Vehicle Model System Schematics and Data Sets

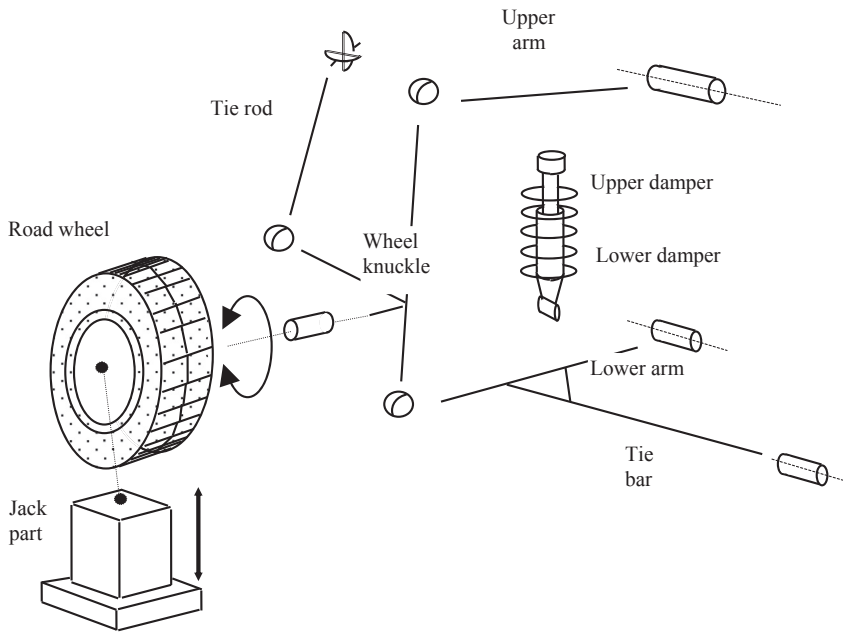

FIGURE A.1

Front suspension components.

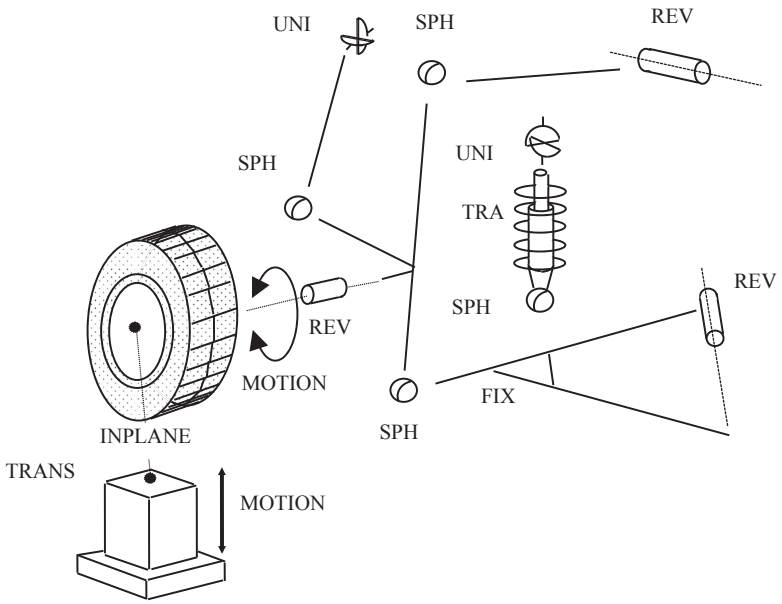

FIGURE A.2

Front suspension with joints.

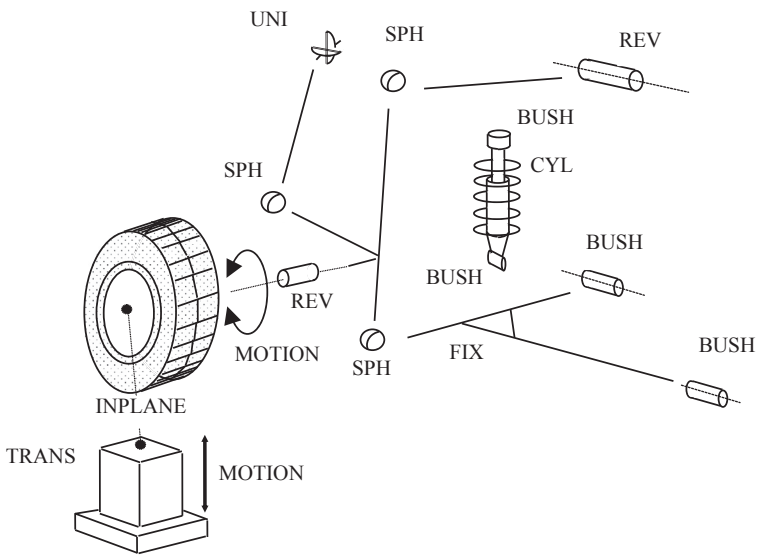

FIGURE A.3

Front suspension with bushes.

