69.66
71.07	80.28						
25.00 RH		-2.05	5.61	-3.35	43.19	71.04	69.44
71.12	81.77						
30.00 RH		-1.80	6.72	-8.60	46.06	70.98	69.23
71.50	83.15						

Datum reference dimensions

Chassis horizontal datum (X): Chassis centreline

Chassis vertical datum (Y):

Chassis longitudinal datum (Z):

Chassis pivot points (from chassis X, Y, Z datum)

- tie rod (rack ball joint) - X 256.89

- Y 277.21

- Z -99.17

Upright pivot points (from upright X, Y, Z datum)

- tie rod (steering arm) - X 150.00

- Y 0.00

- Z -100.00

Upright pivot points (from chassis X, Y, Z datum)		
- tie rod (steering arm)	- X	547.36
	- Y	268.21
	- Z	-99.17

8.15 ECalc

Allows several modules to be calculated from one point.

For example, if the rack location is changed, you can recalculate all modules with one click.

See [ECalc](#)

8.16 Notes

Bump steer values are calculated for all positions of bump and droop, and are shown with both absolute and relative values. Absolute values are the actual toe-in or toe-out dimensions incorporating the specified static wheel setting. Both an angular value (in degrees) and a measurement (in mm) are shown. The measurement is based on the wheel toe reference length, which would usually be the wheel rim diameter. Relative values are calculated from the static wheel position and show the actual bump steer deviation from the static position.

For A-arm and strut suspensions, the Roll&Bump data is also updated with the toe changes. Select Roll&Bump then Result. Do not recalculate, as the Roll&Bump calculation always uses a fixed toe-in, only the Steering calculation uses the calculated toe-in.

Toe out in turn shows the effect of steering on the front wheel alignment.

The front wheels are steered through a range of angles, starting with a maximum LH turn back to the straight ahead position, then to a maximum RH turn. The The maximum turn angle and turn angle increment are set in [Toe Turn](#).

The "toe out in turn" value is the included angle between the two front wheels.

A positive value means that the pair of wheels are "toed in"; a negative value means that the pair of wheels are "toed out".

Increasing negative values means that the wheels are increasingly toeing out as the steering is turned.

Ackermann geometry will increasingly toe out; anti-Ackermann will increasingly toe in.

The individual wheel toe angles are also shown.

In a LH turn, the RH wheel (the outside wheel) will be turning in a "toe-in" direction and the LH wheel (the inside wheel) will be turning in a "toe-out" direction.

In a RH turn, the RH wheel (the inside wheel) will be turning in a "toe-out" direction and the LH wheel (the outside wheel) will be turning in a "toe-in" direction.

When turning, the outside wheel will be turned through the specified angle, and the inside wheel turn angle will be determined by the steering linkage.

Also shown is the amount of steering rack or steering linkage movement required.

For both camber and [caster](#), the actual values and the gain / loss are also shown.

The jacking effect figure is the amount that the bottom ball joint rises and falls as the wheel is turned.

The steering ratio is calculated for each position. It is calculated using the rack C-factor, the distance the rack moves from one position to the next, and the corresponding change in wheel toe angle.

Strictly, it is the average steering ratio between each position rather than the actual steering ratio at that position.

For vehicles equipped with recirculating ball steering box (instead of rack and pinion) and the steering tie rods connected to a drag or cross link, then the inner tie rod ball joint is equivalent to the rack ball joint.

The steering arm actual and effective lengths are calculated.

The actual length is the distance from the upright ball joint to the kingpin axis (normal to the kingpin axis), and the effective length is the distance between the kingpin axis and the steering tie rod (normal to both lines).

The rack C-factor is the distance the rack moves for one turn of the pinion.

For recirculating ball steering, the steering box ratio is the number of turns of the input shaft (the steering wheel) for one turn of the output shaft (the pitman arm).

The steering ratio - nominal (straight ahead) is the kinematic ratio between the steering wheel and the steered wheels

The turning radius is the theoretical turning radius at the centre of the tyre contact.

A line normal to the outside wheel is projected back to the line of the rear axle and this intersection point is used as the turning point. No allowance is made for tyre slip angle.

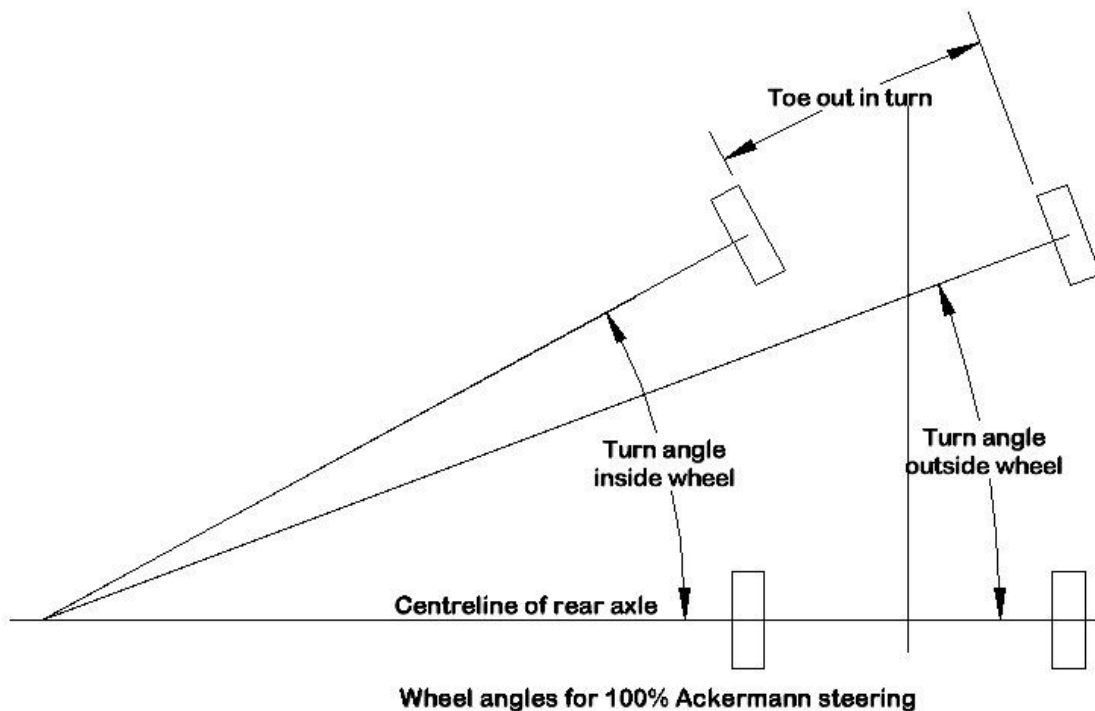
The turning circle (curb-to-curb) is twice the turning radius plus the tyre width.

The steering wheel turns, lock to lock is the number of turns of the steering wheel for the full rack travel or maximum steer angle. It assumes a constant rack C-factor (rack and pinion) or steering box ratio (recirculating ball).

Ackermann calculation.

For 100% Ackermann, the inner wheel must be turned such that the lines drawn from the centre of the tyre contact point (normal to the tyre centreline) both meet on the line drawn from the rear axle. The pair of wheels are "toed out".

Note that "toe out" is negative and "toe in" is positive.



If the inner wheel is turned further than required, then the Ackermann percentage will be greater than 100%.

If the inner wheel is turned less than required, but is still turned greater than the outside wheel, then the Ackermann percentage will be less than 100%.

If the inner wheel is turned the same as the outer wheel, then the Ackermann percent will be 0%. In this instance, the wheels are parallel.

If the inner wheel is turned less than the outer wheel, then the Ackermann percentage will be negative. In this instance the pair of wheels are "toed in".

For small turn angles, the initial wheel alignment setting has a far greater influence than the Ackermann effect.

For example, if the initial wheel alignment is toe-out, then the initial toe-out will be greater than that required for 100% Ackermann, hence the Ackermann percent may be much greater than 100%. At some further turn angle, the steering geometry starts to exert more influence.

Similarly, if the initial wheel alignment is toe-in, then the initial toe-out will be much less than that required for 100% Ackermann (and may even be negative).

All of the above assumes a zero slip angle on all tyres.

This version calculates the actual camber and caster settings. SusProg3D V4.25 and earlier, used the following formula to estimate the camber change in turn.

Camber gain/loss is the actual camber as the wheel is turned through the wheel steer angles. For realistic steer angles, a positive [kingpin](#) inclination angle causes a positive camber on the outer wheel and positive [caster](#) causes a negative camber on the outer wheel. See [DIXO96] for a complete description.

The actual camber angle is $\gamma = \gamma_o + \arccos(\sin\theta_k \cos\delta) + \theta_k + \arccos(\sin\theta_c \sin\delta) - 180$

where γ_o is the initial camber, θ_k is the kingpin inclination angle, θ_c is the castor angle, and δ is the wheel steer angle.

9 Driveline

There are several driveline configurations.

- Independent suspensions and deDion rear suspension have driveshafts, typically incorporating a chassis mounted differential or transmission with a pair of driveshafts to each wheel.
- Live front axle suspensions have propshafts, typically incorporating a longitudinally mounted transfer box with either a single or two-piece propshaft connecting to the front axle.
- Live rear axle suspensions have propshafts, typically incorporating a longitudinally mounted transmission with either a single or two-piece propshaft connecting to the rear axle.
- 4WD vehicles typically have a transmission (gearbox) and a transfer box. The transfer box is driven from the transmission, and the transfer box output shaft(s) are parallel to the transmission shaft. The front propshaft is driven from the transfer box. The rear propshaft can be driven from either the gearbox or the transfer box.

Note that this is equally applicable to the front suspension for inboard front brakes or FWD/4WD, although the terminology is more appropriate for the rear suspension.

Also Roll&Bump | Calculate must successfully execute before this can be calculated.

9.1 Configure

The basic vehicle Driveline configuration is specified in Vehicle | Config, by specifying the brake location, FWD, RWD and suspension geometry.

This section further specifies the Driveline type.

From the Driveline tab, select Configure.

For front IFS, there will be a driveshaft if either inboard brakes or front wheel drive is specified. For front live axle, there will be a propshaft.

For the rear there will be a driveshaft if the suspension type is Jaguar or Chapman strut, or the suspension type is IRS and either inboard brakes or rear wheel drive is specified, or de Dion. There will be a propshaft for live axle (except de Dion).

For a driveshaft:

Specify either "Variable" or "Fixed" length driveshaft.

Variable length is for the type of driveshaft with sliding splines and (usually) fixed hookes-type universal joints.

Fixed length driveshafts are constant length and (usually) have Constant Velocity joints which provide the necessary axial length variations. For fixed length driveshaft, enter the length if required.

In the case of a swing axle suspension there is only one universal joint. The universal joint will be located on the trailing arm "link" that has zero vertical and longitudinal offsets.

If the universal joint is on the rear link, then try and minimise the 'mounting error' reported in the static geometry results. Do this by adjusting the longitudinal offset of the front link, or the longitudinal location of the chassis mounting point.

For the suspension types where the driveshaft is used as a suspension member, for example, Corvettes and Jaguars, there is an additional driveshaft option "Fixed length driveshaft (top lateral link). This uses the driveshaft as the top lateral link.

For a propshaft:

Specify either one-piece or centre bearing (two piece).

Specify the spline location.

- “Input shaft spline” is where the propshaft length (universal joint to universal joint) is fixed, and the input universal joint is part of a sliding yoke that is splined to the transmission output shaft. This is the typical front engine- RWD configuration.
- “Output shaft spline” is the opposite arrangement to the “input shaft spline”, in that the splined end slides on the output shaft. An uncommon arrangement.
- “Fixed flanges, spline” is where the propshaft has a flange at each end (which may be a circular flange, or a yoke that attaches to the universal cross) and the propshaft itself has a sliding spline.

For a 4WD vehicle with a transfer box, the rear propshaft can be driven from either the transmission or the rear of the transfer box. Specify which. In this case, the front propshaft is always driven from the front of the transfer box.

Specify the engine / transmission axis. This requires two points, one is the front of the engine. Often the nose of the crankshaft, or the centre of the crankshaft pulley is a convenient point. The other is the centre of the transmission universal joint (in the static vehicle position). If the rear propshaft doesn't connect to the transmission (it connects to the transfer box) then this point can be any convenient point that defines the rear end of the engine / transmission axis.

For the “long style” torque tube axle, the gearbox universal joint will be the same point as the torque tube mounting.

It is assumed that the transmission output is coaxial with the engine crankshaft.

Specify the transfer box axis. This requires two points, one is the centreline of the front universal. The other is the centre of the transmission universal joint (in the static vehicle position). If the rear propshaft doesn't connect to the transfer box (it connects to the transmission) then this point can be any convenient point that defines the rear end of the transfer box axis.

It is assumed that the transfer box is parallel with the engine / transmission axis.

If there is a centre bearing, specify the centre bearing uj centre, in the static or nominal position.

All axial movement of the propshaft(s) will be either 1) along the line of the engine / transmission, or 2) along the line of the axle pinion shaft, or 3) within the propshaft. If a two piece propshaft is specified as “Fixed flanges, spline” then it is assumed that the length variation is in the second propshaft (ie the propshaft between the centre bearing and the axle).

When specifying propshaft lengths and universal joint centres, remember that it is always to the universal joint centre. This may require that you allow for the distance from the universal joint centre to the face of the attaching flange, and add or subtract this dimension as appropriate.

Torque tube rear axles generally come in two configurations: the “long style” where the torque tube extends all the way from the rear axle to the gearbox and the torque tube ball joint is concentric with the gearbox universal; and the “short style” where the torque tube extends about halfway between the axle and the gearbox with the torque tube ball joint supported on an intermediate cross member, with a short propshaft connecting to the gearbox.

For the “long style”, specify the propshaft as “none”. This will also set the gearbox universal joint to be the same point as the torque tube mounting.

Chassis mounting points:

Note that horizontal values are horizontal measurements from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground](#)

[based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

If there are no driveline components, none of the following commands will be available.

9.2 Car end and car side

The [Front] or [Rear] tab choice will indicate the currently selected vehicle end.

The [LH] or [RH] tab choice will indicate the currently selected vehicle side.

These tabs acts as a toggle, and selecting this tab will switch between each of two.

Depending on the vehicle configuration, some menu bar items may not be available.

When a dialog box is opened, the title will include the currently selected car end and car side. If the car side is not shown, then the dialog box applies to both sides. If the car end is not shown, then the dialog box applies to both ends.

9.3 Driveline components - driveshaft

9.3.1 Gearbox

This is the inboard end of the driveshaft.

From the Driveline tab, select Gearbox.

Enter the values for the gearbox, transmission or differential UJ point.

If it is needed to calculate the UJ location to minimise the amount of driveshaft plunge, do not enter these dimensions.

Chassis mounting points:

Note that horizontal values are horizontal measurements from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

9.3.2 Hub

This is the outboard (or wheel) end of the driveshaft.

From the Driveline tab, select Hub.

Enter the horizontal value of the UJ point.

Note that only a horizontal value is entered as it is assumed that the UJ is on the stub axle centreline.

9.3.3 Length

From the Driveline tab, select Length.

Specify either "Variable" or "Fixed" length driveshaft. Variable length is for the type of driveshaft with sliding splines and (usually) fixed hookes-type universal joints. Fixed length Drivelines are constant length and (usually) have Constant Velocity joints which provide the necessary axial length variations. For fixed length driveshaft, enter the length if required.

After calculation, the distance between the centrelines of the CV joints will also be shown for reference. If it is required that the driveshaft length be equal to the distance between the centrelines of the CV joints then enter a value of 0.00 and the correct value will be calculated.

9.4 Driveline components - propshaft

The engine / transmission centreline, transfer box centreline, and centre bearing (if applicable) are all specified in the driveline configuration.

9.4.1 Length

From the Driveline tab, select Length.

After calculation, the propshaft length(s) will also be shown.

9.5 Calculate the optimum UJ position

From the Driveline tab, select the toggle button, which will be Auto or Fixed. Each selection will change to the next in turn.

Fixed The gearbox universal joint location must be input.

Auto Calculate the gearbox universal joint position to minimise the amount of driveshaft plunge, and be positioned in line with the upright universal joint in plan view.

The upright universal joint location must be input.

Auto will always recalculate the driveshaft length (whether variable or fixed length) to be equal to the distance between the universal joint centrelines in the static position.

AutoCalc is not available for deDion, live axle or Jaguar rear suspensions, and will always be [Fixed].

9.6 Calculate

Before the driveline calculations can be calculated, Roll Bump | Calculate must complete without error.

From the Driveline tab, select Calculate.

This will do all Geometry, Roll Bump and Driveline calculations.

The status bar will display a message 'Calculating...' followed by either 'OK' or an error message.

On fast processors, the 'Calculating...' message may not remain long enough to be visible.

9.7 Results

From the Driveline tab, select Result.

This will open a result window with all the calculated Driveline values.

Because of the amount of data, it may be necessary to increase the width of the window to display all data without text wrapping.

```
SusProg3D SRD912.s3d Rear DriveShaft
Variable (splined) length shaft, inner and outer UJ fixed
Vehicle horizontal datum (X): Vehicle centreline
Vehicle vertical datum (Y): Ground
```

```

Vehicle longitudinal datum (Z):

Chassis pivot points (from vehicle X, Y, Z datum)
- inner universal joint          - X   150.00
                                  - Y   250.00
                                  - Z  2286.00
- outer universal joint          - X   522.66
                                  - Y   268.02
                                  - Z  2286.00

Driveshaft length (nominal, between UJ centres)    373.09
Distance between UJ centres (static)               373.09

                Drive shaft                UJ Angle
                UJ centres                plunge                inner                outer
100.00 bump    372.81                    0.28                    16.96                13.15
 80.00 bump    374.36                   -1.27                    14.15                11.28
 60.00 bump    375.16                   -2.07                    11.33                 9.26
 40.00 bump    375.22                   -2.13                     8.51                 7.08
 20.00 bump    374.54                   -1.45                     5.66                 4.76
      Static    373.09                    0.00                     2.77                 2.27
 20.00 droop   370.85                    2.24                     0.19                 0.40
 40.00 droop   367.73                    5.36                     3.24                 3.28
 60.00 droop   363.62                    9.47                     6.43                 6.44
 80.00 droop   358.30                   14.79                     9.82                 9.98
100.00 droop   351.41                   21.68                    13.52                14.08

Datum reference dimensions
Chassis horizontal datum (X): Chassis centreline
Chassis vertical datum (Y):
Chassis longitudinal datum (Z):

Chassis pivot points (from chassis X, Y, Z datum)
- inner universal joint          - X   150.00
                                  - Y   250.00
                                  - Z  2286.00

Upright pivot points (from upright X, Y, Z datum)
- outer universal joint          - X   150.00

Upright pivot points (from chassis X, Y, Z datum)
- outer universal joint          - X   522.66
                                  - Y   268.02
                                  - Z  2286.00

```

9.8 ECalc

Allows several modules to be calculated from one point.

For example, if the gearbox universal location is changed, you can recalculate all modules with one click.

See [ECalc](#)

9.9 Notes

For a variable length driveshaft the nominal or static driveshaft length will be calculated from the centres of the universal joints at the static position.

For a variable length driveshaft, negative plunge is the amount of extension required from the static length and positive plunge is the amount of compression required from the static length.

For a fixed length driveshaft, negative plunge is the amount of outwards movement that must be provided by the CV joint, and positive plunge is the amount of inwards movement that must be provided. Plunge is measured from the nominal centreline of the CV joint outer housing. All plunge is assumed to be in the inboard joint. In practice, the driveshaft length would be adjusted such that the required plunge is approximately equal in both directions.

The length of a fixed length driveshaft is the distance between the CV joint inner spider centrelines. The CV joint outer housing centreline is used to define the chassis and upright dimensions that locate the inner and outer joints, and to calculate the distance between the CV joint centrelines.

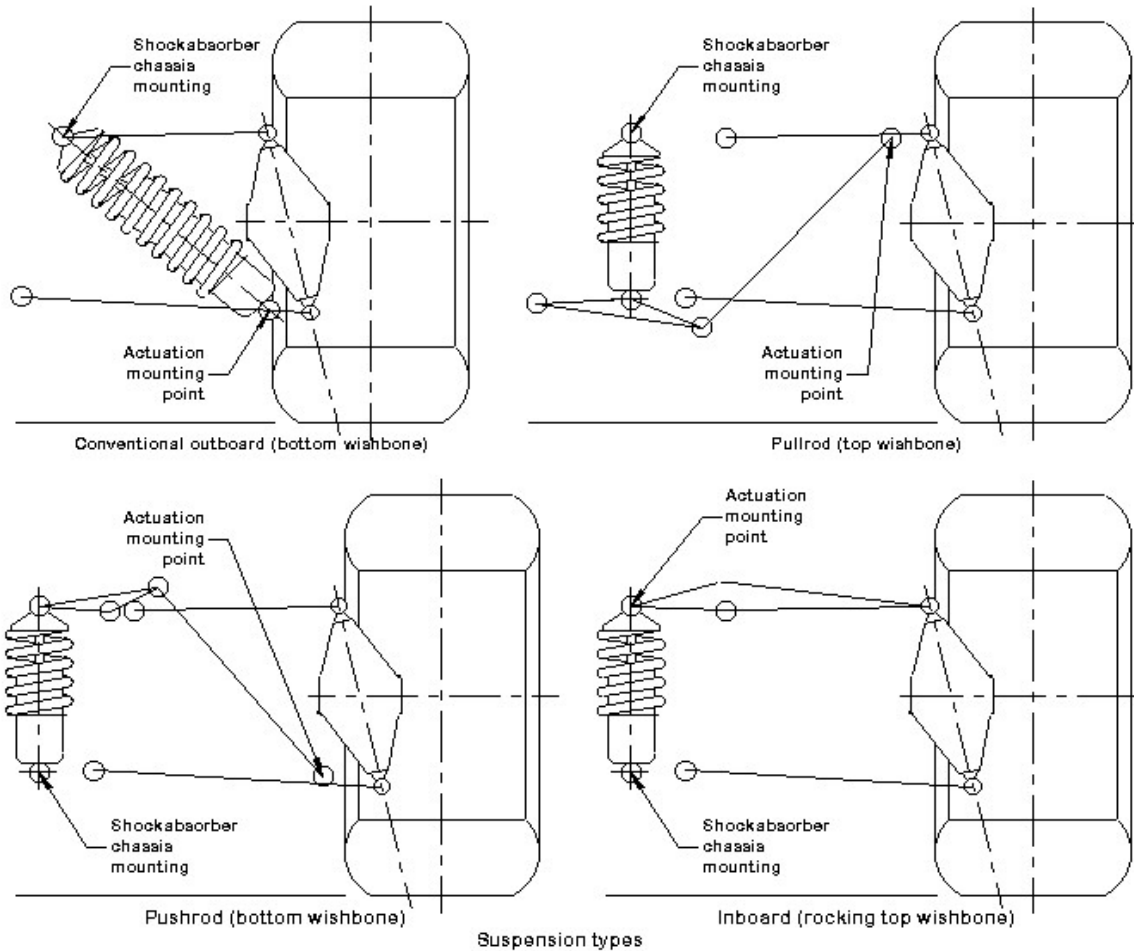
Designers of older vehicles fitted with rubber doughnuts that provide the required axial movement should specify fixed length driveshaft where the length is equal to the uj centreline length. This ensures the minimum deflection of the doughnut in the static position.

Also shown is the amount of angular movement that the driveshafts adopt during suspension travel for both inner and outer universals.

For both one and two-piece propshafts, it is assumed that all length variation is provided at the transmission universal joint, by way of a splined connection. A positive value for plunge means that the spline move inwards, and a negative value means that it moves outwards.

The propshaft angles are the true angles between the two shaft centrelines. They are always shown as positive angles.

10 Spring, shockabsorber & antirollbar



Note that before any of the spring, shockabsorber and/or anti-roll bar can be calculated, Roll Bump | Calculate must complete without error.

Note:

If you change the suspension travel limits when doing Geometry calculations you must redo the Spring Rate calculations to use the new values for the maximum wheel bump and droop travel.

Some of the values require that the full bump and full droop positions have been calculated. If these results are displayed after calculating the Static values, but before doing the Rates calculation, then some of these values may be incorrect. If these results are displayed after doing the Rates calculation, they will be correct.

The values are those that rely on the bump and droop data include the shockabsorber compressed and extended lengths, and the spring compressed length and preload.

Additionally, the spring parameters require that the mass and spring dimensions have been specified.

10.1 Configure

In addition to specifying the basic linkage geometry in Vehicle Configure, the location style of bellcrank, shockabsorber(s), spring(s) and antiroll bar is specified here.

From the Spring, Shock, ARB tab, select Config.

SusProg3D allows for various combinations of bellcrank, one or two shockabsorbers, one or two springs and an antiroll bar. The spring can be located independently from the shockabsorber, or as a coilover mounted on the shockabsorber.

Most racing vehicles have a single shockabsorber with a coilover spring per side.

Other common variations include

- NASCAR front, with two shockabsorbers and a single spring
- Jaguar rear, with two coilover shockabsorbers
- Most production car trailing arm rear, with a single shockabsorber and spring
- Some older production cars have lever arm shockabsorbers. MGB and Austin-Healy are typical. In this case specify the shock as 'Lever arm'. There are no motion ratio calculations for the lever arm shockabsorber.

Shock 1	Specify the location style of the (primary or only) shockabsorber.
Shock 2	Specify the location style of the second shockabsorber. If there is not a second shockabsorber, then choose 'none'.
Spring 1	Specify the location style of the (primary or only) spring.
Spring 2	Specify the location style of the second spring. If there is not a second spring, then choose 'none'.
Bellcrank	Specify the location style of the pushrod or pullrod. If there is not a bellcrank, then choose 'none'.
Antirollbar	Specify the location style of the antirollbar. If there is not an antirollbar, then choose 'none'. Even if there is an antirollbar, it is usually easier to exclude it from the initial calculations until the other suspension components have been dimensioned and calculated.

Specify if the shock body attaches to the chassis or to the A-arm, upright or bellcrank. This is used to correctly display the shock absorber orientation.

The specified configuration will be the same for both sides of the vehicle. For example, if you have currently selected [Front] and [RH], and specify that there is a second shockabsorber, this will apply to both [Front] [RH] and [Front] [LH].

There is complete freedom to specify different LH and RH mounting points for the same component.

The following limitations currently apply:

- The minimum selection is a single shockabsorber, "Shock 1" with a coilover spring, "Spring 1".
- If a spring is specified as 'Coilover' then there must be a corresponding shockabsorber. For example, if Spring 2 is 'Coilover' then Shock 2 cannot be 'none'.
- Bellcrank monoshock and third spring configurations are not supported.
- There is only provision for a single shockabsorber with coilover spring in conjunction with bellcrank actuation. This version does not support the Riley and Scott configuration where the shockabsorber and spring are attached to separate arms on the bellcrank.

If the combination of suspension elements specified is not supported, an error message will display indicating the invalid combination.

10.1.1 Live axle anti-roll bar

The following anti-roll bar options are available.

Chassis ARB - Axle

The anti-roll bar is mounted to the chassis and drop links connect to the axle.

Axle ARB - Chassis

The anti-roll bar is mounted on the axle and drop links connect to the chassis.

Chassis Bellcrank ARB - Axle

This style is only available in conjunction with chassis mounted bellcranks.

In addition, the bellcrank pivots must be on a common axis. The antiroll bar acts through the bellcrank pivots.

In the image, the antiroll bar is shown in purple.

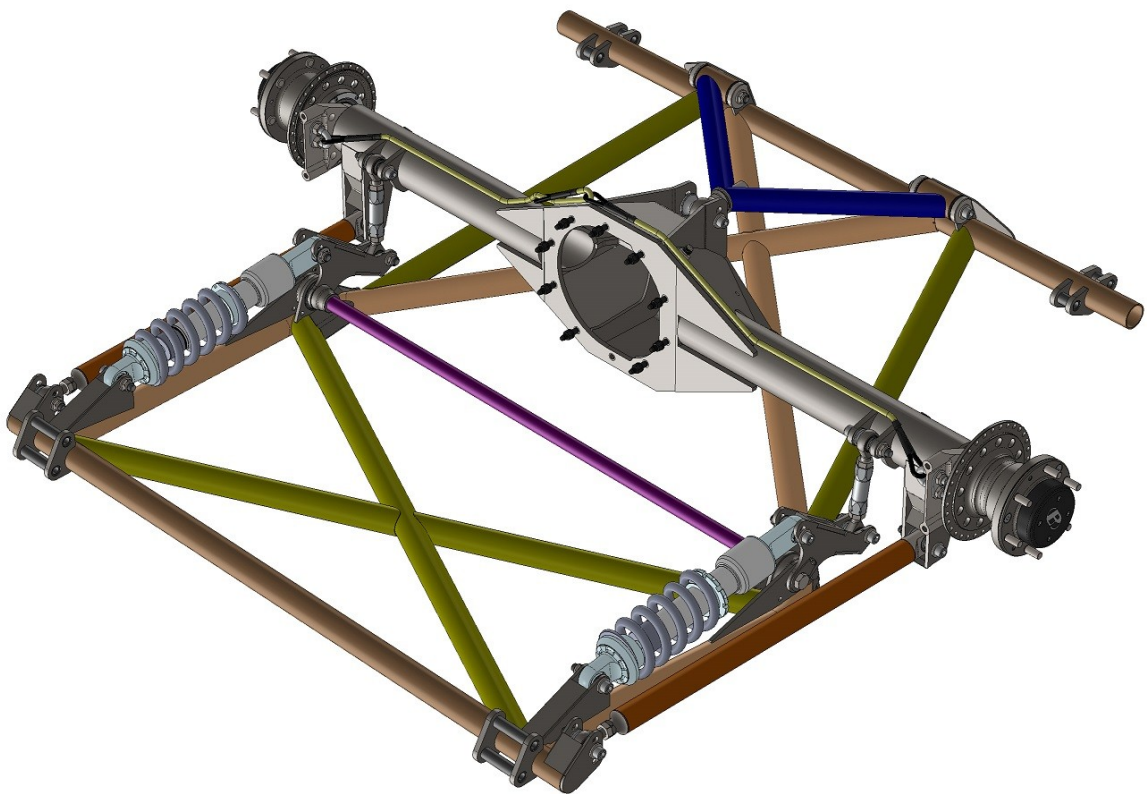


Image Copyright Pace Innovations Pty Ltd and used with permission.

U-bar and Bellcrank

This style is only available in conjunction with chassis mounted bellcranks.

The anti-roll bar is mounted on the chassis and the links connect to the bellcrank.

T-bar and Bellcrank

This style is only available in conjunction with chassis mounted bellcranks.

The anti-roll bar is mounted on the chassis and the links connect to the bellcrank.

10.2 Car end and car side

The [Front] or [Rear] tab choice will indicate the currently selected vehicle end.

The [LH] or [RH] tab choice will indicate the currently selected vehicle side.

These tabs acts as a toggle, and selecting this tab will switch between each of two.

Depending on the vehicle configuration, some menu bar items may not be available.

When a dialog box is opened, the title will include the currently selected car end and car side. If the car side is not shown, then the dialog box applies to both sides. If the car end is not shown, then the dialog box applies to both ends.

10.3 Chassis mounting

From the Spring, Shock, ARB tab, select Chassis Mtg.

Each shockabsorber and 'non-coilover' spring will require a chassis mounting point.

Enter the values for the shock absorber(s) chassis mounting point.

If the spring is not a 'coilover', then enter the values for the spring(s) chassis mounting point.

If the spring is a 'coilover', there is not a spring chassis mounting input, as the spring shares the shockabsorber mounting point.

For struts with 'coilover', there is no chassis mounting input required, as the chassis mounting point is the strut mounting point.

Note that for the bellcrank floating shockabsorber type where the shockabsorber connects between the bellcrank and A-arm, there is no chassis mounting input required. This input is for the shockabsorber mounting to the A-arm. See [suspension actuation point](#).

Torsion bar location

Longitudinal torsion bar connecting to the bottom A-arm.

Actuation point.

Specify if the torsion bar attaches to the rear A-arm chassis mounting or the front A-arm chassis mounting.

Anchor point.

Specify if the torsion bar extends forward along the A-arm pivot axis; extends rearwards along the A-arm pivot axis; or has a specified anchor point (the torsion bar is not co-axial with the A-arm pivot axis).

Chassis anchor point.

If a specified anchor point, enter the point coordinates relative to the chassis datum. After calculation this will show the actual anchor point.

Transverse torsion bar.

Actuation point.

For the transverse torsion bar that uses the bottom trailing link as the arm, this point is the bottom trailing link chassis mounting.

For the transverse torsion bar where the arm "slides" on top of the axle tube, this point should be in the centre of the arm.

Anchor point.

The anchor point is the "fixed" end of the torsion bar, with some type of adjustment for ride height. It is usually on the opposite side of the vehicle, so in this case the sign of the horizontal dimension will be negative.

For a T-bar antiroll bar the chassis mounting points are the points where the lateral chassis mounting tube attaches to the chassis.

Chassis mounting points:

Note that horizontal values are horizontal measurements from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

10.4 Leaf spring chassis mounting

From the Shock, Spring and Arb tab, select Chassis.

The primary chassis location point is the spring centre bolt. The vertical dimension is taken to the underside of the main leaf, the horizontal dimension is taken to the spring centre bolt (which would usually be zero for a horizontal leaf spring, but is positive in the direction of the positive horizontal axis if the mounting is offset), and the longitudinal dimension is taken to the spring centre bolt.

There are three other dimensions, which specify the “tilt” of the spring mounting in plan, front and side view. These are specified in degrees, and are relative to the positive axis directions.

In most cases, if the vehicle is sitting level in the static position (relative to the chassis datums) then all of these dimensions can be left at zero. Small differences will have little effect on the calculations.

“Front view tilt” controls the “tilt” of the spring mounting in front (or rear) view. If the spring mounting pad is not horizontal in front view, then this will be the “tilt” (in degrees) of the mounting pad.

If the positive horizontal axis is	and the positive vertical axis is	and the positive longitudinal axis is	and the design side is	and the design side is higher than the other side, then the angle is
LH	upwards	rearwards	RH	negative
			LH	positive
		forwards	RH	positive
			LH	negative
	downwards	rearwards	RH	positive
			LH	negative
		forwards	RH	negative
			LH	positive
RH	upwards	rearwards	RH	positive
			LH	negative
		forwards	RH	negative
			LH	positive
	downwards	rearwards	RH	negative
			LH	positive
		forwards	RH	positive
			LH	negative

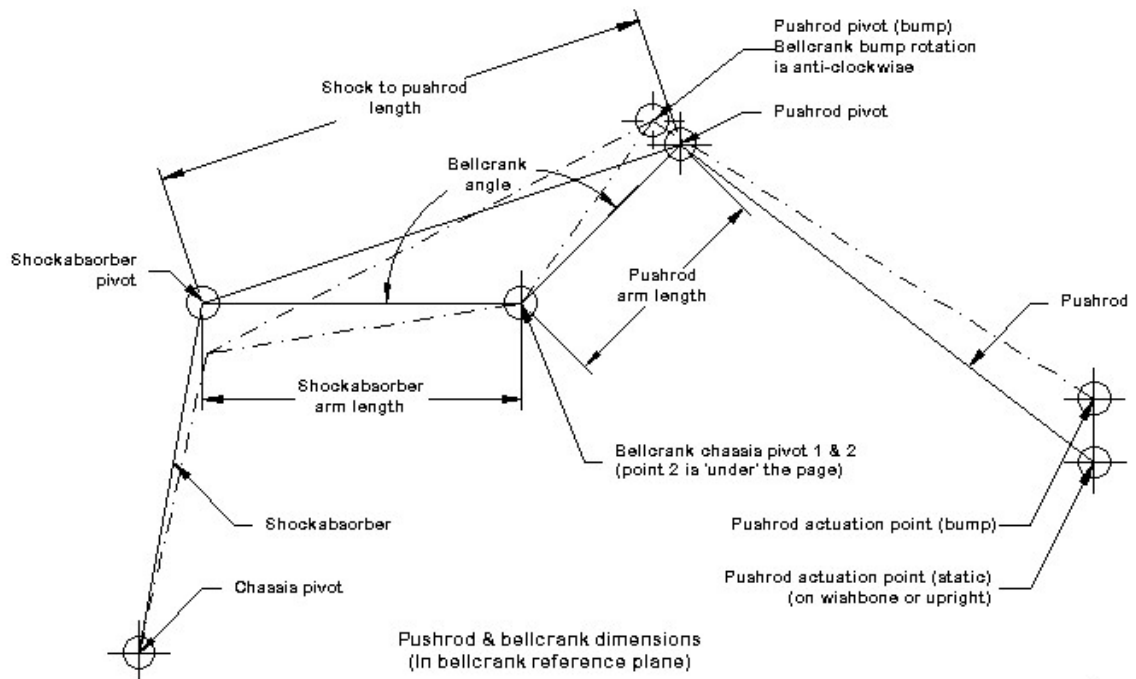
Similarly, "Side view tilt" controls the "tilt" of the spring mounting in side view. If the spring mounting pad is not horizontal in side view, then this will be the "tilt" (in degrees) of the mounting pad.

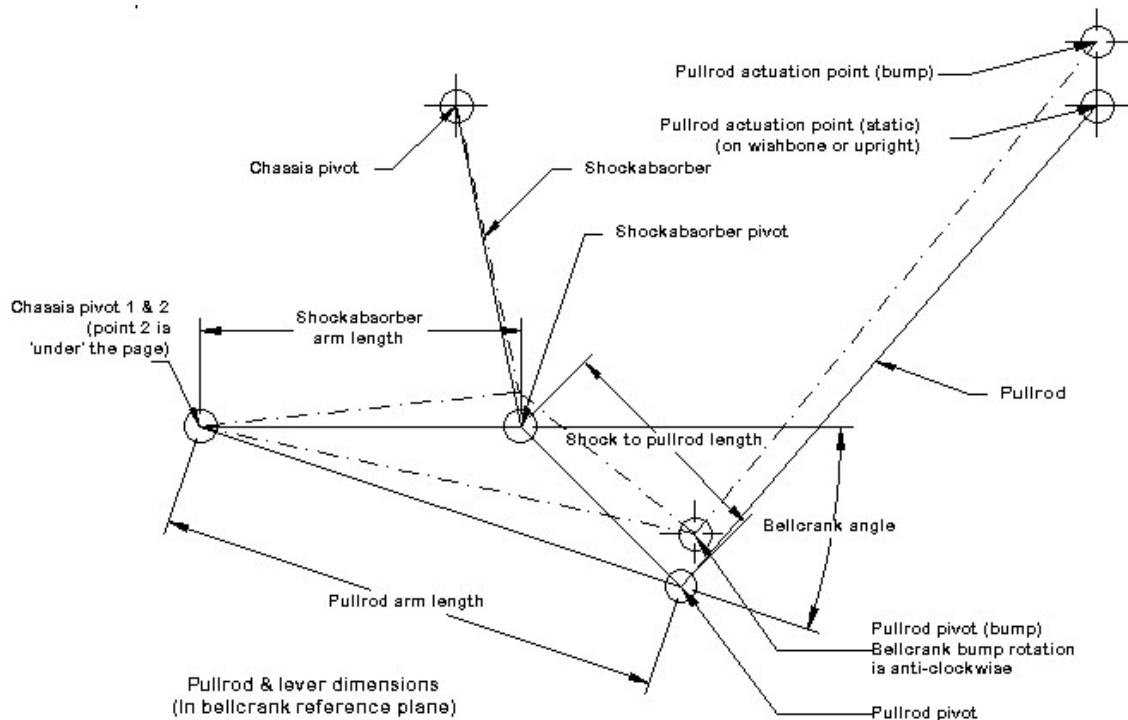
If the positive vertical axis is	and the positive longitudinal axis is	and the rear side is higher than the front side, then the angle is
upwards	rearwards	negative
	forwards	positive
downwards	rearwards	positive
	forwards	negative

Similarly, "Plan view twist" controls the "twist" of the spring mounting in plan view, and is usually zero for a symmetrical vehicle.

If the positive horizontal axis is	and the positive longitudinal axis is	and the design side is	and the design side is further forward than the other side, then the angle is
LH	rearwards	RH	negative
		LH	positive
	forwards	RH	positive
		LH	negative
RH	rearwards	RH	positive
		LH	negative
	forwards	RH	negative
		LH	positive

10.5 Bellcrank mountings





This is only available if a pullrod or pushrod bellcrank has been specified.

From the Spring, Shock, ARB tab, select Bellcrank.

Enter the values for the bellcrank chassis pivot axis.

Point 1 is the chassis pivot point in the reference plane of the bellcrank (and this would usually be in the centre of the bellcrank bearing).

Point 2 is a reference point on the bellcrank pivot axis and can be any convenient point. Note that point 2 values are relative to the bellcrank pivot chassis location point 1. A positive horizontal dimension means that point 2 is further outboard than point 1. If the vertical axis is positive upwards, a positive vertical dimension means that point 2 is above point 1; if the vertical axis is positive downwards, a positive vertical dimension means that point 2 is below point 1. If the longitudinal axis is positive rearward, a positive longitudinal dimension means that point 2 is rearward of point 1; if the longitudinal axis is positive forward, a positive longitudinal dimension means that point 2 is forward of point 1.

If the "Calc pivot 2?" checkbox is ticked, then the bellcrank pivot axis will be calculated such that a line from the shock absorber chassis mounting point to the bellcrank pivot axis forms a right angle; and a line from the pullrod (or pushrod) attachment point on the A-arm (or upright) to the bellcrank pivot axis forms a right angle.

This ensures that the shock absorber chassis mounting point lies on the rotational plane of the bellcrank shock arm; and the pullrod (or pushrod) attachment point on the A-arm (or upright) lies on the rotational plane of the bellcrank pushrod/pullrod arm. In the static position, this will eliminate any axial loading in the bellcrank bearings.

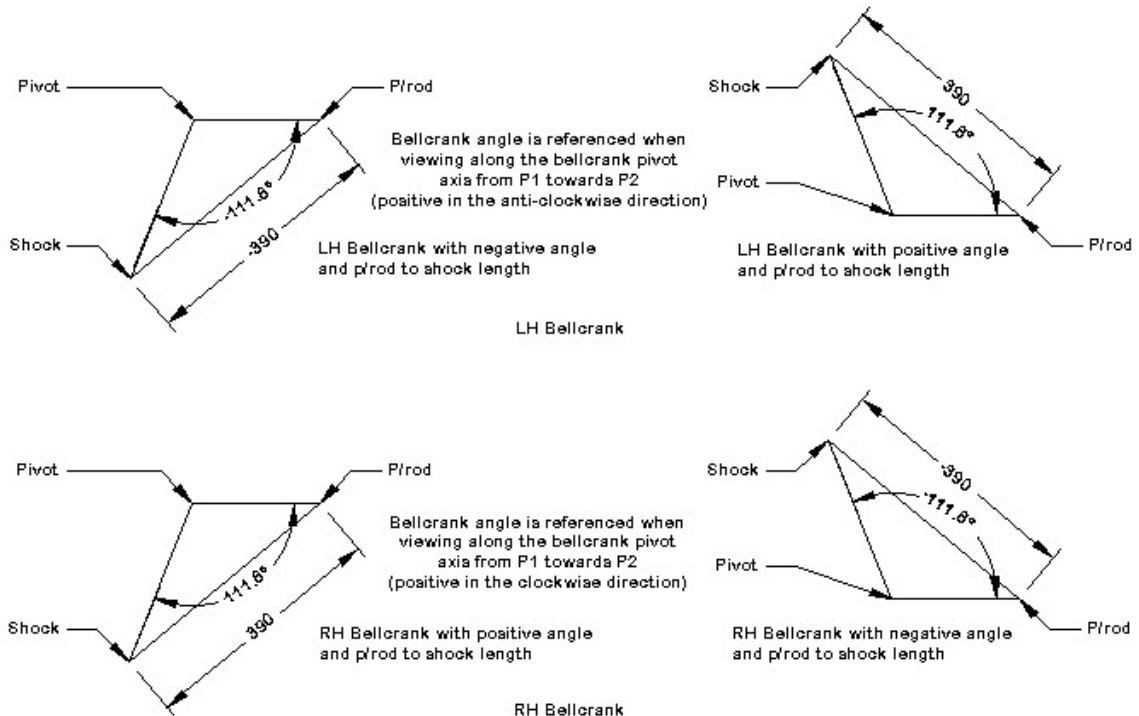
Additionally, the calculation uses the entered value of point 2 to determine the orientation of the bellcrank axis, and will update it with the calculated value.

If the calculated point 2 is not in the desired direction, then remove the -ve sign from the negative dimensions and add a negative sign the positive dimensions and then recalculate.

Note that this functionality is available for shockabsorber and bellcrank configurations.

Specify the direction of bellcrank rotation in bump.

Enter the bellcrank rotation direction when the wheel is moved into a bump position. The bellcrank rotation is referenced looking along the bellcrank pivot axis in the direction of point 1 towards point 2. Ensure that the car side shown in the dialog box title is the same as the vehicle side that you are "bumping", because the LH and RH bellcranks rotate in opposite directions in bump.



Enter the values for the bellcrank.

The bellcrank will have either two or three arms, one for each of the pull or pushrod, one for the shockabsorber (if specified) and one for the antirollbar (if specified).

For the pullrod or pushrod arm, enter the length and offset of the bellcrank arm.

If a bellcrank actuated shockabsorber is specified, enter the length and offset of the bellcrank arm, and either the distance between the shock mounting point and the rod mounting point, or the angle between the two arms. The other dimension will be calculated when the static calculation is done.

Note that if the pullrod calculation is specified as "Autocalc", neither the distance nor the angle can be specified as both will be calculated.

If a bellcrank actuated antirollbar is specified, enter the length and offset of the antirollbar arm, and either the distance between the antirollbar mounting point and the rod mounting point, or the angle between the two arms. The other dimension will be calculated when the static calculation is done.

The arm lengths are measured in bellcrank plan view, and the offsets are relative to the bellcrank reference plane. The offsets are positive if in the same direction as the bellcrank pivot axis reference point, negative if in the opposite direction.

Shock to p/rod pivot length is the distance between the shock absorber connection point and the pushrod connection point.

For the LH bellcrank, the distance is positive when the shock mounting point is closest anti-clockwise, and negative when clockwise.

For the RH bellcrank, the distance is positive when the shock mounting point is closest clockwise, and negative when anti-clockwise.

The bellcrank angle will be 0 when all three points (rod, shock and pivot) are in a straight line with the rod and shock pivots on the same side of the bellcrank pivot.

The bellcrank angle will be 180 when all three points (rod, shock and pivot) are in a straight line with the rod and shock pivots on opposite sides of the bellcrank pivot.

Bellcrank angle is measured in the bellcrank reference plane, with pivot point 2 'away' and the p/rod point to the right.

Bellcrank angle is between -180 and +180 degrees.

For the LH bellcrank, the angle is positive when the shock mounting point is closest anti-clockwise, and negative when clockwise.

For the RH bellcrank, the angle is positive when the shock mounting point is closest clockwise, and negative when anti-clockwise.

Note that both the angle and the shock to p/rod distance will either be both negative, or both positive.

Usually, the LH and RH bellcrank angles and shock to p/rod pivot lengths will be equal and opposite.

Except for the pivot axis reference point, shock to p/rod distance, and pivot point offsets, all bellcrank dimensions are positive and are measured in bellcrank plan view.

For pullrod configurations, the bellcrank is more usually referred to as a lever although the menu input is the same.

Chassis mounting points:

Except for the pivot axis reference point, note that horizontal values are horizontal measurements from the chassis centreline, vertical values are vertical measurements from the chosen chassis vertical datum, either [ground based vertical datum](#), or [chassis based vertical datum](#), and longitudinal values are horizontal measurements from the chosen chassis longitudinal datum.

10.6 Suspension actuation point

This will be the attachment point of the shockabsorber, spring, pushrod or pullrod to the A-arm, suspension link or upright depending on the spring type chosen.

Each of the configured shockabsorbers will require a linkage mounting point.

If a configured spring is not a 'coilover', then the spring will also require a linkage mounting point.

For struts with 'coilover', there is no linkage mounting input required, as that point is on the strut.

For a bellcrank actuated shock this will be the attachment point of the pull or pushrod. The attachment point of the shock to the bellcrank is specified as part of the bellcrank. See Spring, Shock, ARB tab, then Bellcrank.

From the Spring, Shock, ARB tab, select Susp.

Note that for the bellcrank floating shockabsorber type, this input is for the pushrod mtg to the A-arm.

For each of the configured items, there will be a "tab". If there is more than one "tab", then select each in turn to enter the actuation point values.

For a transverse torsion bar where the arm is the lower link there is no linkage mounting input required, as that point is on the birdcage.

For a transverse torsion bar where the arm slides on the top of the axle tube, input the length of the arm. Measured from the centre of the torsion bar to the tip of the arm. The actual actuation point will be where the torsion bar arm contacts the axle tube.

After the static spring geometry has been calculated, the values relative to the suspension datums (if vehicle was specified) and vehicle (if a suspension item was specified) will be shown.

10.6.1 Actuation point on A-arm

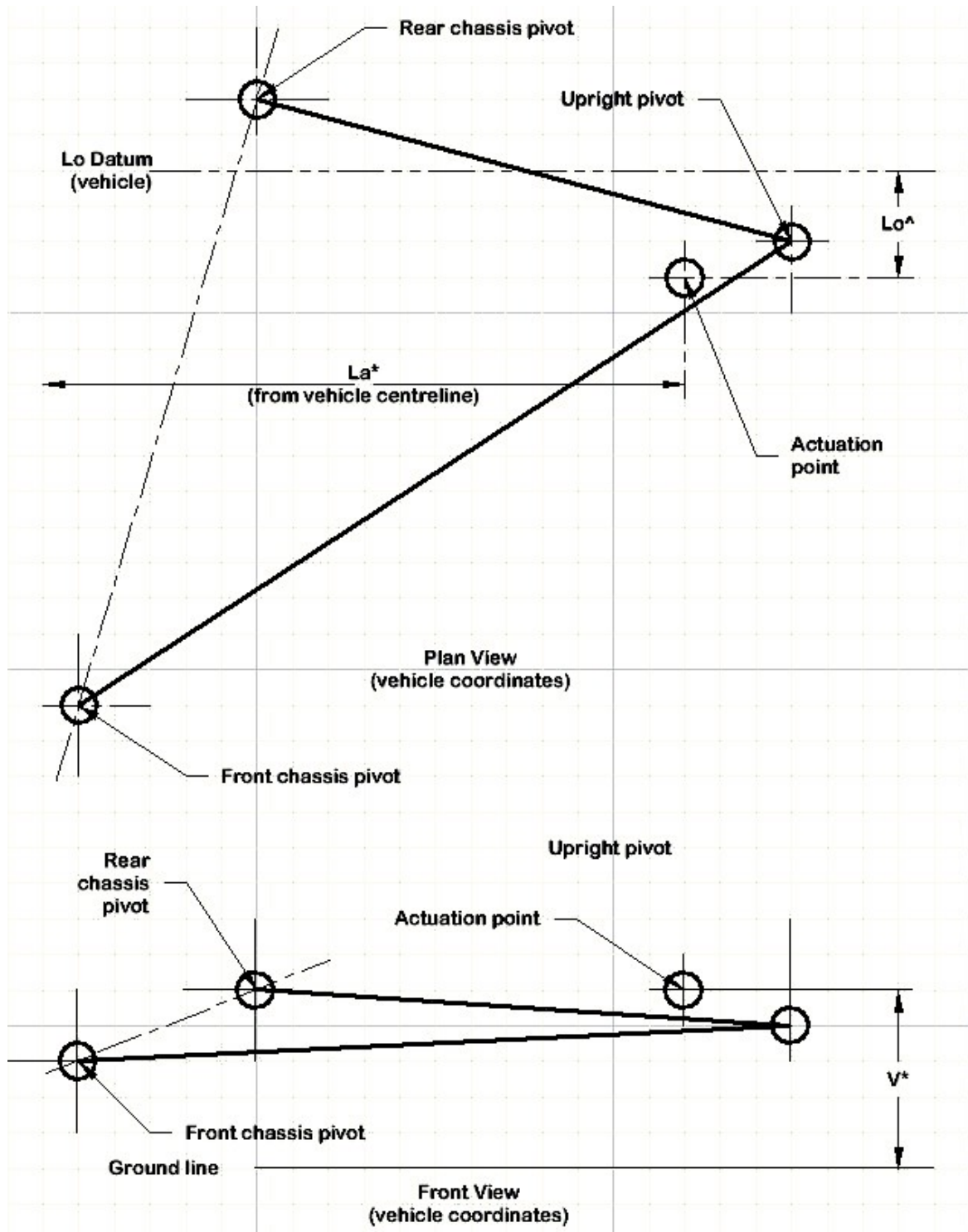
This will be the attachment point of the shockabsorber, spring, pushrod or pullrod to the A-arm.

After the static spring geometry has been calculated, the values relative to A-arm datums (if vehicle was specified) and vehicle (if A-arm was specified) will be shown.

Enter the values for the mounting point on the A-arm.

A choice is available allowing the actuation point to be specified relative to the A-arm itself, or to vehicle coordinates.

A-arm mounting using vehicle coordinates



When the A-arm pivot axis is not in line, or the A-arm is of an awkward shape, then the vehicle coordinates may be easier to measure.

The actuation point is measured relative to the vehicle datums. These datums are the vehicle centreline, the ground plane and the longitudinal reference plane.

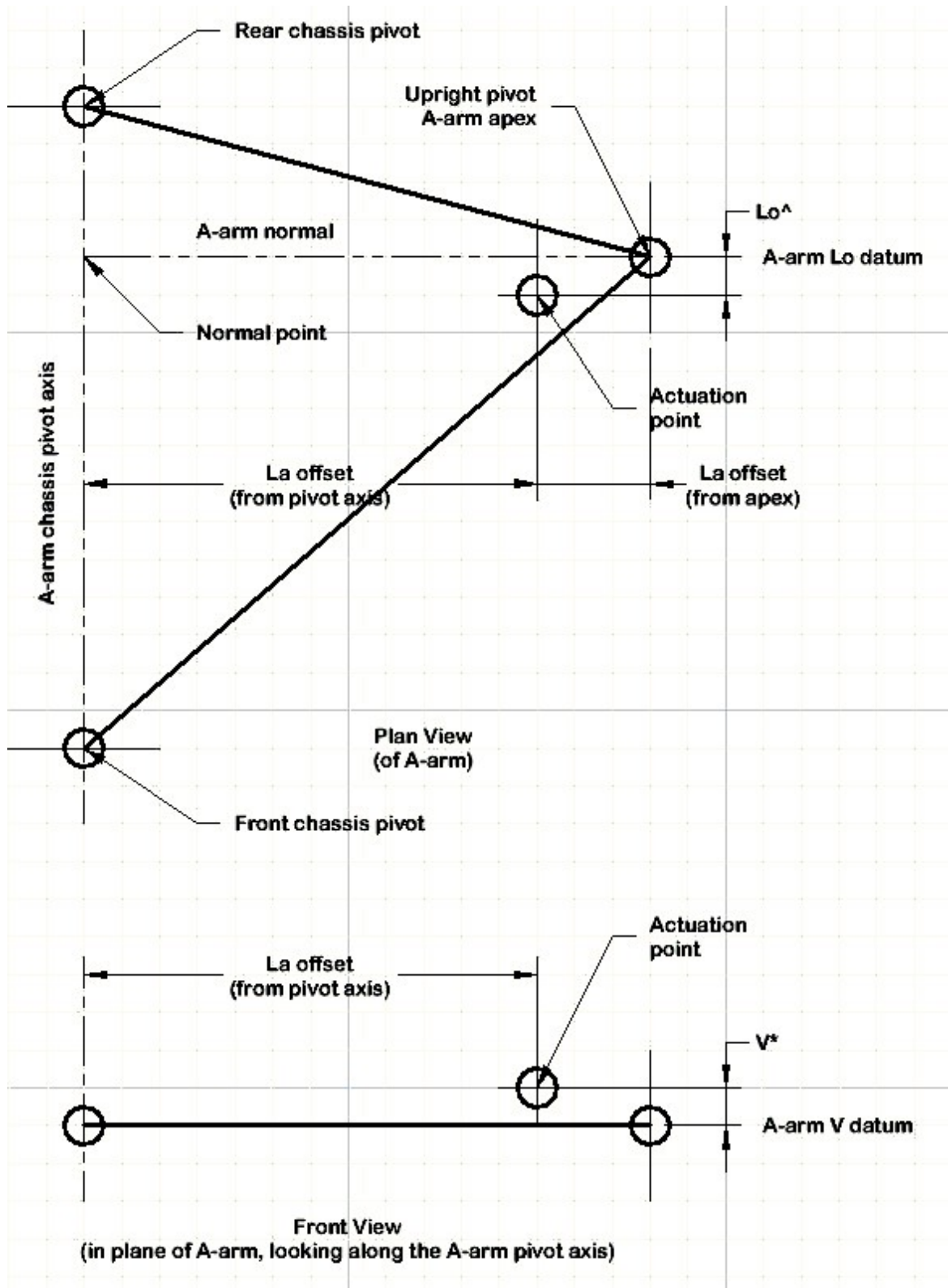
The horizontal dimension is the distance from the vehicle centreline. Horizontal dimension for one side will be positive (in the direction of the positive horizontal axis), and negative for the other.

The vertical value is the distance above the ground. If the vertical axis is positive upward, then this will be positive; if the vertical axis is positive downward, then this dimension will be negative.

The longitudinal value is the distance behind or front the longitudinal reference plane. If the longitudinal axis is positive rearward, then a positive dimension is behind the longitudinal reference plane and a negative dimension is in front of the longitudinal reference plane; if the longitudinal axis is positive forward, then a positive dimension is in front of the longitudinal reference plane and a negative dimension is behind the longitudinal reference plane.

After calculation, the A-arm coordinates will be available, according to the specified options.

A-arm mounting using A-arm chassis pivot axis



When the A-arm "shape" is fixed, then this option is appropriate.

Specify the horizontal dimension from "A-arm chassis pivot axis"

The actuation point is measured relative to the A-arm datums. These datums are the A-arm pivot axis (the base line joining the chassis front & rear pivot points), the line joining the upright pivot point to the normal pivot point (the A-arm normal link length) and the plane of the three pivot points.

The horizontal dimension is specified from the A-arm pivot axis.

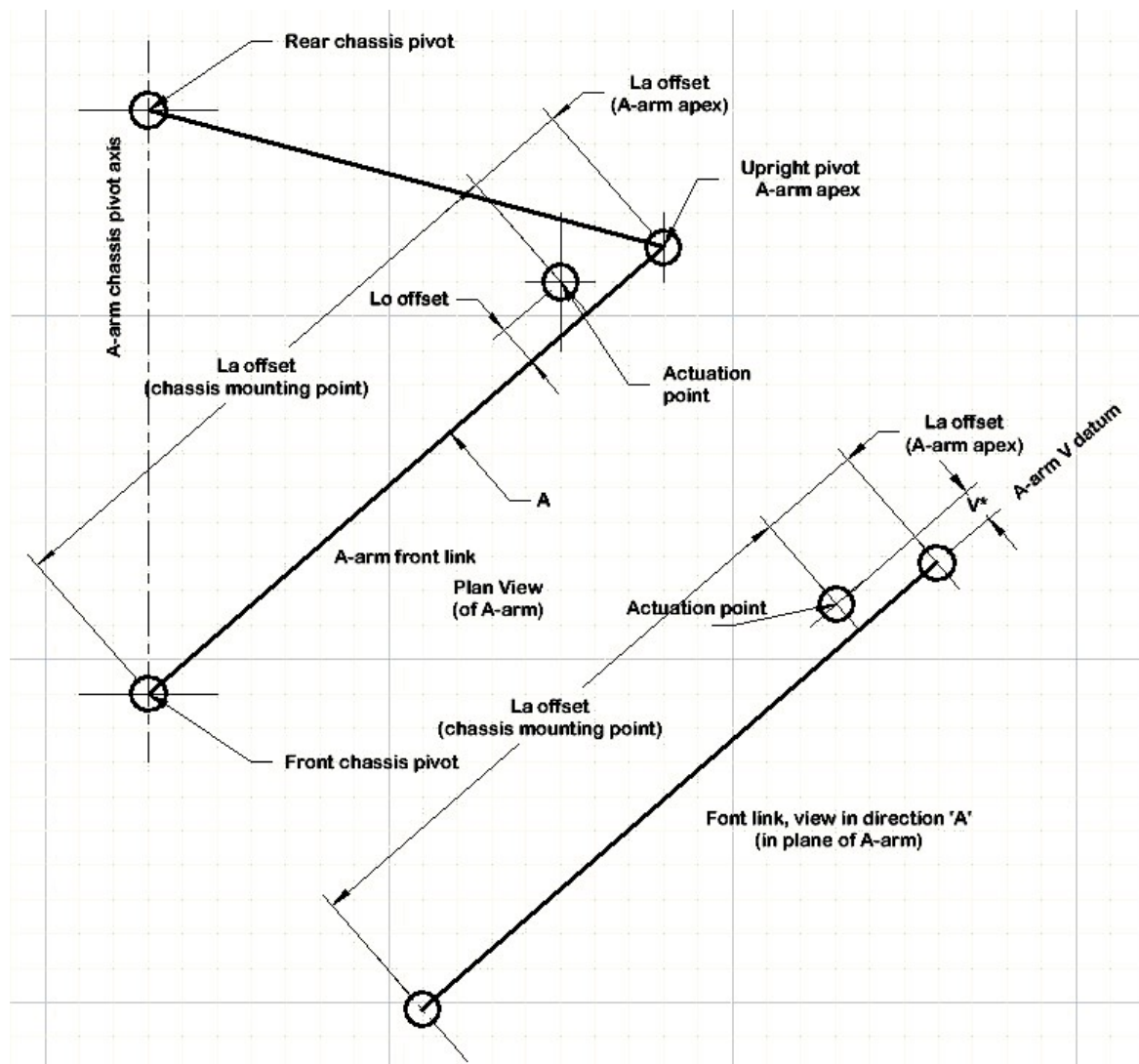
If using the A-arm pivot axis, the horizontal dimension is the distance from the A-arm pivot axis along the normal line to the A-arm apex. Positive dimensions are in the outboard direction (toward the upright), and negative dimensions are in the inboard direction (away from the upright). For the older style rocking top A-arm configuration, this dimension would be negative.

The vertical value is the distance above or below the plane of the A-arm. If the vertical axis is positive upward, then a positive dimension is above the A-arm plane and a negative dimension is below the A-arm plane; if the vertical axis is positive downward, then a positive dimension is below the A-arm plane and a negative dimension is above the A-arm plane.

The longitudinal value is the distance behind or front of the normal line. If the longitudinal axis is positive rearward, then a positive dimension is behind the normal line and a negative dimension is in front of the normal line; if the longitudinal axis is positive forward, then a positive dimension is in front of the normal line and a negative dimension is behind the normal line.

Instead of the 'normal line', a line normal to the A-arm pivot axis from either the front chassis pivot or the rear chassis pivot can be used.

A-arm mounting using A-arm apex or A-arm chassis pivot



When the A-arm is adjustable, especially when formed from two separate links, it is more appropriate to use one of the links as the reference datum.

The actuation point is measured relative to one of the A-arm links. The reference points are the link chassis mounting and upright mounting points. The vertical datum is the plane of the three pivot points.

The horizontal dimension is measured along the link, and can be specified from either the A-arm chassis pivot or the A-arm apex (upright pivot).

If using the A-arm chassis pivot, the horizontal dimension is the distance from the chassis pivot along the link centreline to the upright pivot. Positive dimensions are in the outboard direction (toward the upright), and negative dimensions are in the inboard direction (away from the upright). For the older style rocking top A-arm configuration, this dimension would be negative.

If using the A-arm apex (upright pivot), the horizontal dimension is the distance from the upright pivot along the link centreline to the chassis pivot. Positive dimensions are in the inboard direction (away from the upright).

The vertical value is the distance above or below the plane of the A-arm. If the vertical axis is positive upward, then a positive dimension is above the A-arm plane and a negative dimension is below the A-arm plane; if the vertical axis is positive downward, then a positive dimension is below the A-arm plane and a negative dimension is above the A-arm plane.

The longitudinal value is the distance behind or front of the link centreline. If the longitudinal axis is positive rearward, then a positive dimension is behind the link centreline and a negative dimension is in front of the link centreline; if the longitudinal axis is positive forward, then a positive dimension is in front of the link centreline and a negative dimension is behind the link centreline.



Typical adjustable A-arm.

Adjusting the camber and or [caster](#) changes the link lengths, hence the shock mount moves relative to the A-arm chassis pivot axis. The shock mount remains fixed relative to the upright ball joint end of the camber control link. When the [caster](#) link is bolted to the camber link, the assembly is equivalent to a rigid A-arm.

In this example the mounts are referenced from the upright end of the rear link.

The shock mount X dimension will be positive (around 75mm), the Y dimension positive (around 50mm) and the Z dimension zero (because the mount is on the link centreline).

The antirollbar mount (it fixes with a horizontal bolt through the link) would have dimensions X = 110mm, Y = 0mm, Z = 40mm.

Image © 2010 Gary Rogers Motorsport. Used with permission.

10.6.2 Actuation point on trailing link

This will be the attachment point of the shockabsorber, spring, pushrod or pullrod to the suspension link.

After the static spring geometry has been calculated, the values relative to the link datums (if vehicle was specified) and vehicle (if link was specified) will be shown.

Enter the values for the mounting point on the suspension trailing link.

The actuation point is measured relative to either the link chassis mounting or the link suspension mounting, and the link centreline.

The horizontal value is the distance from the link chassis pivot along the link centreline to the link axle pivot point.

The vertical value is the distance above or below the link centreline. If the vertical axis is positive upward, then a positive dimension is above the link centreline and a negative dimension is below the link centreline; if the vertical axis is positive downward, then a positive dimension is below the link centreline and a negative dimension is above the link centreline.

The longitudinal value is always 0.00.

10.6.3 Actuation point on upright

This will be the attachment point of the shockabsorber, spring, pushrod or pullrod to the upright.

After the static spring geometry has been calculated, the values relative to upright datums (if vehicle was specified) and vehicle (if upright was specified) will be shown.

Enter the values for the upright suspension actuation mounting point.

10.6.4 Actuation point on strut

The anti-roll bar attachment point of the shockabsorber, spring, pushrod or pullrod to the upright.

For integral strut tube and knuckle, the mounting point is measured relative to the wheel mounting flange, the axle centreline and a vertical line through the axle centreline parallel to the strut rod axis with the strut rod vertical (in side view).

[See integral strut tube and knuckle.](#)

For separate strut tube and knuckle, the mounting point is dimensioned from the strut rod centreline (with positive H dimensions towards the outside of the vehicle) and negative V dimensions for those below the bottom of the strut.

[See separate strut tube and knuckle.](#)

10.6.5 Actuation point on Dual-axis strut

The anti-roll bar mounting point is dimensioned from the strut rod centreline (with positive H dimensions towards the outside of the vehicle) and negative V dimensions for those below the bottom of the strut.

[See Dual-axis strut.](#)

10.6.6 Actuation point on kingpin swivel

10.7 Pushrod, pullrod & shock absorber static lengths

This is only available for pushrod and pullrod bellcrank.

There are three alternative calculation methods.

1. Autocalc.
2. Specify the pullrod (or pushrod) length, or
3. Specify the shock absorber length, or

From the Spring, Shock, ARB tab, select Pullrod or Pushrod.

If a bellcrank actuated shock is specified (with or without a bellcrank antirollbar)

Option 1

Select 'Autocalc' for AutoCalculation of the shock absorber and push/pullrod length.

This will adjust the bellcrank arm angle so that the centrelines of both the shock absorber and push/pullrod are at right angles to the bellcrank arms, and calculate the static shock length and the push/pullrod length.

This can be used for the initial design where the shock absorber and push/pullrod lengths may not be known, and provide a convenient starting point for the design refinement process. Note that this option does not guarantee that there is enough suspension linkage travel to allow the required suspension travel.

After calculation, the pushrod (or pullrod) and shock absorber lengths will be shown. The revised bellcrank dimensions can be seen in the bellcrank dialog box.

Option 2

Select "pullrod length"

Enter the pushrod (or pullrod) length at the static ride height.

The bellcrank dimensions must be fully specified and the bellcrank dimensions will remain unchanged.

After calculation, the static shock length will be shown.

Option 3

Select "shock length".

Enter the shock absorber length at the static ride height.

The bellcrank dimensions must be fully specified and will remain unchanged.

After calculation, the pushrod (or pullrod) length will be shown.

If a bellcrank actuated antiroll is specified (without a bellcrank shock).

Option 1

Select 'Autocalc' for AutoCalculation of the push/pullrod length.

This will align the bellcrank so that the centreline of push/pullrod is at right angles to the bellcrank arm.

This can be used for the initial design where the push/pullrod length may not be known, and provide a convenient starting point for the design refinement process. Note that this option does not guarantee that there is enough suspension linkage travel to allow the required suspension travel.

After calculation, the pushrod (or pullrod) length will be shown.

Option 2

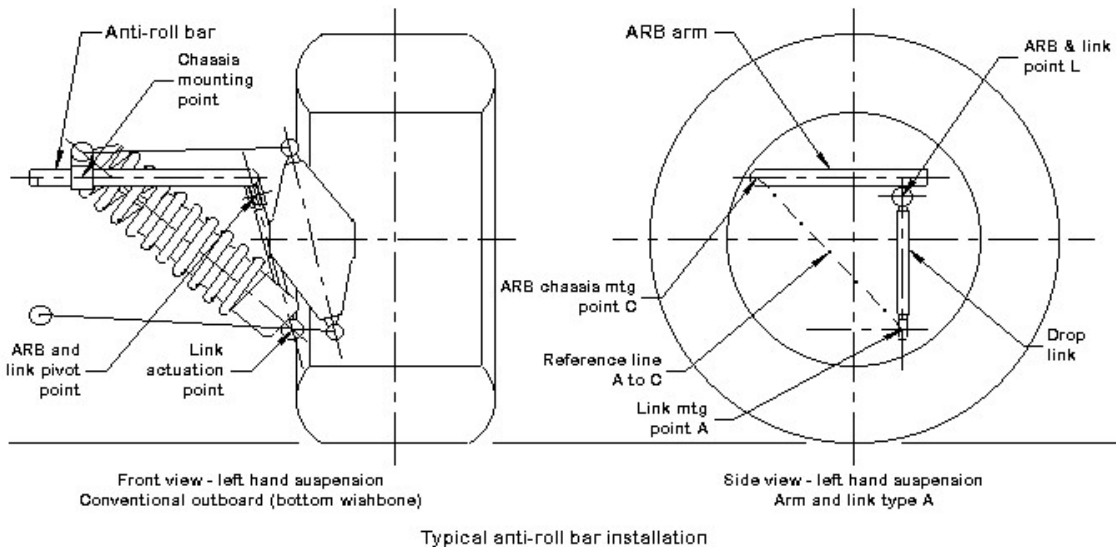
Select "pullrod length"

Enter the pushrod (or pullrod) length at the static ride height.

For both options, the bellcrank dimensions must be fully specified and will remain unchanged.

The lengths to the bellcrank chassis pivot are shown for reference.

10.8 Anti-roll bar link dimensions



From the Spring, Shock, ARB tab, select ARB.

For all anti-roll bar types where the anti-roll bar mounts to the chassis, the anti-roll bar chassis mounting is point C, the link actuation is point A, (on the A-arm, upright or bellcrank as appropriate) and the anti-roll bar & link pivot is at point L.

For live axle rear suspensions with the anti-roll bar mounted on the axle, the anti-roll bar axle mounting is point C, the link actuation is point A, (on the chassis) and the anti-roll bar & link pivot is point L.

Initially these will be zero, but will be correct after Calculate Static. These should be checked to confirm that the anti-roll bar arm is correctly specified.

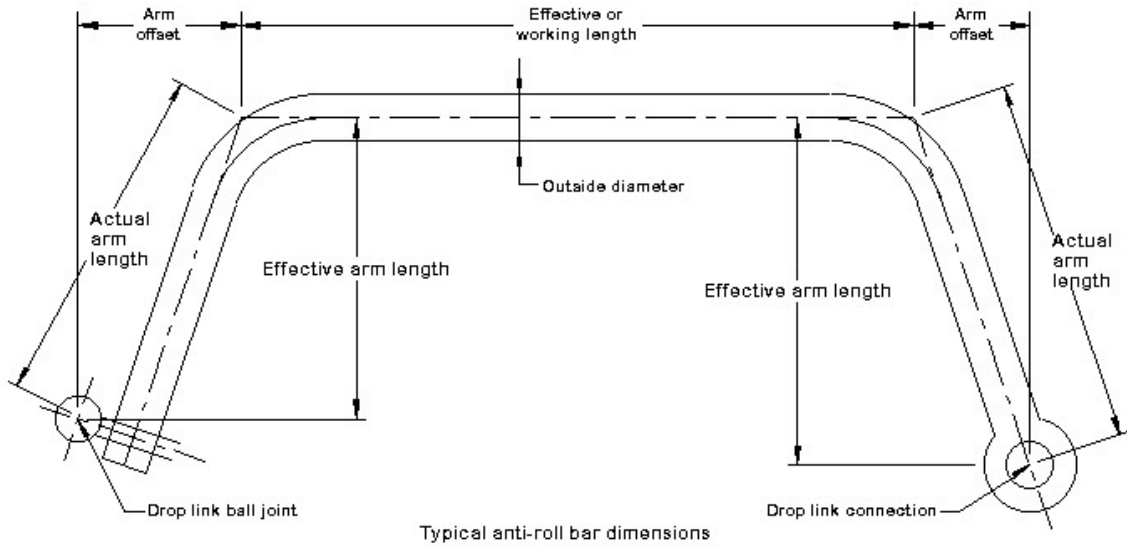
If the anti-roll bar attaches directly to the actuation point, enter the anti-roll bar link length as zero 0.00 and click "Specify".

If the anti-roll bar attaches to a link, then either enter the link length and click "Specify", or leave it as 0.00 and specify "AutoCalc".

If "AutoCalc", SusProg3D will calculate a link length so that the link will connect to the anti-roll bar arm at approximately right angles (in side view). This can be used for the initial design where the link length may not be known, and provide a convenient starting point for the design refinement process.

If the link and arm orientation is incorrect, then click "Invert", Apply and recalculate.

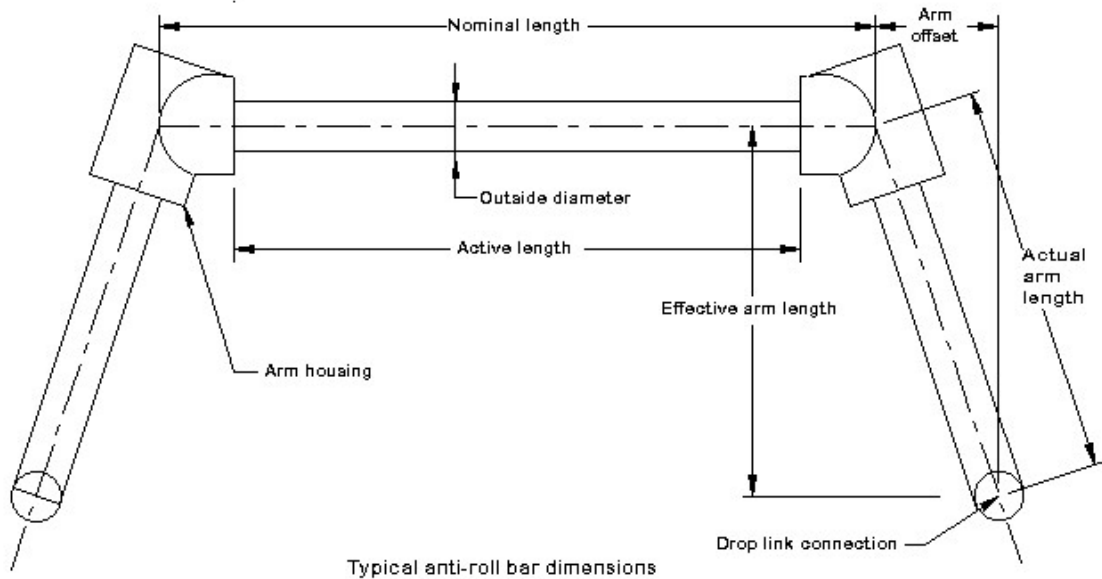
10.9 Anti-roll bar dimensions



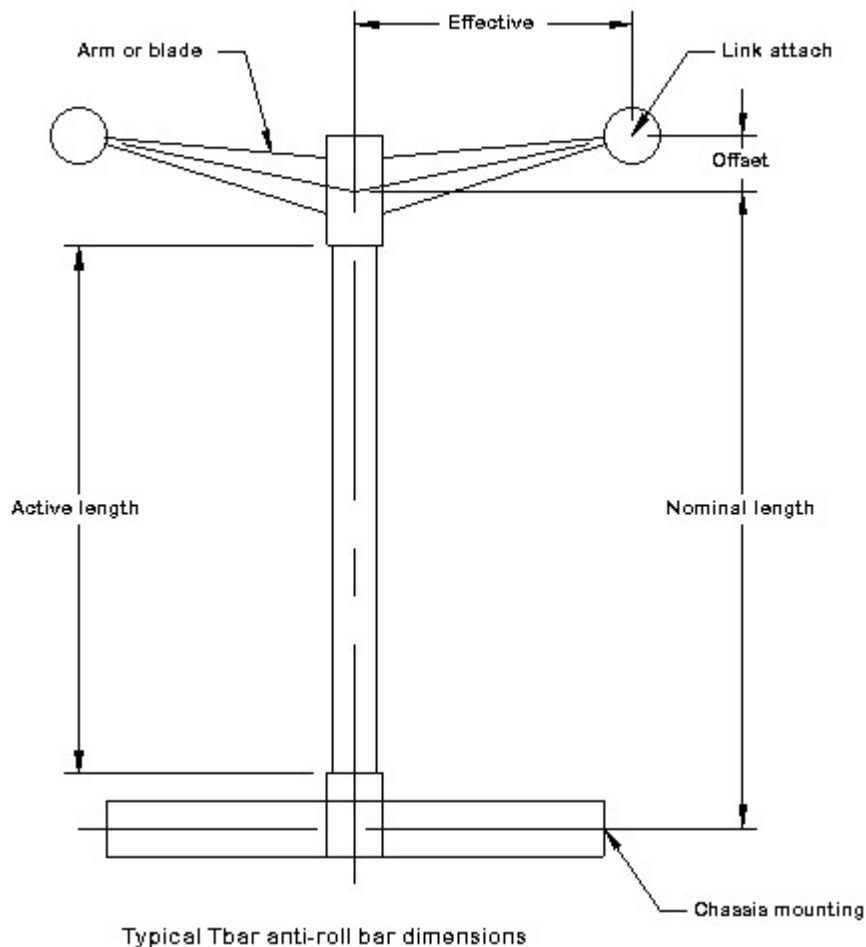
From the Spring, Shock, ARB tab, select ARB.

Enter the appropriate dimensions.

Active length is the effective or working length of the anti-roll bar.



Nominal length is distance between the arm mountings (where the arms are attached to housings) or the distance between the arm bend points.



For a T-bar anti roll bar, the active length is that length of the vertical section that actually twists under load. The nominal length is the distance from the chassis mounting centreline to the T-bar arm centreline.

If a solid bar, then leave the inside diameter as zero.

Enter the arm offset (if any) and either the actual or effective arm length. Use the choice box to indicate which dimension should remain as entered, and SusProg3D will calculate the other.

Specify whether the anti-roll bar arm is bent (from the same material as the anti-roll bar) or is a separately attached arm. A separate arm is considered rigid and has no effect on the anti-roll bar spring rate, a "bent arm" is considered to deflect and has the effect of softening the anti-roll bar spring rate.

Refer to the [anti-roll bar rate](#) calculations.

See [Anti-roll bar link dimensions](#) for additional input.

After Spring, Shock, ARB | Calculate, the calculated values will be correctly displayed.

Some anti-roll bar vendors test their bars on an "Intercomp Sway Bar Tester" or similar machine. If the vendor supplied spring rate does not agree with the SusProg3D calculated rate, use the "Cf" to specify a correction factor. There may be differences in the material specifications and heat treatment methods which cause differences between the theoretical and the actual spring rates.

10.10 Spring parameters

10.10.1 Coil spring parameters

From the "Spring, Shock, Arb" or the "Rates" tab, select Spring.

The "Spring, Shock, Arb" Calc should be done before designing the spring.

Units

- | | |
|----------|---|
| Metric | If working in the metric system you can choose for spring data to be presented in SI (Metric) or US Customary (Imperial) units.
If you specify Metric, then rates are N/mm, loads are Newtons, stress is MPa and dimensions are mm.
If you specify Imperial, then rates are lb/in, loads are lbs, stress is psi and dimensions are inches.
Note that the spring mounting lengths and spring seats will remain in mm. |
| Imperial | If working in the US Customary (Imperial) system, then rates are lb/in, loads are lbs, stress is psi and dimensions are inches. |

Spring system

For coilover spring, specify the type of spring. Either a single spring (constant rate) or dual springs (primary and secondary combination, with or without a stop ring).

Non-coilover springs are all single springs (constant rate).

Spring rate and load

Specify either suspension frequency (Hz) or the wheel rate (N/mm or lb/in) to be used in the calculation.

Specify the appropriate value for frequency or wheel rate. When you finish inputting the value, the other values in this group will recalculate.

The static spring load is derived from the individual corner mass and the static spring motion ratio. These values are also used to calculate the frequency from the wheel rate, and the wheel rate from the frequency. The static spring rate is then calculated using the motion ratio.

For a pushrod monoshock spring, the rates used are half the "real" spring rates.

For a Jaguar IRS with two coilover shock absorbers per side, the spring rate and all of the spring design data is for a single spring. It is assumed that both springs are identical.

For struts with 'coilover springs', the spring axis is assumed to be coaxial with the strut axis (ie the strut rod and tube centreline). This will be the situation for most race cars, particularly those with threaded adjustments for the bottom spring mount. Most production cars have the spring axis coaxial with the strut top mounting and the bottom ball joint or centreline of the wheel contact patch. This situation creates additional stresses within the spring as it undergoes an additional bending component as well as the usually axial length change. There is no allowance for this type of spring offset and with small amounts should have a negligible effect on calculated rates.

Spring seats

Enter the axial distance the spring seats are from the shock shaft and body mounting points.

For a strut, the "shock shaft" mounting reference point is the strut top mount, and the "shock body" mounting reference point is the strut rod bottom point.

If a main and tender spring combination, enter the thickness of the spacer between the two springs. If there is no spacer, enter zero.

The distance between the mounting points is shown for reference.

For a coilover, these are the shock mountings and for a strut they are the strut top mount and the strut rod bottom point.

The resultant static spring length is shown for reference.