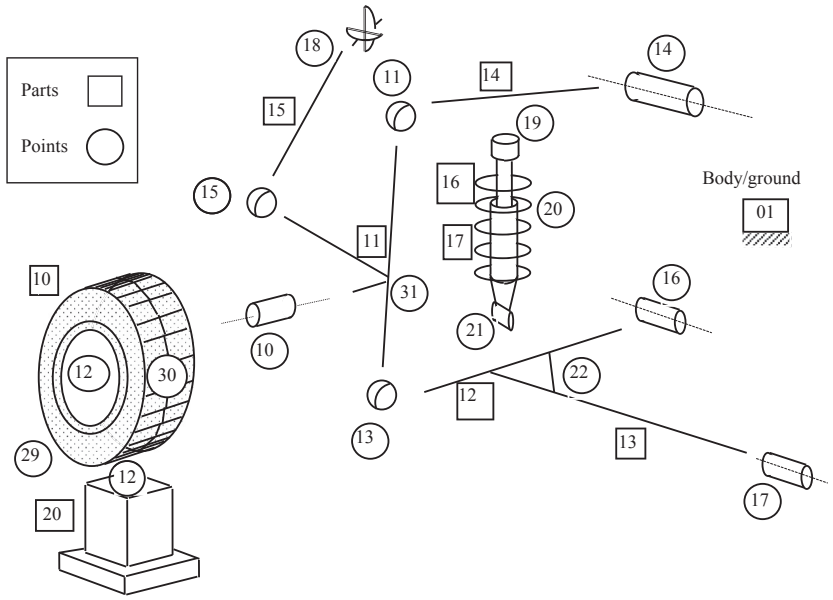

FIGURE A.4

Front suspension numbering convention.

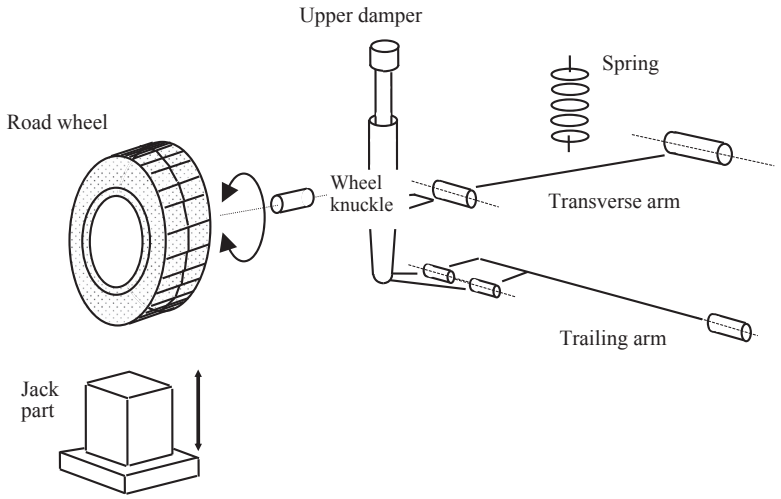

FIGURE A.5

Rear suspension components.

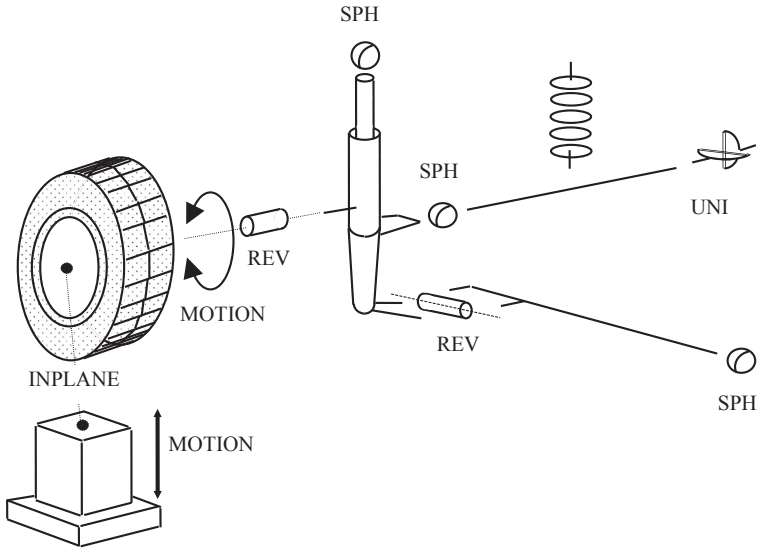

FIGURE A.6

Rear suspension with joints.