Note that this spring length is the distance between the spring seats. In the case of a main and tender spring combination it is the length of each of the springs in the static position plus the spacer thickness.

If using dual springs with a stop ring, then specify the distance between the corresponding faces of the stop ring and the spacer ring in the static position.

Specify the type of coil spring end. Both ends will be the same. For a main and tender spring combination, both springs will have the specified spring end type.

Coil spring design (single spring, constant rate).

Specify the wire section, either "Round" or "Rectangular".

Choose Calculated, Actual, Coils or Wire.

"Calculated" will use the spring rate that is specified in "Spring rate and load" together with the specified spring seat dimensions, and will calculate a spring to provide the specified static load at that length.

This option is most appropriate when a custom wound spring is required.

The "Actual, Coils or Wire" option will use specified spring dimensions. This means that the spring length at the static load will be calculated, and the lower spring seat (the spring seat on the shock absorber body) will be adjusted to suit. In addition, when any dimensions are changed that would effect the static spring length, the spring seat will be adjusted. Also, this spring rate will be "back calculated" to determine the wheel rate and suspension frequency. This option is most appropriate when an "off the shelf" spring must be used. Generally the spring manufacturers offer a range of springs identified with the free length and rate, but may not indicate the wire diameter or coil count. In this case you can use either Coils or Wire dia to generate an appropriate spring although the coil count and wire diameter may differ slightly.

For example, the Eibach catalog does not indicate the wire diameter or the coil count, but does include the solid height. So you can use either "Coils" or "Wire" option and adjust the dimension until the solid height is correct.

Calculation option	Required input	Calculated data
Calculated	Suspension frequency or spring rate Spring seat dimensions Spring inside diameter	The wire diameter or wire section, number of active coils and spring free length will be calculated with a minimum of 5 active coils and a maximum corrected static stress of 586 MPa (85,000 psi)
Actual	Number of active coils Spring wire diameter or wire thickness and width Spring inside diameter Spring free length	The spring rate will be calculated.
Coils	Number of active coils Spring inside diameter Spring free length Spring rate	The wire diameter or thickness and width will be calculated.
Wire	Spring inside diameter	The number of active coils will be calculated.

Calculation option	Required input	Calculated data
	Spring wire diameter or wire thickness and width Spring free length Spring rate	

Use the Apply button to do the calculation.

After calculating, the load-deflection graph can be viewed.

The horizontal axis is the spring deflection and the vertical axis the load.

Full droop is the dotted line, static is the solid line, and full bump is the dash dot dot line.

The diagonal line represents the spring rate. Steeper is stiffer.

If the droop load/deflection lines are not shown, then the spring is not loaded in the full droop position.

If the bump load/deflection line intersection is off the end of the spring rate line, then this means that the spring has already gone solid before the full bump position.

The number of coils, wire size and inside diameter are used to display an appropriate looking spring.

Coil spring design, primary and secondary spring combinations.

The spring that becomes solid first is the secondary spring; the other spring is the primary spring. The secondary spring is also known as the "helper" or "tender". It doesn't matter in which order the springs are fitted to the shock absorber, the same spring will always become solid first.

The transition point is that point at which the secondary spring becomes solid. Up to that point, the effective spring rate is always lower than either of the individual spring rates. At, and beyond, the transition point, the effective spring rate is that of the primary spring.

The formula to determine the initial spring rate (ie up to the transition point, when both springs are "active")

$$R_i = \frac{R_m \times R_t}{R_m + R_t}$$

The formula to determine the transition point between the initial and the final rate

$$TP = \frac{F_{ct}}{R_i}$$

where R_i is the initial spring rate, R_m is the primary (main) spring rate, R_t is the secondary (tender) spring rate, TP is the transition point, F_{ct} is the secondary spring solid load.

Generally speaking, there are two ways to employ secondary springs, and it really depends at what point you want the spring rate to change.

1. The secondary spring is solid before reaching the static position. At the static position the effective rate is the same as the main spring rate. Sometimes, if the main spring is free (ie has no deflection) in the droop position, then a very light secondary spring (aka tender spring) is used to "fill the gap". In this case the effective initial spring rate is very low, but serves to keep the main spring "in place". More usually, the secondary spring goes solid between the full droop and static position. In this case the secondary is stiffer than the primary spring, so as to obtain an appropriate load-deflection curve.
The transition point is determined by the secondary spring solid load.
2. The secondary spring is effective through droop and into the initial bump travel. The secondary spring only becomes solid after the static position. This gives a constant spring rate through droop and the first part of bump, with an increased spring rate

approaching full bump.

The transition point is determined by the secondary spring solid load.

3. The secondary spring is effective through droop and into the initial bump travel. A stop ring can be used to adjust the transition point. The secondary spring may not become solid. This gives a constant spring rate through droop and the first part of bump, with an increased spring rate approaching full bump.

This means that the transition point can be adjusted and the effective spring rate changed at a point before the secondary spring becomes solid.

When designing a main and tender spring combination (without a stop ring), using the "Calculated" option it is assumed that the secondary spring is solid between the full droop and static position.

When designing a main and tender spring combination (without a stop ring), using one of the Actual, Coils or Wire dia options, and the secondary spring is solid between the static and full bump position the static spring rate will be set to the initial spring rate, otherwise the static spring rate will be set to the primary spring rate.

When designing a main and tender spring combination (with a stop ring), it is assumed that neither spring is solid, or the secondary spring is solid between the static and full bump position. If the secondary spring is solid between the full droop and static position a warning message will display.

Calculation option	Required input	Calculated data
Calculated	Suspension frequency or spring rate Spring seat dimensions Spring inside diameter	The wire diameter or wire section, number of active coils and spring free length will be calculated with a minimum of 5 active coils and a maximum corrected static stress of 586 MPa (85,000 psi)
Actual	Number of active coils Spring wire diameter or wire thickness and width Spring inside diameter Spring free length	The spring rate will be calculated.
Coils	Number of active coils Spring inside diameter Spring free length Spring rate	The wire diameter or thickness and width will be calculated.
Wire	Spring inside diameter Spring wire diameter or wire thickness and width Spring free length Spring rate	The number of active coils will be calculated.

Use the Apply button to do the calculation.

After calculating both springs, the load-deflection graph can be viewed.

The horizontal axis is the spring deflection and the vertical axis the load.

Full droop is the dotted line, static is the solid line, and full bump is the dash dot dot line.

The transition point is shown with a dashed line.

The diagonal line represents the spring rate. Steeper is stiffer.

If the droop load/deflection lines are not shown, then the spring is not loaded in the full droop position.

If the bump load/deflection line intersection is off the end of the spring rate line, then this means that both springs have already gone solid before the full bump position.

The number of coils, wire size and inside diameter are used to display an appropriate looking spring.

If a stop ring is used then both the load and deflection at the point the stop ring is effective will be shown. The graph will also show the rates, transition point and loads as if there was no stop ring.

Note that the primary and secondary springs may be “reversed”. When calculating the primary-secondary system characteristics, the secondary spring is defined as that spring with the lowest solid load, ie it is the spring that will become solid first. If your transition deflection and load are not what you expect, then it is probable that the primary spring has a lower solid load than the secondary spring.

When designing the primary spring, if the solid load of the primary spring is less than that of the secondary spring, a message will be shown asking if you wish to swap the springs around.

The solid load of the system (ie the load at which both springs are solid) is the same as the spring with the higher solid load.

The total deflection of the system is the sum of the maximum deflection (ie free length – solid length) of each spring.

Stress

The corrected torsional stress is calculated for three deflections of the spring, using the load calculated for that deflection. “Static” is the spring in the static ride height position, “full bump” is in the full bump position, and “solid” is when the spring is solid.

The main spring should not go solid at full bump. At the very least this will be a very abrupt transition to an “infinite” spring rate.

The secondary spring is usually designed to be solid at some part of the usual suspension travel, hence the use of the solid stress when designing secondary springs.

All calculated stress values include the Wahl factor.

This calculator is not intended as a comprehensive spring calculator. The number of coils, wire size and inside diameter are used to display an appropriate looking spring.

For detailed spring design refer to appropriate literature and manufacturers.

These calculations are based on SAE HS-795.

The allowable stress includes factors such as material, forming process, post-forming treatments, fatigue limits and surface finish. The values used are indicative only. Consult your spring supplier.

The Modulus of Elasticity – Shear, G , used in these calculations is 79300 MPa (11.5×10^6 psi) and is applicable for common cold wound spring materials.

For materials commonly used in hot coiled springs G is 76000 MPa (11.0×10^6 psi). This implies a 4% increase in wire diameter and corresponding decrease in the number of coils.

Do you need the spring to be preloaded in the full droop position?

If you don't get to full droop in your normal operating regime, then there is no reason to require that the spring is preloaded. In fact, it can make changing springs much easier, as when the car is jacked up and the suspension has dropped to full droop, the spring is free and can be more easily handled. If it has a significant preload in this position, either spring clamps or removal of suspension components may be required to assist in changing springs.

On the other hand, if you do get to full droop (particularly off-road vehicles with long suspension travel and requiring effective springs at the full droop position, particularly after jumps) then it is better to have some preload.

For cars that get to full droop only in a pit stop situation (when the car is on jacks for wheel changes) and do not have any preload, then it would probably suffice to have some kind of spring guide or sleeve so that the spring seats correctly when the car is dropped back off the jacks.

Another consideration if you do not have preload and you have removable spring collars, then these may need to be lockwired or otherwise retained in position if they are not consistently located by the spring.

What do I need calculate?

Getting the required spring and wheel rates can be an iterative process.

1. Make sure that the basic "Spring, Shock, ARB" calculates OK and that you have specified realistic limits for suspension travel, and that "Roll and Bump" calculates OK.
2. Use the "Spring, Shock, ARB" selections to specify the chassis and suspension mounting points.
3. Now use "Spring, Shock, ARB -> Spring" to specify and calculate the spring characteristics.
4. When you have a spring that looks OK, then "Apply" the spring.
Hint: Use ECalc and tick the "Geometry", "Roll and Bump", "Spring, Shock, ARB" and "Rates". Leave the ECalc dialog open, and whenever you click Apply, all the selected calculations will be done.
5. And redo "Calc" to update all the "Results".
6. And then do "Rates" calculation to see the wheel rates.

If you need to change the geometry or travel limits, then repeat from step 1.

If you need to change the spring chassis or suspension mountings, then repeat from step 2.

If you need to change the spring characteristics, then repeat from step 4.

Which calculation option should I use?

This really depends on your requirements. If you are going to use an "off the shelf" spring, then use the "Actual" option. But, you might still start with the "Calculated" option if you are going to determine a starting spring rate based on suspension frequency. Enter a frequency and see what is the spring rate. Locate the adjustable spring seat in the centre of its adjustment range to get the static length. Then calculate a spring. Don't worry about the number of coils or wire diameter, but note the free length. Now choose a spring close to this rate and free length from your preferred supplier. Switch to "Actual", enter the spring dimensions and do the calculations.

As another example, if you have a vehicle with fixed spring seats then choose the "Calculated" option, as this will not change the spring seat dimensions. But you still might want to try the "Actual" option. Particularly if you can use a "shorter" spring and add a custom spacer to the fixed spring seat to make up the difference.

You might have a number of alternative springs. Most vendors offer a range of spring rates with the same free length. Say you design for a 400lb/in 8" free length spring. What do you need to do when you swap in that set of 500lb/in 8" springs? So do the calculations with "Actual", and note the 400lb/in spring seat dimension and the new 500lb/in spring seat dimension. Convert the difference to the number of turns of the spring seat adjuster. So now you know that swapping springs means turning the spring seat up or down by that number of turns, and the ride height will be maintained.

Alternatively, you can make up spacers of the appropriate thickness so that you do not need to adjust the spring seats. Basically what you are doing is compensating for the difference in static loaded length. This is an alternative to the approach suggested by Carroll Smith, which involves custom making each set of springs with the same static loaded length, and which would then have differing free lengths.

10.10.2 Torsion bar parameters

From the "Spring, Shock, Arb" or the "Rates" tab, select Spring.

The "Spring, Shock, Arb" Calc should be done before designing the spring.

Units

- Metric** If working in the metric system you can choose for spring data to be presented in SI (Metric) or US Customary (Imperial) units.
If you specify Metric, then rates are N/mm, loads are Newtons, stress is MPa and dimensions are mm.
If you specify Imperial, then rates are lb/in, loads are lbs, stress is psi and dimensions are inches.
Note that the spring mounting lengths and spring seats will remain in mm.
- Imperial** If working in the US Customary (Imperial) system, then rates are lb/in, loads are lbs, stress is psi and dimensions are inches.

Spring rate and load

Specify either suspension frequency (Hz) or the rectilinear spring rate (N/mm or lb/in) to be used in the calculation.

Specify the appropriate value for frequency or spring rate. When you finish inputting the value, the other values in this group will recalculate.

The static spring load is derived from the individual corner mass and the static spring motion ratio. These values are also used to calculate the frequency from the spring rate, and the spring rate from the frequency.

The static spring load is derived from the individual corner mass and the static spring motion ratio. These values are also used to calculate the frequency from the wheel rate, and the wheel rate from the frequency. The static spring rate is then calculated using the motion ratio.

The torsional spring rate is for the torsion bar. It is calculated from the length and diameter.

Spring calculation

The effective length and diameter are used to display an appropriate looking torsion bar.

There are five calculation options.

All options require appropriate values for the spring load and lever arm length.

Except for "Actual", all options require appropriate values for the spring rate.

If you choose "Actual" or "Stress", the length and diameter will be calculated to obtain the required spring rate and static load with a maximum shear stress according to the Class selected. The Class number corresponds to the maximum operating shear stress, MPa

If you choose "Length" and specify the torsion bar length, the diameter will be calculated to obtain the required spring rate and static load. The shear stress and class number will be calculated.

If you choose "Dia" and specify the torsion bar diameter, the length will be calculated to obtain the required spring rate and static load. The shear stress and class number will be calculated.

If you choose "Actual", the effective length and diameter must be specified. The torsion bar rates, wind up angles, stress and class number will be calculated. The spring rate, frequency and wheel rate will be calculated.

Use the Apply button to do the calculation.

Stress

The operating shear stress is calculated at three positions of the spring. The minimum stress is the when the spring is in the full droop position, the static stress is the spring in the static ride height position, and the maximum stress is in the full bump position.

The total operating stress range is the maximum stress minus the minimum stress. The smaller the total operating stress range the greater the fatigue life.

Ideally the spring should have a positive stress in the droop position. According to SAE HS-796 torsion bars with a maximum operating shear stress greater than 700 MPa should not be subject to reversal of load direction.

This calculator is not intended as a comprehensive spring calculator. The length and diameter are used to display an appropriate looking spring.

For detailed spring design refer to appropriate literature and manufacturers.

These calculations are based on SAE HS-796.

The allowable stress includes factors such as material, forming process, post-forming treatments, fatigue limits and surface finish. The values used are indicative only. Consult your spring supplier.

SAE H-796 suggests a maximum operating shear stress of 900MPa (130,500 psi) for passenger car suspensions. Operating shear stresses up to 1250MPa (181,000 psi) require close attention to material and production quality.

The Modulus of Elasticity – Shear, G , used in these calculations is 76000 MPa (11.0×10^6 psi) for torsion bars 16mm diameter and over, and 79300 MPa (11.5×10^6 psi) for diameters under 16mm.

10.10.3 Leaf spring parameters

From the “Spring, Shock, Arb” or the “Rates” tab, select Spring.

The “Spring, Shock, Arb” Calc should be done before designing the spring.

Units

Metric If working in the metric system you can choose for spring data to be presented in SI (Metric) or US Customary (Imperial) units.
If you specify Metric, then rates are N/mm, loads are Newtons, stress is MPa and dimensions are mm.
If you specify Imperial, then rates are lb/in, loads are lbs, stress is psi and dimensions are inches.
Note that the spring mounting lengths and spring seats will remain in mm.

Imperial If working in the US Customary (Imperial) system, then rates are lb/in, loads are lbs, stress is psi and dimensions are inches.

Spring rate and load

Specify either suspension frequency (Hz) or the spring rate (N/mm or lb/in) to be used in the calculation.

Specify the appropriate value for frequency or spring rate. When you finish inputting the value, the other values in this group will recalculate.

The static spring load is derived from the individual corner mass and the static spring motion ratio. These values are also used to calculate the frequency from the wheel rate, and the wheel rate from the frequency. The static spring rate is then calculated using the motion ratio.

The leaf spring type can be a single leaf (constant width and thickness), multileaf (constant width and stepped leaves) or two stage (constant width and stepped leaves).

For a two stage spring it is assumed that the second stage leaves are flat. When the spring has positive camber, the spring rate is the stage 1 spring rate. When the spring is flat or has negative camber the spring rate is the stage 2 spring rate.

The spring effective length is the distance between the centres of the link holes (for plain end leaf) or the eyes (for eye end leaf), measured along the underside surface of the main leaf.

The leaf thickness is the thickness of the individual leaf.

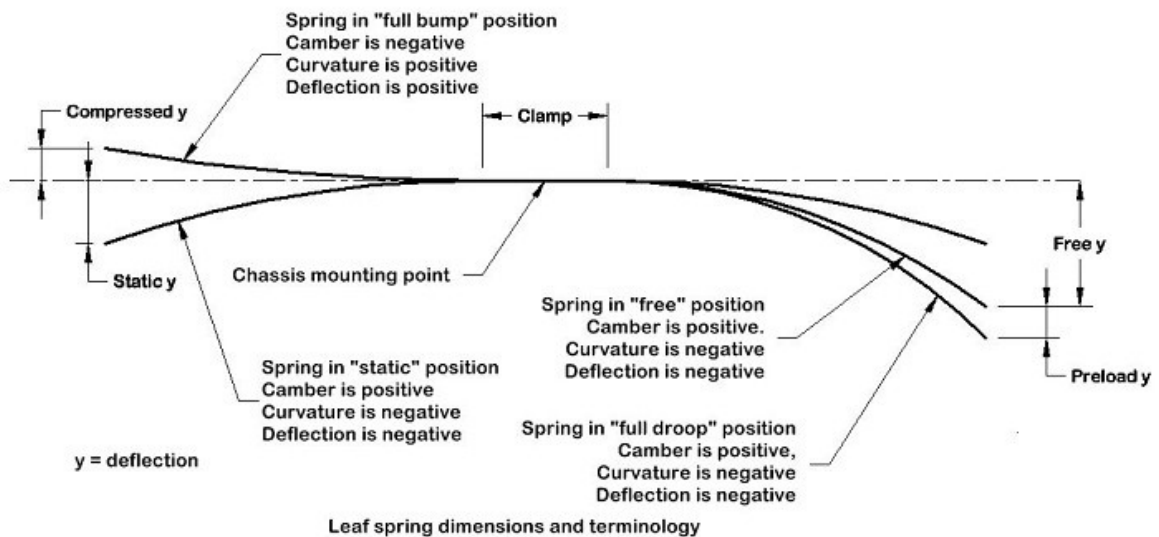
The maximum number of leaves is 10.

The inactive length (aka clamp length) is the length of the spring rendered inactive by the action of the U-bolts or clamping bolts.

For metal-to-metal type spring seats, this length is usually assumed to be equal to the distance between the insides of the U-bolts.

For soft seats (using rubber type isolation, as in many passenger car installations) the inactive length may approach zero.

Currently, the supported types of spring end are plain end (specifically where the spring is connected via a short tension link) and downturned eye (where the spring connects directly to the upright).



Spring calculation

The number of leaves and leaf dimensions are used to display an appropriate looking leaf spring.

There are two calculation options.

If you choose "Calculated", the spring rate will be that derived from the "Spring rate and load" section.

If the the spring is two stage and the spring has positive camber in the static position, then the stage 1 spring rate will be that derived from the "Spring rate and load" section. The stage 2 spring can be specified, and must be greater than the stage 1 spring rate.

If the the spring is two stage and the spring is either flat or has negative camber in the static position, then the stage 2 spring rate will be that derived from the "Spring rate and load" section. The stage 1 spring can be specified, and must be less than the stage 2 spring rate.

If you choose "Actual", the spring rate(s) must be specified.

If the the spring is two stage and the spring has positive camber in the static position, then the stage 2 spring must be greater than the stage 1 spring rate.

If the the spring is two stage and the spring is either flat or has negative camber in the static position, then the stage 1 spring rate must be less than the stage 2 spring rate.

The wheel rates and suspension frequency will be back calculated from the spring rate.

Use the Apply button to do the calculation.

The spring deflections shown in the static spring parameters and the spring deflections shown in the roll and bump data are relative to a flat spring.

The static spring deflection is the deflection of the main leaf from the “flat” position, fitted to the vehicle, in the normal static ride position.

The compressed spring deflection is the deflection of the main leaf from the “flat” position, fitted to the vehicle, in the maximum bump position. If this figure is positive, then the leaf spring has deflected past the flat position.

The free spring deflection is the deflection of the main leaf from the “flat” position in the unloaded position. This is the same as when the spring is removed from the vehicle.

The spring preload deflection is the deflection of the main leaf from the “free” position, fitted to the vehicle, in the maximum droop position. If this figure is negative, then either the main leaf is deflected this additional amount, or the suspension has to move this amount before the spring starts to take up the load.

With a two stage spring, the second stage leaves are all flat. The second stage becomes effective when the main leaf changes curvature from zero to positive.

[AE-21](#) defines Camber as the arch height of the main leaf, and is positive or negative analogous to opening. For the usual automotive leaf springs, camber is positive in the free position. Curvature (1/R) is the reciprocal of radius (R). The curvature of a flat leaf is zero. Curvature is considered positive in the direction in which it increases with added load. Positive curvature corresponds with negative camber.

10.11 Calculate

This option will allow all the static values to be calculated and therefore available within the dialog boxes.

Before the spring calculations can be calculated, Roll Bump | Calculate and Steering | Calculate must complete without error.

From the Spring, Shock, ARB tab, select Calculate.

This will do all Geometry, Roll Bump and Steering calculations.

The status bar will display a message ‘Calculating...’ followed by either ‘OK’ or an error message.

On fast processors, the ‘Calculating...’ message may not remain long enough to be visible.

10.12 Results

From the Spring, Shock, ARB tab, select Result.

This will open a result window with all the calculated suspension values for the static position. The dialog boxes will also now show the updated static values.

Because of the amount of data, it may be necessary to increase the width of the window to display all data without text wrapping.

```
SusProg3D SRD912.s3d Rear Suspension
Vehicle horizontal datum (X): Vehicle centreline
Vehicle vertical datum (Y): Ground
Vehicle longitudinal datum (Z):
```

LH and RH side identical

Arb	Wheel rate		Motion ratio	Length	Spring deflection
	N/mm	lb/in			
twist					
Shockabsorber			2.221	301.00	
Coil spring	30.52	174.27	2.221	176.50	33.28
Anti-roll bar 0.00	65.51	374.06	2.223		
Pushrod and bellcrank					
- Pushrod mounting (A-arm)			- X	496.34	
			- Y	170.52	
			- Z	2186.00	
- Pushrod length				355.05	
				Shock	P1
Bellcrank P2 Pushrod Rollbar					
- bellcrank pivots			- X	103.85	190.00
139.24	190.44	103.85			
			- Y	400.77	350.00
263.84	350.75	400.77			
			- Z	2086.97	2086.00
2086.87	2186.00	2086.97			
- Pushrod arm length & offset				100.00	0.00
- shockabsorber arm length & offset				100.00	0.00
- Pushrod pivot to shockabsorber pivot				140.73	
- angle between arms				89.44	
- anti-clockwise rotation in bump (LH)					
- anti-roll bar link arm length & offset				100.00	0.00
- Pushrod pivot to antirollbar link pivot				140.73	
- angle between arms				89.44	
Shockabsorber					
- shockabsorber mounting (chassis)			- X	100.00	
			- Y	400.00	
			- Z	1786.00	
- length - compressed (full bump)				251.85	
- static				301.00	
- extended (full droop)				343.75	
- stroke				91.90	
- motion ratio (static)				2.22	
Corner weight (unsprung)					
88.18 lb				40.000 kg	
Corner weight (sprung)					
507.06 lb				230.000 kg	
Corner weight (total)					
595.25 lb				270.000 kg	
Suspension frequency					
110.00 cpm				1.83 Hz	
Coil spring					
- spring seat (shockabsorber shaft)				36.00 mm	
1.417 in					
- spring seat (shockabsorber body)				88.50 mm	
3.484 in					
- spring rate				150.53 N/mm	
859.54 lb/in					

- static load		5009.25 N
510.801 kg	1126.12 lb	
- static length		176.50 mm
6.949 in		
- free length		209.78 mm
8.259 in		
- compressed length		127.35 mm
5.014 in		
- preload		-9.48 mm
-0.373 in		
Coil spring parameters		
- spring rate		150.53 N/mm
859.54 lb/in		
- type of ends		Closed and ground
- total number of coils		7.00
- number of active coils		5.00
- coil ID		57.15 mm
2.250 in		
- wire dia		12.68 mm
0.499 in		
- free length		209.78 mm
8.259 in		
- solid length		82.42 mm
3.245 in		
- solid load		19170.27 N
1954.824 kg	4309.65 lb	
- natural frequency		186.19 Hz
- torsional stress (corrected) - static		558.36 MPa
80983.18 psi		
	- full bump	1382.97 MPa
200583.06 psi		
	- solid	2136.82 MPa
309920.53 psi		
Anti-roll bar		
- arm length (actual)		300.00
- arm length (effective)		300.00
- arm length (offset)		0.00
- drop link length		300.00
- anti-roll bar mounting (chassis)	- X	100.00
	- Y	100.00
	- Z	2386.00
- arb arm/link pivot	- X	100.00
	- Y	400.00
	- Z	2386.95
Anti-roll bar config is u-bar, actuated from bellcrank. Shape is bar & lever.Style B (LH side).		
- active length		200.00 mm
7.874 in		
- outside diameter		25.00 mm
0.984 in		
- inside diameter		25.00 mm
0.984 in		
- spring rate (nominal; Cf = 1.00)		323.84 N/mm
1849.18 lb/in		
Chassis pivot points (from chassis X, Y, Z datum)		

- shockabsorber mounting	- X	100.00
	- Y	400.00
	- Z	1786.00
- bellcrank pivot (P1)	- X	190.00
	- Y	350.00
	- Z	2086.00
- bellcrank pivot axis (P2 offset from P1)	- X	-50.76
	- Y	-86.16
	- Z	0.87
- anti-roll bar mounting	- X	100.00
	- Y	100.00
	- Z	2386.00
A-arm pivot points (X from A-arm chassis pivot, Y from A-arm plane, Z from A-arm normal)		
- Pushrod mounting	- X	220.00
	- Y	25.00
	- Z	0.00

10.13 ECalc

Allows several modules to be calculated from one point.

For example, if the shock absorber mounting is changed, you can recalculate all modules with one click.

See [ECalc](#)

11 Spring and anti-roll bar rate calculations

If the vehicle is configured with an anti-roll bar, both spring, shockabsorber and anti-roll bar must successfully calculate the static data before doing the rates calculation. If you wish to do only the spring rate calculations, the go to Spring, Shock, ARB | Config and set the anti-roll bar type to 'none'. You can later reset the anti-roll bar configuration to the correct type, and all previously entered data will still be retained.

11.1 Car end and car side

The [Front] or [Rear] tab choice will indicate the currently selected vehicle end.

The [LH] or [RH] tab choice will indicate the currently selected vehicle side.

These tabs acts as a toggle, and selecting this tab will switch between each of two.

Depending on the vehicle configuration, some menu bar items may not be available.

When a dialog box is opened, the title will include the currently selected car end and car side. If the car side is not shown, then the dialog box applies to both sides. If the car end is not shown, then the dialog box applies to both ends.

11.2 Vehicle mass

From the Rates tab, select Mass.

The unsprung corner mass are for the upright, tyre and wheel assembly. For a live axle, each rear corner will include half the mass of the axle.

The vehicle corner mass are the mass of each corner as measured by each individual corner scale. This includes both the sprung and unsprung mass.

The sprung corner mass are calculated.

Only the sprung mass (total, for the appropriate end of the vehicle under design) is used.

Once all the values have been entered, the totals and distributions can be calculated with the Calc button.

11.3 Maximum suspension travel in bump and droop

From the Rates tab, select Travel.

For the initial calculation, it is suggested that the suspension travel limits be set using the [Roll&Bump Config settings](#).

The shock absorber limiting dimensions, compressed length and extended length can be entered. These are the "actual" dimensions.

After the Rates calculation, the shock absorber lengths for the specified wheel travel limits will be shown.

To limit the wheel travel, and to use the "actual" shock lengths, select Limit by Shock Length and then Apply.

This will recalculate the wheel travel limits.

Initially, it is better to specify a slightly greater wheel travel with the shock being over compressed and over extended. Then you are assured that the suspension linkages aren't going to "bind up" once you limit the travel by the shock lengths.

If you have two shock absorbers per corner, then the wheel travel bump limit will be set by the shock with the longest compressed "actual" length, and the wheel travel droop limit will be set by the shock with the shortest extended "actual" length.

The Rates Results will indicate if the shock is over compressed or extended.

If using the shock absorber lengths to calculate the wheel travel limits, and when doing the Travel Limits "Apply" or doing the Rates calculation, you get an error, typically an "Excessive bump travel. Suspension linkage will not connect" or "Excessive droop travel. Suspension linkage will not connect" or "Invalid floating point operation" then this usually indicates that the extended shock length is too long and the suspension linkage has exceeded its droop limit, or that the compressed shock length is too short and the suspension linkage has exceeded its bump limit. Decrease the shock extended length or increase the shock compressed length as appropriate.

11.4 Do the calculations for the complete range of bump and droop travel

Before the full range of bump and droop calculations can be calculated, Roll Bump | Calculate, Steering | Calculate and Spring, Shock, ARB | Calculate must complete without error.

From the Rates tab, select Calculate.

This will do all Geometry, Roll Bump, Steering and Spring, Shock, ARB calculations.

The status bar will display a message 'Calculating...' followed by either 'OK' or an error message.

On fast processors, the 'Calculating...' message may not remain long enough to be visible.

Warning:

If specifying travel limits by choosing the shock absorber open and closed lengths, it is suggested that only small changes are made to the lengths as established by choosing the wheel travel limits. There is currently minimal checking that a requested shock absorber length is mechanically feasible, and consequently the calculations can fail. This is especially applicable to pushrod suspension where the bellcrank may be operating near its limits and the requested shock absorber length will not connect to the bellcrank. The indication of failure will typically be a status bar error message.

11.5 Results

From the Rates tab, select Result.

This will open a result window with all the calculated suspension values.

Because of the amount of data, it may be necessary to increase the width of the window to display all data without text wrapping.

```
SusProg3D SRD912.s3d Rear Suspension roll and bump
Vehicle horizontal datum (X): Vehicle centreline
Vehicle vertical datum (Y): Ground
Vehicle longitudinal datum (Z):

Roll starts at Static.

LH and RH side identical

                Bellcrank   Pushrod   Shock
                rotation bellcrank bellcrank
                angle     angle     angle
```

Pushrod and bellcrank						
100.00 bump	29.66	62.57	122.64			
80.00 bump	22.87	68.48	114.59			
60.00 bump	16.61	74.12	107.48			
40.00 bump	10.77	79.56	101.12			
20.00 bump	5.26	84.83	95.34			
Static	0.00	90.00	90.00			
20.00 droop	-5.08	95.12	85.00			
40.00 droop	-10.05	100.25	80.23			
60.00 droop	-14.99	105.47	75.61			
80.00 droop	-20.00	110.89	71.03			
100.00 droop	-25.23	116.69	66.36			
		Wheel rate	Motion	Length	Spring	Arb
		N/mm	lb/in	ratio	deflection	
twist						
Shockabsorber						
100.00 bump			1.917	251.85		
80.00 bump			1.938	262.25		
60.00 bump			1.992	272.45		
40.00 bump			2.065	282.32		
20.00 bump			2.145	291.84		
Static			2.221	301.00		
20.00 droop			2.294	309.85		
40.00 droop			2.352	318.45		
60.00 droop			2.387	326.87		
80.00 droop			2.382	335.25		
100.00 droop			2.312	343.75		
Coil spring						
100.00 bump	40.98	233.98	1.917	127.35	82.42	
80.00 bump	40.09	228.93	1.938	137.75	72.02	
60.00 bump	37.92	216.53	1.992	147.95	61.83	
40.00 bump	35.31	201.60	2.065	157.82	51.95	
20.00 bump	32.72	186.84	2.145	167.34	42.44	
Static	30.52	174.27	2.221	176.50	33.28	
20.00 droop	28.60	163.33	2.294	185.35	24.43	
40.00 droop	27.20	155.32	2.352	193.95	15.83	
60.00 droop	26.43	150.90	2.387	202.37	7.40	
80.00 droop	26.54	151.53	2.382	210.75	-0.97	No
spring preload						
100.00 droop	28.17	160.85	2.312	219.25	-9.48	No
spring preload						
LH side:						
		Wheel rate	Motion	Length	Spring	Arb
		N/mm	lb/in	ratio	deflection	
twist rotation						
Shockabsorber						
4.00 roll LH			2.030	278.81	12.82	
3.00 roll LH			2.073	284.54	9.47	
2.00 roll LH			2.121	290.15	6.23	
1.00 roll LH			2.170	295.64	3.07	
0.00 roll			2.221	301.00	0.00	
1.00 roll RH			2.271	306.24	-3.00	
2.00 roll RH			2.320	311.36	-5.95	
3.00 roll RH			2.366	316.38	-8.85	
4.00 roll RH			2.408	321.30	-11.71	

Coil spring						
4.00 roll LH	36.54	208.64	2.030	154.31	55.46	
3.00 roll LH	35.01	199.93	2.073	160.04	49.73	
2.00 roll LH	33.47	191.11	2.121	165.65	44.12	
1.00 roll LH	31.96	182.48	2.170	171.14	38.64	
0.00 roll	30.52	174.27	2.221	176.50	33.28	
1.00 roll RH	29.18	166.62	2.271	181.74	28.04	
2.00 roll RH	27.96	159.66	2.320	186.86	22.91	
3.00 roll RH	26.88	153.50	2.366	191.88	17.89	
4.00 roll RH	25.96	148.21	2.408	196.80	12.98	
Anti-roll bar						
4.00 roll LH	80.09	457.34	2.011			
8.12						
3.00 roll LH	76.06	434.33	2.063			
6.08						
2.00 roll LH	72.28	412.74	2.117			
4.05						
1.00 roll LH	68.76	392.64	2.170			
2.02						
0.00 roll	65.51	374.06	2.223			
0.00						
1.00 roll RH	62.52	357.03	2.276			
2.02						
2.00 roll RH	59.82	341.56	2.327			
4.05						
3.00 roll RH	57.39	327.72	2.375			
6.08						
4.00 roll RH	55.26	315.56	2.421			
8.12						
RH side:						
		Wheel rate	Motion	Length	Spring	Arb
Bellcrank						
		N/mm	lb/in		deflection	
twist rotation			ratio			
Shockabsorber						
4.00 roll LH			2.408	321.30	-11.71	
3.00 roll LH			2.366	316.38	-8.85	
2.00 roll LH			2.320	311.36	-5.95	
1.00 roll LH			2.271	306.24	-3.00	
0.00 roll			2.221	301.00	0.00	
1.00 roll RH			2.170	295.64	3.07	
2.00 roll RH			2.121	290.15	6.23	
3.00 roll RH			2.073	284.54	9.47	
4.00 roll RH			2.030	278.81	12.82	
Coil spring						
4.00 roll LH	25.96	148.21	2.408	196.80	12.98	
3.00 roll LH	26.88	153.50	2.366	191.88	17.89	
2.00 roll LH	27.96	159.66	2.320	186.86	22.91	
1.00 roll LH	29.18	166.62	2.271	181.74	28.04	
0.00 roll	30.52	174.27	2.221	176.50	33.28	
1.00 roll RH	31.96	182.48	2.170	171.14	38.64	
2.00 roll RH	33.47	191.11	2.121	165.65	44.12	
3.00 roll RH	35.01	199.93	2.073	160.04	49.73	
4.00 roll RH	36.54	208.64	2.030	154.31	55.46	

Anti-roll bar				
4.00 roll LH	55.26	315.56	2.421	
8.12				
3.00 roll LH	57.39	327.72	2.375	
6.08				
2.00 roll LH	59.82	341.56	2.327	
4.05				
1.00 roll LH	62.52	357.03	2.276	
2.02				
0.00 roll	65.51	374.06	2.223	
0.00				
1.00 roll RH	68.76	392.64	2.170	
2.02				
2.00 roll RH	72.28	412.74	2.117	
4.05				
3.00 roll RH	76.06	434.33	2.063	
6.08				
4.00 roll RH	80.09	457.34	2.011	
8.12				

Motion ratio for shockabsorber/spring is calculated at each increment of bump and droop travel, and at each roll position. Motion ratio for anti-roll bar is calculated at each roll position.

If the motion ratio setting is Wheel:Shock then the motion ratio for the shockabsorber/spring is the ratio of wheel travel divided by the change in length of the shock absorber (produced by that same wheel travel).

If the motion ratio setting is Shock:Wheel then the motion ratio for the shockabsorber/spring is the ratio of the change in length of the shock absorber (produced by the wheel travel) divided by that same wheel travel.

Motion ratio for the anti-roll bar is the square root of the ratio of the nominal and actual wheel rates of the anti-roll bar. It is provided to enable a direct comparison to be made with the spring motion ratio.

If it is not possible to calculate the anti-roll bar linkage geometry, both the wheel rate and the motion ratio will be shown as zero. This can sometimes happen if the anti-roll bar actuation point moves so far (in bump or droop) that the anti-roll bar link cannot connect to the end of the anti-roll bar arm.

Spring preload length is the amount the spring is compressed when the suspension is in the full droop position. If this value is negative, then the free length of the spring is too short by this amount, and the spring is not compressed in full droop. The comment "nsp" may also appear if an intermediate droop position causes the spring to unload.

If designing for monoshock suspension, note that SusProg3D assumes two springs per vehicle end. The spring rates shown will need to be doubled to equal the actual (single) spring rate.

If designing for Jaguar suspension with two springs per A-arm, note that SusProg3D assumes two springs per vehicle end. The spring rates shown will need to be halved to equal the actual (single) spring rate.

For "live axles", the wheel rates in bump are for equal movements on both wheels, ie pure heave.

For "live axles", the spring and anti-roll bar rate in roll take into account the "spring base". The roll rates will usually be much softer than bump rates.

11.6 ECalc

Allows several modules to be calculated from one point.

For example, if the spring rate is changed, you can recalculate all modules with one click.

See [ECalc](#)

12 Weight transfer & roll-stiffness calculations

This module can be used independently of all other modules, and the data required can be input using the Parameters and Mass dialog boxes. Data can also be saved. If using data which has been entered or calculated in other modules, note that changing those values in this module will also change them in their related modules. This may require that the other modules will need to be recalculated to maintain consistent results. The roll axis is based on the static front and rear roll centre heights.

Vehicle dynamic calculations are based on [BAST90, BAST93] and provide for the tyre spring rate, moments due to the unsprung weights, different front and rear tracks and separate suspension roll angles which are often not included in other calculations. For example, [COST80] does not include the tyre spring rate and only calculates a single chassis roll angle, and both [SMIT88] and [CAMP81] ignore the effects of the unsprung weights. The weight transfer calculations in [PUHN76] and [COST80] both agree closely with those of [BAST90].

In general, including the tyre spring rate decreases the overall roll stiffness and requires a greater vehicle roll angle, and including the unsprung weights generate additional roll moments and again lead to a greater vehicle roll angle.

Using the data for the Porsche 928, [CAMP81] calculates a chassis roll angle of 1.71°. Using the same data, [COST80] calculates a chassis roll angle of 1.84° and SusProg3D calculates a suspension roll angle of 1.85° (average of 1.62° front & 2.08° rear). For weight transfer, [SMIT88] calculates 317kg (split 76% front, 24% rear), [COST80] 429kg (68/32), [PUHN76] 425kg (67/33) and [BAST90] 429kg (63/37) The Porsche data shows that when the suspension spring rate is very high and approaches the tyre spring rate, then a significant amount of the vehicle roll is provided by the tyre deflection.

Frequencies are calculated for both the sprung and the unsprung masses using the bump spring rate.

If the tyre spring rate is entered as zero, it is treated as "infinitely stiff". In this case the sprung mass frequency is based on the sprung mass and the effective spring rate (at the wheel).

If the tyre spring rate is entered, then both the effective spring rate (at the wheel) and the tyre spring rate are used. This will generally lead to a lowering of the sprung mass frequency.

The calculations are based on [BAST93] Appendix A1.3 and A1.5.

12.1 Parameters

From the Dynamic tab, select Parameters.

Data values can be derived from two sources: Vehicle or Custom.

Vehicle data

The values will be the current vehicle values.

If any changes or calculations are done which effect the parameter values, they will be updated.

Data can only be changed by updating and recalculating the underlying vehicle data.

Custom data

All data can be updated in the Parameter input.

No changes are made to the underlying vehicle data.

All spring rates (spring, anti-roll bar and tyre) are for one wheel only and are the effective wheel rates as measured at the tyre contact point. Either the spring or anti-roll bar rate may be zero, but not both. A typical tyre rate is 180-360 N/mm (1000-2000 lb/in).

The roll rates for "live axle" allow for the 'spring base', which is derived from the mounting points.

Note that if the tyre rate is zero, then this is assumed to be an "infinitely stiff" tyre with no deflection under load.

If using Metric units, all length dimensions are in mm, all weights are in kg, and all rates are in N/mm.