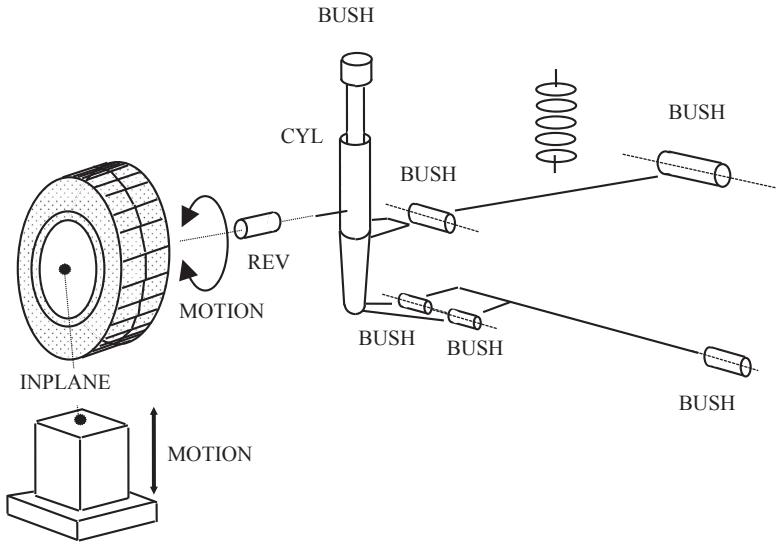

FIGURE A.7

Rear suspension with bushes.

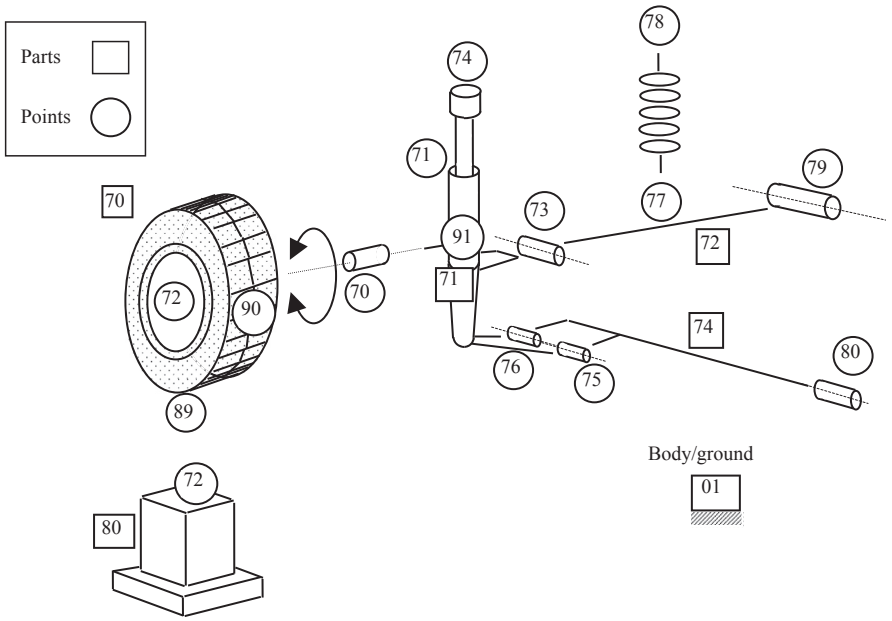

FIGURE A.8

Rear suspension numbering convention.

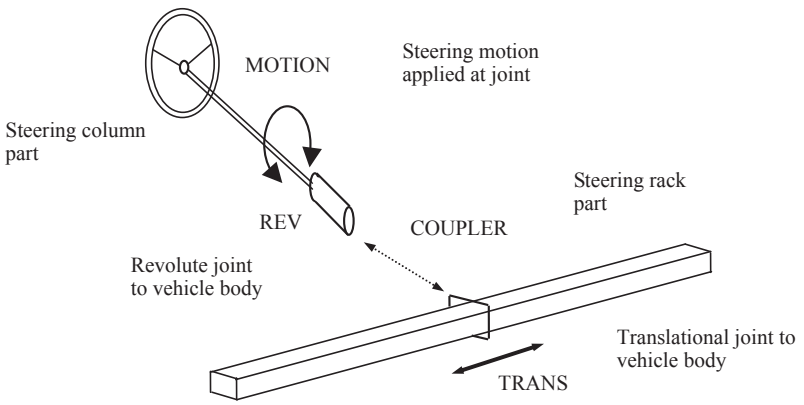

FIGURE A.9

Steering system components and joints.

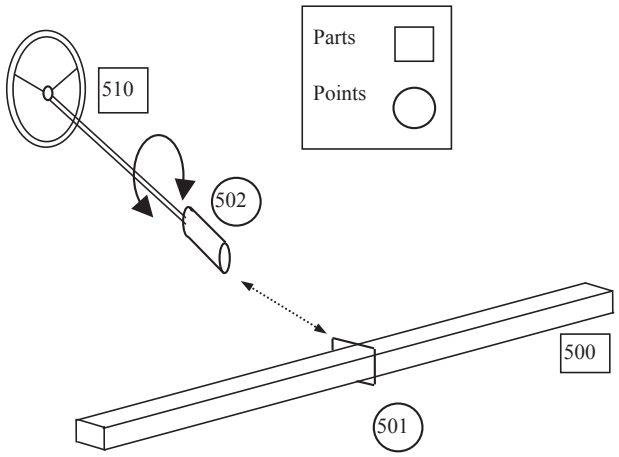

FIGURE A.10

Steering system numbering convention.