If using Imperial units, all length dimensions are in inches, all weights are in lb, and all rates are in lb/in.

Cornering force is the number of "g" lateral acceleration.

Sprung mass is the total sprung mass for each end of the vehicle.

Unsprung mass is the total unsprung mass (ie both wheels) for each end of the vehicle.

CofG height is for the complete vehicle, above the ground line. Refer [CofG calculation](#) for a description of a method to calculate CofG height.

To facilitate "What if?" calculations, a range can be entered for cornering acceleration, and, if in Custom mode, roll centre range.

Both front and rear roll centres allow for a minimum, step and maximum roll centre height.

If doing a calculation for a single roll centre, then specify the minimum as the the required roll centre and the step as zero. The maximum will be ignored.

To do a series of calculations for a range of roll centres, specify the minimum, step and maximum roll centres. Calculations will be done starting at the minimum roll centre, then increasing by the step amount until the maximum.

If both the front and rear roll centres have minimum, step and maximum values, the calculations will do all the rear roll centres for each front roll centre.

Similarly, a range of cornering accelerations can be specified.

The results will be shown in tabular form in the results output.

For subsequent analysis, it may be easier to export the results in CSV format. This can be directly imported by Excel.

In this case, after entering the values, use the Apply button to load the values and keep the dialog open. Then, after doing the "DynamicCalc" you can use the "Open" or "Open with" button to open the CSV file.

12.2 Calculate

Prior to calculation, and if the Parameter data is specified as "Vehicle data", then the parameter data will be refreshed from the vehicle data.

This ensures that any changes to vehicle data input or calculated values are always used when calculating.

From the Dynamic tab, select DynamicCalc.

The status bar will display a message 'Calculating...' followed by either 'OK' or an error message.

On fast processors, the 'Calculating...' message may not remain long enough to be visible.

12.3 Dynamic Results

From the Dynamic tab, select DynamicResult.

This will open a result window with all the calculated weight transfer and chassis roll values.

Because of the amount of data, it may be necessary to increase the width of the window to display all data without text wrapping.

SusProg3D SRD912.s3d Dynamic			
Tyre rolling radius (nominal)	front/rear	260.83 mm	269.34 mm
Track	front/rear	1400.00 mm	1350.00 mm
Spring base	front/rear	1400.00 mm	1350.00 mm
Anti-roll bar base	front/rear	1400.00 mm	1350.00 mm
Wheelbase		2286.00 mm	
Vehicle CofG	- from ground	305.00 mm	
	- from front axle cl	1327.35 mm	
Sprung CofG	- from ground	312.62 mm	
	- from front axle cl	1348.15 mm	
Wheel rates in bump			
	- front - tyre	171.62 N/mm	979.95
lb/in			
	- spring	17.55 N/mm	100.19
lb/in			
	- combined	15.92 N/mm	90.90
lb/in			
	- rear - tyre	171.62 N/mm	979.95
lb/in			
	- spring	30.52 N/mm	174.27
lb/in			
	- combined	25.91 N/mm	147.96
lb/in			
Wheel rates in roll			
	- front - tyre	171.62 N/mm	979.95
lb/in			
	- spring	17.55 N/mm	100.19
lb/in			
	- arb	50.13 N/mm	286.26
lb/in			
	- combined	48.54 N/mm	277.15
lb/in			
	- rear - tyre	171.62 N/mm	979.95
lb/in			
	- spring	30.52 N/mm	174.27
lb/in			
	- arb	65.51 N/mm	374.06
lb/in			
	- combined	61.57 N/mm	351.59
lb/in			
Frequency (in bump)			
	- sprung mass	1.59 Hz	95.16
cpm			
	- unsprung mass	11.71 Hz	702.70
cpm			
	- sprung mass	1.69 Hz	101.15
cpm			
	- unsprung mass	11.34 Hz	680.21
cpm			

Anti-roll stiffness - front - tyres		2935 N·m/deg	2165
lb-ft/deg	71.7%		
lb-ft/deg	7.3%	- spring	300 N·m/deg
			221
lb-ft/deg	20.9%	- arb	857 N·m/deg
			632
lb-ft/deg		- combined	830 N·m/deg
			612
Anti-roll stiffness - rear - tyres		2729 N·m/deg	2013
lb-ft/deg	64.1%		
lb-ft/deg	11.4%	- spring	485 N·m/deg
			358
lb-ft/deg	24.5%	- arb	1042 N·m/deg
			768
lb-ft/deg		- combined	979 N·m/deg
			722
Anti-roll stiffness - car - tyres		5665 N·m/deg	4178
lb-ft/deg	67.8%		
lb-ft/deg	9.4%	- spring	785 N·m/deg
			579
lb-ft/deg	22.7%	- arb	1899 N·m/deg
			1401
lb-ft/deg		- combined	1809 N·m/deg
			1335
Roll couple distribution - front		45.9%	
Roll direction LH (RH turn)			
	Lateral	Roll centre	Sprung CoG
	Corner weights		
	Roll		Roll angles
Test	Accel	height	Weight transfer
Front		Rear	Suspension
	Gradient		
#	G	Front	Rear
LH	RH	LH	RH
Rear	Total	deg/g	roll axis
			Front
			Rear
			Front
			Rear
1	1.00	80.39	85.65
287.52	102.48	384.56	155.44
0.60	1.16	1.16	0.43
			0.56
			0.72
2	1.50	80.39	85.65
333.78	56.22	441.85	98.15
0.90	1.74	1.16	0.65
			0.83
			1.09
3	2.00	80.39	85.65
380.04	9.96	499.13	40.87
1.20	2.31	1.16	0.87
			1.11
			1.45

12.4 Notes

In these calculations it has been presumed that the roll angle for the plane of the front axle is equal to that for the plane of the rear axle. This in general presupposes a high figure for chassis torsional rigidity. [PUHN76] suggests that the chassis stiffness should be at least 10 times the total suspension roll stiffness. [VALK92] suggests a minimum of 3000 ft-lbs/deg for light road-racing cars.

Some typical examples include the Ford GT40 Mk1 at 12500 ft-lb/deg [CAMP76], the '62 Lotus 24 at 700 ft-lb/deg and the Lotus 25 at 2400 ft-lb/deg with engine installed [BAMS90], the '94 FIA Class 1 DTM Opel Calibra at 30000 N-m/deg (22124 ft-lb/deg) which is three times the stiffness of the production car [RACE43], and the '93 F1 Lola T93/30 with a design stiffness of 30000 ft-lb/deg [MACK93].

Avon quote the following spring rates for their ACB10 1994-96 Formula Ford tyres when fitted to 5.5Jx13 rims.

The vertical spring rate of the 7317M (6.0/21.0-13) front tyre is 175 N/mm at 18psi, increasing to 183 N/mm at 20psi and 190 N/mm at 22psi. For the 7319M (7.0/22.0-13) rear tyre it is 174 N/mm at 18psi, 181 N/mm at 20psi and 189 N/mm at 22psi [RACE36]

The CofG height as entered, is the height of the CofG of the complete vehicle above the static ground plane. This is recalculated to provide the sprung mass CofG height (above static ground plane), the distance of the CofG from the front axle cl and its height above the roll axis.

Weight transfer is the amount of weight transferred from the inner to the outer wheels. It should always be remembered that the total weight transfer from the inside wheels to the outside wheels of a vehicle is determined by the total weight of the vehicle, its track, the height of the centre of gravity and the cornering force. It is only possible by means of anti-roll bars, etc, to alter the fore-and-aft distribution of the weight transfer.

The vehicle roll angle consists of two components; the roll angle due to the deflection of the tyres, plus the roll angle due to suspension movement. For example, if the tyre roll angle is 0.67° and the suspension roll angle is 2.18° then to obtain a vertical outer wheel the suspension geometry should provide -0.67° camber at 2.18° roll. The total vehicle roll angle is 2.25° .

13 Longitudinal pitch centre calculations

The longitudinal pitch centre is the theoretical point about which the chassis will rotate in side view.

It is identical in concept and geometrical construction to the roll centre. The difference is that the roll centre is defined in the vertical plane of the axle, and the longitudinal pitch centre in the the plane of the front and rear wheel wheel pair.

One specific application is to see how the longitudinal pitch centre moves when the front suspension bumps and the rear suspension droops, typically under braking.

The original function did a calculation for each combination of front axle bump and droop and rear axle bump and droop and presented to data in a tabular format.

Use the Dynamic -> PitchCalc to do the set of calculations and then Dynamic -> PitchResults to see the data.

Because the data was somewhat confusing, a new interactive graphical function has been added.

The suspension bump and droop data is entered in Dynamic -> PitchData and then the pitch centre is calculated and the location shown graphically in Dynamic -> PitchGraphic.

The older functionality has been retained but will probably be removed in a future release.

13.1 PitchData

From the Dynamic tab, select PitchData.

There is space for 20 data points, each point having a front suspension travel and a rear suspension travel. Each data point has a trackbar, with the slider indicating the relative suspension travel. The upper section is wheel bump, the lower section wheel droop, with the static position in the centre. A blue line is drawn in the static position.

The trackbar has a resolution of 1% of the bump or droop value. So if the bump is 125mm (5") then each "click" of the slider will be 1.25mm (0.050")

Data can be entered by using the trackbar slider to set a value. When the mouse is over a trackbar, the values will display.

If you click on the central part of the trackbar, the slider will move.

To select a trackbar without changing the value, click outside the central section. When selected, the trackbar will have a dotted line border. The data point number and value will show in the data input box.

When the trackbar is selected, the arrow keys will move the slider up and down.

When a trackbar is selected, the data value can be entered in the numerical input box. Use the TAB key to exit the input box.

Data can be entered into each trackbar individually. Or specify the first and last data point, then use the "join ends" button to calculate and set each intermediate data point.

The data is available to the graphical display as it is entered. The input can be left open while the graphic is calculated and displayed. Clicking "OK" will close the dialog.

13.2 PitchCalc

From the Dynamic tab, select PitchCalc.

The status bar will display a message 'Calculating...' followed by either 'OK' or an error message.

On fast processors, the 'Calculating...' message may not remain long enough to be visible.

13.3 PitchResults

From the Dynamic tab, select PitchResult.

This will open a result window with all the calculated longitudinal pitch centre values.

13.4 PitchGraphic

From the Dynamic tab, select PitchGraphic.

The graphic will display the front and rear wheels on a ground line. There is a vertical line representing the front axle centreline.

The panel showing the pitch centre data can be moved with the mouse. It will show the current values for the suspension travel together with the vertical and longitudinal co-ordinates of the pitch centre. You can choose to show the LH, RH or both points.

The pitch centre vertical dimension is relative to the ground plane; the longitudinal dimension is relative to the front axle centreline.

The initial calculation and display will be the first data set.

Use the ">" button to calculate the next data point, the "<" button to calculate the previous data point. The "<<" and ">>" buttons will go to the first and last data points respectively.

Use the "+" and "-" buttons to zoom in or out.

If you have specified an undertray, this will be shown, and will give a more visual indication of the vehicle movement.

14 AutoCalc

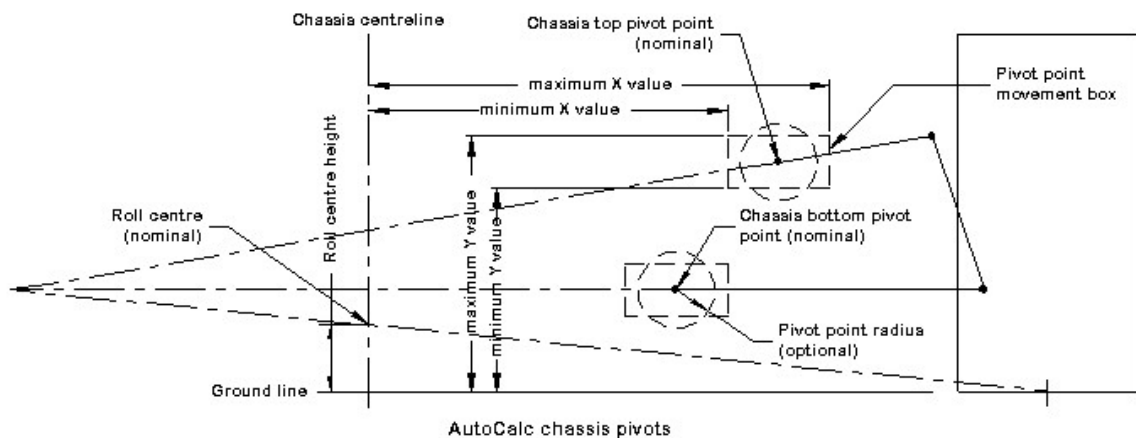
What if, or what combination of suspension chassis mounting points will give the desired geometry. This is AutoCalc.

Before using AutoCalc, the suspension geometry data must be entered and successfully Roll&Bump. This data set is the base or reference data.

AutoCalc will inherit all existing settings for chassis pivot point calculation and wheel alignment adjustment.

Be careful specifying the Geometry Configuration option. If an option is specified which requires that a A-arm link length is fixed, and the associated chassis pivot point is moved, then this will vary the track by the required distance, to maintain the specified link length. This may not be the required action. It is safest to use the "Wheel location and alignment" option (ie keeping a constant track) before using AutoCalc. If no other values are changed, this will not affect the calculations other than allowing the suspension link lengths to vary as required. The option of still having fixed link lengths may be useful in the case where the fixed length link has little or no lateral variation and the resultant track variation is acceptable, or the appropriate vehicle regulations require that the link length(s) remain unchanged (but do allow relocation of the pivot point). If fixed link lengths are specified and the base A-arm axis is not in-line, then this will change the basic suspension geometry accordingly.

It is also suggested that toe-in be set to zero before running AutoCalc.



14.1 Config

From the AutoCalc tab, select Config.

Use the "Vehicle" button to load the initial calculation values from the Vehicle design values.

If the horizontal and vertical values for the front and rear pivot points are the same, the "inline" option will be specified. If they are different, the "offset" option will be specified.

The chassis pivot point closest to the axle centreline (in plan view) will be specified as the "control" point.

Select the required calculation option for both top and bottom A-arm.

Inline (front reference) The front and rear A-arm pivot points are set to the same horizontal and vertical values and consequently the A-arm pivot axes are in-line. The "control" values are the front pivot point.

Inline (rear reference)	The front and rear A-arm pivot points are set to the same horizontal and vertical values and consequently the A-arm pivot axes are in-line. The "control" values are the rear pivot point.
Offset (front ref)	If the front and rear A-arm pivots are not in-line, then the 'offsets' between the two points will be maintained. The individual horizontal and vertical offsets are calculated from the base data, where the 'offset' is the difference between the front and rear dimension. For 'Offset (front ref)' the front pivot point will range between the specified minimum and maximum horizontal and vertical values. For 'Offset (rear ref)' the rear pivot point will range between the specified minimum and maximum horizontal and vertical values. The 'other' pivot point will maintain the base 'offset', and both pivot points will move in the same direction. For example, if the base configuration has the front pivot horizontal = 300 and rear pivot horizontal = 320 (this gives a rear horizontal offset of 20), and horizontal Min = 290 and Max = 310 and 'Offset - (front ref)' is specified, then the front pivot will range from 290 to 310 and the rear pivot point will range from 310 to 330 with the rear pivot always 20 greater than the front.
Offset (rear ref)	
Front (rear fixed)	
Rear (front fixed)	Only the rear pivot point will vary through the specified range. The front pivot point will be fixed at the existing position. The rear pivot horizontal and vertical values will vary within the specified minimum and maximum horizontal and vertical values.

The dialog will also show the following calculation settings.

The datum side. This is the side of the vehicle used for base chassis dimensions. The chassis dimensions for the other side of the vehicle will be set identical.

The geometry instant centre location, either fixed chassis points or swing axle and roll centre.

The geometry wheel location and alignment.

The roll and bump roll centre location.

The roll and bump roll axis alignment.

All of these are all set in the Geometry | Config and RollAndBump | Config.

14.2 Car end and car side

The [Front] or [Rear] tab choice will indicate the currently selected vehicle end.

The [LH] or [RH] tab choice will indicate the currently selected vehicle side.

These tabs acts as a toggle, and selecting this tab will switch between each of two.

Depending on the vehicle configuration, some menu bar items may not be available.

When a dialog box is opened, the title will include the currently selected car end and car side. If the car side is not shown, then the dialog box applies to both sides. If the car end is not shown, then the dialog box applies to both ends.

14.3 Chassis limits

From the AutoCalc tab, select Chassis Limits.

14.3.1 Double wishbone

Use the "Vehicle" button to load the initial calculation values from the Vehicle design values.

Enter the desired minimum, maximum and step values. Initially the minimum and maximum are set to the base values (either the front or the rear pivot point). The default step value is 1.0mm or 0.050".

For A-arm suspension, it will apply to both top and bottom A-arms. For struts, it will only apply to the bottom A-arm.

For 'fixed chassis pivot points' the horizontal and vertical co-ordinates will vary as described. For 'fixed swing axle and roll centre' the horizontal co-ordinates will vary as described, and the vertical co-ordinate will always be calculated to achieve the required swing axle and roll centre.

14.3.2 Strut

Certain values are not applicable to strut suspensions.

If fixed chassis pivot points are specified, then the chassis top pivot vertical value will remain constant (Maximum and minimum values can be input, but will default to the nominal value before execution).

Similarly, if fixed swing axle and roll centre is specified, then the swing axle values are not used, only the roll centre values.

If a range of chassis top pivot horizontal values are specified, these will only be used if the camber adjustment location is the chassis top pivot, otherwise they will be ignored and the appropriate value calculated which may lie outside the specified range. To avoid unnecessary calculations, do not specify a chassis top pivot vertical value range (unless you also specify that the camber adjustment location is the chassis top pivot).

14.4 Upright limits

From the AutoCalc tab, select Upright Limits or Strut Limits

Use the "Vehicle" button to load the initial calculation values from the Vehicle design values.

Enter the desired minimum, maximum and step values. Initially the minimum and maximum are set to the base values. The default step value is 1.0mm or 0.050".

For A-arm suspension, it will apply to both top and bottom upright A-arm pivot points. For struts, it will only apply to the bottom A-arm pivot point.

14.5 Specify the test and reporting requirements

From the AutoCalc tab, select Test Limits.

Use the "Vehicle" button to load the initial calculation values from the Vehicle design values.

The 'print' column checkbox is used to control the report output, the 'test' column checkbox is used to determine the successful pivot point combinations.

Check the appropriate 'test' column checkbox to choose which values will be used to determine if a particular combination of pivot points meets your requirements. If nothing is selected, nothing will be checked.

If more than one test is to be checked, then the calculation is aborted when the first test fails. For example, if the Roll Centre is checked and Roll Centre is out of limit, then bump and droop camber is not calculated or checked. This is done to speed up the process. Conversely, a successful combination must pass all the tests specified.

The pivot location radius selections allow for specifying that the pivot point must not move further than the specified distance from the base point. Both front and rear pivot points will be tested, and both must be within the specified distance.

If the roll centre location is checked, enter the maximum and minimum height for the static roll centre.

The static roll centre is recalculated for each combination of chassis pivot points and/or swing axle lengths and that roll centre movement is measured from this new static roll centre location.

If the roll centre movement is checked, enter a value for the maximum distance that the roll centre can migrate from the static roll centre while the chassis rolls through the total roll amount. Roll increments are set in Roll&Bump | Increments. The roll centre travel shown in the results will be the maximum roll centre travel, which could be at any of the roll positions.

If "min" is checked, then the maximum roll centre movement for each test combination will be compared with the previous results, and if it is less, then that combination will be added to the test results. This can be used to answer the question "I don't know the actual value, I want the minimum roll centre movement". If a value for roll centre movement is specified, this will be the starting value, otherwise the roll centre movement of the first combination will be used.

Specify if the roll centre movement is to be calculated as the distance between the actual and static roll centres, or as the difference in heights between the actual and static roll centres. If the geometry calculations are being done with "dynamic" roll centres, then the former may be the most appropriate choice; if "semi-dynamic" then the later may be the most appropriate choice.

If the Bump Camber is checked, enter the values that the wheel camber at the maximum bump position must be within. The maximum value is the numerically larger of the two values. For example, if the wheel must camber to at least -3.00° but no more than -3.35° , then maximum bump camber will be -3.00° and minimum bump camber will be -3.35° . (Values are inclusive). The maximum bump distance is set in Geometry | Travel.

If the Droop Camber is checked, enter the values for which the wheel camber at the maximum droop position must be within. For example, if the wheel must camber to between -1.00° and $+1.00^\circ$ on full droop, then maximum droop camber will be $+1.00^\circ$ and minimum droop camber will be -1.00° . (Values are inclusive). The maximum droop distance is set in Geometry | Travel

All pivot location data plus the tested items will be included in the report output. If you wish to include additional items, then check the appropriate 'print' column checkbox.

An output line will only be created for test point combinations that meets the test limits.

14.6 Do all the iteration calculations

From the AutoCalc tab, select Calculate.

Before calculating, check that the output file is correctly specified.

Specify the output file format.

- If 'Text' is specified, the output will be written as plain ASCII text.
- If 'CSV' is specified, the output will be formatted in Comma Separated Variable format. This format can be imported into most spreadsheet packages. A single header line plus multiple detail lines will be written.

If the suggested file name or directory location is not appropriate, use "Save as" to specify the file locations and file name.

Press "Calc" to start the calculations.

A progress box will appear with two bar graphs. The top one is titled "Combinations tested" and will indicate the progress in calculating all the combinations requested. The bottom one is titled "Combinations within specified limits" and will indicate the number of combinations that meet the required parameters.

If you get excessive (or not enough) acceptable results, then change the test limit values.

If you wish to exit the calculation process, press [Halt]. The calculation will immediately stop and the output file will contain all those tests completed.

The progress box will show the number of combinations tested, the number within the specified limits and the output file name.

When the calculations have completed you can view the results.

Use the "Open" to view the output file using the associated application.

For example, if the output file is 'Text' then it will be opened with the application associated with .txt files. This is usually NotePad.

If the output file is 'CSV' then it will be opened with the application associated with .csv files. This is usually Microsoft Excel.

If you want to use an application not associated with that particular file type, then use "Open with..." and choose the application.

14.7 Results

This file will be created when the 'Text' option is specified.

The file has a suffix of ".TXT".

Use the "Open" button to view the output file using the associated application. This is usually NotePad.

If you want to use an application not associated with ".txt", then use "Open with..." and choose the application.

Abbreviations used are 'ctf' for chassis top front pivot point, 'ctr' for chassis top rear pivot point, 'cbf' for chassis bottom front pivot point, 'cbr' for chassis bottom rear pivot point, 'rc' for roll centre, 'bc' for bump camber and 'dc' for droop camber.

Both front & rear pivot point horizontal and vertical values will be printed.

Because of the amount of data, it may be necessary to increase the width of the window to display all data without text wrapping.

```

AutoCalc Nominal Chassis Dimensions
Chassis pivot points (from vehicle X, Y, Z datum)
- top A-arm chassis pivot (front/rear)      - X   300.00   300.00
                                           - Y   383.20   373.28
                                           - Z  -132.50   132.50
- bottom A-arm chassis pivot (front/rear)   - X   250.00   250.00
                                           - Y   165.84   165.85
                                           - Z  -132.50   132.50
- tie rod                                   - X   256.89
                                           - Y   277.21
                                           - Z   -99.17
Upright pivot points (from vehicle X, Y, Z datum)
- top A-arm upright pivot                   - X   546.72
                                           - Y   379.05
                                           - Z    10.89

```

- bottom A-arm upright pivot	- X	598.74	
	- Y	140.41	
	- Z	-10.13	
- tie rod (steering arm)	- X	547.36	
	- Y	268.21	
	- Z	-99.17	
- spindle reference point	- X	697.72	
	- Y	260.82	
	- Z	0.01	
- spindle / wheel cl point	- X	697.72	
	- Y	260.82	
	- Z	0.01	
Instant centres			
Front view swing axle length (at IC point)		3173.79	
Front view swing axle height (at IC point)		364.50	
Roll centre height		80.39	
Roll centre offset		0.00	
Side view IC length (at IC point)		6718.62	
Side view IC height (at IC point)		141.43	
Side view IC height (at rear axle centreline)		48.12	
Side view IC angle (from tyre contact patch centre)		1.21	
Suspension roll axis		-2.1%	
Brake force split 60% front 40% rear			
Brake anti-dive %		9.5%	
Track (wheel centreline on ground)			
		1400.00	
Top A-arm link lengths (front/rear)			
Top A-arm (normal length)		285.39	275.12
Top A-arm (base length)		246.72	
Bottom A-arm link lengths (front/rear)		265.19	
Bottom A-arm (normal length)		370.46	377.64
Bottom A-arm (base length)		349.67	
Steering tie rod length		265.00	
Tyre centreline on ground from Z datum		290.61	
Tyre centreline on ground from vehicle centreline		0.00	
		700.00	
Tyre rolling radius (nominal)			
		260.83	
Tyre diameter (overall)			
		542.53	
Rim diameter			
		330.20	
Rim width			
		203.20	
Rim mounting offset			
		0.00	
Wheel mounting spacer			
		0.00	
Wheel alignment in straight ahead position			
Camber angle			
		-0.50	
Top king pin point (actual)			
	- X	546.72	
	- Y	379.05	
	- Z	10.89	
Bottom king pin point (actual)			
	- X	598.74	
	- Y	140.41	
	- Z	-10.13	
Upright pivot inclination (kpi)			
		12.31	
Upright pivot scrub radius (tyre cl on ground)			
		70.58	
Caster angle and trail			
		5.00	22.72
Steering offset			
		74.15	
Spindle offset from kingpin axis (side/front view)			
		0.00	122.36
Static toe (degree) toein			
		0.17	

5653	309.00	380.00	309.00	380.00	252.00	166.00	252.00
	166.00	78.13	3516.57	9.55	2.01	5.07	1400.01
5654	310.00	380.00	310.00	380.00	252.00	166.00	252.00
	166.00	78.12	3517.48	10.50	2.01	4.88	1400.01
5655	311.00	380.00	311.00	380.00	252.00	166.00	252.00
	166.00	78.12	3518.26	11.46	2.01	4.71	1400.01
5656	312.00	380.00	312.00	380.00	252.00	166.00	252.00
	166.00	78.11	3519.10	12.42	2.01	4.53	1400.01
5657	313.00	380.00	313.00	380.00	252.00	166.00	252.00
	166.00	78.11	3520.24	13.39	2.01	4.35	1400.02
5658	314.00	380.00	314.00	380.00	252.00	166.00	252.00
	166.00	78.10	3520.67	14.36	2.01	4.18	1400.01
5659	315.00	380.00	315.00	380.00	252.00	166.00	252.00
	166.00	78.09	3521.74	15.34	2.01	4.00	1400.01
5660	316.00	380.00	316.00	380.00	252.00	166.00	252.00
	166.00	78.09	3522.31	16.32	2.01	3.83	1400.01
5661	317.00	380.00	317.00	380.00	252.00	166.00	252.00
	166.00	78.08	3523.55	17.30	2.01	3.66	1400.02
5662	318.00	380.00	318.00	380.00	252.00	166.00	252.00
	166.00	78.07	3524.28	18.28	2.01	3.49	1400.01
5663	319.00	380.00	319.00	380.00	252.00	166.00	252.00
	166.00	78.07	3524.86	19.27	2.01	3.33	1400.01
6047	319.00	380.00	319.00	380.00	252.00	166.00	252.00
	166.00	78.07	3524.86	19.27	2.01	3.33	1400.01

8064 combinations tested
31 within specified limits

14.8 Read the CSV results file with Excel

This file will be created when the 'CSV' option is specified.

The file has a suffix of ".CSV".

Use the "Open" button to view the output file using the associated application. This is usually Microsoft Excel.

If you want to use an application not associated with ".csv", then use "Open with..." and choose the application.

The number of columns will depend on the selected 'print' and 'test' options selected. The number of rows will be the number of combinations within the specified limits plus a header and trailer row.

There may be limitations in the number of rows that a spreadsheet can hold. For example, Excel 7.0 has a limit of 16,384 rows. Later versions have increased this limit to 65,536 rows.

15 Excel import and export

From the Excel tab, there are several functions available to export SusProg3D data to Excel, and to import SusProg3D data from Excel.

- Calc2Excel enables calculated data (ie roll and bump values, spring rates, etc) to be exported to an Excel spreadsheet.
While the Calc2Excel dialog and the Excel workbook are open, any calculations (ie Calc, ECalc or VCalc) will automatically update Excel.
The available data is listed under [Calculated data Excel names](#).
- Input2Excel enables input data (ie chassis mounting points, upright dimensions, etc) to be exported to an Excel spreadsheet.
Data is exported when the "Export" button is clicked.
The available data is listed under [Input data Excel names](#).
- Excel2Input enables input data (ie chassis mounting points, upright dimensions, etc) to be imported from an Excel spreadsheet.
Data is imported when the "Import" button is clicked.
The available data is listed under [Input data Excel names](#).
- Excel2CAD enables input data (ie chassis mounting points, upright dimensions, etc) to be imported from an Excel spreadsheet.
Data is imported when the "Import" button is clicked.
The available data is listed under [CAD input data Excel names](#).

There are three ways to link SusProg3D to an Excel workbook:

1. Open the Excel workbook (by any of the Windows methods), then select the appropriate Excel tool; or
2. Select the appropriate Excel tool, and use the "Open Excel" button to choose the Excel workbook; or
3. Select the appropriate Excel tool, and open the Excel workbook (by any of the Windows methods).

If multiple tools are open at the same time, they can each reference the same Excel workbook.

Clicking "Show Excel log" will display a log of the basic Excel interaction results. It may be helpful if the calculation doesn't update Excel as expected. See [Error and warning messages](#)

If the "Close Excel on exit?" is ticked, then Excel will close when the Excel tool is closed, or, if there are multiple Excel tools open, when the last Excel tool is closed.

If the "Close Excel on exit?" is not ticked, then Excel will remain open when the Excel tool is closed, or, if there are multiple Excel tools open, when the last Excel tool is closed.

The following versions of Excel are supported

V9.0	Excel2000 (not officially supported, but should work OK)
V10.0	Excel2002
V11.0	Excel2003
V12.0	Excel2007
V14.0	Excel2010
V15.0	Excel2013
V16.0	Excel2016

To determine your Excel version,

click on Help, then click on About Microsoft Excel, or
click on the Office button, then click on Excel Options, then click on Resources, or
enter the following formula into a cell =INFO("release")

15.1 German language version of Excel

Note that the range name prefix "S3D" is not valid for the German language version of Excel.

SPALTE is German for COLUMN, so in the same way that C3 is an invalid prefix for an English Excel range name, S3 is an invalid prefix for a German Excel range name.

The prefix "SPG" should be used instead.

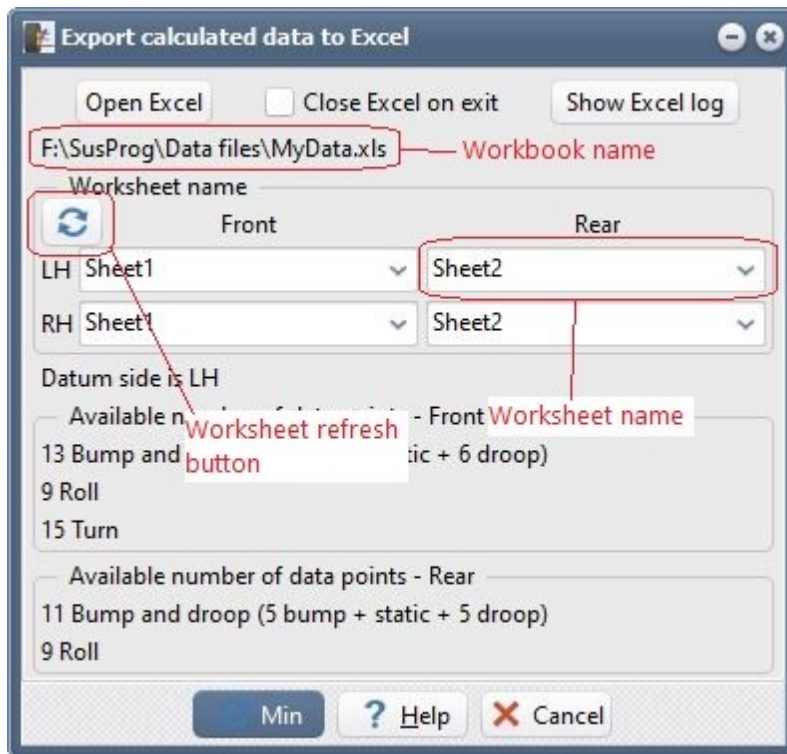
Note that all documentation and messages will still refer to "S3D" even though "SPG" is being used.

15.2 Creating worksheets

A single Excel workbook (usually a data file with the .xls or .xlsx suffix) can contain multiple worksheets.

If you want to create a single vehicle workbook, with data for both front and rear suspensions, then you will need two worksheets, one for the front suspension, and a second for the rear suspension.

Each Excel tool has four selection boxes for the appropriate work sheet name; Front LH, Front RH, Rear LH and Rear RH.



If a sheet name contains the text "Front" then this sheet will be added to the worksheet list for the front selection boxes, if a sheet name contains the text "Rear" then this sheet will be added to the worksheet list for the rear selection boxes. Similarly if a sheet name contains the text "LH" then this sheet will be added to the worksheet list for the LH selection boxes, if a sheet name contains the text "RH" then this sheet will be added to the worksheet list for the RH selection boxes.

Otherwise all worksheet names will be added to all selection boxes.

For each selection box, select the appropriate worksheet name.

If there are no separate sheets for RH and LH then both RH and LH selection boxes should have the same sheet name.

If Excel is saved, then the current worksheet assignments will be saved to the workbook and will be reused when this Excel workbook is next used.

Exporting data from SusProg3D to Excel

For all the individual "Calcs", and for ECalc only the currently specified vehicle end will be calculated, and that data will be exported. The worksheet name(s) specified for that vehicle end will become the active worksheet.

If there are different worksheet names for the LH and RH, then each worksheet will become the active worksheet in turn.

For VCalc, both vehicle ends will be calculated (Front first, then Rear), and that data will be exported. The worksheet name(s) specified for that vehicle end will become the active worksheet. If there are different worksheet names for the LH and RH, then each worksheet will become the active worksheet in turn.

Importing data from Excel to SusProg3D

By default, the Excel import tool will only import data from the worksheet for the currently specified vehicle end.

But if VCalc is open, then both vehicle ends will be imported (Front first, then Rear).

If there are different worksheets for the LH and RH, then each side of the vehicle will be updated with the appropriate data, otherwise the range name must include the car side, or, if omitted, the data will be assumed symmetric and the data will be applied to both sides of the vehicle.

One advantage to having individual LH and RH sheets is that the named ranges do not need the LH or RH suffix. If the worksheet name does not have the LH or RH suffix then the named ranges must include the LH or RH suffix, if not the data for the current vehicle side will be used.

Worksheet names

Worksheet names are not case sensitive.

Worksheet names cannot be greater than 31 characters in length.

Worksheet names cannot contain the characters /, \, [,], *, ?, or :.

Worksheet names can include spaces.

Duplicate worksheet names are not allowed.

Whenever the worksheet names are renamed, and an Excel tool is open, the worksheet refresh button must be used to update the list of valid worksheets and the individual worksheet assignments should be checked.

Every time a worksheet is updated with data, or data is read from a worksheet, worksheet assignments are saved to the workbook's custom document properties. Each Excel tool has its own set of worksheet names.

To view or create Excel custom document properties:

- In Excel, click the File tab.
- Click Info.
- Click Properties at the top of the page, and then select Advanced Properties.
SusProg3D uses the following Name/Value pairs.
Note that the worksheet name must be the name of an actual worksheet.

Calc2Excel	S3D_C2E_Front	Worksheet name for the worksheet containing the Front LH suspension data
------------	---------------	--

	S3D_C2E_Front	Worksheet name for the worksheet containing the Front RH suspension data
	S3D_C2E_RearL	Worksheet name for the worksheet containing the Rear LH suspension data
	S3D_C2E_RearR	Worksheet name for the worksheet containing the Rear RH suspension data
Input2Excel	S3D_I2E_FrontL	Worksheet name for the worksheet containing the Front LH suspension data
	S3D_I2E_FrontR	Worksheet name for the worksheet containing the Front RH suspension data
	S3D_I2E_RearL	Worksheet name for the worksheet containing the Rear LH suspension data
	S3D_I2E_RearR	Worksheet name for the worksheet containing the Rear RH suspension data
Excel2Input	S3D_E2I_FrontL	Worksheet name for the worksheet containing the Front LH suspension data
	S3D_E2I_FrontR	Worksheet name for the worksheet containing the Front RH suspension data
	S3D_E2I_RearL	Worksheet name for the worksheet containing the Rear LH suspension data
	S3D_E2I_RearR	Worksheet name for the worksheet containing the Rear RH suspension data
Excel2CAD	S3D_E2C_Front	Worksheet name for the worksheet containing the Front LH suspension data
	S3D_E2C_Front	Worksheet name for the worksheet containing the Front RH suspension data
	S3D_E2C_RearL	Worksheet name for the worksheet containing the Rear LH suspension data
	S3D_E2C_RearR	Worksheet name for the worksheet containing the Rear RH suspension data

15.3 Creating named ranges - 1

In Excel, you will need to create named ranges.

- To name a group of cells, select the cells, then Formulas -> Define Name. Change the Scope from "Workbook" to the name of the sheet.
- Use Formulas -> Name Manger to see all the named ranges. Note that all names should be scoped to their specific sheets.

Depending on the individual item, the required range will be either a single cell, or an appropriately sized range of cells.

Name the Excel range as follows:

Name syntax: S3D_Range_Group_Item[_CarSide]

All names start with "S3D". This is to ensure that there is no clash with any other named ranges in your workbook. Items in square brackets are optional. Names are not case sensitive. The separation character is an underline "_".

Items in the Linkage, WheelAlignment and WheelAndTyre groups require a either a named single cell (for a specific item) or an appropriately sized named range of cells (for all items).

If the range size is smaller than the total number if items in that group, then the number of data items will be truncated to fit in the range.

Items in the Datum groups require either a named single cell or, for XYZ items, an appropriately sized range of 1, 2 or 3 cells.

The Range identifier is optional and is any combination of one, two or three characters, "B", "R" and "T". If omitted it defaults to "BRT".

For item requiring a group of cells, the required range size is determined by your roll and bump travel and increment setting, and, for the front, the toe turn settings.

For example, if the maximum bump is 85mm and the bump increment is 10mm, there will be 9 bump points; if the maximum droop is 75mm and the droop increment is 10mm, there will be 8 droop points; for a total of 18 bump and droop points (9 bump + 1 static + 8 droop).

Similarly, if the maximum roll is 4 degrees and the roll display increment is 0.5 degree, there will be 17 roll points.

Similarly, if the maximum turn angle is 30 and the increment 5, there will be 13 turn points

These numbers are shown as the "Excel range size required".

In this example, "B" = 18, "R" = 17 and "T" = 13.

The range size is dependent on the Range identifier, and is the sum of the appropriate characters. In this example, if the Range is "BRT" then $18 + 17 + 13 = 48$ cells required.

The range should cover the required number of contiguous cells, and can be either in one row or in one column.

If the range is only a single cell, then the "static" data will be exported.

If the range is less than the number of required points, all cells will be blank, and an error raised.

If the range is greater than the number of required points, the "extra" cells will be blank.

All names shall include a group identifier.

All names shall include an item identifier.

The CarSide is optional. If specified it must be either "LH" or "RH". If it is not specified, data will be provided for the datum side.

For example, to include the LH camber, the name will be "S3D_Point_Camber_LH".

Any item identifier suffixed with XYZ means that all three orthogonal dimensions are available. The axis character will have the same meaning as the specified axis settings. You can specify 1, 2 or 3 of the axis characters, and they can be in any order (eg XY, ZYX, ZX, etc). The cell range must match the number of axis characters.

If a single axis character is specified (eg X, Y or Z) then the cell range must be either a single row (of the appropriate number of columns) or a single column (of the appropriate number of rows).

If two axis characters are specified (eg XY, YZ or ZX) then the cell range must be a rectangle of either two rows (of the appropriate number of columns) or two columns (of the appropriate number of rows).

If three axis characters are specified (eg XYZ) then the cell range must be a rectangle of either three rows (of the appropriate number of columns) or three columns (of the appropriate number of rows).

If you omit the axis characters, then they will default to XYZ, ordered in the horizontal, vertical and longitudinal directions.

Warning! If you are specifying XYZ items (ie all three coordinates) and the the number of data points is also 3, then the data will be exported with the X Y and Z values in rows, with the data points in columns.

With the exception of the "Datum" group items, all XYZ coordinates default to "ground based", and bump means that the chassis is closer to the ground (ie the wheels have "bumped" and hence the chassis has lowered relative to the ground plane).

Alternatively, calculated data can be exported as coordinates relative to the chassis datum.

To specify that data should be relative to the chassis datum, name a single cell as "S3D_RefDatum" and the contents of that cell should contain some descriptive text that contains the word "Chassis".

If the name "S3D_RefDatum" is not found, or it does not contain the word "Chassis", then all data will default to vehicle (ground) datum.

For the "Datum" group items, all XYZ coordinates are "datum based".

Note that not all items are applicable for a particular suspension configuration.

For the shock and spring group names, "Shock" and "Shock1", "Spring" and "Spring1" refer to the primary (or only) shock and spring; "Shock2" and "Spring2" refer to the secondary shock and spring for that corner of the vehicle.

Either "Center" or "Centre", "Tire" or "Tyre" spellings are OK.

15.4 Creating named ranges - 2

Generally, you will want to have separate worksheets for the front and rear suspensions.

For this, you will need to create two Excel worksheets as "Front" and "Rear".

Each worksheet will need the same set of named ranges.

The easiest way is to create the front worksheet first with all the named ranges, then just copy it to create the rear worksheet.

- If you haven't already done so, rename 'Sheet1' to 'Front'. Make sure you are on worksheet 'Front'.
- Now create all the named ranges (as described in the previous topic). Specify Scope as 'Front'.
- Now create a 'Rear' worksheet by copying the 'Front' sheet.

Click on the 'Front' sheet tab (to make sure that is the current sheet).

On the Home tab, in the Cells group, click Format and then under Organize Sheets, click Move or Copy Sheet.

You can also right-click on a selected sheet tab, and then click Move or Copy.

Where the dialog says 'Before sheet', select 'Sheet2'.
Then 'tick' the 'Create a copy' box, then OK.

- Excel will copy the 'Front' sheet, and create a new sheet called 'Front (2)'. Rename it to 'Rear'.
- To see a complete list of the named ranges
Use Formulas -> Name Manger to see all the named ranges. Note that all names should be scoped to their specific sheets.

If you have existing front and rear worksheets, and need to add a named range to one or both sheets

- If you need to add a name range to a sheet later on, then make that sheet the current sheet. Add the named range (as described in the previous topic) ensuring that the Scope as the sheet name.
- This technique can also be used to create bespoke LH and RH sheets, so that the workbook contains four worksheets, FrontLH, FrontRH, RearLH and RearRH. One advantage to having individual LH and RH sheets is that the named ranges do not need the LH or RH suffix.

If you have existing front and rear worksheets, and need to add a named range to one or both sheets

- If you need to add the name range to one sheet only, then make that sheet the current sheet.
If you need to add the named range to both sheets, then make the front sheet the current sheet.
- Create the name range (as described in the previous topic), but make sure that the name is prefixed with the sheet name and an exclamation mark.
For example, if you want to create a name "S3D_BRT_Point_Camber" on the 'Front' worksheet, then the name will be "Front!S3D_BRT_Point_Camber". Note the exclamation mark. There are no spaces in the name.
Then click "Add".
You should see the name added, together with its sheet name on the right.
- Now, to add the same "S3D_BRT_Point_Camber" to the 'Rear' worksheet.
Make the 'Rear' worksheet the current worksheet.
Create the name range (as described in the previous topic), prefixed with the sheet name and an exclamation mark.
For example, if you want to create a name "S3D_BRT_Point_Camber" on the 'Rear' worksheet, then the name will be "Rear!S3D_BRT_Point_Camber".
Then click "Add".
You should see the name added, together with its sheet name on the right.
- This technique can also be used to create LH and RH sheets, so that the workbook contains four worksheets, FrontLH, FrontRH, RearLH and RearRH. One advantage to having individual LH and RH sheets is that the named ranges do not need the LH or RH suffix.

15.5 Calculated data Excel names

Name the Excel range as follows:

Name syntax: S3D[_Range]_Group_Item[_CarSide]

All names start with "S3D". This is to ensure that there is no clash with any other named ranges in your workbook. Items in square brackets are optional. Names are not case sensitive. The separation character is an underline "_".

The Range identifier is optional and is any combination of one, two or three characters, "B", "R" and "T".

If omitted it defaults to "BRT" and exports all bump and droop + all roll + all turn (front only) points.

The Range identifier "B" will include all the bump and droop points, "R" will include all the roll points and "T" (front only) will include all the turn points.

The order is significant, for example "RBT" will output the roll points, then the bump and droop points and finally the turn points in that order.

If, for example, you only need the bump and droop points, then the range identifier will be "B".

All names shall include a Group identifier.

All names shall include an item identifier. If you omit the axis characters, then they will default to XYZ, ordered in the horizontal, vertical and longitudinal directions.

The CarSide is optional. If specified it must be either "LH" or "RH". If it is not specified, the data will be used for both sides.

When using one set of data for both sides, it is usual for the horizontal dimensions to be positive for one side of the vehicle, and negative for the other. In this case it is suggested that positive dimensions are used, and that the default car side is also set to the same side. This will ensure that the other side of the vehicle is assigned the negative dimensions.

Calculated data can be exported as coordinates relative to the vehicle (ie ground) datum, or relative to the chassis datum.

Unless otherwise specified, all data will be relative to vehicle (ground) datum.

To specify that data should be relative to the chassis datum, name a single cell as "S3D_RefDatum" and the contents of that cell should contain some descriptive text that contains the word "Chassis". If the name "S3D_RefDatum" is not found, or it does not contain the word "Chassis", then all data will default to vehicle (ground) datum.

To identify the source file, name a single cell as "S3D_File_Name" and if the file version is required, name a single cell as "S3D_File_Version"

Range identifier	Group identifier	Item identifier	LH and RH values	Description
BRT	Point	AccelAnti	Yes	Anti-lift percentage. For the front suspension with front wheel drive, reduces droop travel under forward acceleration
		AccelAnti or AntiSquat	Yes	Anti-squat percentage. For the rear suspension with rear wheel drive, reduces bump travel under forward acceleration.
		Axle*XYZ (where * is 1 to 9)	Yes	The available values will vary according to the specific geometry type. See Axle mounting points for itemised descriptions.
		BrakeAnti or AntiDive	Yes	Anti-dive percentage. For the front suspension, reduces bump travel under forward braking.
		BrakeAnti or AntiLift	Yes	Anti-lift percentage. For the rear suspension, reduces

Range identifier	Group identifier	Item identifier	LH and RH values	Description
				droop travel under forward braking.
		Bump	Yes	Wheel travel. Positive values are bump, negative values are droop.
		Camber	Yes	Wheel camber, degrees
		Caster	Yes	Wheel caster or inclination , degrees
		Chassis*XYZ (where * is 1 to 9)	Yes	The available values will vary according to the specific geometry type. See Chassis mounting points for itemised descriptions.
		Description	Yes	Wheel travel / chassis roll description
		FrontICLength	Yes	Front view swing axle length. Instant centre to wheel contact centre, along the ground
		FrontICXYZ	Yes	Front view instant centre.
		KPBXYZ	Yes	Kingpin bottom pivot point (or equivalent). If the upright has a single bottom pivot point, then this will be the same point. If the upright has two bottom pivot points, then this will be the virtual pivot point.
		KPGXYZ	Yes	Where the line of the kingpin , from the KPT to the KPB (or equivalent) intersects the ground plane.
		KPI	Yes	Kingpin inclination (or equivalent) , degrees
		KPTXYZ	Yes	Kingpin top pivot point (or equivalent). If the upright has a single top pivot point, then this will be the same point.

Range identifier	Group identifier	Item identifier	LH and RH values	Description
				If the upright has two top pivot points, then this will be the virtual pivot point.
		Pinion	Yes	Pinion angle, degrees (relative to ground plane)
		RCHeight	No	Roll centre vertical position (from ground)
		RCOffset	No	Roll centre horizontal position (from vehicle centreline)
		RideHeightRefXYZ	Yes	Ride height reference point location. If you need both front and rear ride height reference point locations then use Vehicle_RideHeightRefXYZ Using vehicle datum the vertical dimension is the actual ride height. Using chassis datum the vertical dimension is the vertical location of the ride height reference point from the chassis datum.
		Roll	Yes	Chassis roll, degrees. Positive values are LH roll, negative values are RH roll.
		Scrub	Yes	Wheel horizontal movement from Static position In front view
		ScrubRadius or KPIOffset	Yes	Distance from the intersection of the kingpin (or equivalent) and the wheel contact centre, in front view. Positive offset is when the KPI line intersects inboard of the wheel contact patch centreline.
		SidelCAngle or SidelCAngleG	Yes	Angle of the line joining the side view IC and the wheel contact patch from horizontal

Range identifier	Group identifier	Item identifier	LH and RH values	Description
		SidelCAngleH	Yes	Angle of the line joining the side view IC and the wheel hub centre from horizontal
		SidelCAxleHeight or SidelCAxleHeight G	Yes	Where the line joining the side view IC and the wheel contact patch "crosses" the "other" axle. Height above ground.
		SidelCAxleHeight H	Yes	Where the line joining the side view IC and the wheel hub centre "crosses" the "other" axle. Height above ground.
		SidelCHeight	Yes	Side view pitch centre height. Instant centre to ground
		SidelCLength	Yes	Side view pitch centre length. Instant centre to wheel contact centre, along the ground
		SteeringOffset	Yes	The radial distance from the wheel contact point to the steering axis (extended to the ground plane)
		Toe or ToeDegree	Yes	Wheel toe, degrees (toe in is positive) (Versions prior to V4.87A reported toe in as negative)
		ToeIn or ToeOffset	Yes	Wheel toe in, in mm or inches (toe in is positive) (Versions prior to V4.87A reported toe in as negative)
		Tramp	Yes	Wheel longitudinal movement from Static position In side view
		Trail	Yes	Distance from the intersection of the kingpin (or equivalent) and the wheel contact centre, in side view. Positive trail is when the KPI line intersects ahead of the wheel contact patch centreline.

Range identifier	Group identifier	Item identifier	LH and RH values	Description
		TyreRC or TireRC	Yes	Tyre radius on centreline
		TyreRE or TireRE	Yes	Tyre radius at contact patch centroid
		TyreRO or TireRO	Yes	Tyre contact patch centroid offset from tyre centreline
		Upright*XYZ (where * is 1 to 6)	Yes	The available values will vary according to the specific geometry type. See Upright mounting points for itemised descriptions.
		WheelCentreXYZ or WheelCenterXYZ	Yes	Location of the spindle/wheel centre.
		WheelHubXYZ	Yes	Location of the spindle/wheel hub mounting face.
		WheelContactXYZ or WheelCPCxyz	Yes	Location of the wheel contact patch centroid on ground. Vehicle datum: The vertical value will always be zero (ie on ground) Chassis datum: The vertical value will be distance above or below the chassis datum.
		WheelTCGxyz	Yes	Location of the wheel centreline projected to ground. The horizontal value is the "half track" The longitudinal value is the distance to the longitudinal datum. Vehicle datum: The vertical value will always be zero (ie on ground) Chassis datum: The vertical value will be distance above or below the chassis datum.
T If omitted will default to T B and R are not allowed	ToeOutInTurn			The toe out in turn data. This is only available for the front suspension. All of the data for each turn angle will be included. This data requires a single range of cells, N rows by 25 columns,

Range identifier	Group identifier	Item identifier	LH and RH values	Description
				<p>where N is the number of calculated points. See toe-out in turn increment to calculate N.</p> <p>The data will be presented in the following sequence.</p> <ul style="list-style-type: none"> Steering turn angle Steering wheel angle Toe out in turn Wheel toe angle LH and RH Rack travel or pitman arm rotation Ackermann percentage Camber (actual) LH and RH Camber (change) LH and RH Caster (actual) LH and RH Caster (change) LH and RH Jacking effect LH and RH Steering ratio LH and RH Caster trail LH and RH KPI offset LH and RH Steering offset LH and RH <p>If the Excel range is larger than required, the 'excess' cells will be left blank.</p> <p>If the Excel range is smaller than required then an error message 'Range check error' will be shown.</p>
BRT	Shock* Spring* (where * is 1 or 2. If omitted, defaults to 1)	ChassisXYZ	Yes	Chassis mounting point. For a "coilover" spring, this is the shock chassis mounting point.
		Length	Yes	For a shockabsorber, length is the distance between chassis and suspension mounting points. For a spring, it is the actual spring length between the spring abutments.
		MotionRatio	Yes	Motion ratio.
		SuspensionXYZ	Yes	Suspension mounting point. For a "coilover" spring, this is the shock suspension mounting point.

Range identifier	Group identifier	Item identifier	LH and RH values	Description
BRT	Spring* (where * is 1 or 2. If omitted, defaults to 1)	Deflection	Yes	Spring deflection from the free length
		WheelRate	Yes	Wheel rate
		SpringRate	Yes	Spring rate
BRT	AntiRollBar	ArmLinkXYZ	Yes	The antirollbar arm and link pivot point.
		ChassisXYZ	Yes	Chassis mounting point.
		MotionRatio	Yes	Motion ratio.
		SuspensionXYZ	Yes	Suspension mounting point.
		Twist	Yes	Twist angle (degrees)
		WheelRate	Yes	Wheel rate
		ArbRate	Yes	Antirollbar rate
BRT	Bellcrank	AntirollBarXYZ	Yes	Bellcrank anti-roll bar link pivot
		PivotAxis1XYZ	Yes	Bellcrank pivot axis on chassis - P1
		PivotAxis2XYZ	Yes	Bellcrank pivot axis on chassis - P2
		Rod2Bellcrank	Yes	Angle between the pushrod or pullrod and the bellcrank arm
		RodXYZ	Yes	Bellcrank pull or push rod pivot
		Rotation	Yes	Bellcrank rotation angle (from static)
		Shock2Bellcrank	Yes	Angle between the shock and the bellcrank arm
		ShockXYZ	Yes	Bellcrank shock pivot
	SuspensionXYZ	Yes	Pushrod or pullrod actuation point on the suspension	

Range identifier	Group identifier	Item identifier	LH and RH values	Description
BRT	Driveline (for driveshafts)	ChassisXYZ	Yes	Driveshaft universal joint - chassis
		Item* (where * is 1 to 4)	Yes	1 is the driveshaft or CV joint plunge, 2 is the inner joint angle, 3 is the outer joint angle, 4 is the driveshaft length.
		SuspensionXYZ	Yes	Driveshaft universal joint - suspension. For independent suspension, usually on the upright, strut or trailing arm
BRT	Driveline (for propshaft)	Item* (where * is 1 to 6)	No	1 is the spline travel, 2 is the centre bearing plunge, 3 is the gearbox universal joint angle (for torque tube), 4 is the gearbox universal joint angle (to propshaft) 5 is the centre bearing universal joint angle (2-piece shafts) 6 is the axle pinion universal joint angle (to propshaft)
Not applicable	Vehicle	PitchCentre or PitchCenter	Yes	<p>Longitudinal pitch centre data</p> <p>All of the pitch centre data will be included.</p> <p>This data requires a single range of cells, 2N+1 rows by M+1 columns, where N is the number of front suspension bump and droop points and M is the number of rear suspension bump and droop points.</p> <p>The data will be presented in the same format and sequence as output in the PitchResults.</p> <p>If the Excel range is larger than required, the 'excess' cells will be left blank.</p> <p>If the Excel range is smaller than required then an error message 'Range check error' will be shown.</p>
BRT		RideHeightRefXYZ	No	Ride height reference point location.

Range identifier	Group identifier	Item identifier	LH and RH values	Description
				<p>If you only need one ride height reference point location then use Point_RideHeightRefXYZ</p> <p>Using vehicle datum the vertical dimension is the actual ride height.</p> <p>Using chassis datum the vertical dimension is the vertical location of the ride height reference point from the chassis datum.</p> <p>Although ride height can be specified using a combination of 2 or 3 points, when exporting data to Excel, all four ride height reference points will be exported. See Specifying Ride Height</p> <p>Requires a N x 12 cell range (N rows x 12 columns).</p> <p>The first 3 columns are the front LH, the second 3 columns are the front RH, the third 3 columns are the rear LH and the final 3 columns are the rear RH ride height reference point.</p> <p>If the Excel range is larger than required, the 'excess' cells will be left blank.</p> <p>If the Excel range is smaller than required then an error message 'Range check error' will be shown.</p>
BRT		RideHeight	No	<p>Ride height, distance from ground to reference point.</p> <p>Although ride height can be specified using a combination of 2 or 3 points, when exporting data to Excel, all four ride heights will be exported. See Specifying Ride Height.</p> <p>Requires a N x 4 cell range (N rows x 4 columns).</p> <p>The first column is the front LH, the second column is the front RH, the third column is the rear</p>

Range identifier	Group identifier	Item identifier	LH and RH values	Description
				<p>LH and the fourth column is the rear RH ride height.</p> <p>If the Excel range is larger than required, the 'excess' cells will be left blank.</p> <p>If the Excel range is smaller than required then an error message 'Range check error' will be shown.</p>
BRT	WheelAlignment	Item* (where * is 0 to 6) If blank, will default to Item00	Yes	<p>This is the static wheel alignment</p> <p>0 or 00 means "all items" and requires a 6 cell range.</p> <p>1 or 01 is the camber, 2 or 02 is the caster or inclination, 3 or 03 is the toe, 4 or 04 is the wheel location (horizontal), 5 or 05 is the wheel location (longitudinal), 6 or 06 is the toe reference length.</p>
Not applicable	WheelAndTyre or WheelAndTire	Item* (where * is 0 to 11) If blank, will default to Item00	Yes	<p>Measurement units. Note that all dimensions will be either "mm" or "inches" according to the units used in the wheel input.</p> <p>0 or 00 means "all items" and requires an 11 cell range.</p> <p>1 or 01 is the rim diameter, 2 or 02 is the rim width, 3 or 03 is the rim mounting offset / ET, 4 or 04 is the tyre tread width, 5 or 05 is the tyre width, 6 or 06 is the tyre radius, 7 or 07 is the tyre rate, 8 or 08 is the toe reference length, 9 or 09 is the description, 10 is the tyre diameter, 11 is the wheel spacer thickness.</p>
Not applicable	Linkage	Link* (where * is 0 to 9)	Yes	<p>The available values will vary according to the specific geometry type. See Suspension</p>

Range identifier	Group identifier	Item identifier	LH and RH values	Description
		If blank, will default to Link00		link lengths below for itemised descriptions. 0 or 00 means "all items" and requires a 9 cell range.

15.6 Input data Excel names

Name the Excel range as follows:

Name syntax: S3D_Group_Item[_CarSide]

All names start with "S3D". This is to ensure that there is no clash with any other named ranges in your workbook. Items in square brackets are optional. Names are not case sensitive. The separation character is an underline "_".

All names shall include a group identifier.

All names shall include an item identifier. If you omit the axis characters, then they will default to XYZ, ordered in the horizontal, vertical and longitudinal directions.

The CarSide is optional. If specified it must be either "LH" or "RH". If it is not specified, the data will be used for both sides.

The Range identifier is not used for input data.

When importing data from Excel, if an item is not found, then the value in the data file will remain unchanged.

Group identifier	Item identifier	LH and RH values	Description
DatumPoint	Axle*XYZ (where * is 1 to 9)	Yes	The available values will vary according to the specific geometry type. See Axle mounting points for itemised descriptions.
	Chassis*XYZ (where * is 1 to 9)	Yes	The available values will vary according to the specific geometry type. See Chassis mounting points for itemised descriptions.
	RideHeightXYZ		Has been replaced by S3D_Vehicle_RideHeightRefXYZ
	Strut*XYZ (where * is 0 to 10 or 0 to 12)	Yes	0 or 00 means "all items" and requires either a 3 x 10 or 3 x 12 cell range depending on the strut type. The available values will vary according to the specific geometry type. See Strut datum dimensions for itemised descriptions. If "all items" is not used, and individual items are specified, then S3D_DatumPoint_Strut01 must be specified so that the type of strut can be identified.

Group identifier	Item identifier	LH and RH values	Description
	Upright*XYZ (where * is 0 to 6 or 0 to 10)	Yes	0 or 00 means "all items". If there are no camber shims, requires a 3 x 6 cell range. If there are camber shims, requires a 3 x 10 cell range. The available values will vary according to the specific geometry type. See Upright mounting points for itemised descriptions
DatumShock* DatumSpring*	ChassisXYZ (where * is 1 or 2. If omitted, defaults to 1)	Yes	Chassis mounting point. For a "coilover" spring, this is the shock chassis mounting point.
	Length	Yes	Shock absorber or Spring length (static)
DatumBellcrank	PushrodArmLength or PullrodArmLength	Yes	Pushrod or pullrod arm length.
	PushrodArmOffset or PullrodArmOffset	Yes	Pushrod or pullrod arm offset
	ShockArmLength	Yes	Shock arm length
	ShockArmOffset	Yes	Shock arm offset
	Pushrod2ShockLength or Pullrod2ShockLength	Yes	Distance between pullrod (or pushrod) and shock pivots
	Pushrod2ShockAngle or Pullrod2ShockAngle	Yes	Angle between pullrod (or pushrod) and shock arms, degrees
	Pushrod2ShockCalc or Pullrod2ShockCalc	Yes	Specify 0 to calculate using distance, 1 to calculate using angle

Group identifier	Item identifier	LH and RH values	Description
	Pullrod2Shock Calc		
	ArbArmLength	Yes	Antirollbar arm length
	ArbArmOffset	Yes	Antirollbar arm offset
	Pushrod2ArbLength or Pullrod2ArbLength	Yes	Distance between pullrod (or pushrod) and antirollbar pivots
	Pushrod2ArbAngle or Pullrod2ArbAngle	Yes	Angle between pullrod (or pushrod) and antirollbar arms, degrees.
	Pushrod2ArbCalc or Pullrod2ArbCalc	Yes	Specify 0 to calculate using distance, 1 to calculate using angle
	PivotAxis1XYZ	Yes	Bellcrank pivot axis on chassis - P1
	PivotAxis2XYZ	Yes	Bellcrank pivot axis on chassis - P2
	PivotAxisCalc	Yes	Specify 1 to calculate pivot axis on chassis - P2 If not found, or is not 1, then pivot axis on chassis - P2 must be input
	RotationDirection	Yes	Bellcrank rotation direction in bump, 0 for clockwise, 1 for anti-clockwise

Group identifier	Item identifier	LH and RH values	Description
	PushrodLength or PullrodLength	Yes	Pushrod or pullrod length
	LinkCalc	Yes	Specify 0 for Autocalc, 1 for Pushrod (or pullrod) length, 2 for shock length.
DatumAntiRo llBar	ChassisXYZ	Yes	Chassis mounting point.
	LinkCalc	Yes	Specify 1 for Autocalc, 0 for Specify
	LinkLength	Yes	Antirollbar link length
	LinkType	Yes	Specify 0 for type A, 1 for no link, 2 for type B
Vehicle	RideHeightRefXYZ	No	<p>Ride height reference point location.</p> <p>Ride height can be specified using a combination of 2 or 3 points on LH and/or RH sides of the vehicle. See Specifying Ride Height.</p> <p>When importing data from Excel, data will be read from all non-blank cells and loaded into the input data. There must be at least two (one front and one rear) or three (one front and two rear, or two front and one rear) cells with valid dimensions.</p> <p>Requires either a 12 cell range.</p> <p>2 rows x 6 columns</p> <p>The first row is the front LH and RH and the second row is the rear LH and RH ride height reference point.</p> <p>4 rows x 3 columns</p> <p>The first row is the front LH, second row is front RH, third row is rear LH and the fourth row is rear RH ride height reference point.</p>
	RideHeight	No	<p>Static ride height, distance from ground to reference point.</p> <p>Ride height can be specified using a combination of 2 or 3 points on LH and/or RH sides of the vehicle. See Specifying Ride Height.</p>

Group identifier	Item identifier	LH and RH values	Description
			<p>When importing data from Excel, data will be read from all non-blank cells and loaded into the input data. There must be at least two (one front and one rear) or three (one front and two rear, or two front and one rear) cells with valid dimensions.</p> <p>Requires a 4 cell range.</p> <p>1 row x 4 columns</p> <p>The first column is the front LH, the second column is the front RH, the third column is the rear LH and the fourth column is the rear RH ride height.</p> <p>2 rows x 2 columns</p> <p>The first row is the front LH and RH, the second row is the rear LH and RH ride heights.</p> <p>4 rows x 1 column</p> <p>The first row is the front LH, the second row is the front RH, the third row is the rear LH and the fourth row is the rear RH ride height.</p>
	RideHeightComment	No	<p>Ride height reference point description.</p> <p>Requires a 4 cell range.</p> <p>4 rows x 1 column</p> <p>The first row is the front LH, the second row is the front RH, the third row is the rear LH and the fourth row is the rear RH ride height reference point description.</p>
WheelAlignment	Item* (where * is 0 to 6) If blank, will default to Item00	Yes	<p>This is the static wheel alignment.</p> <p>0 or 00 means "all items" and requires a 6 cell range.</p> <p>1 or 01 is the camber,</p> <p>2 or 02 is the caster or inclination,</p> <p>3 or 03 is the toe,</p> <p>4 or 04 is the wheel location (horizontal),</p> <p>5 or 05 is the wheel location (longitudinal),</p> <p>6 or 06 is the toe reference length.</p>
WheelAndTyre or WheelAndTire	Item* (where * is 0 to 11) If blank, will default to Item00	Yes	<p>Measurement units.</p> <p>For the rim diameter, if the value is less than 50 then it will be imported as inches, otherwise mm.</p> <p>For the rim width, if the value is less than 25 then it will be imported as inches, otherwise mm.</p> <p>All other dimensions will be imported as "mm" or "inches" according to the units used in the wheel input.</p>

Group identifier	Item identifier	LH and RH values	Description
			0 or 00 means "all items" and requires an 11 cell range. 1 or 01 is the rim diameter, 2 or 02 is the rim width, 3 or 03 is the rim mounting offset / ET, 4 or 04 is the tyre tread width, 5 or 05 is the tyre width, 6 or 06 is the tyre radius, 7 or 07 is the tyre rate, 8 or 08 is the toe reference length, 9 or 09 is the description, 10 is the tyre diameter, 11 is the wheel spacer thickness.
Linkage	Link* (where * is 0 to 9) If blank, will default to Link00	Yes	The available values will vary according to the specific geometry type. See Suspension link lengths below for itemised descriptions. 0 or 00 means "all items" and requires a 9 cell range.

15.7 CAD input data Excel names

Name the Excel range as follows:

Name syntax: S3D_Group_Item[_CarSide]

All names start with "S3D". This is to ensure that there is no clash with any other named ranges in your workbook. Items in square brackets are optional. Names are not case sensitive. The separation character is an underline "_".

All names shall include a group identifier.

All names shall include an item identifier. If you omit the axis characters, then they will default to XYZ, ordered in the horizontal, vertical and longitudinal directions.

The CarSide is optional. If specified it must be either "LH" or "RH". If it is not specified, the data will be used for both sides.

The Range identifier is not used for input data.

When using one set of data for both sides, it is usual for the horizontal dimensions to be positive for one side of the vehicle, and negative for the other. In this case it is suggested that positive dimensions are used, and that the default car side is also set to the same side. This will ensure that the other side of the vehicle is assigned the negative dimensions.

Group identifier	Item identifier	LH and RH values	Description
CAD or CMM	Chassis*XYZ (where * is 1 to 5)	Yes	The available values will vary according to the specific geometry type.

Group identifier	Item identifier	LH and RH values	Description
			See Chassis mounting points below for itemised descriptions.
	Comment	No	Comment text
	DatumXYZ	No	CAD datum offset from vehicle datum
	SpindleXYZ	Yes	Spindle reference point
	StrutAxisTXYZ	Yes	A point on the top of the strut rod. Must be on the rod axis.
	StrutAxisBXYZ	Yes	A point on the bottom of the strut rod or tube. Must be on the rod or slider axis. Together, StrutAxisT and StrutAxisB define the strut rod axis.
	Suspension*XYZ (where * is 1 to 8)	Yes	Suspension mounting on the upright / trailing arm / A-arm 1 is the shockabsorber mounting point 2 is the spring mounting point 3 is the anti-roll bar link mounting point 4 is the pull or pushrod mounting point 5 is the second shockabsorber mounting point (if there are 2 shockabsorbers) 6 is the second spring mounting point (if there are 2 springs) 7 is the inclination control link (for Ford Integral Link) 8 is the toe link mounting (for A-arm mounted toe control links)
	Upright*XYZ (where * is 1 to 6)	Yes	The available values will vary according to the specific geometry type. See Upright mounting points below for itemised descriptions.
	WheelCentreXYZ	Yes	Spindle / wheel centre
WheelAndTyre or WheelAndTire	Item* (where * is 0 to 11) If blank, will default to Item00	Yes	Measurement units. For the rim diameter, if the value is less than 50 then it will be imported as inches, otherwise mm. For the rim width, if the value is less than 25 then it will be imported as inches, otherwise mm. All other dimensions will be imported as "mm" or "inches" according to the units used in the wheel input. 0 or 00 means "all items" and requires an 11 cell range.

Group identifier	Item identifier	LH and RH values	Description
			1 or 01 is the rim diameter, 2 or 02 is the rim width, 3 or 03 is the rim mounting offset / ET, 4 or 04 is the tyre tread width, 5 or 05 is the tyre width, 6 or 06 is the tyre radius, 7 or 07 is the tyre rate, 8 or 08 is the toe reference length, 9 or 09 is the description, 10 is the tyre diameter, 11 is the wheel spacer thickness.

15.8 Chassis mounting points

For a double A-arm suspension:

- 1 = top front link
- 2 = top rear link
- 3 = toe control link (usually the rack end ball joint)
- 4 = bottom front link
- 5 = bottom rear link
- 6 = top A-arm virtual pivot point
- 7 = top A-arm normal pivot point
- 8 = bottom A-arm virtual pivot point
- 9 = bottom A-arm normal pivot point

Virtual and normal points (6, 7, 8 & 9) are calculated data only, and are not applicable for Datum groups

For a strut suspension

- 1 = strut top mounting
- 3 = toe control link (usually the rack end ball joint)
- 4 = bottom front link
- 5 = bottom rear link
- 8 = bottom A-arm virtual pivot point
- 9 = bottom A-arm normal pivot point

Virtual and normal points (8 & 9) are calculated data only, and are not applicable for Datum groups

Chapman strut

- 1 = strut top mounting
- 4 = trailing arm mounting
- 5 = inner universal joint

Ford Integral Link

- 2 = camber control link
- 3 = toe control link
- 4 = lower control a-arm front
- 5 = lower control a-arm rear
- 8 = lower control a-arm virtual pivot point
- 9 = lower control a-arm normal pivot point

Virtual and normal points (8 & 9) are calculated data only, and are not applicable for Datum groups

For a 3 or 4 link live axle	1 = top link mounting, 2 = bottom link mounting
For twin trailing arm live axle	2 = arm mounting
For a torque tube live axle	2 = torque tube mounting
For a torque arm live axle	1 = torque arm mounting, 2 = bottom link mounting
For a Mumford link	5 = Mumford bellcrank (or lever) pivot point 6 = Mumford bellcrank (or lever) axis reference point
For a Panhard rod	4 = Panhard rod chassis mounting
For a Watts linkage, with the Watts lever pivoting on the chassis	5 = Watts lever pivot point 6 = Watts lever axis reference point
For a Watts linkage, with the Watts lever pivoting on the axle	4 = Watts horizontal link mounting

15.9 Upright mounting points

For the typical independent suspension upright

Item	Value	Description
01	XYZ	Top mounting for an upright with single top mounting, or Top front mounting for an upright with two top mountings.
02	XYZ	Top rear mounting for an upright with two top mountings. Leave blank if not applicable.
03	XYZ	Toe control link mounting
04	XYZ	Bottom mounting for an upright with single bottom mounting, or Bottom front mounting for an upright with two bottom mountings.
05	XYZ	Bottom rear mounting for an upright with two bottom mountings. Leave blank if not applicable.
06	Single number	Spindle reference point

The following items are only available for input data (Input2Excel and Excel2Input)

07	Text (Export) Single integer number (Import)	Exporting to Excel, the option number + shim pack description will be exported 0 No provision for camber shim adjustment 1 Camber shim adjusts top pivot only 2 Camber shim adjusts both top pivot and toe control pivot 3 Camber shim adjusts lower pivot only 4 Camber shim adjusts both lower pivot and toe control pivot Importing from Excel only the option number is required, any text will be ignored.
08	Single number	Individual shim thickness
09	Single integer number	Number of shims
10	Single number	Total shim pack thickness

Ford integral link

Item	Value	Description
01	XYZ	Inclination control link mounting.
02	XYZ	Camber control link mounting
03	XYZ	Toe control link mounting
04	XYZ	Lower control a-arm mounting.
05	XYZ	Not applicable, leave blank.
06	Single number	Spindle reference point

For the typical independent suspension strut. Note that these are calculated data items for Calc2Excel export only. For strut input data see [Strut datum dimensions](#).

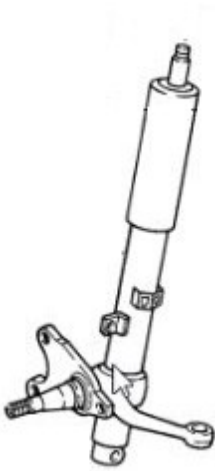
Item	Value	Description
01	XYZ	Not applicable, will default to zero
02	XYZ	Not applicable, will default to zero
03	XYZ	Toe control link mounting
04	XYZ	Bottom mounting for a strut with single bottom mounting, or Bottom front mounting for a strut with two bottom mountings.

Item	Value	Description
05	XYZ	Bottom rear mounting for a strut with two bottom mountings. If not applicable will default to zero
06	Single number	Spindle reference point

15.10 Strut datum dimensions

There are two different styles of strut, and each has a different way to specify dimensions.

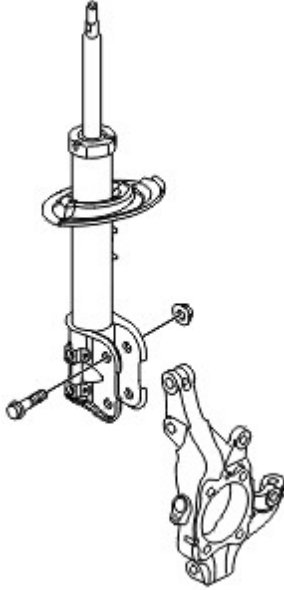
For fixed knuckle/strut types



Item	Value	Description
01	Single character	Strut type, either "A" or "B"
02	XYZ	Strut rod top Not used for strut type B when importing from Excel. Will default to zero.
03	XYZ	Strut rod bottom
04	Single number	Strut axis length Not used for strut type A when importing from Excel. Will default to zero.
05	Single number	Strut axis angle Not used for strut type A when importing from Excel. Will default to zero.
06	XYZ	Bottom A-arm mounting (for a single A-arm mount), or Bottom front link mounting (for the double ball joint bottom mount)
07	XYZ	Bottom rear link mounting (for the double ball joint bottom mount) Leave blank if not applicable.
08	Single number	Steering arm ball joint location, either 0 (on knuckle) or 1 (on strut tube) If not specified when importing from Excel will default to 0

09	XYZ	Steering arm ball joint
10	Single number	Spindle reference point

For the "bolted on" knuckle to strut tube type



Item	Value	Description
01	Single character	Strut type, either "C" or "D"
02	XYZ	Strut tube (knuckle mounting) A
03	XYZ	Strut tube (knuckle mounting) B Not used for strut type D when importing from Excel. Will default to zero.
04	XYZ	Knuckle (strut mounting) A
05	XYZ	Knuckle (strut mounting) B Not used for strut type D when importing from Excel. Will default to zero.
06	Single number	Strut axis length
07	Single number	Adjustment angle for Strut type C Strut axis angle for strut type D
08	XYZ	Bottom A-arm mounting (for a single A-arm mount), or Bottom front link mounting (for the double ball joint bottom mount)
09	XYZ	Bottom rear link mounting (for the double ball joint bottom mount) Leave blank if not applicable.
10	Single number	Steering arm ball joint location, either 0 (on knuckle) or 1 (on strut tube) If not specified when importing from Excel will default to 0
11	XYZ	Steering arm ball joint
12	Single number	Spindle reference point

15.11 Axle mounting points

For a 3 or 4 link live axle	1 is the top link mounting, 2 is the bottom link mounting
For twin trailing arm live axle	2 is the arm mounting
For a torque tube live axle	2 is the torque tube mounting
For a torque arm live axle	3 is the torque arm mounting effective point
For a Mumford link	5 is the Mumford horizontal link mounting
For a Panhard rod	5 is the Panhard rod axle mounting
For a Watts linkage, with the Watts lever pivoting on the chassis	5 is the Watts horizontal link mounting
For a Watts linkage, with the Watts lever pivoting on the axle	6 is the Watts lever pivot point 7 is the Watts lever axis reference point

15.12 Suspension link lengths

For A-arm and multi-link independent suspension	1 = top front link 2 = top rear link 3 = top A-arm base length (for top A-arm only) 4 = top A-arm normal length (for top A-arm only) 5 = toe control link 6 = bottom front link 7 = bottom rear link 8 = bottom A-arm base length (for bottom A-arm only) 9 = bottom A-arm normal length (for bottom A-arm only)
Ford Integral Link	2 = camber control link 5 = toe control link 6 = lower control a-arm, front link 7 = lower control a-arm, rear link 9 = lower control a-arm, normal link
Chapman strut	5 = trailing arm rear link 6 = trailing arm front link 7 = driveshaft
For a 3 or 4 link live axle	1 = top link, 2 = bottom link
For twin trailing arm live axle	2 = trailing arm
For a torque arm live axle	2 = bottom link

For a Mumford link	4 = Mumford lateral link 5 = Mumford intermediate link
For a Panhard rod	4 = Panhard rod
For a Watts linkage	4 = Watts lateral link

15.13 Error and warning messages

The most common errors are caused by the named range specification being smaller than the number of data points.

Any error messages will display in a pop-up window and will be included in the Excel log. Some error messages will also be repeated in the status message (bottom LH of the main SusProg3D window).

Data export failed:

S3D_BRT_Spring1_WheelRate Variant or safe array index out of bounds

**Exception EExcelError in module SusProg3D.exe at 00000000074AAEA.
S3D_BRT_Spring1_WheelRate Variant or safe array index out of bounds**

Data export failed: Front (results) S3D_BRT_Spring1_WheelRate requires a minimum 17 rows, but has only 8. Update the range specification!

The error messages will typically include the name in error (S3D_BRT_Spring1_WheelRate in the examples above).

The module address (74AAEA in the example above) will differ.

16 Tools

16.1 Create Chassis Datum from vehicle coordinates

From the Tool tab, select Datum then "Create from vehicle coordinates".

The intended use of this tool is to convert vehicle (ie ground based) coordinates to chassis datum coordinates.

Before using this tool, all the required calculations should be done, as the calculated vehicle coordinates will be used to create the chassis datum referenced mounting points.

Chassis datum (description):

Vertical datum	Identify the vertical datum plane by name. Typically "Undertray" or "Chassis build datum"
Longitudinal datum	Identify the longitudinal datum reference point by name. This could be a suspension mounting point or any convenient hard point on the chassis structure.

Chassis datum (vehicle coordinates):

The chassis datum surface is defined by three points:

- Two points define the longitudinal centreline, one at the front and one at the rear. While these two point will usually be on the vehicle centreline, that is not essential. But the two points will be used to define the centreline of the chassis datum surface.
- The third point defines the "twist" or "side rake" in the chassis datum plane as seen from front or rear view.

The chassis longitudinal datum is controlled by specifying a fourth point, the longitudinal datum reference point.

This is a convenient point from which all longitudinal dimensions are taken. This point need not be on the chosen chassis datum surface, and can be at any height.

All four points are dimensioned from the vehicle ground datum.

Centreline reference point - front	This point defines the chassis datum surface longitudinal centreline. Any convenient point, but it must be in the chassis datum plane, and should be on the chassis centreline. Ideally this point will be somewhere around the front axle, or the front edge of the actual chassis datum plane.
Centreline reference point - rear	This point defines the chassis datum surface longitudinal centreline. Any convenient point, but it must be in the chassis datum plane, and should be on the chassis centreline. Ideally this point will be somewhere around the rear axle, or therear edge of the actual chassis datum plane.
Lateral reference point	This point must be in the chassis datum plane, and offset to one side from the chassis datum longitudinal centreline. It is used to specify the amount of "twist" or "side rake". If there is no "twist" or "side rake" then specify this point the same as the centreline reference point - rear, but with a horizontal value about the same as half the track.
Longitudinal reference point	This point defines the zero datum for all longitudinal dimensions.

It may be a convenient chassis point (the back edge of the chassis datum plane), a fixed chassis feature (the front edge of the front bulkhead), or a legislated reference point (a particular chassis frame reference hole).

Chassis datum surface:

This defines the size of the chassis datum surface. If using a ground based datum, then leave all these dimensions zero. If using an actual chassis datum, like a surface plate or a build table or jig, then this will define a rectangular surface representative of the actual chassis datum surface.

Front edge of datum surface The distance the front edge of the chassis build surface is from the longitudinal datum.

Rear edge of datum surface The distance the rear edge of the chassis build surface is from the longitudinal datum.

Datum surface width The chassis build surface width.

Now click the "Apply" button.

All the chassis mounting points (suspension, shock, spring, steering) will be calculated.

For further details on using a [ground based vertical datum](#).

For further details on [converting from a ground based to a chassis based vertical datum](#).

For further details on using a [chassis based vertical datum](#).

16.2 Realign Datum Location

From the Tool tab, select Datum, then "Move vertically and/or longitudinally".

The intended use of this tool is to move either or both the vertical and longitudinal datums, and recalculate all chassis pickup points so they are referenced from the new datum plane(s).

Chassis datum (description):

Vertical datum Identify the vertical datum plane by name. Typically "Undertray" or "Chassis build datum"

Longitudinal datum Identify the longitudinal datum reference point by name.
This could be a suspension mounting point or any convenient hard point on the chassis structure.

Realign existing chassis datum Initially, both these dimensions should be zero.

Following the initial calculations, you may decide that the chassis datum originally specified is no longer appropriate.

To move the vertical datum in the +ve direction, enter a positive value for the vertical axis; to move the vertical datum in the -ve direction, enter a negative value for the vertical axis.

To move the longitudinal datum in the +ve direction, enter a positive value for the longitudinal axis; to move the longitudinal datum in the -ve direction, enter a negative value for the longitudinal axis.