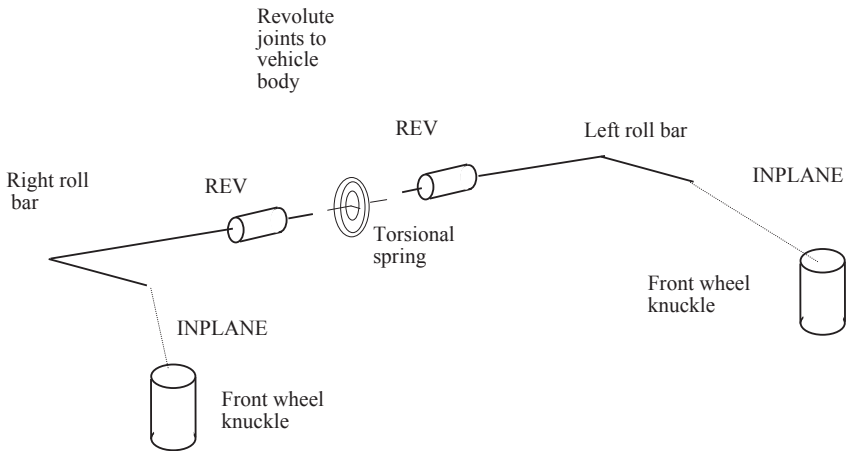

FIGURE A.11

Front roll bar system components and joints.

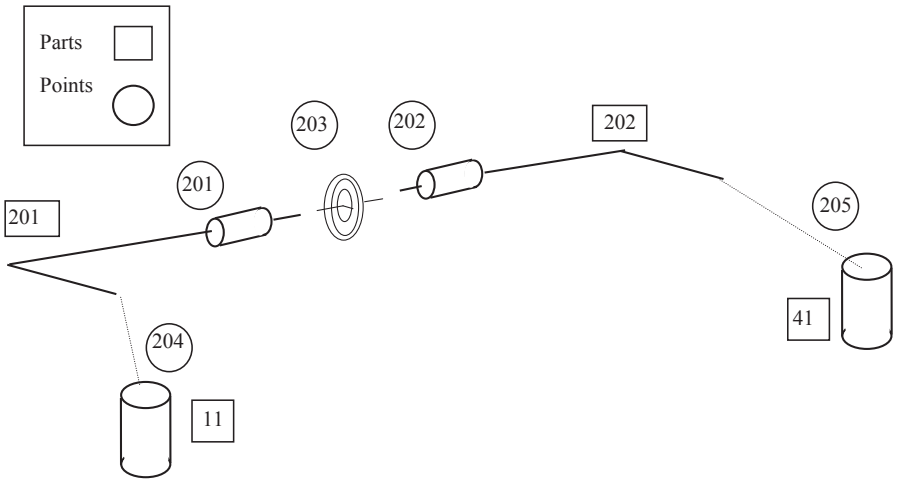

FIGURE A.12

Front roll bar system numbering convention.

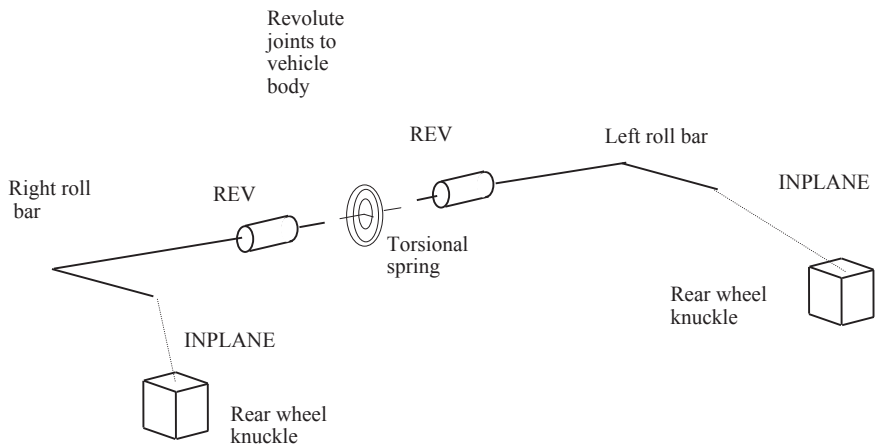

FIGURE A.13

Rear roll bar system components and joints.

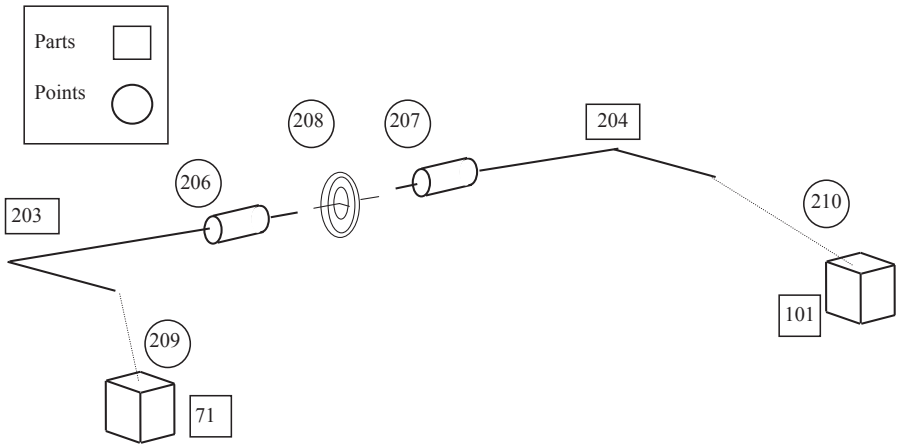

FIGURE A.14

Rear roll bar system numbering convention.

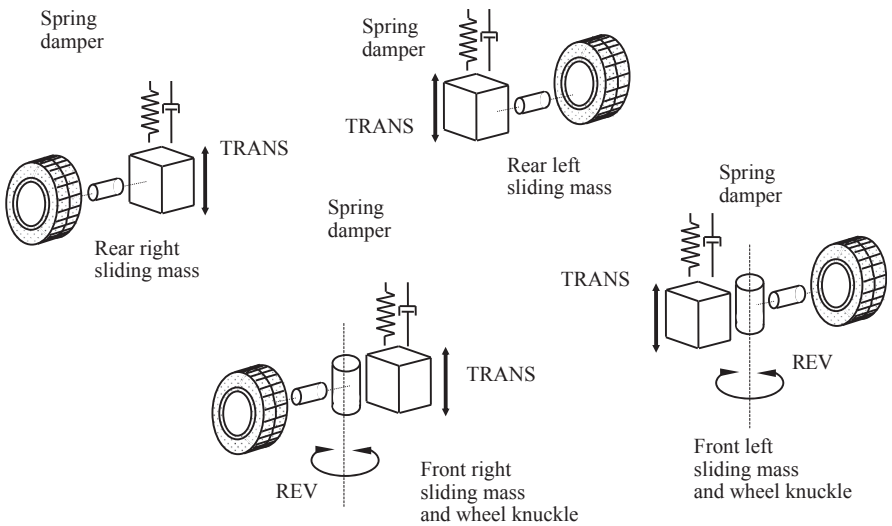

FIGURE A.15

Lumped mass model suspension components and joints.

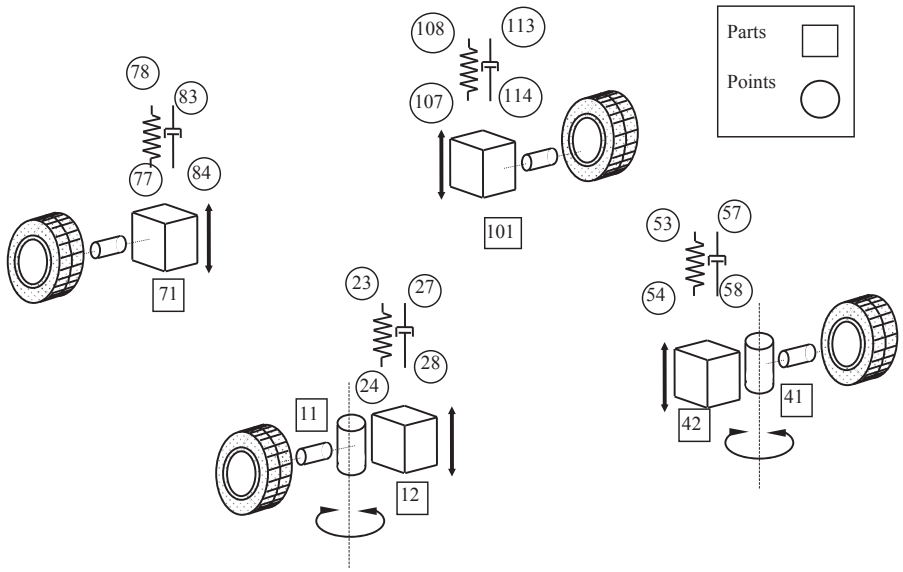

FIGURE A.16

Lumped mass model suspension numbering convention.

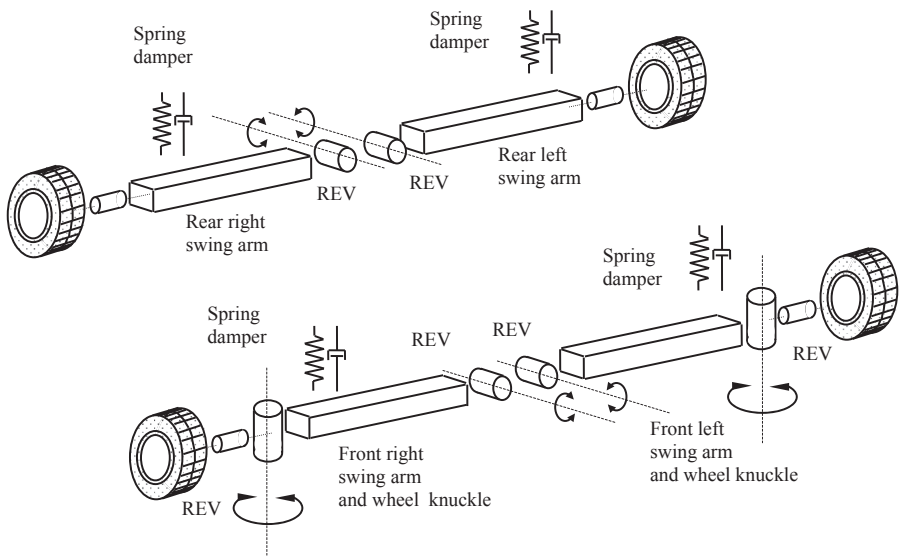

FIGURE A.17

Swing arm model suspension components and joints.