Update the vertical and longitudinal datum comments to describe the new datum locations.

Use the 'Apply' button to recalculate the chassis vertical and longitudinal values accordingly.

Finally, do a complete recalculation so that all the dimensions in the various result outputs are updated.

Note that the longitudinal datum reference point dimensions do not change as the point is referenced relative to the datums, and has effectively moved with them.

For further details on using a [ground based vertical datum](#).

For further details on [converting from a ground based to a chassis based vertical datum](#).

For further details on using a [chassis based vertical datum](#).

16.3 CAD to SusProg3D

This tool converts vehicle coordinates to the SusProg3D upright, strut or trailing arm datum coordinates.

Input coordinates can be obtained from CAD drawings, a Coordinate Measuring Machine (CMM) or by measuring an existing vehicle.

A 3D Coordinate Measuring Machine (CMM) is often used to measure a complete vehicle, providing dimensional data in CMM or world coordinates.

The current vehicle configuration and car end will determine the available conversion tool.

[CAD upright](#), [CAD strut](#), [CAD Trailing Arm](#), [CAD Axle](#), or [CAD A-arm / Control arm](#) will do all the required conversion calculations.

If your data source produces output in an Excel format, the CAD data can be imported from an Excel spreadsheet. See [CAD input data Excel names](#) for details.

Although this section specifically refers to CAD and CMM data, the tool can also be used to convert from "ground based" dimensions to upright, strut, a-arm or trailing arm datum based dimensions.

Note that the "Calc" will only calculate data for the current tab, so you will need to "Calc" each tab as required.

"Vehicle" will copy all calculated data to the appropriate inputs. If a tab has not been calculated, then that data will not be copied.

You can do a single "Vehicle" after all the required tab sheets have been calculated.

16.3.1 CAD Setup

If the CAD coordinate origin is not on the vehicle centreline, or on the ground line, then specify the offset of the CAD datum.

For example, if the vertical datum is a chassis reference point, then this point will be above the ground. If the vertical datum is positive upwards (usually the case), the this offset will also be positive.

It is seldom necessary to allow for the longitudinal offset.

A comment can be added.

Before using this tool, the following data must be specified:

Wheel data	The rim mounting offset (as this determines the relationship between the wheel/spindle centre and the wheel mounting flange), If specifying toe using a length and offset, the toe reference length (as this is used to determine the wheel toein dimension).
Geometry type	The geometry type, set in Vehicle -> Config, determines the upright type and the number and location of the linkage mounting points.
Suspension type	The suspension type, set in Spring, Shock, ARB -> Config determines the number and function of the various suspension mounting points which are directly attached to the upright, strut, trailing arm or A-arm. Currently, only the CAD data for a single shockabsorber and spring is supported.

From the Tool tab set the [CarEnd] and the [CarSide].

It is easiest if the [CarSide] is set to the side which has the positive horizontal dimensions, then you don't have to enter all negative dimensions.

If the vehicle is symmetrical, then tick the "identical" box, and then this will update both LH and RH dimensions.

If the vehicle is not symmetrical, then leave this box unticked. You will then need to switch sides, open a second copy of the tool, and input the CAD data for the other side. Remember that if you are doing the side which is the negative horizontal axis, then all the horizontal dimensions must be entered as negative.

16.3.2 CAD Upright

Select CAD2SusProg, then the Upright tab.

If the CAD origin is not on the ground plane, or not on the vehicle centreline, then go to Setup and specify the CAD origin offset.

The following data points are required:

Spindle/wheel centre	This is the CAD coordinate of the point in the centre plane of the wheel, on the spindle (or axle) centreline.
Spindle reference	This is the CAD coordinate of a second point on the spindle (or axle). It must not be the same as the spindle/wheel centre point, and is usually the end of the axle. It can be either inboard or outboard of the spindle/wheel centre point. The greater the distance between this point and the spindle/wheel centre point, the more accurate the calculations.
Upright mounting points	These are the CAD coordinates of the centre of the linkage mounting ball joint or bearing. The number of points will vary according to the particular upright type.
Steering arm balljoint (front suspension only)	This is the CAD coordinate of the centre of the steering arm ball joint. If you don't have this coordinate, then leave it as zero. The tool will still calculate a value, but it will be inaccurate. You will not be able to do any steering calculations.
Shock mounting	If applicable, this is the CAD coordinate of the shock mounting on the upright.
Spring mounting	If applicable, this is the CAD coordinate of the spring mounting on the upright.

Anti-roll bar mounting If applicable, this is the CAD coordinate of the anti-roll bar mounting on the upright.

Pull or pushrod mounting If applicable, this is the CAD coordinate of the pull or pushrod mounting on the upright.

Now press "Calc".

This will calculate all the upright data points, relative to the upright datums; the tyre rolling radius; and the wheel alignment and location.

The wheel alignment is calculated from the two spindle points, and these determine the camber and toe. But due to the multitude of upright designs, it is not possible to determine the [caster](#).

If the upright has a single ball joint for the top A-arm and a single ball joint for the bottom A-arm, then "rotate" the upright until the top and bottom longitudinal values are the same.

If the wheel spindle is on the [kingpin](#) axis (in side view) then both these dimensions should be zero.

If the wheel spindle is not on the kingpin axis (in side view) then this dimension will be noted as "Kingpin axis to spindle offset".

If the upright has multiple ball joints, or "virtual" pivot points, then "rotate" the upright until it is in the "zero [caster](#)" orientation (in side view).

If you want to use these calculated values to update the vehicle data, then press "Vehicle".

The upright dimensions will be carried over to the Geometry | Upright input dialog.

The tyre rolling radius will be carried over to the Geometry | Wheel input dialog.

The wheel alignment and location will be carried over to the Geometry | Alignment input dialog.

If appropriate, the suspension mounting point will be carried over to Spring, Shock, Arb | Suspension input dialog.

16.3.3 CAD Strut

Select CAD2SusProg, then the Strut tab.

If the CAD origin is not on the ground plane, or not on the vehicle centreline, then go to Setup and specify the CAD origin offset.

The following data points are required:

Spindle/wheel centre This is the CAD coordinate of a point in the centre plane of the wheel, on the spindle (or axle) centreline.

Spindle reference This is the CAD coordinate of a point on the spindle (or axle). It must not be the same as the spindle/wheel centre point, and is usually the end of the axle. It can be either inboard or outboard of the spindle/wheel centre point.

The greater the distance between this point and the spindle/wheel centre point, the more accurate the calculations.

Strut rod (top) This is the CAD coordinate of the top end of the strut rod. Usually the strut rod has a threaded end and a pilot section which protrudes through the strut mounting, and where the retaining nut is fitted.

Although it is not intended that this point is the same as the strut mounting point, the strut mounting coordinates can be used.

Strut rod (bottom) This is the CAD coordinate of the bottom end of the strut tube.

Bottom balljoint (A-arm) This is the CAD coordinate of the centre of the suspension linkage ball joint.

Steering arm balljoint This is the CAD coordinate of the centre of the steering arm ball joint.

If you don't have this coordinate, then leave it as zero. The tool will still calculate a value, but it will be inaccurate. You will not be able to do any steering calculations.

Strut mounting (on chassis)

This is the CAD coordinate of the centre of the strut top chassis mounting.

Now press "Calc".

This will calculate all the strut data points, relative to the strut datums; the tyre rolling radius; and the wheel alignment and location.

If the wheel spindle is not on the strut rod axis (in side view) then this dimension will be noted as "Strut rod axis to spindle offset".

The strut dimensions are all calculated relative to a vertical strut rod axis (in side view).

If you want to use these calculated values to update the vehicle data, then press "Vehicle".

The strut dimensions will be carried over to the Geometry | Strut input dialog, the strut type will be set to "Fixed knuckle/strut A" and the steering arm location will be set to "knuckle".

The tyre rolling radius will be carried over to the Geometry | Wheel input dialog.

The wheel alignment and location will be carried over to the Geometry | Alignment input dialog.

16.3.4 CAD Trailing Arm

Select CAD2SusProg, then the Trailing Arm tab.

If the CAD origin is not on the ground plane, or not on the vehicle centreline, then go to Setup and specify the CAD origin offset.

The following data points are required:

Spindle/wheel centre	This is the CAD coordinate of a point in the centre plane of the wheel, on the spindle (or axle) centreline.
Spindle reference	This is the CAD coordinate of a point on the spindle (or axle). It must not be the same as the spindle/wheel centre point, and is usually the end of the axle. It can be either inboard or outboard of the spindle/wheel centre point. The greater the distance between this point and the spindle/wheel centre point, the more accurate the calculations.
Trailing arm mounting points	This is the CAD coordinate of the centre of the chassis or linkage mounting ball joint or bearing. The number of points will vary according to the particular trailing type.
Shock mounting	If applicable, this is the CAD coordinate of the shock mounting on the trailing arm.
Spring mounting	If applicable, this is the CAD coordinate of the spring mounting on the trailing arm.
Anti-roll bar mounting	If applicable, this is the CAD coordinate of the anti-roll bar mounting on the trailing arm.
Pull or pushrod mounting	If applicable, this is the CAD coordinate of the pull or pushrod mounting on the trailing arm.

If the vehicle is symmetrical, then tick the "identical" box, and then this will update both LH and RH uprights.

If the vehicle is not symmetrical, then leave this box unticked. You will then need to switch sides, open a second copy of the tool, and input the CAD data for the other side. Remember that if you are

doing the side which is the negative horizontal axis, then all the horizontal dimensions must be entered as negative.

Now press "Calc".

This will calculate all the trailing arm data points, relative to the trailing arm datums; the tyre rolling radius; and the wheel alignment and location.

The trailing arm vertical datum plane will be located through the two axle reference points and the outer (or front) trailing arm chassis pivot point.

The trailing arm horizontal datum plane will be located on the wheel mounting flange, normal to the axle centreline.

The trailing arm longitudinal datum plane will be located on the axle centreline, normal to the other two planes.

The trailing arm dimensions are all calculated relative to this "zero inclination" orientation (in side view).

If you want to use these calculated values to update the vehicle data, then press "Vehicle".

The upright dimensions will be carried over to the Geometry | Trailing Arm input dialog.

The tyre rolling radius will be carried over to the Geometry | Wheel input dialog.

The wheel alignment and location will be carried over to the Geometry | Alignment input dialog.

If appropriate, the shock and spring mounting points will be carried over to Spring, Shock, Arb | Suspension input dialog.

16.3.5 CAD Axle

This tool converts CAD or 3D Coordinate Measuring Machine (CMM) data to the SusProg3D axle datum coordinates.

This function will be implemented on request.

Due to the number of alternative live axle designs, and in particular the way in which camber and toe are provided, it is not practical to develop a single tool that will allow for all foreseeable combinations and variations.

Should you have a need for this functionality, we will be pleased to incorporate it and make sure that it meets your requirements.

16.3.6 CAD A-arm / CAD Control arm

Select CAD2SusProg then the A-arm or the Control arm tab.

If the CAD origin is not on the ground plane, or not on the vehicle centreline, then go to Setup and specify the CAD origin offset.

The following data points are required:

Chassis mounting points	These are the CAD coordinates of the centre of the front and rear A-arm / Control arm chassis mounting ball joints or bearings.
Upright mounting points	These are the CAD coordinate of the centre of the front and rear A-arm / Control arm upright mounting ball joint or bearing.
Shock mounting	If applicable, this is the CAD coordinate of the shock mounting on the A-arm / Control arm
Spring mounting	If applicable, this is the CAD coordinate of the spring mounting on the A-arm / Control arm
Anti-roll bar mounting	If applicable, this is the CAD coordinate of the anti-roll bar mounting on the A-arm / Control arm

Pull or pushrod mounting If applicable, this is the CAD coordinate of the pull or pushrod mounting on the A-arm / Control arm

[Caster](#) link mounting If applicable, this is the CAD coordinate of the [caster](#) control link mounting on the Control arm

Now press "Calc".

This will calculate all the A-arm / Control arm data points, relative to the A-arm / Control arm datum.

If you want to use these calculated values to update the vehicle data, then press "Vehicle".

The A-arm / Control arm dimensions will be carried over to the appropriate Spring, Shock, Arb | Suspension input dialog.

16.4 Mumford linkage

The tool is based on some simplified assumptions.

The view and calculations use the static vehicle coordinates for all calculations, and the orientation is normal to both ground and the vehicle centreline. This plane is located fore and aft on the bellcrank pivot point.

The tool assumes that the bellcrank and lever pivot axes are both normal to this plane. If your pivot axes are not parallel to the ground (in side view), and parallel to the vehicle centreline (in plan view) there will be slight differences between the results calculated by the tool, and the results calculated by the geometry calculations, when using the data provided by the tool.

Before using the tool, the basic geometry must be entered and calculated. Specify the geometry configuration settings with Wheel location and alignment set to "Axle alignment". This calculation will probably fail, but it will calculate the axle and chassis link mounting points and convert them to the ground based coordinates required for this tool.

The data will refresh after each Geometry calculation. If you need to change the axle mounting points, or the chassis linkage mounting points, then these must be done in the Geometry section, followed by a calculation. The calculated coordinates will then be updated in the tool.

The tool can be used to investigate the changes to the Mumford linkage as one of the parameters is changed. These parameters are the bellcrank angle, lever lengths, and the linkage instant centre height. Generally one dimension can be changed while holding another fixed, and all other dimensions will be recalculated accordingly.

The recalculation will be done after entering a new value and then pressing the "Calc" button.

It is then easy to see the effect of changing one dimension, and the interaction with the other linkage components.

The tool uses the following rules.

1. Only the static position is calculated.
2. The bellcrank arm and the lever arm that connect to the lateral links are the same length.
3. The bellcrank arm and the lever arm that connect to the intermediate link are the same length.
4. If the roll centre height is being changed, it is assumed that the roll centre is in the axle plane, on the vehicle centreline.
5. In all cases, the lateral and intermediate link length will be calculated.

Calculation options.

Specify roll centre, hold lever arms at 90 to lateral links. The length of the lateral link arms will be calculated such that the lateral link arms are 90° to the lateral link.

	<p>The length of the intermediate link arms will be the same as the lateral link arms.</p> <p>The bellcrank angle will be calculated so that the two link pivot points are the same height above the ground (ie the line joining the ends of the bellcrank arms is parallel to the ground).</p> <p>The lever is straight, and approximately parallel to the bellcrank intermediate arm.</p>
Specify bellcrank angle and roll centre height.	<p>The bellcrank will be positioned so that the two link pivot points are the same height above the ground (ie the line joining the ends of the bellcrank arms is parallel to the ground) and the bellcrank arm lengths calculated.</p> <p>The length of the intermediate link arms will be the same as the lateral link arms.</p> <p>The lever is straight, and approximately parallel to the bellcrank intermediate arm.</p>
Specify bellcrank angle and lever lengths.	<p>The bellcrank will be positioned so that both arms are at the same angle to the vertical.</p> <p>The lever is straight, and approximately parallel to the bellcrank intermediate arm.</p>
Specify roll centre, normalise linkage.	<p>The length of the lateral link arms will be calculated such that the lateral link arms are 90° to the lateral link.</p> <p>The length of the intermediate link arms will be calculated such that the intermediate link arms are 90° to the intermediate link.</p> <p>The bellcrank angle will be calculated. The lever will probably be "bent".</p>

The graphic is provided to give a better feedback and visualisation of how the various components "fit". It is sometimes difficult to appreciate these relationships from numbers only.

When a solution has been developed, use the Vehicle button to transfer the data back to the main geometry. Now that the geometry is being provided with the complete Mumford linkage specification, update the geometry configuration settings and change the Wheel location and alignment to "All top and bottom links + Mumford linkage". This will use the Mumford linkage to generate the roll centre. Note that there may be differences in the calculated roll centre for the reasons discussed above. In particular, if the suspension roll axis is not parallel to the ground, then there will be significant differences in the location of the Mumford linkage instant centre, and the roll centre. The steeper the roll axis, and the further the plane of the Mumford linkage is from the axle centreline, the greater this difference.

16.5 Upright shim calculator

This tool enables the wheel camber to be calculated for the range of shims. The basic geometry must be calculated before using this tool.

The wheel alignment is shown for the nominal shim stack. This is the number of shims and the shim thickness as specified in the upright input.

Enter the minimum number of shims used (which is usually none) and the maximum number of shims.

Then "Calc".

The graph will update and show the number of shims (along the X axis) and the wheel camber (along the Y axis).

The grid will also update and show the camber for each shim stack.

16.6 Crossmember

This tool is available in the "Tools" menu, under "Xmbr"

Some older unit body vehicles, and contemporary hot rod conversions, utilize a separate front suspension crossmember. Typically this crossmember is a self contained assembly with suspension a-arm mounts, spring and shock mounts and steering rack mounts. In turn, the crossmember is bolted or welded to the chassis side frame.

This tool provides the mapping between the mounting points on the crossmember (relative to the crossmember datums) and the same points on the chassis (relative to the chassis datums).

The relationship between the crossmember and the chassis is defined by three points, P1, P2 and P3. These three points are specified for both chassis and crossmember.

P1 is used as the primary location; P2 and P3 are used as secondary locations.

Together, P1 and P2 locate the crossmember in plan view and front view. Ideally P1 is a point on the positive horizontal axis, and P2 is a point on the negative horizontal axis. The line P1-P2 should be horizontal in front view, at right angle to the chassis centreline in plan view, and centred about the chassis centreline.

If the distance between the chassis P1 and P2 points is not identical to the distance between the crossmember P1 and P2 points, then the crossmember will be located with both P1 points coincident, and with the two P2 points on the same line.

Point P3 then controls the side view "tilt" of the crossmember. The crossmember is "tilted" so that the crossmember P3 point is in the plane of the three chassis points.

Crossmember chassis mounting points P1, P2 and P3.

These are the mounting points on the crossmember for the chassis.

Note that these points are relative to the crossmember datums. The horizontal dimensions must include the minus sign if the point is on the negative horizontal axis.

What are the crossmember datums? They can be any convenient surfaces. It largely depends on the design of the crossmember and/or the crossmember build jig. Where the centre portion of the crossmember is made from a length of RHS, it is convenient to use the top and back faces of the RHS as the vertical and longitudinal datums.

Chassis crossmember mounting points P1, P2 and P3.

These are the mounting points on the chassis for the crossmember.

Note that these points are relative to the chassis datums. The horizontal dimensions must include the minus sign if the point is on the negative horizontal axis.

Crossmember suspension mounting points.

Note that these will be the LH or the RH side points according to the description.

These points are relative to the crossmember datums.

As per the usual way of defining the chassis mounting points, the horizontal dimension will always be shown as positive (even though it may be on the "negative" side of the chassis).

Chassis suspension mounting points.

Note that these will be the LH or the RH side points according to the description.

These points are relative to the chassis datums.

As per the usual way of defining the chassis mounting points, the horizontal dimension will always be shown as positive (even though it may be on the "negative" side of the chassis).

The buttons between each pair of mounting points specifies if a mounting point is chassis "C" or crossmember "X" located. If it is located on the chassis, there is no input (as the point is not transferred to or from the crossmember).

The calculation option specifies which data is calculated: "Calculate crossmember" will calculate the crossmember mounting points from the chassis mounting points; and "Calculate chassis" will calculate the chassis mounting points from the crossmember.

Each of the crossmember and chassis data sets contains an "Import", "Export XX" and "Export symmetric" button.

"Import" will read the data from the current vehicle, and "Export XX" will update the current vehicle data for the one side only, and "Export symmetric" will update the current vehicle data for both sides with the same data.

Application note - an existing crossmember.

We have an existing crossmember and need to see where it should be fitted to the chassis side frames.

A set of mounting points is defined for the chassis, locating the crossmember at an appropriate height and with no "tilt".

The crossmember is measured up using the centre section as the datum, and all points entered.

All applicable "C or X" buttons are clicked onto "X".

We then click "Calculate chassis" and then "Calc".

This maps the crossmember suspension mounting points onto the chassis.

Open up the chassis input dialog and the alignment dialog.

Back to the crossmember tool, and click the "Export symmetric" button. This updates the chassis input dialog with the appropriate values. Now do a geometry calc.

Now we can see where the suspension mounts are, and the suspension characteristics.

We now decide that the [caster](#) needs to be changed.

We decide that it is easiest to simply tilt the crossmember, so we change the chassis P3 point. Repeat the crossmember to chassis calculation, export the results, then do the geometry calc, and see that the [caster](#) has changed.

Maybe we need to drop the suspension a bit. So just adjust the chassis P1 and P2 points a bit lower. Now redo all the calcs. See how the crossmember points remain unchanged, but the chassis points are now lower.

Finally, export the crossmember points (use "Export symmetrical") so that they will be saved with the data file.

Application note - design a new crossmember

We have previously designed our double a-arm suspension (perhaps copied from another vehicle) but need to have all the a-arm, rack, and shock mounts on a separate crossmember.

We are going to use a section of RHS as the centre section and will use the top and back surfaces as the crossmember datums. The RHS is positioned to clear the engine and this establishes all the P1, P2 and P3 points.

We then "Import" the chassis mounting points.
All applicable "C or X" buttons are clicked onto "X".

We then click "Calculate crossmember" and then "Calc".
This maps the chassis suspension mounting points onto the crossmember.

Now we can use those crossmember dimensions to build our crossmember.

Remember to export the crossmember points (use "Export symmetrical") so that they will be saved with the data file.

16.7 Coil spring design

From the Tools tab, select Coil Spring.

Spring system

Either a single spring (constant rate) or dual springs (primary and secondary combination).

Units

Choose for spring data to be presented in SI (Metric) or US Customary (Imperial) units.

Metric Spring rates in N/mm, spring loads in Newtons, spring dimensions in mm and stress in MPa.

Imperial Spring rates in lb/in, spring loads in lbs, and spring dimensions in inches and stress in psi.

Spring natural frequency in Hz (cps).

Spring seats

Specify the type of coil spring end. Both ends will be the same. For a main and tender spring combination, both springs will have the specified spring end type.

Spring calculation.

Specify the wire section, either "Round" or "Rectangular".

Choose either "Actual spring", "No of coils" or "Wire diameter" or "Wire section".

"Actual spring" will use the specified number of coils, inside diameter, wire diameter or wire section and free length.

Use this option if you have a spring, and need to calculate the spring rate.

"No of coils" will use the specified number of coils, inside diameter, free length and spring rate.

Use this option if you have (or need) a spring with a specific spring rate and need to calculate the wire diameter or wire section.

For a rectangular wire spring, the thickness will be width / 4.

"Wire diameter" or "Wire section" will use the specified inside diameter, wire diameter or wire section, free length and spring rate.

Use this option if you have (or need) a spring with a specific spring rate and need to calculate the number of coils.

After calculating both springs, the load-deflection graph can be viewed.

The horizontal axis is the spring deflection and the vertical axis the load.

Full droop is the dotted line, static is the solid line, and full bump is the dash dot dot line.

The transition point is shown with a dashed line.

The diagonal line represents the spring rate. Steeper is stiffer.

If the droop load/deflection lines are not shown, then the spring is not loaded in the full droop position.

If the bump load/deflection line intersection is off the end of the spring rate line, then this means that both springs have already gone solid before the full bump position.

There may be a difference in the calculated coil count and wire diameter or wire section compared to the actual spring, especially if the spring is made from non-circular wire or material with a different Modulus of Elasticity. This will not matter, as the important parameters are the rate, solid length and solid load. As long as these are correct, the combination rate and transition deflection and load will be correct.

Eibach refer to the solid length as “block length” and the solid load as “block load”.

Primary and secondary spring combinations.

The spring that becomes solid first is the secondary spring; the other spring is the primary spring. The secondary spring is also known as the “helper” or “tender”. It doesn’t matter in which order the springs are fitted to the shock absorber, the same spring will always become solid first.

The transition point is that point at which the secondary spring becomes solid. Up to that point, the effective spring rate is always lower than either of the individual spring rates. At, and beyond, the transition point, the effective spring rate is that of the primary spring.

The formula to determine the initial spring rate (ie up to the transition point, when both springs are “active”)

$$R_i = \frac{R_m \times R_t}{R_m + R_t}$$

The formula to determine the transition point between the initial and the final rate

$$TP = \frac{F_{ct}}{R_i}$$

where R_i is the initial spring rate, R_m is the primary (main) spring rate, R_t is the secondary (tender) spring rate, TP is the transition point, F_{ct} is the secondary spring solid load.

Generally speaking, there are three ways to employ secondary springs, and it really depends at what point you want the spring rate to change.

1. The secondary spring is solid before reaching the static position. At the static position the effective rate is the same as the main spring rate. Sometimes, if the main spring is free (ie has no deflection) in the droop position, then a very light secondary spring (aka tender spring) is used to “fill the gap”. In this case the effective initial spring rate is very low, but serves to keep the main spring “in place”. More usually, the secondary spring goes solid between the full droop and static position. In this case the secondary is stiffer than the primary spring, so as to obtain an appropriate load-deflection curve.
2. The secondary spring is effective through droop and into the initial bump travel. The secondary spring only becomes solid after the static position. This gives a constant spring rate through droop and the first part of bump, with an increased spring rate approaching full bump.

3. A stop ring can be used to adjust the transition point. This means that the transition point can be adjusted and the effective spring rate changed at a point before the secondary spring becomes solid.

Note that the primary and secondary springs may be “reversed”. When calculating the primary-secondary system characteristics, the secondary spring is defined as that spring with the lowest solid load, ie it is the spring that will become solid first. If your transition deflection and load are not what you expect, then it is probable that the primary spring has a lower solid load than the secondary spring.

When designing the primary spring, if the solid load of the primary spring is less than that of the secondary spring, a message will be shown asking if you wish to swap the springs around.

The solid load of the system (ie the load at which both springs are solid) is the same as the spring with the higher solid load.

The total deflection of the system is the sum of the maximum deflection (ie free length – solid length) of each spring.

Stress

The main spring should not go solid at full bump. At the very least this will be a very abrupt transition to an “infinite” spring rate.

The secondary spring is designed to be solid at some part of the usual suspension travel, hence the use of the solid stress when designing secondary springs.

All calculated stress values for round wire springs include the Wahl factor.

This calculator is not intended as a comprehensive spring calculator. The number of coils, wire size and inside diameter are used to display an appropriate looking spring.

For detailed spring design refer to appropriate literature and manufacturers.

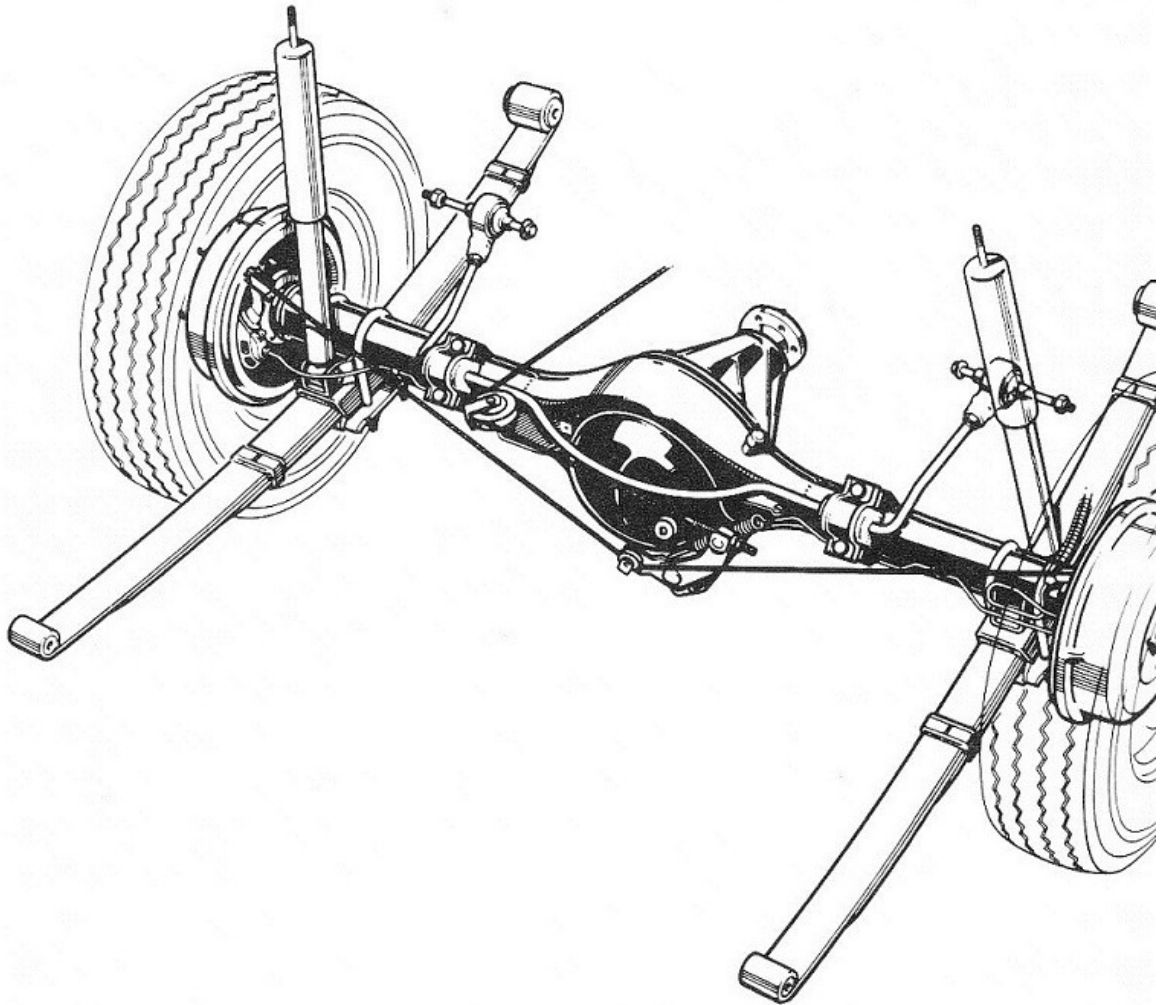
These calculations are based on SAE HS-795.

The allowable stress includes factors such as material, forming process, post-forming treatments, fatigue limits and surface finish. The values used are indicative only. Consult your spring supplier.

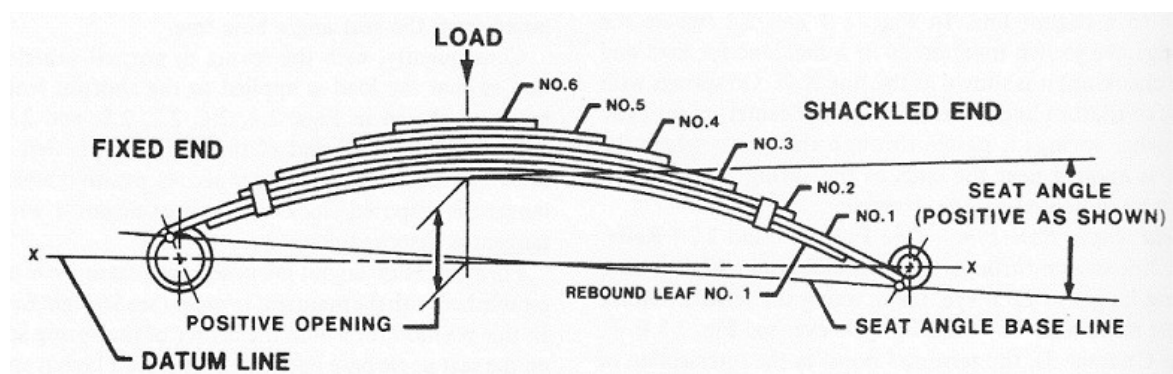
The Modulus of Elasticity – Shear, G , used in these calculations is 79300 MPa (11.5×10^6 psi) and is applicable for common cold wound spring materials.

For materials commonly used in hot coiled springs G is 76000 MPa (11.0×10^6 psi). This implies a 4% increase in wire diameter and corresponding decrease in the number of coils.

16.8 Leaf spring design



Typical leaf spring rear suspension - Ford Capri.
Underslung spring with upturned eye at both ends.



Typical underslung spring as positioned in a load testing machine (upside down from the installed vehicle position). Note that the datum line is between the spring eye centres. In this example, the fixed eye is upturned, and the shackled eye is downturned.

The SAE load test specifies that when the load is measured, the spring ends shall be free to move in the direction of the datum line. The ends are usually mounted on carriages with rollers. The spring shall be supported on its ends, such that the datum line is horizontal.

The load shall be applied from above to the shortest leaf. [The load] shall be transmitted from the testing machine head through a standard SAE loading block. The loading block shall be centered over the centre bolt with the legs of the V resting on the spring.

Choose to work in either metric (SI) or imperial units.

Metric units are mm, N, N/mm and Mpa.

Imperial units are inch, pound, pound/inch and psi.

Spring eye.

Specify either plain, upturned, downturned or berlin eye. Currently any combination of upturned and downturned eyes, both eyes berlin, or both ends plain are supported.

Specify the inside diameter of the eye.

Specify the spring type.

- | | |
|----------|---|
| Single | This is a single leaf of constant width and constant thickness. |
| Multi | This is a uniform strength spring with leaves of "common curvature". |
| TwoStage | This is a dual rate spring. The first stage is a uniform strength spring with leaves of "common curvature", the second stage is a uniform strength spring with flat leaves. The rate change point is when the first stage leaves are flat, and then engage the second stage leaves. |

Stiffening factor (SF).

Selection of the correct SF value in the final spring design is predicated on factors gained from experience, since the value may vary from less than 1.10 to 1.50, depending on the design specifications.

For passenger car springs with tapered leaf ends and more or less "uniform" stress design, use SF = 1.10

For passenger car springs with tapered leaf ends and extended leaf lengths, use SF = 1.15

If you are testing an existing spring and have the actual load required to produce the specified static deflection, then adjust the SF so that the calculation returns the required static load.

Specify the number of leaves.

For a single leaf spring this will always be 1.

For a multi leaf spring enter a number between 1 and 10 (inclusive).

For a two stage spring enter a number for the number of leaves in the first stage, and the number of leaves in the second stage. Each stage must have at least 1 leaf, and the total number of leaves cannot exceed 10.

Specify the leaf width.

All leaves are the same width.

Specify the leaf thickness.

Each leaf can have a different thickness. Thickness for each leaf must be entered.

Main leaf length is measured along the tension side of the leaf, to a point perpendicular to the centre of the eye. Ideally measured with the main leaf flat.

Specify the length from the centre of the fixed eye to the centre bolt. Usually the centre bolt is closer to the fixed eye.

Inactive length.

Length of the spring rendered inactive by the action of the U-bolts or clamping bolts. For metal-to-metal type spring seats, this length is usually assumed to be equal to the distance between the insides of the U-bolts, except for some curved seats where it is apt to be slightly shorter. For soft seats (using rubber type isolation, as in many passenger car installations) the inactive length may approach zero.

As the inactive length is increased, both the spring rate and stress will increase. For a given deflection, the load will increase; for a given load, the deflection will decrease.

Specify the design opening height. Measured in the design load position from the datum line to the tension side of the main leaf. As shown in the above diagram, the opening height is positive.

Specify either the design load or the design deflection. The design deflection is the deflection from the free position (ie no load on the spring) to the design opening height.

Specify the metal to metal clearance. This is the maximum distance the spring can deflect from the design position. Usually until the spring or the axle contacts the vehicle chassis.

Do the calculation, using the appropriate button.

The vertical spring rate will be calculated. For a two-stage spring both the initial and the final spring rates will be shown.

The design and full bump stress will be calculated.

For automotive suspensions, the design load stress is usually in the range of 600 - 750 MPa (87000 - 109000 psi) for passenger cars. The maximum stress should not exceed the minimum yield stress of the spring material. For properly heat treated alloy steel, the minimum yield stress is generally accepted as 1200 Mpa (174000 psi).

When a spring is subjected to windup under engine or brake torque or any other forced external means, stresses in addition to those due to the vertical load may be present and should be considered in computing the stress.

Spring control Φ

If the axle is not mounted in the centre of the spring then this indicates the amount the axle will rotate in bump and droop.

After the spring has been calculated, click on the 'load-deflection graph' tab to see the graphical representation of the load vs deflection. The solid line is the design load and deflection; the dashed line is the load and deflection when the main leaf is flat. For a two-stage spring this is the transition point from the initial rate to the final rate.

If the currently loaded vehicle data file has a leaf spring, then use the 'Load data' button to get the spring dimensions.

Similarly, the 'Save data' button will save the spring data into the currently loaded vehicle data file.

For a complete explanation and additional calculations refer to [AE-21](#) or [HS-788](#)

17 Display

When the main SusProg3D display has focus, the F6 key or Ctrl-C will copy the display (as a bitmap image) to the clipboard. This image can be pasted (using Ctrl-V or the Paste command) into various applications such as Paint or Wordpad.

The Print button will print the graphic direct to the printer. See [Print the graphic](#) for details.

17.1 Display settings

From the menu bar, select Settings then Display.

Background.

The background colour can be specified.

The control panel format can be either “Vertical” or “Horizontal”.

The colours and spacing of the grid lines can be specified.

The major grid lines will be drawn the specified distance apart in the major colour, and the minor grid lines will be drawn in between at the specified interval in the minor colour.

For metric systems, major grid spacing of 100mm with 5 or 10 divisions is a good choice. This gives a grid of 20mm or 10mm squares.

For imperial systems, major grid spacing of 10inches with 10 divisions is a good choice. This gives a grid of 1inch squares.

Both imperial and metric dimensions are stored. This means that when you switch between metric and imperial, the appropriate grid spacing will be used.

When the dialog is opened the grid display will be turned on. Note that the grid is only visible when the view is along one axis. When the dialog is closed, the grid display will revert to the currently specified Control Panel setting.

The major grid lines can be labeled with the actual dimension (relative to the zero datum).

Zoom

Specify the “zoom percentage”. This is the amount that the graphic will be increased by (when the “+” key is pressed) or decreased by (when the “-“ key is pressed).

17.2 Control

Select the Display tab, then Control.

The control panel contains the controls to allow manipulation of the display. The panel can be shown in either a horizontal or vertical format. See [Display settings](#).

The display can then be manipulated and viewed as required.

The ‘+’ (plus) and ‘-’ (minus) keys will zoom the display out and in.

Note that the graphic will be centered at the specified “Centre of Rotation” and that all zooming and rotations will be about this point. Initially this is the centre of axle hub centreline. See [View orientation](#).

Attitude

Rotate the suspension graphic by “clicking” the appropriate arrow button.

The yaw axis is the vertical axis. This corresponds to turning the vehicle.

The pitch axis is the horizontal axis. This corresponds to the vehicle nosing up or down.

The roll axis is the longitudinal axis. This corresponds to rolling the vehicle.

Attitude delta

Choose the amount, in degrees, by which each click will rotate the vehicle.

The "Reset" button will reset all rotations back to zero.

Bump, droop and turn

There are five buttons (for the front suspension) and three buttons (for the rear suspension).

"Clicking" the "+" button, or pressing the up arrow key, will bump the chassis, one bump increment at a time. When the maximum bump is reached, the button will be "greyed out".

"Clicking" the "0" button will reset the chassis to the static position.

"Clicking" the "-" button, or pressing the down arrow key, will droop the chassis, one droop increment at a time. When the maximum droop is reached, the button will be "greyed out".

In the static position, for the front suspension, the turn buttons will be enabled.

"Clicking" the ">" button, or pressing the right arrow key, will turn the wheels right one turn increment at a time. When the maximum right turn is reached, the button will be "greyed out".

"Clicking" the "0" button will reset the chassis to the straight ahead position.

"Clicking" the "<" button, or pressing the left arrow key, will turn the wheels left one turn increment at a time. When the maximum left turn is reached, the button will be "greyed out".

The caption will indicate the current bump, droop or turn position.

Roll

There are three buttons.

"Clicking" the "+" button, or pressing the right arrow key, will roll the chassis right, one roll increment at a time. When the maximum right roll is reached, the button will be "greyed out".

"Clicking" the "0" button will reset the chassis to the 0 roll position. Note that this position may not be the same as the Static ride height position.

"Clicking" the "-" button, or pressing the left arrow key, will roll the chassis left, one roll increment at a time. When the maximum left roll position is reached, the button will be "greyed out".

The caption will indicate the current roll position.

Car Side

Choose LH, RH or both sides

To aid in distinguishing sides, LH construction lines are red, RH construction lines are green.

Fixed

Choose either Wheel or Chassis as the fixed item.

If the Wheel is fixed, then the chassis will drop in bump and rise in droop while the wheel remains in contact with the ground plane.

Conversely, if the Chassis is fixed, then the wheel will rise in bump and drop in droop while the chassis remains at a constant height relative to the ground plane.

Note that selecting the "roll points" will automatically switch to "Fixed Wheel".

Include

For each of the items, tick the checkbox to include the item in the suspension graphic, and clear it to exclude it.

With the exception of "Wheel", all checkbox items will display the appropriate item when selected, and not display it when cleared.

For "Wheel" there are three display options:

When [AsLines] is selected the wheel will be shown in outline using three circles (corresponding to the centreline and the tyre tread width).

When [Full] is selected and the "Wheel" checkbox is cleared, the display will be a transparent wheel and tyre, enabling all suspension components to be visible.

When [Full] is selected and the "Wheel" checkbox is selected, the display will be a "solid" wheel and tyre, hiding any suspension components that are behind the wheel.

Colours

The background and grid colours can be specified. See [Display settings](#).

The default colours used for the various items are

Red	A-arm front links LH construction lines
Green	A-arm rear links RH construction lines
Blue	Toe control link (A-arm and strut suspensions only)

17.3 ECalc

Select the Display tab, then ECalc.

Specify which calculations are required. All calculations (except Geometry) are dependent on other calculations. Where this is the case, the dependent calculations will also be selected.