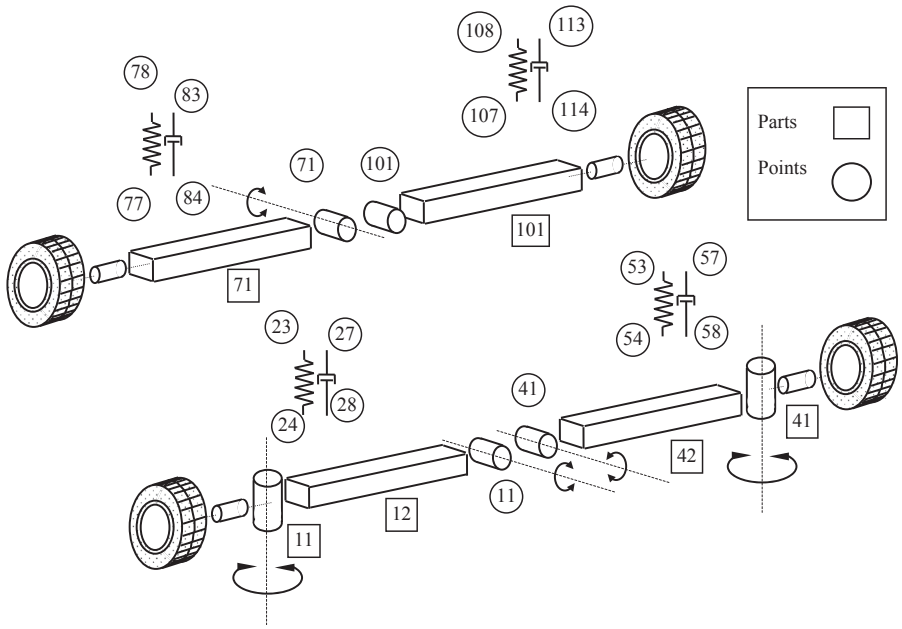

FIGURE A.18

Swing arm model suspension numbering convention.

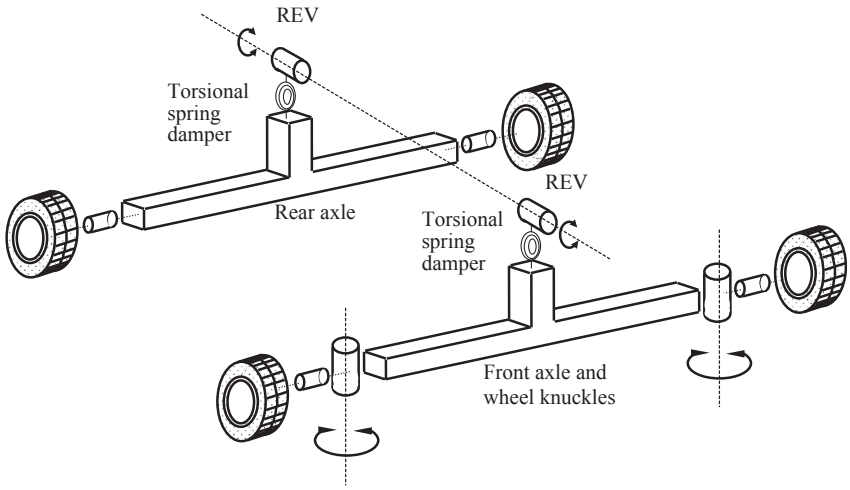

FIGURE A.19

Roll stiffness model suspension components and joints.

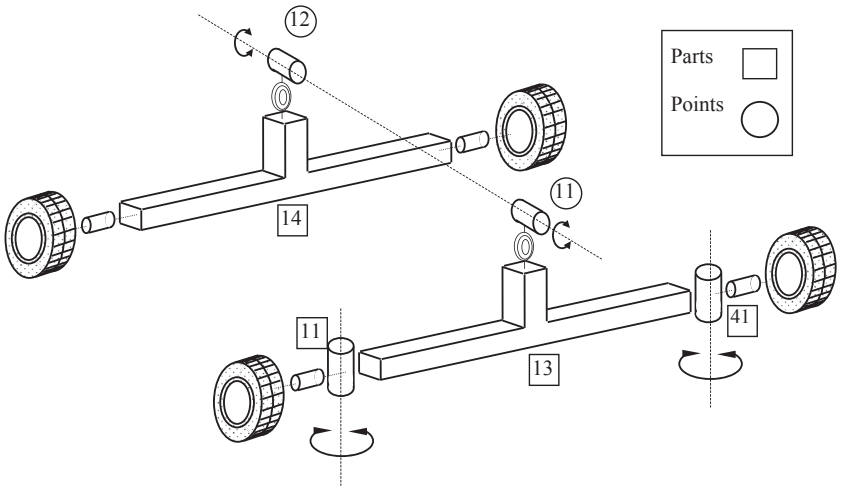

FIGURE A.20

Roll stiffness model suspension numbering convention.

Table A.1 Road Wheel Mass and Moment of Inertia Data

Description	Part ID	CM	Mass (kg)	Mass Moments of Inertia (kgmm^2)		
		Marker		Ix	Iy	Iz
Front right wheel	10	10	21.204	577.59E3	577.59E3	931.077E3
Front left wheel	40	40[a]	21.204	577.59E3	577.59E3	931.077E3
Rear right wheel	170	70[a]	21.204	577.59E3	577.59E3	931.077E3
Rear left wheel	100	100[a]	21.204	577.59E3	577.59E3	931.077E3

[a] *The wheel parts are generated automatically by the TIRE statement. The centre of mass is taken to be at the location of the J marker for each tyre, i.e., locations 10, 40, 70, 100.*

Table A.2 Front Right Suspension Mass and Moment of Inertia Data

Description	Part ID	CM	Mass (kg)	Mass Moments of Inertia (kgmm^2)		
		Marker		Ix	Iy	Iz
Wheel knuckle	11	1100	11.678	65.647E3	120.541E3	77.691E3
Lower arm	12	1200	3.4405	37.856E3	0.348E3	37.933E3
Tie bar	13	1300	2.64	0.023E3	3.876E3	3.876E3
Upper arm	14	1400	2.187	11.520E3	4.071E3	15.218E3
Tie rod	15	1500	0.575	3.876E3	0.023E3	3.876E3
Upper damper	16	1600	0.389	63.948E3	63.948E3	0.822E3
Lower damper	17	1700	6.215	107.364E3	107.364E3	4.972E3

Table A.3 Front Left Suspension Mass and Moment of Inertia Data

Description	Part ID	CM	Mass (kg)	Mass Moments of Inertia (kgmm^2)		
		Marker		Ix	Iy	Iz
Wheel knuckle	41	4100	11.678	65.647E3	120.541E3	77.691E3
Lower arm	42	1200	3.4405	37.856E3	1.348E3	37.933E3
Tie bar	43	1300	2.64	0.023E3	3.876E3	3.876E3
Upper arm	44	1400	2.187	11.520E3	4.071E3	15.218E3
Tie rod	45	1500	0.575	3.876E3	0.023E3	3.876E3
Upper damper	46	1600	0.389	63.948E3	63.948E3	0.822E3
Lower damper	47	1700	6.215	107.364E3	107.364E3	4.972E3

Table A.4 Rear Right Suspension Mass and Moment of Inertia Data

Description	Part ID	CM	Mass (kg)	Mass Moments of Inertia (kgmm^2)		
		Marker		Ix	Iy	Iz
Wheel knuckle	71	7100	12.036	165.994E3	196.457E3	34.224E3
Transverse arm	72	7200	6.424	101.389E3	15.215E3	113.237E3
Trailing arm	74	7400	4.322	12.826E3	190.372E3	199.393E3
Upper damper	73	7300	0.982	1.003E3	1.003E3	0.1E3

Table A.5 Rear Left Suspension Mass and Moment of Inertia Data

Description	Part ID	CM	Mass (kg)	Mass Moments of Inertia (kgmm^2)		
		Marker		Ix	Iy	Iz
Wheel knuckle	101	10,100	12.036	165.994E3	196.457E3	34.224E3
Transverse arm	102	10,200	6.424	101.389E3	15.215E3	113.237E3
Trailing arm	104	10,400	4.322	12.826E3	190.372E3	199.393E3
Upper damper	103	10,300	0.982	1.003E3	1.003E3	0.1E3

Table A.6 Body, Rollbars and Steering Mass and Moment of Inertia Data

Description	Part ID	CM	Mass (kg)	Mass Moments of Inertia (kgmm^2)		
		Marker		Ix	Iy	Iz
Body	200	20,000	1427.3	379.0E6	2235.0E6	2269.0E6
Front right roll bar	201	20,100	1.4	10.0	10.0	20.0
Front left roll bar	202	20,200	1.4	10.0	10.0	20.0
Rear right roll bar	203	20,300	1.4	10.0	10.0	20.0
Rear left roll bar	204	20,400	1.4	10.0	10.0	20.0
Steering rack	500	50,000	0.48	13,357.0	48.0	13,357.0
Steering column	510	51,000	2.2	24.0E3	24.0E3	40,762.0