The "Select all" button will select all items (if some items have not been selected). The "Clear all" button will "unselect" all items (except for the basic Geometry).

1 Geometry	will calculate and display the basic static geometry. In the display control, Travel will be limited to 'Static' only, and Include will select Construction lines only.
2 Roll and Bump	will calculate and display the full Roll and Bump geometry, including the maximum travel points. In the display control, Travel will include the full range, and Include will select Construction lines only.
3 Steering	will include the steering in the geometry Roll and Bump calculations. In the display control, Include will include the toe control link. Note that this is only applicable to A-arm and strut suspension types.
4 Driveline	If there is a Driveline, this will include the Driveline in the geometry calculations. In the display control, Include will include the Inner UJ, Outer UJ and Driveline.
5 Spring, Shock, ARB	will calculate and display the static position of the specified suspension components; bellcrank, shockabsorber, spring and anti-roll bar. In the display control, Travel will be limited to 'Static' only, and Include will select Spring, Shock, Anti-roll bar and Construction lines. If the spring does not display, see below.
6 Rates	will calculate and display the full spring data for the full suspension travel. In the display control, Travel will include the full range, and Include will select Spring, Shock, Anti-roll bar and Construction lines.

Make sure that all the required data is input.

The calculations can be initiated in either of two ways:

- Press "Calc"
- If ECalc is open when a dialog Apply button is clicked, then the data will be updated and all the ECalc selected calculations will be performed

The data will be recalculated (the specified suite of calculations will be done) and if all calculations complete without error the display will be refreshed.

If any of the calculations fail, then an error message like this will be raised. '[Front] Spring, Shock, ARB calculation failure. Incomplete or invalid input data.'

You may need to close ECalc and use the individual section Calcs until they complete correctly.

Note that calculations are always carried out in sequence. Even when initiated from the menu bar, each of the dependent calculations will be calculated in sequence. If any calculation fails, the appropriate error message will be shown. That error will need to be corrected.

For example, if Rates is to be calculated, and an error message indicates a problem with the Roll & Bump calculation, then Roll & Bump will need to be corrected and calculate error free before the calculation sequence can continue.

Occasionally a calculation may not complete and appear to hang. A timeout has been added to control this. If a calculation has not completed within this period, then it will be terminated and an error message shown. This is a fatal condition and SusProg3D will be terminated. To avoid losing any data changes either do a Save before doing the calculation, or tick the Save data file when calculating setting option.

Spring not displaying.

If the spring does not display, it is probably because it has not been specified. Make sure that the spring has been specified, specifically that the number of coils, wire diameter and coil inside diameter are all greater than zero.

Shockabsorber body length.

When the Static calculations are done, and the shockabsorber compressed length has not been calculated, a nominal shockabsorber body length of 2/3 of the static length will be used.

When the Rates are calculated and the shockabsorber compressed length is known, the shockabsorber body length is calculated so that the shockabsorber is fully closed in the maximum bump position.

17.4 View orientation

There are five view orientation tab buttons – Xtras, Front, Left, Rear, Right, Plan[↑] and Plan[↓].

These will show the front view, left side view, rear view, right side view and plan view respectively.

Plan[↑] will be oriented so that the front of the vehicle is "up", with the left side of the vehicle on the left side of the screen. The view is from above the vehicle.

Plan[↓] will be oriented so that the front of the vehicle is "down", with the right side of the vehicle on the left side of the screen. The view is from above the vehicle.

There is a button to control the way the graphic is drawn. Clicking this button will switch between [Full] and [Lines].

If it is [Full], then the graphic will be drawn in full with representations of the suspension elements.

If it is [Lines], then all graphics will be drawn as single lines with the mounting or actuation point drawn as a dot.

There is a button to turn the display of the grid on or off. Clicking this button will switch between [Grid] and [NoGrid].

When [Grid] is on, a grid will be drawn. The colour and spacing of the grid can be specified. See [Display settings](#). Note that the grid is only visible when the view is along one axis.

There is a button to hold the current graphic orientation on a recalculation. Clicking this button will switch between [Hold] and [NoHold].

If "Hold" is selected, then whenever the vehicle data is recalculated and the display redrawn, the vehicle will remain in the same position. If "NoHold" is selected, then the vehicle will always be redrawn in front view, with the graphic centred on the axle hub centreline.

There is a Reset button.

Clicking this will reset the "Centre of Rotation" to the centre of the axle hub centreline, resize the graphic to fit in the display screen, and redraw in front view, centred in the display screen.

Zoom in and out

The "+" and "-" keys will zoom the graphic in and out. See [Display settings](#). The graphic is zoomed about the "Centre of Rotation"

Show me the coordinate.

"Axis aligned" means that one of the axis is pointing straight out of, or straight into, the screen, eg front, left, right, rear and plan. In the Control panel, when two of the axes are at 0, 90, 180, or 270 then this is "axis aligned". The third axis can be any value.

When the graphic is "axis aligned", and the [Grid] button is on, the grid will be shown.

When the graphic is "axis aligned" (with or without the grid showing), when the left mouse button is clicked a hint widow will show with the vehicle coordinates of the pixel at the cursor. The values will be shown for the two axes in the plane of the graphic.

The hint window will display about 0.5 seconds after the mouse click, and will remain for about 2.5 seconds. The values will also show on the status line (bottom left hand corner) and will remain until another hint needs to be shown.

Centre of Rotation

The Centre of Rotation (CoR) is the point about which the graphic will be zoomed and rotated.

The graphic will be positioned so that the CoR is always in the centre of the display.

Initially the CoR is in the centre of the axle hub centreline (and this is the way the previous versions worked).

To change the CoR, the graphic must be "axis aligned". Position the cursor at the required location, hold down the Control key and click the left mouse button. The graphic will be reposition with the "clicked point" now in the centre of the display. All subsequent zoom and rotation will take place around the new Centre of Rotation.

Note that the CoR is relocated only in the two axes in the plane of the graphic. If you need to relocate the CoR in all three axes, then you will need to do it twice.

For example, to reposition the CoR on the top a-arm front chassis pivot point, first show the graphic in Front view. The Control-click on the top a-arm front chassis pivot point. This will centre the graphic in front view and set the CoR vertical and horizontal coordinates. Now switch to any of the left, Right or Plan views. Again Control-click on the top a-arm front chassis pivot point. This will centre the graphic, and also set the CoR longitudinal coordinate. Now when you zoom or rotate, the top a-arm front chassis pivot point will always be in the centre of the display. If you get lost, use the Reset tab button.

Xtras

View along bellcrank axis

Often it is advantageous to view the motion of the bellcrank and the attached components looking along the bellcrank pivot axis.

This option positions the chosen bellcrank P1 in the centre of the screen, looking along the bellcrank axis towards P2.

A rotation can be specified to align the display as required by rotating around the bellcrank axis.

18 Technical and implementation notes

This section contains additional information and calculation notes.

18.1 Acceleration anti geometry

The anti-squat % and anti-lift % are calculated as part of the geometry and roll and bump calculations.

- Anti-lift in the front suspension only occurs with front wheel drive, and reduces droop travel under forward acceleration.
- Anti-squat in the rear suspension only occurs with rear wheel drive, and reduces bump travel under forward acceleration.

The vehicle wheelbase, centre of gravity height and torque split ratio are used in these calculations.

The wheelbase is calculated from the specified datum positions and wheel locations. See [Wheelbase and Datum](#).

The centre of gravity height is specified, see [Mass](#).

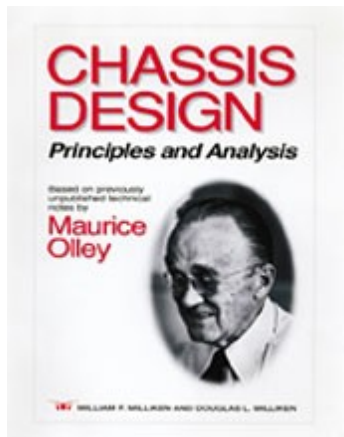
Enter the front axle torque percentage, see [Configuration](#).

Note that if the % figures are negative, then this is the opposite condition. Negative anti-lift would increase front droop travel, and negative anti-squat would increase rear bump travel.

For a more detailed discussion see [GILL92] Chapter 7 and [MILL95] Section 17.3.

18.2 Anti-roll bar calculations

Anti-roll bar or stabilizer bar rate calculations are based on either [MILL02] or [AE-21].



[MILL02] is Chassis Design Principles and Analysis, aka the “Olley” book.



[AE-21] is Spring Design Manual, aka SDM

SusProg3D uses the Olley formulae for an anti-roll bar with rigid arms which assumes that there is no arm deflection (at least in the ‘hard’ position); and uses the SDM formulae for the typical “bent bar” type where the arm is the same material as the anti-roll bar centre section and includes the arm deflection.

If a rigid arm, assume there is no arm deflection, so we can use the Olley method. The reference is Section 8.7 Roll Stabilizer. Note that this method starts with a known bar diameter and calculates the resultant effective wheel roll rate.

To calculate the antiroll bar roll rates, given all the anti-roll bar and link dimensions. The motion ratio MR is the ratio of linear movement of the end of the anti-roll bar arm to the wheel travel.

1. If L = the total length of the active section of the anti-roll bar and I = its polar moment, the torsional stiffness of the rod, K_θ , is

$$K_\theta = \frac{T}{\theta} = \frac{GI}{L}$$

where G = Shear Modulus and for a round bar $I = \pi d^4/32$.

2. In roll only half the rod length operates for each wheel. Therefore the linear rate measured at the arm actuation point normal to the arm, K_A , is

$$K_A = \frac{2K_\theta}{R^2}$$

where R is the effective length of the anti-roll bar arm.

3. Use the specified bar diameter and wall thickness and calculate $D^4 = d_o^4 - d_i^4$

Calculate the arb torsional stiffness $K_\theta = \frac{T}{\theta} = \frac{GI}{L}$

$$K_w = \frac{2K_\theta R_2^2}{R_3^2 R_1^2}$$

and the linear rate at wheel contact

$$\text{and } K_A = \frac{K_w}{MR^2}$$

where G = shear modulus, for a round bar $I = \pi d^4/32$, L = active bar length, R_3 =

effective length of the anti-roll bar arm and the R_2^2/R_1^2 term is the same as the motion ratio squared, ie MR^2

Note that Olley uses K_A to denote the linear rate at the outer A-arm ball joint.

SusProg3D calculates the motion ratio at the wheel contact point, hence the use of K_w

to denote the linear rate at the wheel contact point and K_A to denote the linear rate normal to the anti-roll bar arm end.

4. Now, to convert the linear rate to the roll rate, Olley has

$$K_{\phi_{aux}} = \frac{4K_{\theta}R_2^2 \left(\frac{t}{2}\right)^2}{R_1^2 R_3^2}$$

and if we replace R_2^2/R_1^2 with MR^2 this simplifies to

$$K_{\phi_{aux}} = \frac{4K_{\theta} \left(\frac{t}{2}\right)^2}{R_3^2} \times MR^2$$

and further to

$$K_{\phi_{aux}} = 2K_A \left(\frac{t}{2}\right)^2 \times MR^2$$

and finally

$$K_{\phi_{aux}} = \frac{K_A t^2}{2} \times MR^2 \quad \text{or} \quad K_{\phi_{aux}} = \frac{K_W t^2}{2}$$

To calculate the antiroll bar diameter, given all the anti-roll bar and link dimensions, motion ratio MR and the effective wheel roll rate is the inverse of the above formulae.

If a "bent arm" type of anti-roll bar, we need to take into account the deflection of the arms. We will use the method from the Spring Design Manual, Chapter 8, Stabilizer Bars. Note that this method starts with a required effective wheel rate and calculates the required bar diameter.

In SDM the reference is Part III Design and Manufacture of Torsion Bar Springs Chapter 8 Stabilizer Bars. It is a reprint of [HS-796].

1. Use the required effective wheel roll rate to calculate the bar roll rate

$$k_R = k_{RW} \times \left(\frac{f_W}{f_A}\right)^2 \times \left(\frac{L}{T}\right)^2 \quad \text{where } k_R = \text{bar roll rate, } k_{RW} = \text{effective roll}$$

rate at the wheels, and the $\left(\frac{f_W}{f_A}\right)^2$ term is the same as the motion ratio squared, ie MR^2 .

The $\left(\frac{L}{T}\right)^2$ term is only applicable for a live axle, where L = the distance between

the anti-roll bar links on the axle and T = the track. For an independent suspension

$$\left(\frac{L}{T}\right)^2 = 1$$

2. Use the arm end deflection, bar roll rate and bar diameter formulae to calculate the bar diameter.
3. And then for the "bent bar" calculate the minimum inside bend radius,

$$R_i \geq 1.25d$$

To calculate the effective wheel roll rate, given all the anti-roll bar and link dimensions, motion ratio MR and the bar diameter is the inverse of the above formulae.

As a proof for the correctness of the two methods, the same answers should be obtained when using a bar diameter to calculate a roll rate, or using a roll rate to calculate a bar diameter.

Olley includes the observation that "In practice, because of tire deflection, bending of the arm, and deflection of the rubber joints, the actual added roll rate may not be much more than half the theoretical".

And the SDM says "Usually the roll rate of the steel bar is reduced 15-30% by rubber deflections".

Compared to the bar roll rate of a bar with rigid arms, using the full SDM formulae gives a bar roll rate approx. 30% softer.

Although Olley uses Imperial units (lbs and inches) and the SDM uses SI units (Newtons and mm) the formulae are consistent for both systems.

The only difference is that Youngs Modulus $E = 206800\text{MPa}$ or $30,000,000\text{psi}$ and the Shear Modulus, G , is 76000MPa ($11.0 \times 10^6\text{psi}$) for bars 16mm diameter and over, and 79300MPa ($11.5 \times 10^6\text{psi}$) for diameters under 16mm.

18.3 Asymmetric suspension

Full provision for asymmetric suspension, including linkage geometry, suspension elements, wheel and tyre sizes or the wheel alignment settings is provided.

Symmetry is controlled at the individual input form level.

When the input form is displayed, the current LH and RH data values are compared and, if identical, the "identical" check box is ticked. If there is a difference between any of the current LH and RH data values, then the "identical" check box will be cleared.

To apply the input data values to both sides of the vehicle, select or "tick" the "identical" check box.

To apply the input data values only to one side of the vehicle, and to leave the other side with the current values, then clear the "identical" check box.

18.4 Bibliography

The following books contain items of interest and discussions on the design and modification of vehicle suspension systems.

- AE-21 "Spring Design Manual" 2nd edition SAE International, Warrendale 1996
- ADAM93 Adams, Herb "Chassis Engineering" HP Books, Los Angeles 1993
- BAMS90 Bamsey, Ian "Lotus 25 Climax FWMV A Technical Appraisal" J H Haynes, Somerset 1990
- BAST90 Bastow, Donald "Car Suspension and Handling" 2nd edition Pentech Press Limited, London 1990
- BAST93 Bastow, Donald & Howard, Geoffrey "Car Suspension and Handling" 3rd edition Pentech Press Limited, London & Society of Automobile Engineers Ltd, Warrendale 1993
- CAMP76 Campbell, Colin "Design of Racing Sports Cars" Robert Bentley, Cambridge 1976
- CAMP81 Campbell, Colin "New Directions in Suspension Design" Robert Bentley, Cambridge 1981
- COST80 Costin, Michael & Phipps, David "Racing and Sports Car Chassis Design" Robert Bentley, Cambridge 1980
- CRA94a Crahan, Thomas "Modeling Steady State Suspension Kinematics and Vehicle Dynamics of Road Racing Cars - Part I: Theory and Methodology" SAE paper 942505
- DANI98 Daniels, Jeffrey "Car Suspension at Work" Motor Racing Publications, Croydon 1998
- DIXO96 Dixon, John C "Tires, Suspension and Handling" Society of Automotive Engineers, Inc, Warrendale 1996
- ELLI93 Ellis, J R "Vehicle Handling Dynamics" Mechanical Engineering Publications Ltd, London 1994
- GILL92 Gillespie, Thomas D "Fundamentals of Vehicle Dynamics" Society of Automotive Engineers, Inc, Warrendale 1992
- GLIM04 Glimmerveen, John H "Hands-On Race Car Engineer" Society of Automotive Engineers, Inc, Warrendale 2004
- HANE03 Haney, Paul "The Racing & High-Performance Tire" Society of Automotive Engineers, Inc, Warrendale 2003
- HS-788 Manual on Design and Application of Leaf Springs, HS-788, Society of Automotive Engineers, Inc, Warrendale 1982
- HS-795 Manual on Design and Application of Helical and Spiral Springs, HS-795, Society of Automotive Engineers, Inc, Warrendale 1997
- HS-796 Manual on Design and Manufacture of Torsion Bar Springs, HS-796, Society of Automotive Engineers, Inc, Warrendale 2000
- MACK93 Macknight, Nigel "The Modern Formula 1 Race Car: From Drawing Board to Racetrack" Motorbooks International, Osceola 1993
- MILL95 Milliken, William F & Milliken, Douglas L "Race Car Vehicle Dynamics" SAE International, Warrendale 1995
- MILL02 Milliken, William F & Milliken, Douglas L "Chassis Design Principles and Analysis" SAE International, Warrendale 2002
SAE Order No R-206
- PUHN76 Puhn, Fred "How to Make Your Car Handle" HP Books, Tucson 1976

- RACE36 "Racecar Engineering Vol 3 No 6" Q Editions Ltd, Caterham 1994
- RACE43 "Racecar Engineering Vol 4 No 3" Q Editions Ltd, Caterham 1994
- REIM96 Reimpell, Jörmesen & Stoll, Helmut "The Automotive Chassis: Engineering Principles" SAE International, Warrendale 1996
- SHIG81 Shigley, Joseph & Uicker, John "Theory of Machines and Mechanisms" McGraw-Hill International, Kogakusha 1981
- SMIT75 Smith, Carroll "Prepare to Win" Aero Publishers, Fallbrook 1975
- SMIT78 Smith, Carroll "Tune to Win" Aero Publishers, Fallbrook 1978
- SMIT85 Smith, Carroll "Engineer to Win" Osprey Publishing, London 1985
- SMIT88 Smith, Steve "Advanced Race Car Suspension Development" Steve Smith Autosports, Santa Ana 1988
- SMIT98 Smith, Carroll "Carroll Smith's Engineer in Your Pocket" 1998
- STAN83 Staniforth, Allan "Race & Rally Car Source Book" Haynes Publishing Group, Yeovil 1983
- STAN94 Staniforth, Allan "Competition Car Suspension Design, Construction, Tuning" Haynes Publishing Group, Yeovil 1994. Reprinted 1997
- TERR73 Terry, Len & Baker, Alan "Racing Car Design & Development" Motor Racing Publications, Croydon 1973
- VALK92 van Valkenburgh, Paul "Race Car Engineering & Mechanics" HP Books, Los Angeles 1992

18.5 Braking anti geometry

The front anti-dive % and the rear anti-lift % are calculated as part of the geometry and roll and bump calculations.

- Anti-dive in the front suspension reduces bump travel under forward braking.
- Anti-lift in the rear suspension, reduces droop travel under forward braking.

The vehicle wheelbase, centre of gravity height and brake split ratio are used in these calculations.

The wheelbase is calculated from the specified datum positions and wheel locations. See [Wheelbase and Datum](#).

The centre of gravity height is specified, see [Mass](#).

Enter the front wheel brake percentage, see [Configuration](#).

Note that if the % figures are negative, then this is the opposite condition. Negative anti-dive would increase front bump travel, and negative anti-lift would increase rear droop travel.

For a more detailed discussion, see [GILL92] Chapter 7 and [MILL95] Section 17.3.

18.6 Caster / inclination / kingpin / KPI

Caster and Inclination

These are related concepts, but not necessarily equal.

I think that the concept of caster, as applied to the front suspension, is well understood.

And this discussion is based on a typical front wheel steering, rear wheel drive vehicle. With no rear wheel steering and minimal or no bump steer.

I have not been able to find any published discussion relating to rear wheel caster.

It would seem that because the forces on the rear wheel are opposite to those on the front wheels, then, caster should also be opposite, ie negative caster.

In the case of the front steered wheel, caster is defined as the line joining the upper and lower kingpin pivot points (or their equivalent).

But many rear wheel suspensions don't have these two clearly defined points.

Those that do include the double A-arm where the toe control link is positioned mid-way between the upper and lower upright pivot points.

And the multi-link linkage (aka 5-link), where, again, the toe control link is positioned mid-way between the upper and lower upright virtual pivot points.

But even double A-arm rear suspension geometries do not always have clearly defined upper and lower upright pivot points which would correspond to a kingpin axis.

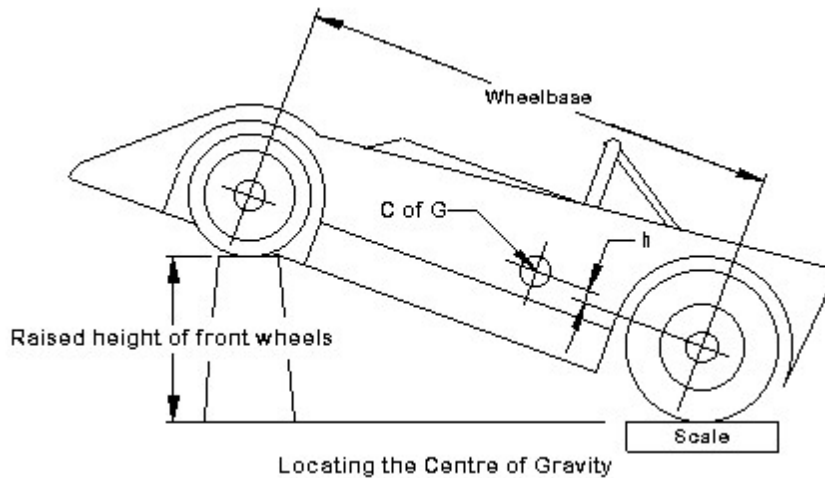
And strut type suspensions that use an A-arm and toe link.

SusProg3D now follows the convention that:

All front suspensions	Will use "caster" and have clearly defined upper and lower upright or strut pivot points, which correspond to the upper and lower kingpin points, with caster, king pin inclination (KPI), scrub radius and caster trail. Those upper and lower upright or strut pivot points can be actual or virtual A-arm pivot points.
All rear multi-link suspensions (including double A-arms) that use an upright and toe link. All rear strut suspensions that use an A-arm and toe link	Will use either "caster" or "inclination". If using "Inclination", the zero inclination position will be that as input in the appropriate upright / strut dialog . The initial static inclination will be as specified (in Alignment) or calculated. All other inclination values will be the difference between the calculated and the initial static inclination. If using "Caster", the initial static caster will be as specified (in Alignment) or calculated. All other caster values will be the difference between the calculated and the initial static caster.
All other rear suspensions.	Will use "inclination". The zero inclination position will be that as input in the appropriate upright / strut / trailing arm dialog . The initial static inclination will be as specified (in Alignment) or calculated. All other inclination values will be the difference between the calculated and the initial static inclination.

See also [Wheel alignment](#).

18.7 Centre of gravity calculation



The CofG height is the vertical location of the CofG, measured above the ground. A method for measuring the CofG height is as follows. Fill all liquids (oil, water & fuel) to the required levels and make a note. Ensure that fluids cannot leak when the vehicle is elevated. Be aware that any fluid movement or leakage during a test can falsify the results. Replace the springs and/or shock absorbers with rigid links so that any suspension movement is prevented. Set the vehicle up on a level with the rear wheels on a pair of scales, and note the readings. Then elevate the front wheels with blocks, hoist or forklift ensuring that the vehicle is supported by the front wheels, and not the chassis. The higher the front wheels can be raised, the more accurate the calculations and measurements, but the more unstable the vehicle will become. **BE CAREFUL.** Note the new rear wheel weights. The rear wheels may be blocked on the scales, but the front wheels must be free rolling to avoid any weight effect on the scales.

$$h = \frac{\Delta W \times \sqrt{L^2 - X^2}}{W_t \times X}$$

$$CofG_{height} = R_r + h$$

SusProg3D will calculate the CofG height of the sprung mass only, with the assumption that the CofG of each unsprung wheel assembly is located at the centre of the wheel. This gives reasonably accurate answers for most suspension systems, as almost all the heavy unsprung items are centred about the wheel centreline.

$$CofG_{heightsprung} = \frac{(W_t \times CofG_{height}) - (W_{uf} \times R_f) - (W_{ur} \times R_r)}{W_t - (W_{uf} + W_{ur})}$$

In the above equations, W_t is the total vehicle weight (kg, vehicle level), W_{uf} & W_{ur} are the front & rear unsprung weight (kg), DW is the increase in weight on rear wheels (kg, vehicle elevated), h is the height of CofG above horizontal through rear axle centreline (mm), L is the wheelbase (mm), X is the distance the front tyres are elevated (mm) and R_f & R_r are the front & rear tyre rolling radius (mm). If using FPS units, all weights are in lbs and all dimensions are in inches.

There is an inter-dependency between mass, wheelbase, track, ride height, centre of gravity location, and tyre size. Changing any one of these has an influence on the CofG location.

Vehicle and Chassis CofG

The Vehicle CofG height is specified in the Mass input, and is calculated as described above.

To calculate the Vehicle CofG horizontal and longitudinal location, the coordinate location of each of the four wheels (specifically the tyre contact point) must be known. This is done by either specifying the

Datum location, the wheel alignment location, or by doing the static geometry calculation. Both front and rear must be known.

As a quick check, the calculated longitudinal location should be equal to the wheelbase times the rear distribution percentage.

Now that the Vehicle CofG location is known, it can be used to calculate the Chassis CofG (ie the CofG of the sprung mass). This calculation requires the same data as the Vehicle CofG calculation, but uses the sprung masses rather than the total masses, and also requires the tyre rolling radius for all four wheels.

As a quick check, the longitudinal location should be equal to the wheelbase times the rear axle sprung mass divided by the total sprung mass. If the Vehicle CofG is higher than the axle centreline heights (ie the tyre rolling radius), then the Chassis CofG will be slightly higher than the Vehicle CofG; if the Vehicle CofG is lower than the axle centreline heights (ie the tyre rolling radius), then the Chassis CofG will be slightly lower than the Vehicle CofG.

When the Vehicle CofG height is specified, it will always be used to recalculate the Chassis CofG height.

Both of the Vehicle and Chassis CofG locations are referenced to the front axle centreline, the vehicle centreline, and the ground plane.

SusProg3D also needs to calculate the Chassis CofG referenced to the chassis datums.

To do this it needs the ride height data, so you should ensure that the ride height settings correspond to the ride heights used in the above calculations.

As a quick check, the longitudinal location should be the same as the distance from the front axle centreline, plus the distance the front axle centreline is from the longitudinal datum.

For all of the above calculations, if the calculated location is not close to the "quick check" location, or the longitudinal location is zero, then one or more of the required reference dimensions is probably missing.

Now SusProg3D has the required data (ie the mass and CogG location of each of the four wheel assemblies, and the main sprung mass) it can "back calculate" the Vehicle CofG for any changes in ride height, track, wheelbase or tyre size. The CofG of each of the wheel assemblies is assumed to be at the centre of the wheel.

For example, if you change the ride height, both the Vehicle and Chassis CofG height will change.

18.8 Convert from ground based to chassis based vertical datum.

This may be useful where the initial design is done with ground based dimensions, but to facilitate chassis construction, it may be more convenient to reference dimensions to fixed chassis planes (for example, the chassis undertray and front bulkhead). The "Create from vehicle coordinates" datum tool can be used to move both the vertical and longitudinal datums, and recalculate all chassis pickup points so they are dimensioned from the new datum planes.

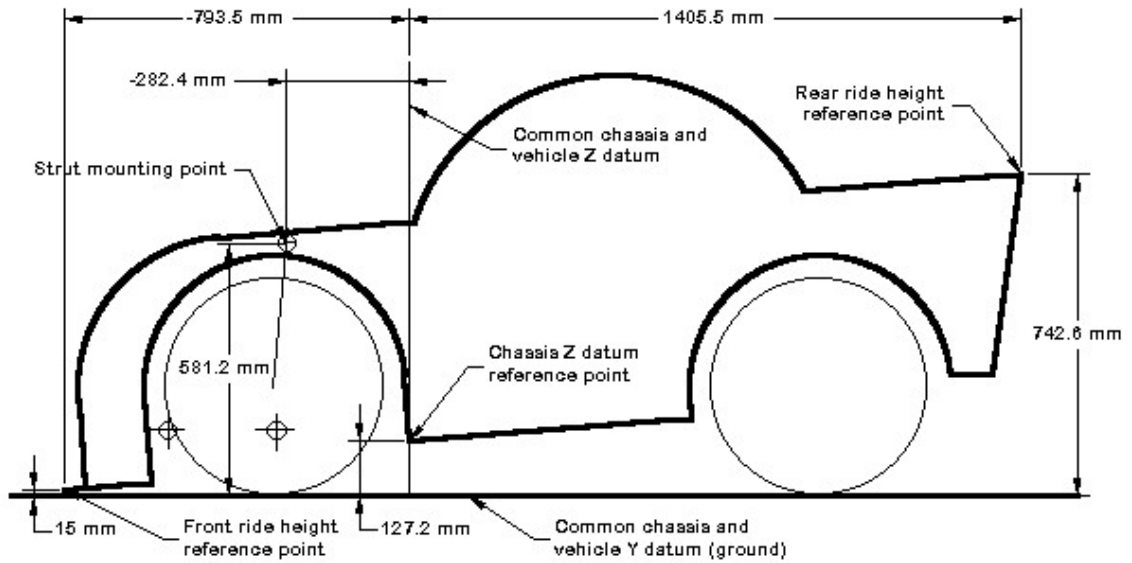


Fig 1 Chassis dimensions based on ground datum with vehicle in static ride position

Firstly, the vehicle should be calculated so that all the vehicle coordinates are correct. Make sure that the appropriate ride heights have been correctly specified.

Now, identify the surface that is to be used as the new chassis datum. In this example we will use the flat section of chassis between the wheels as our chassis datum. Our build surface will be a flat surface approx 2.4m x 1.2m (8' x 4').

We will use a point central between the two front side sill edges, and a point central between the two rear side sill edges, as our centreline reference points, and the right hand front side sill edge as our horizontal reference point. There is rake in side view, but no side rake in end view.

We will be using the front edge of the side sill as our longitudinal reference point.

Using the Tool | Datum dialog, and "Create from vehicle coordinates".

Enter the chassis datum vehicle coordinates:

Centreline reference point - front	0.0, 127.2, 0.0
Centreline reference point - rear	0.0, 135.5, 783.0
Lateral reference point	600.0, 127.2, 0.0
Longitudinal reference point	600.0, 127.2, 0.0
Front edge datum surface	-600.0
Rear edge datum surface	1800.0
Width datum surface	1200.0

Now "Apply".

All the chassis coordinates will be recalculated relative to the new chassis datum.

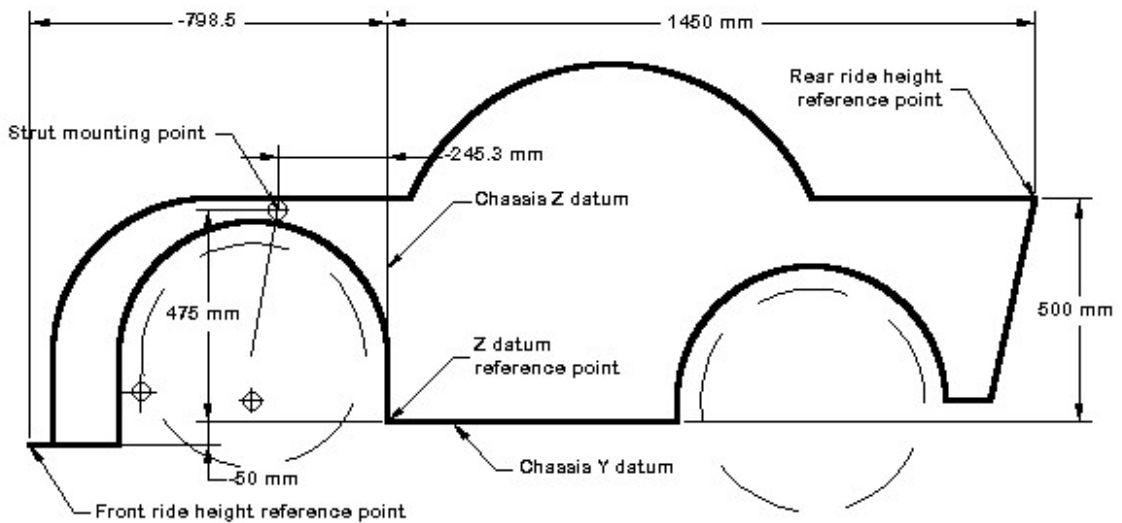


Fig 2a Chassis dimensions based on undertray line and rear of front wheel arch

Note that the ride height reference points will be recalculated, but the ride heights will remain unchanged.

In this example, because we use the vehicle sill section for our new chassis datum, the front spoiler is now below the build table surface. This means that we must limit the length of the build table, or remove the spoiler before putting the chassis on the build table. Or we can move the chassis datum surface down 50mm. This would mean that we need 50mm blocks to support the side sills, but we can have the complete chassis and bodywork on the build table.

This time we will use the "Move vertically and/or longitudinally" datum tool.

To move the vertical datum in the direction of the positive vertical axis, enter a positive value for 'vertically'; to move the vertical datum in the direction of the negative vertical axis, enter a negative value for 'vertically'.

Enter realign chassis datum value as -50.0, 0.0

Use the 'Recalc' button to recalculate the chassis vertical and longitudinal values accordingly.

Now do a complete vehicle calculation. All of the calculated vehicle coordinates should remain unchanged. It is only the chassis datum defined inputs that have been changed.

In the above example, the vertical axis, Y, is positive upwards and the longitudinal axis, Z, is positive rearwards.

18.9 Dimensioning chassis points using chassis based vertical datum

Before measuring, the chassis should be positioned such that the chosen vertical datum plane is horizontal. This is usually the chassis undertray or major structure. Most often this will also correspond to the position of the chassis in the build jig or mounted on a surface plate.

All chassis points vertical dimensions are measured vertically from the datum.

The chosen datum should be identified, eg "chassis undertray".

A point on the chassis is chosen as the longitudinal datum reference, and all longitudinal dimensions are measured horizontally forward and backward from a vertical line through this point.

The chosen datum should be identified, eg "rear corner of front wheel arch".

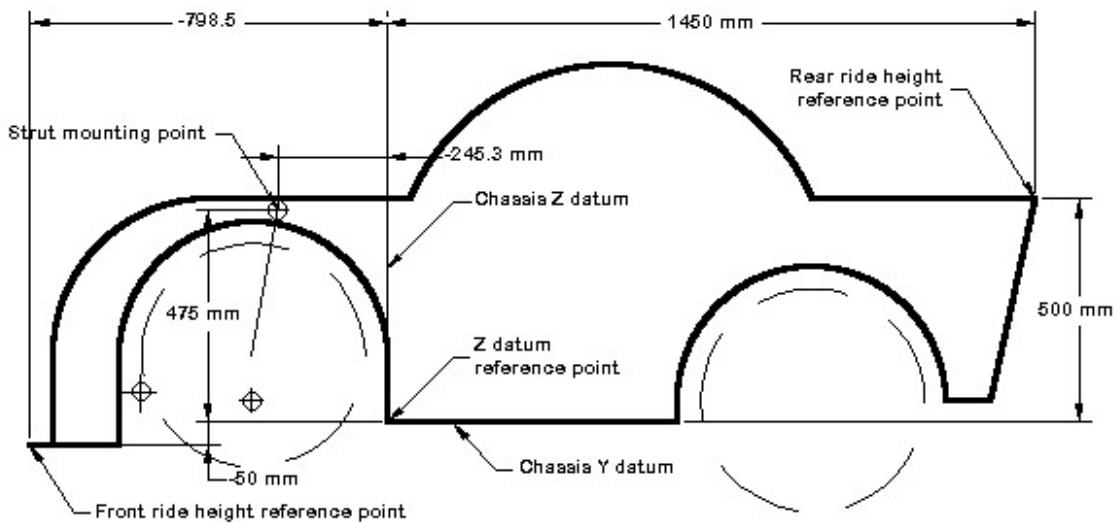


Fig 2a Chassis dimensions based on undertray line and rear of front wheel arch

In the figure above, the chassis is in the build position with the undertray level.

A point on the corner of the rear edge of the front wheel arch and chassis undertray line is chosen as the longitudinal datum point.

The top strut mounting point horizontal, vertical and longitudinal dimensions are then measured.

The horizontal dimension is from the vehicle centreline.

The vertical dimension is from the chassis vertical datum (the undertray line), 475.0mm (approx 18.701").

The longitudinal dimension is forward from the longitudinal datum vertical, -245.3mm (approx 9.657").

In the same way, all the other chassis points are measured.

It is also necessary to specify two ride height reference points. For this vehicle, one point is the front splitter, the other is the rear deck lid. Any convenient point can be used, but they must be one front and the other rear, ideally at least the length of the wheelbase apart.

In the same way as before, the two points are measured.

Front ride height reference point vertical and longitudinal measurements are -50.0mm and -798.5mm (approx -1.969" and -31.437").

Rear ride height reference point vertical and longitudinal measurements are 500mm and 1450.0mm (approx 19.685" and 57.087").

The static ride heights must also be specified.

It is required that the vehicle adopt a similar position to that shown in fig 2b below, so the static ride heights are specified as 15.0mm and 742.6mm respectively (approx 0.590" and 29.236").

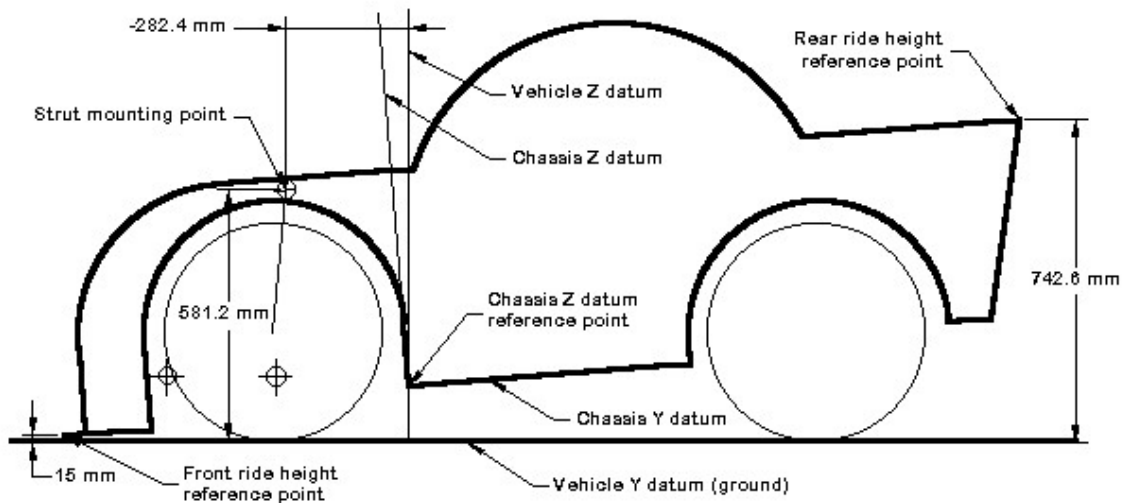


Fig 2b Chassis dimensions based on ground datum with vehicle in static ride position

As part of the static geometry calculations, the chassis points are referenced to the vehicle vertical datum (ground) and the vehicle longitudinal datum.

The vehicle longitudinal datum is a vertical line through the longitudinal datum reference point, but is now normal to the ground (instead of normal to the undertray line as it is in fig 2a).

Consequently, the top strut mounting point vertical and longitudinal dimensions are 581.2mm (approx 22.881") and -282.4mm (approx 11.118"), measured from the vehicle vertical and longitudinal datum.

In the above example, the vertical axis, Y, is positive upwards and the longitudinal axis, Z, is positive rearwards.

18.10 Dimensioning chassis points using ground based vertical datum

Before measuring, the vehicle should be in the static ride position.

All chassis point vertical dimensions are measured vertically from the ground.

The chosen datum should be identified, eg "ground".

A point on the chassis is chosen as the longitudinal datum reference, and all longitudinal dimensions are measured horizontally forward and backward from a vertical line through this point.

The chosen datum should be identified, eg "rear corner of front wheel arch".

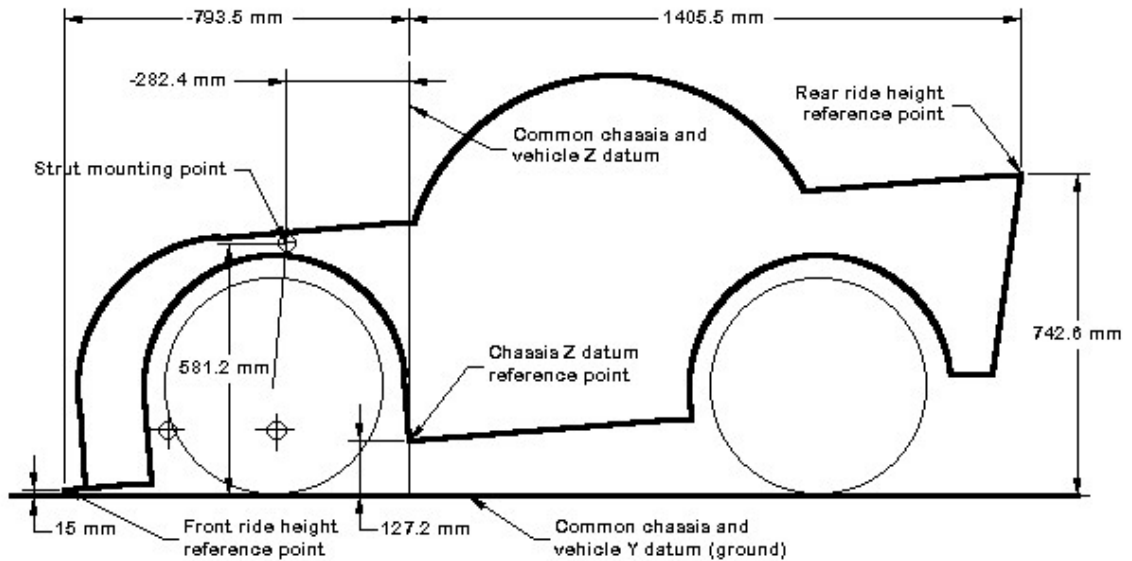


Fig 1 Chassis dimensions based on ground datum with vehicle in static ride position

In the figure above, the vehicle is in the static ride position.

A point on the corner of the rear edge of the front wheel arch and chassis undertray line is chosen as the longitudinal datum point.

The top strut mounting point horizontal, vertical and longitudinal are then measured.

The horizontal dimension is from the vehicle centreline.

The vertical dimension is from the ground, 581.2mm (approx 22.881").

The longitudinal dimension is forward from the longitudinal datum vertical, -282.4mm (approx 11.118").

In the same way, all the other chassis points are measured.

It is also necessary to specify two ride height reference points. For this vehicle, one point is the front splitter, the other is the rear deck lid. Any convenient point can be used, but they must be one front and the other rear, ideally at least the length of the wheelbase apart.

In the same way as before, the two points are measured.

Front ride height reference point vertical and longitudinal measurements are 15.0mm and -793.5mm (approx 0.590" and -31.217").

Rear ride height reference point vertical and longitudinal measurements are 742.6mm and 1405.5mm (approx 29.236" and 55.335").

The static ride heights must also be specified.

Since the vehicle is already in the static ride position, the static ride heights are the same as the ride height reference point vertical dimensions, 15.0mm and 742.6mm respectively. Note that ride height dimensions are always positive.

In the above example, the vertical axis is positive upwards and the longitudinal axis is positive rearwards.

18.11 Display the SusProg program version

Select Help | About to open a message box displaying details about SusProg3D and operating system version.

18.12 Instant centres

How instant centres are calculated for the different suspension types.

18.12.1 Live axle

There is no option to specify the roll centre. The roll centre is determined by the Watts linkage pivot point, the Panhard rod or the 4 trailing links, depending on the particular location style.

18.12.2 Semi-trailing arm

There is no option to specify swing axle length and roll centre.

Swing axle length is determined by the intersection of the chassis pivot point axis and the vertical plane of the axle centreline.

18.12.3 Strut

The geometry instant centres and swing arm lengths are defined by the intersection of two planes. The strut rod slider axis and the chassis top mounting point together define one of the planes, and the three pivot points of the bottom A-arm define the other. The two instant centres are the roll centre (in front view) and the pitch centre (in side view).

The front view instant centre, roll centre and swing arm length are calculated from the strut slider axis and the A-arm pivot to bottom ball joint line, in the plane of the axle.

The side view instant centre and swing arm length are calculated from the strut slider axis and the A-arm pivot axis, in the plane of the wheel.

From the Geometry tab, select Config to specify how the instant centre will be calculated.

The instant centres can be either

- derived from the specified chassis mounting points, or
- specified directly, and will determine the chassis mounting points.

From the Geometry tab, select ICs to specify or check the instant centre dimensions.

The strut rod slider axis and the chassis top mounting point together define one of the projection planes which determine the instant centre locations. If the anti-squat is specified as "Strut" then the anti-squat will be calculated from the strut rod inclination and a horizontal bottom A-arm.

If the instant centre location is determined by "Suspension link chassis mounting points" then the instant centres will be calculated. All required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified. The instant centre values shown in Geometry | ICs will all be "read only".

If the instant centre location is determined by "Swing axle lengths and roll/pitch centre heights" then the bottom A-arm chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified in Geometry | ICs

- either the front view swing axle length or roll centre height can be specified (but not both), and

- either the side view swing axle length or the side view instant centre height or the anti angle can be specified (but not more than one of them).

This option will calculate the bottom A-arm chassis mounting vertical dimensions.

18.12.4 Trailing arm, upper and lower lateral links

The geometry instant centres and swing arm lengths are defined by the intersection of two planes. The bottom lateral link and the trailing arm pivot point define one of the planes, and the top lateral link and the trailing arm pivot point define the other. The instant centre axis is the intersection of these two planes.

The two instant centres are the roll centre (in front view) and the pitch centre (in side view).

The front view instant centre, roll centre and swing arm length are calculated where the instant centre axis intersects the plane of the axle.

The side view instant centre and swing arm length are calculated where the instant centre axis intersects the plane of the wheel.

The instant centres will be calculated. All required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified. The instant centre values shown in Geometry | ICs will all be “read only”.

18.12.5 Tri-link strut

The geometry instant centres and swing arm lengths are defined by the intersection of two planes. The strut rod slider axis and the chassis top mounting point together define one of the planes, and the lateral links and the trailing link define the other. The two instant centres are the roll centre (in front view) and the pitch centre (in side view).

The front view instant centre, roll centre and swing arm length are calculated from the strut slider axis and the lateral link pivots, in the plane of the axle.

The side view instant centre and swing arm length are calculated from the strut slider axis and the trailing link pivots, in the plane of the wheel.

From the Geometry tab, select Config to specify how the instant centre will be calculated.

The instant centres can be either

- derived from the specified chassis mounting points, or
- specified directly, and will determine the chassis mounting points.

From the Geometry tab, select ICs to specify or check the instant centre dimensions.

If the instant centre location is determined by “Suspension link chassis mounting points” then the instant centres will be calculated. All required chassis mounting point horizontal, vertical and longitudinal dimensions must be specified. The instant centre values shown in Geometry | ICs will all be “read only”.

If the instant centre location is determined by “Swing axle lengths and roll/pitch centre heights” then the bottom A-arm chassis mounting horizontal and longitudinal dimensions must be specified, and the appropriate instant centre and swing arm length dimensions must be specified in Geometry | ICs

- either the front view swing axle length or roll centre height can be specified (but not both), and
- either the side view swing axle length or the side view instant centre height or the anti angle can be specified (but not more than one of them).

This option will calculate the bottom lateral link chassis mounting vertical dimensions.

18.13 Longitudinal pitch centre calculations

The front and rear side view instant centres can be combined to produce a vehicle pitch centre. This is analogous to the front view roll centre which combines the left and right instant centres.

Because the vehicle pitch centre requires both the front and rear side view instant centres, the roll and bump calculations must be done for each end of the vehicle. The vehicle pitch centre will be calculated for each combination of front and rear suspension bump and droop travel, and will show the distance of the vehicle pitch centre from the front axle centreline (positive rearward, and negative forward) and the height of the vehicle pitch centre above the ground line. The ground line will be the line joining the front and rear wheel tyre contact points.

18.14 Measurements

When making measurements, particularly on existing vehicles, it is very important that they be to the dead centre of the actual connecting point. It may be necessary to look at spares or disassemble components to decide exactly where these pivot points are. Remember that the accuracy of your measurements is critical in getting accurate answers.

18.15 Motion ratio calculations

Shock absorber and spring motion ratios are calculated as the ratio between the wheel travel and the shock or spring travel.

Depending on the combination of geometry settings, and the method of calculation, there can be slight differences in the reported motion ratios.

This situation only occurs for those suspension types where the steering (or toe control) can be specified and calculated separately from the geometry.

For example, with double a-arm suspension it is possible to do the geometry and roll&bump calculations without specifying any of the toe control coordinates or link lengths, and then the calculations are done without any toe change. This simplifies the calculations when the main priority is the establishment of instant centres, roll centres and camber change without having to be concerned with toe control links.

When the steering is specified, and a steering calc is done, then the toe control link will be included in the calculation and the appropriate toe change calculated.

Another way to include the toe change in the calculations is to use a geometry configuration wheel location and alignment setting that includes the steering or toe control linkage.

The following examples are for a double a-arm suspension

Using the individual calculations

If the geometry config wheel location and alignment is any except "Top and bottom A-arms + steering linkage + turn" Geometry static calculation will use the specified wheel toe setting. Roll&bump calculations will hold the specified wheel toe setting. In other words, no bump steer. If the shock and spring calculations are now done, the motion ratio calculations will be using the "no bump steer" wheel alignment settings.

If the geometry config wheel location and alignment is any except "Top and bottom A-arms + steering linkage + turn" Geometry static calculation will use the specified wheel toe setting. Roll&bump calculations will hold the specified wheel toe setting. In other words, no bump steer. Steering calculation will redo the Roll&Bump calculations and the correct bump steer will be recalculated.

If the shock and spring calculations are now done, the motion ratio results will be slightly out because the motion ratio calculations will be using partly "bump steer" data and partly "no bump steer" data.

If the geometry config wheel location and alignment is "TopRoll&bump linkage + turn" Geometry static calculation will calculate the wheel toe setting. TopRoll&bump calculations will calculate the wheel toe setting. In other and bottom A-arms + steering words, the correct bump steer.

If the shock and spring calculations are now done, the motion ratio calculations will be using the "bump steer" wheel alignment settings.

The ECalc dialog is a way of doing multiple calculations from a single point.

Using ECalc

If the geometry config wheel location and alignment is any except "Top and bottom A-arms + steering linkage + turn" If the Steering is excluded from the calculation options, the shock and spring motion ratio calculations will be using the "no bump steer" wheel alignment settings.

All geometry config wheel location and alignment options If the Steering is included in the calculation options, the shock and spring motion ratio calculations will be using the "bump steer" wheel alignment settings.

For the most accurate motion ratio calculations, use ECalc with steering selected.

It is suggested that when the basic geometry and steering have been established, the geometry config wheel location and alignment be changed to "Top and bottom A-arms + steering linkage + turn". This will ensure that all calculations are then done with the full bump steer wheel alignment.

18.16 Pushrod and pullrod suspension.

When the Bellcrank pivot axis, point 2 "Calc?" box is checked, reference values for the bellcrank pivot axis point 2 will be calculated.

- If the static chassis longitudinal values for the pushrod (or pullrod) actuation point, bellcrank pivot axis point 1 and chassis shock absorber mounting are identical, then these components are considered as operating in the vertical plane with the bellcrank pivot axis parallel to both the car cl and ground plane.
- If the static chassis longitudinal values for the pushrod (or pullrod) actuation point, bellcrank pivot axis point 1 and chassis shock absorber mounting are different, then these components are considered as operating in the plane of those three points, with the bellcrank pivot axis normal to that plane.

When the Bellcrank pivot axis, point 2 "Calc?" box is cleared, then entered values for the bellcrank pivot axis point 2 will be used to determine the bellcrank pivot axis. The distance between point 1 and 2 does not matter, and can be any convenient value.

The bellcrank pivot axis (either calculated or specified) is then considered fixed for all subsequent bump and droop calculations.

Bellcrank rotation direction in bump is the bellcrank rotation direction when the wheel is moved into a bump position. The bellcrank rotation is referenced looking along the bellcrank pivot axis in the direction of point 1 towards point 2. Ensure that the car side shown in the dialog box title is the same as the vehicle side that you are "bumping", because the LH bellcrank and RH bellcrank rotate in opposite directions in bump.

The bellcrank angle is similarly defined as the **anti-clockwise** angle between the two arms, viewed along the bellcrank pivot axis, in the direction of point 1 towards point 2.

18.17 Semi-trailing arm application

A common requirement for vehicles with semi-trailing arms is to establish the bump steer characteristics if the arm is located in a different static position from the initial design position, for example by lowering the chassis (where the pickup points are fixed on the chassis structure) or by fitting different tyre sizes (which moves the axle up or down) and maintaining the vehicle ride height.

- First ensure the vehicle is sitting at the initial ride height and the correct wheel and tyres are fitted.
- Measure all the required values and input.
- Run the calculations and verify.
- Specify the configuration option as “Chassis mounts + semi-trailing arm”. This will keep the trailing arm chassis mountings and lengths fixed.
- If the requirement is to lower the chassis (say 50mm) and retain the same tyre size, subtract 50mm from the static ride heights. Recalculate the geometry, roll & bump and steering. The geometry and bump steer characteristics of the lowered vehicle will be displayed.
- If the requirement is to change the tyre size (say by fitting a lower profile tyre with a 15mm smaller rolling radius) and adjusting the spring abutments to maintain the original chassis ride height, subtract 15mm from the tyre rolling radius. Recalculate the geometry, roll & bump and steering. The geometry and bump steer characteristics of the lowered vehicle will be displayed.

Note that in both cases the distance of the axle centreline from the Z datum will change slightly in order to keep the arm link lengths unchanged.

18.18 Strut application

A common requirement for vehicles with strut suspension is the relocation of the chassis link pivot points (or changing the length of the lower link) to provide the required wheel camber, particularly when the vehicle ride height and/or different wheel and tyre sizes have been fitted.

1. Ensure the vehicle is sitting at the required ride height and the correct wheel and tyres are fitted.
2. Measure all the required values and input.
3. Run the calculations and verify.

To relocate the lower control arm pivot point to achieve a specific static negative camber and keep original lower control arm length.

1. Specify the instant centre location as “Suspension link chassis mounting points”
2. Note the chassis lower lateral control arm pivot horizontal value.
3. Specify the configuration option as “Bottom A-arm + strut top mounting + wheel toe”. This will keep the strut top mounting and the bottom A-arm lower horizontal control arm length fixed.
4. If you require more (less) negative camber, increase (decrease) the chassis pivot point horizontal dimension of the mounting for the lower lateral control arm.
5. Calculate, and check the wheel alignment.
6. Repeat 4 and 5 until the wheel alignment camber is the dimension required.

Change the length of the lower control arm and keep the original pivot point.

1. Specify the instant centre location as "Suspension link chassis mounting points"
2. Note the lower lateral control arm length.
3. Specify the configuration option as "Bottom A-arm + strut top mounting + wheel toe". This will keep the strut top mounting and the bottom A-arm lower lateral control arm mounting fixed.
4. If you require more (less) negative camber, increase (decrease) the link length of the lower lateral control arm.
5. Calculate, and check the new lower lateral control arm length.
6. Repeat 4 and 5 until the wheel alignment camber is the dimension required.

Now use the Steering module to determine the required adjustments to achieve the desired bump steer and toe-out in turn characteristics.

When measuring a strut, particularly when still fitted to the vehicle, be particularly careful to measure from the correct strut datums and centrelines. After calculating all the static values, you can verify all points from vehicle coordinates and adjust if necessary. The steering ball joint and the strut rod axis bottom point will often be the most difficult points to dimension accurately.

18.19 Suspension geometry

Even for inline suspension pivots where the upright moves strictly vertically, castor shown in the chassis bump segments will vary slightly in bump and droop. This is a consequence of the apparent change of upright height in vehicle side view as the wheel is cambered, and consequently the castor angle appears to change. Changes to static castor require the A-arm upright pivot points to move fore and aft. There is a similar effect due to toe-in and toe-out which move the upright pivots forward and backward. Toe-in tends to increase the castor, toe-out to reduce it. This readily illustrates the way in which a change to one wheel setting can introduce slight variations into the other settings. Although these variations are extremely small, SusProg3D automatically compensates for them, and the wheel is always set to the exact static setting specified, and the adjustable link lengths calculated accordingly.

There are two linkage instant centres (IC).

The front view instant centre is in the vertical plane of the axle centreline. This IC then defines the roll centre and swing axle length. Camber change and wheel track variations are a function of the position of the front view IC.

The side view instant centre is in the vertical plane of the wheel centreline. [Caster](#) change and anti-dive or anti-squat characteristics are a function of the position of the side view IC.

If the suspension linkages are such that they are parallel and do not intersect at an instant centre, then the instant centre height and length will be zero.

Side view instant centre locations are referenced to the specific axle, and for the front axle, will be positive in the rearward direction, and negative in the forward direction. For the rear axle, will be positive in the forward direction, and negative in the rearward direction.

The side view "anti-line" is that line joining the tyre contact point to the instant centre, or, if there is no intersection point, is the line from the tyre contact point parallel to the plane of the A-arm. If the instant centre location is negative, then the "anti-line" will be extended in the opposite direction.

The "axle height" dimension is where the "anti-line" cuts the vertical line from opposite axle tyre contact point.

The "anti-line" angle is the angle between the "anti-line" and the ground line.

The front and rear side view instant centres can be combined to produce a vehicle pitch centre. This is analogous to the front view roll centre which combines the left and right instant centres.

The vehicle pitch centre is calculated as part of the [PitchCalculation](#).

For a more detailed discussion, see [MILL95] and [REIM96].

In a similar fashion, the suspension roll axis is defined.

For a typical independent suspension, there is an "instant plane" defined by the wheel contact centre point, the front view instant centre, and the side view instant centre. Where the "instant planes" of the left and right suspensions intersect, then this is the suspension roll axis. The suspension roll axis line intersects the plane of the axle at the roll centre.

For a typical live axle suspension, the suspension roll axis is determined by the linkage intersection points. Again, the roll centre is where this axis intersects the plane of the axle.

The suspension roll axis inclination is shown as a percentage (ie the roll axis inclination angle, in radians, times 100). If the suspension roll axis is inclined downwards (towards the front of the vehicle) then this is shown as a negative value.

For a more detailed discussion, see [MILL02]

SusProg3D uses the specified wheel alignment settings, and either the specified track and wheel axle centreline offset from the datum, or the specified A-arm link lengths to position the upright and wheel. This then determines the lengths of the A-arm links or the remaining A-arm links and both the track and wheel axle centreline offset from the datum.

For the rear suspension, the term castor is applied differently to that when used for the front suspension. In the settings dialog box, the value for castor is taken to be the inclination of the upright from the vertical, and is consistent with accepted usage. This is the value shown as "Castor angle" in the various displays and printouts.

As noted elsewhere, bump and droop travels are measured at the centreline of the tyre. This can sometimes cause the calculations to fail for maximum droop, where at first glance, there is adequate suspension travel. Typically what happens is that as the wheel approaches full droop it assumes an increasing amount of negative camber. This raises the wheel contact point relative to the upright bottom pivot point, requiring more upright droop travel to compensate. Eventually a situation can be reached where the distance the bottom upright pivot has to be dropped to achieve the required wheel travel is such that the length of the top A-arm is shorter than the distance to the top upright pivot. This is usually only a problem with short top links (especially if they have little or no inclination above horizontal in the static position) and large amounts of droop travel. A similar situation can also arise on large bump travel.

For A-arm and strut type suspensions, the steering calculations are decoupled from the roll and bump calculations. This means that when doing the roll & bump calculations, the wheel toe setting is fixed (ie there is no toe change in bump and droop). The steering calculations, however, use the specified (or calculated as the case may be) steering arm and rack pivot locations to calculate the toe change in bump and droop. These toe changes are also applied to the roll and bump data, and if the roll & bump data is redisplayed, these toe changes will be shown. If, however, after doing the steering, the roll & bump is recalculated, then the roll & bump display will again be based on fixed toe-in. By decoupling the toe change from the basic geometry calculations, it means that toe control pivot points do not need to be continually changed as changes are made to upright and or chassis pivot points.

18.20 Tri-strut application

A common requirement for vehicles with strut suspension is the relocation of the chassis link pivot points (or changing the length of the lateral links) to provide the required wheel camber, particularly when the vehicle ride height and/or different wheel and tyre sizes have been fitted.

As an example, it may be required to relocate of the lateral link chassis pivot points to achieve a specific static negative camber.

1. First ensure the vehicle is sitting at the required ride height and the correct wheel and tyres are fitted.
2. Measure all the required values and input.

3. Run the calculations and verify.

To relocate the lateral link chassis pivot points to achieve a specific static negative camber and keep original link lengths.

1. Specify the instant centre location as "Suspension link chassis mounting points"
2. Note both chassis lower lateral control arm pivot horizontal value.
3. Specify the configuration option as "All links + strut top mounting (fixed wheel alignment)". This will keep the strut top mounting and the lateral link lengths fixed.
4. If you require more (less) negative camber, increase (decrease) the chassis pivot point horizontal dimension of both lateral links.
5. Calculate, and check the wheel alignment.
6. Repeat 4 and 5 until the wheel alignment camber is the dimension required.

Change the length of the lateral links and keep the original pivot points.

1. Specify the instant centre location as "Suspension link chassis mounting points"
2. Note both chassis lower lateral control arm lengths.
3. Specify the configuration option as "All links + strut top mounting (fixed wheel alignment)". This will keep the strut top mounting and the lateral link mountings fixed.
4. If you require more (less) negative camber, increase (decrease) the length of both lateral links.
5. Calculate, and check the wheel alignment.
6. Repeat 4 and 5 until the wheel alignment camber is the dimension required.

Now use the Steering module to check the desired bump steer characteristics.

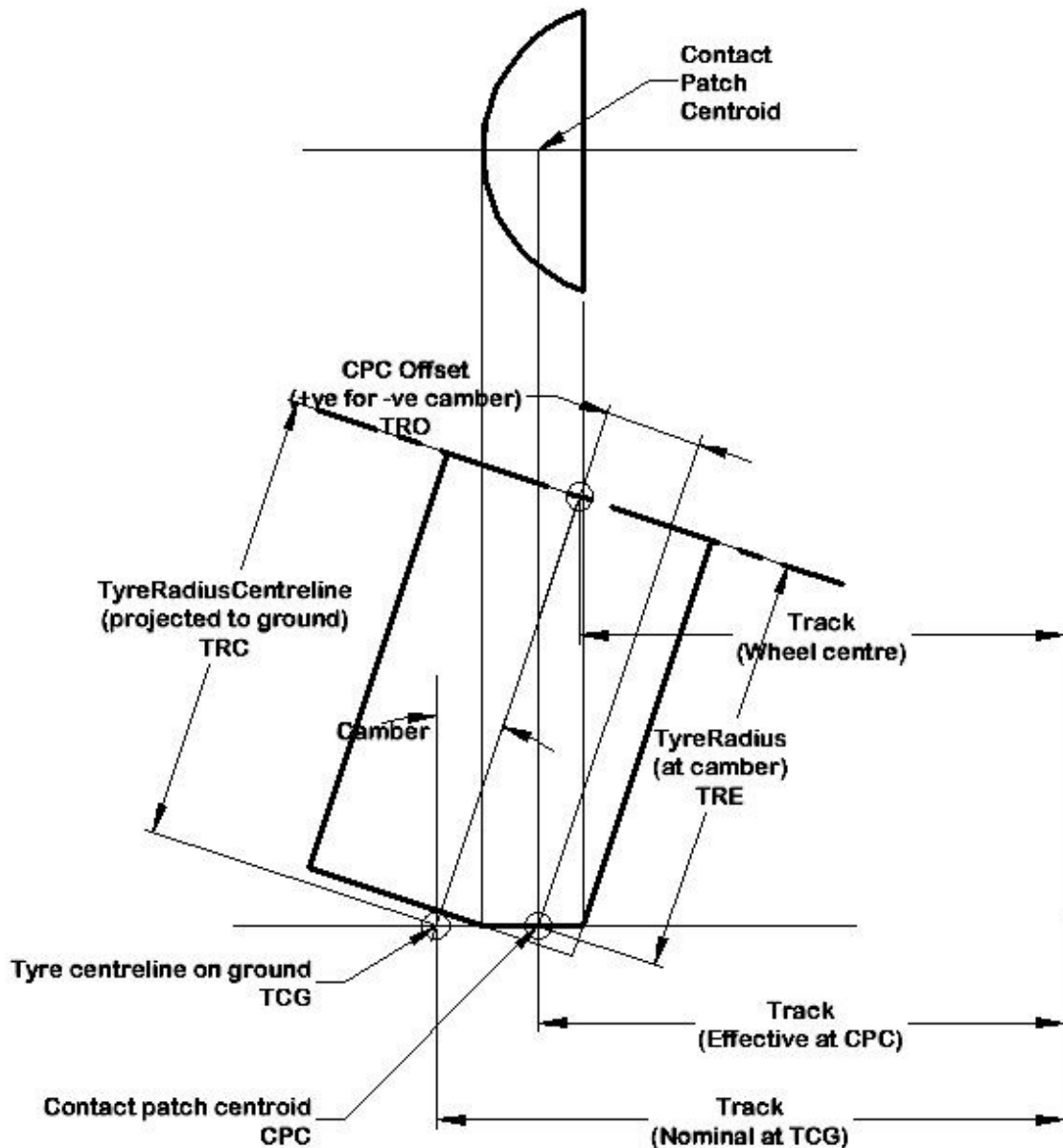
When measuring a strut, particularly when still fitted to the vehicle, be particularly careful to measure from the correct strut datums and centrelines. After calculating all the static values, you can verify all points from vehicle coordinates and adjust if necessary. The strut rod axis bottom point will often be the most difficult point to dimension accurately.

18.21 Tyre camber parameters

As the tyre is cambered, the effective tyre radius and the horizontal location of the centroid of the tyre contact patch can migrate from the static, ie zero camber, position.

All SusProg3D versions prior to V5.100 assumed that the effective tyre radius was fixed and there was no horizontal contact patch movement.

If the tyre parameter data is left blank, the tyre radius will be fixed and the contact patch centroid offset will be zero for all camber.



It is suggested that the effective tyre radius and the contact patch centroid offset be measured at the nominal static camber and the maximum expected negative camber.

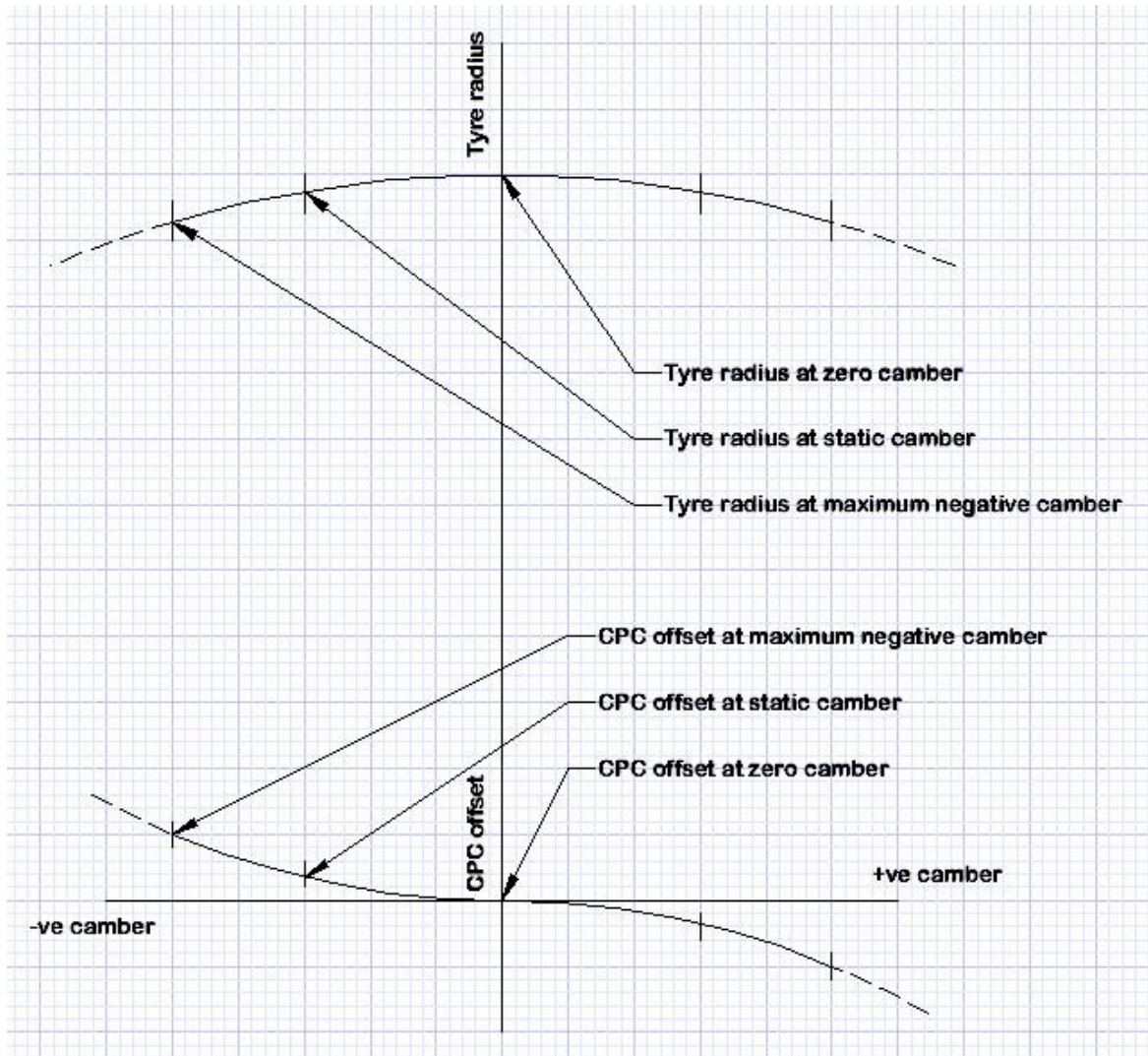
Although load variation is not supported, it may be desirable to use a higher load when measuring the parameters at the maximum negative camber to more closely represent the actual load conditions in that position.

Note that the entered values for camber, tyre radius and contact offset are all positive numbers.

These three points are then used to generate a 4th dimension polynomial, $f(x) = ax^4 + bx^3 + cx^2 + dx + e$ where x is the camber and $f(x)$ is the resultant tyre effective radius or contact patch centroid offset. It is also assumed that the tyre is symmetrical in that the effective tyre radius and contact patch centroid offset is identical for both positive and negative cambers.

Generally speaking, polynomial interpolation is accurate, but polynomial extrapolation can be unreliable. This is the main reason why it is suggested that the third data point be measured at the maximum expected negative camber. If the suspension is such that the maximum positive camber (usually at maximum droop) is numerically greater than the maximum negative camber, and is thus subject to extrapolation, then this is considered to be relatively unimportant.

If the polynomial calculation fails, or if the tyre parameter data is left blank, the tyre radius will be fixed and the contact patch centroid offset will be zero for all camber.



There are a number of values that traditionally have been taken relative to the tyre centreline on ground (TCG). Where appropriate, these values have been retained, and additional values relative to contact patch centroid (CPC) added.

For most uses, track is still measured to the tyre centreline (TCG) but an additional track measured between contact patch centroids will be available.

King pin offsets are also usually measured to the tyre centreline (TCG) and additional king pin offsets relative to contact patch centroid (CPC) will be available.

All of the instant centre calculations, swing axle lengths and roll centres will be calculated from the contact patch centroids (CPC).

The tyre radius centreline (TRC), effective tyre radius (TRE) and the contact patch centroid offset (TRO) at each calculated data point will be available.

18.22 Units and conversions

25.40 mm = 1.000 inch

1 kg = 9.80665 Newton = 2.204622 lb

1 kg/cm \approx 0.981 N/mm \approx 5.6 lb/in

1 MPa \approx 145 psi

1 g = 9.80665 m/s² \approx 32.174 fps²

G = 79290 MPa \approx 11.5 x 10⁶ psi (Shear Modulus for 4130 & 4340 steel)

E = 206800 MPa \approx 30 x 10⁶ psi (Young's Modulus for typical steel)

For metric users, all spring and wheel rate calculations are now using SI units. Rates are N/mm (Newtons per mm), loads are N (Newtons). Vehicle weights are in kg (kilograms).

18.23 Upper transverse leaf spring, lower reversed A-arm and trailing link

Currently the only spring eye supported is the downturned eye. This is the standard TriumphGT6 spring.

Although specified as a symmetric half elliptic leaf spring, geometrically it is equivalent to a pair of back-to-back quarter elliptic springs.

The centre of the spring (the centre of the clamped section) is considered to be rigidly fixed to the chassis.

The position of the centre of the spring eye is calculated by assuming a circular arc for the active section of the main leaf.

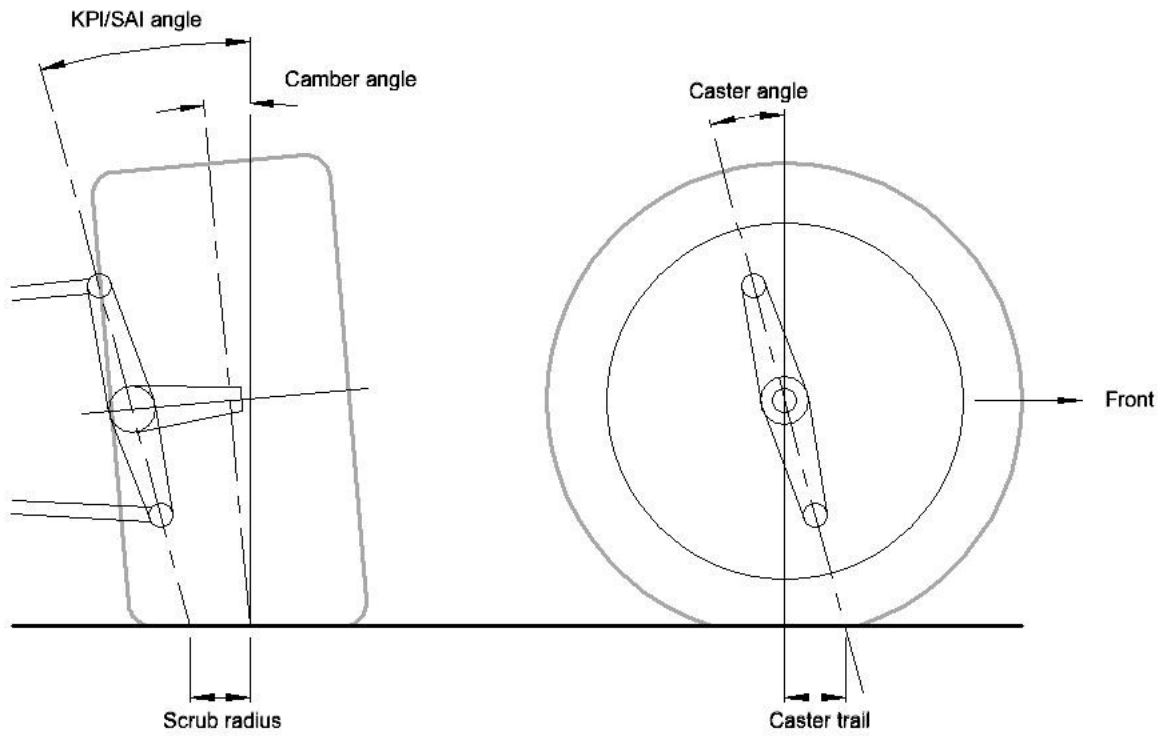
There is no horizontal or torsional deflection.

18.24 Wheel alignment

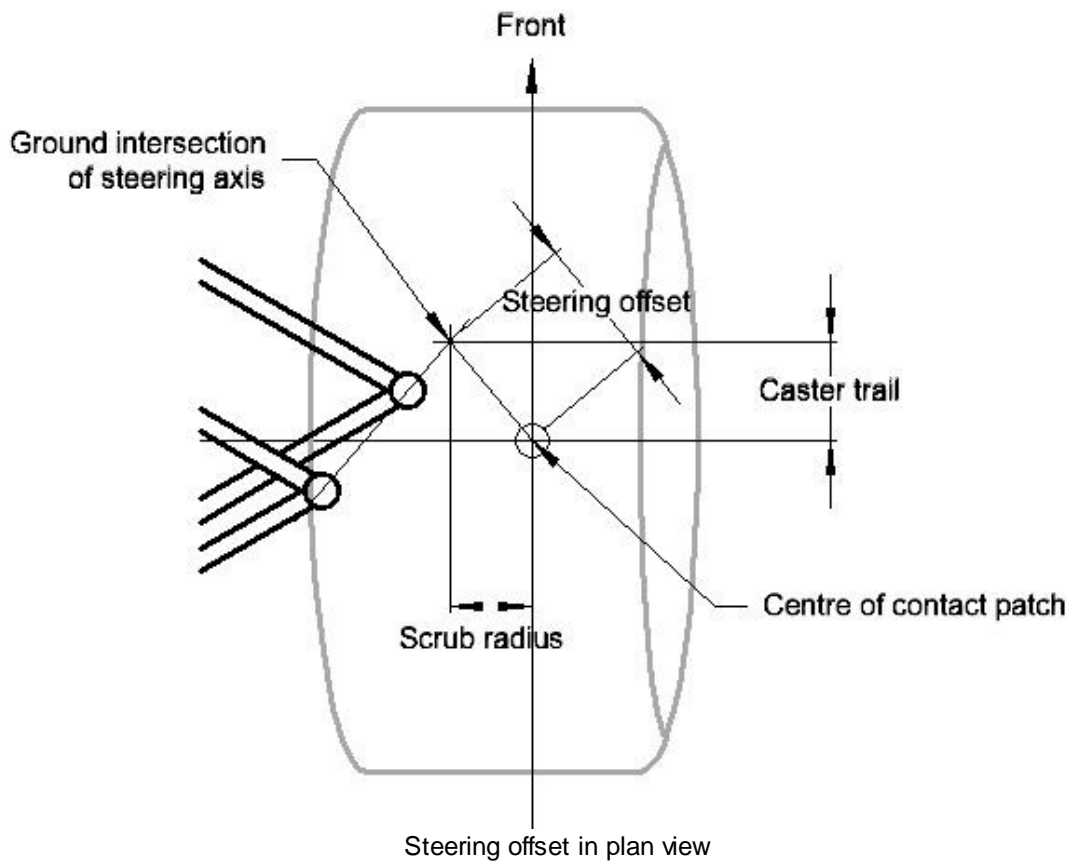
Conventionally, scrub radius and caster trail are measured in 2D front and side view.

The ISO definition of Steering Offset is the radial distance from the contact patch centre to the steering axis (extended to the ground plane). This is shown in the top view.

KPI = King pin inclination, SAI = Steering axis inclination.



Scrub radius and caster trail in 2D front and side views



Steering offset in plan view

19 Licence agreement

This manual and software are protected by both Australian copyright law and International treaty provisions, with the following single exception. R D Small authorises you to make archival copies of the software for the sole purpose of backing-up this software and protecting this software from loss.

This software is licensed to run on a single computer.

Suspension designs that you independently generate using the SusProg3D software may be used, given away, or sold without additional licence or fees. You are not required to say that your suspension designs were developed using SusProg3D.

The sample suspension designs on the SusProg3D distribution provide a demonstration of the various features of SusProg3D. They are intended for educational purposes only. R D Small grants you (the registered owner of this copy of SusProg3D) the right to edit or modify these sample designs for your own use, but you may not give them away or sell them.

Warranty

With respect to the physical media and the physical documentation enclosed, R D Small warrants the same to be free of defects in materials and workmanship for a period of 60 days from the date of purchase. In case of notification within the warranty period of defects in material or workmanship, R D Small will replace the defective media or documentation. If you need to return a product, call R. D. Small. The remedy for breach of this warranty shall be limited to replacement and shall not encompass any other damages, including but not limited to loss of profit, and special, incidental, consequential, or other similar claims.

Disclaimer

R D Small specifically disclaims all other warranties, expressed or implied, including but not limited to implied warranties of merchantability and fitness for a particular purpose with respect to defects in the media or documentation, and the software license granted herein in particular, and without limiting operation of the software license with respect to any particular application, use, or purpose.

Modifying road car suspension systems may result in the vehicle failing the requirements of the relevant state Road Traffic Authority and therefore being declared unroadworthy and unregistered.

The price of man in motion is the occasional accident and/or collision. Testing vehicle performance may be dangerous. Motor racing is dangerous. This software package is about improving the performance of the motor vehicle. It deals with developing and changing suspension characteristics. Anyone who uses this program and or manual as a guide for vehicle modification does so entirely at their own risk.

In no event shall R D Small be liable for any loss of profit or any other commercial damage, including but not limited to special, consequential or other damages arising from the application of any information, dimensional changes or data because of using this package.

Governing Law

This statement shall be construed, interpreted, and governed by the laws of the State of Queensland, Australia.

Version 5.170A Tuesday, 30 June 2026. Copyright © 2026 Robert D Small.

SusProg3D™ and AutoCalc™ are trademarks of Robert D. Small.

Both this help file and the accompanying software Copyright © 1985, 2026 Robert D. Small.

All rights reserved.

All other brand or product names are trademarks or registered trademarks of their respective holders.

20 Evaluation version

The Evaluation version of SusProg3D provides both fixed upright or strut dimensions, and fixed wheel and tyre sizes.

Front upright (A-arm suspension)

The toe control point can be varied as required. Both the top and bottom pickup points are fixed.

Rear upright (A-arm suspension)

Both the toe control point and the universal joint location can be varied as required. Both the top and bottom pickup points are fixed.

Front & Rear Strut

Both the toe control point and the universal joint location can be varied as required. Both the strut rod axis (top and bottom points) and the A-arm bottom pickup points are fixed. The strut dimensions are identical for front and rear.

Front & Rear Wheel & Tyre

All wheel and tyre dimensions are fixed.

21 Network licensing

Network licensing is available for fixed LAN networks using TCP/IP.

A single SusProg3D licence server is required.

Multiple SusProg3D clients are supported, but must remain connected (via the LAN) to the SusProg3D licence server for the duration of the SusProg3D session.

*Portions of this software are Copyright © 1993 - 2004, Chad Z. Hower (Kudzu) and the Indy Pit Crew
- <http://www.nevrona.com/Indy/>*

Index

- S -

spindle reference point 154