Table A.7 Lumped Mass Model Mass and Moment of Inertia Data

Description	Part ID	CM	Mass (kg)	Mass Moments of Inertia (kgmm^2)		
		Marker		Ix	Iy	Iz
Right wheel knuckle	11	1100	11.678	65.647E3	120.541E3	77.691E3
Left wheel knuckle	41	4100	11.678	65.647E3	120.541E3	77.691E3
Front right mass	12	1200	15.447	86.818E3	159.445E3	102.765E3
Front left mass	42	4200	15.447	86.818E3	159.445E3	102.765E3
Rear right mass	71	7100	23.764	280.209E3	402.062E3	346.854E3
Rear left mass	101	10,100	23.764	280.209E3	402.062E3	346.854E3

Table A.8 Swing Arm Model Mass and Moment of Inertia Data

Description	Part ID	CM	Mass (kg)	Mass Moments of Inertia (kgmm^2)		
		Marker		Ix	Iy	Iz
Right wheel Knuckle	11	1100	11.678	65.647E3	120.541E3	77.691E3
Left wheel Knuckle	41	4100	11.678	65.647E3	120.541E3	77.691E3
Front right arm	12	1200	15.447	86.818E3	159.445E3	102.765E3
Front left arm	42	4200	15.447	86.818E3	159.445E3	102.765E3
Rear right arm	71	7100	23.764	280.209E3	402.062E3	346.854E3
Rear left arm	101	10,100	23.764	280.209E3	402.062E3	346.854E3

Table A.9 Roll Stiffness Model Mass and Moment of Inertia Data

Description	Part ID	CM	Mass (kg)	Mass Moments of Inertia (kgmm^2)		
		Marker		Ix	Iy	Iz
Right wheel knuckle	11	1100	11.678	65.647E3	120.541E3	77.691E3
Left wheel knuckle	41	4100	11.678	65.647E3	120.541E3	77.691E3
Front axle	13	1300	30.894	173.636E3	318.89E3	205.53E3
Rear axle	14	1400	47.528	560.418E3	804.124E3	693.708E3

Table A.10 Front Right Suspension Geometry

Point Id.	Coordinates (mm)			Euler Angles (deg)			ZP (mm)		
	X	Y	Z	ψ	θ	ϕ	X	Y	Z
1100	966.1	743.9	165.9						
1200	1006.0	525.0	113.0	12D	−13.5D	0D			
1300	722.0	444.0	115.0						
1400	1064.0	500.0	566.0	28.5D	9D	0D			
1500	1129.0	534.0	189.0						
1600	954.4	509.6	497.3	163.66D	164.61D	0D			
1700	954.4	509.6	497.3	163.66D	164.61D	0D			
10	966.1	743.9	165.9	0D	90D	0D			
11	986.6	639.3	572.1						
13	962.2	703.1	90.7						
14	973.0	417.8	548.4	119.05D	91.03D	0.0D			
15	1106.2	673.9	171.7						
16	1050.0	348.3	137.0	−75.95D	90.87D	−172.78D			
17	474.0	332.0	115.0	−66.15D	90D	0.0D			
18	1145.0	392.0	196.0				1245.0	392.0	196.0[a]
19	945.9	480.4	607.7	163.66D	164.61D	0.0D			
20	954.4	509.6	497.3	163.66D	164.61D	0.0D			
21	987.0	620.0	76.5	−89.72D	98.11D	0.0D			
22	984.2	562.3	113.9						
23	945.9	480.4	607.7						
24	965.5	547.4	354.1						
25	945.9	480.4	607.7						
26	954.4	509.6	497.3						
27	945.9	480.4	607.7						
28	987.0	620.7	76.5						
31	966.1	693.1	165.9						
32	965.3	547.4	354.1						
33	945.9	480.4	607.7	163.66D	164.61D	0D			

[a] *The ZP orientation is only applied to the marker which belongs to the rack part and is used for the universal joint connecting the rack to the tie rod.*

Table A.11 Front Left Suspension Geometry

Point Id.	Coordinates (mm)			Euler Angles (deg)			ZP (mm)		
	X	Y	Z	ψ	θ	ϕ	X	Y	Z
4100	966.1	−743.9	165.9						
4200	1006.0	−525.0	113.0	12D	−13.5D	0D			
4300	722.0	−444.0	115.0						
4400	1064.0	−500.0	566.0	28.5D	9D	0D			
4500	1129.0	−534.0	189.0						
4600	954.4	−509.6	497.3	−343.66D	164.61D	−180D			
4700	954.4	−509.6	497.3	−343.66D	164.61D	−180D			
40	966.1	- 743.9	165.9	0D	90D	0D			
41	986.6	−639.3	572.1						
43	962.2	−703.1	90.7						
44	973.0	- 417.8	548.4	−299.05D	91.03D	−180.0D			
45	1106.2	−673.9	171.7						
46	1050.0	−348.3	137.0	−104.05D	90.87D	−7.22D			
47	474.0	−332.0	115.0	−113.85D	90D	−180D			
48	1145.0	−392.0	196.0				1245.0	−392.0	196.0[a]
49	945.9	−480.4	607.7	−343.66D	164.61D	−180.0D			
50	954.4	−509.6	497.3	−343.66D	164.61D	−180D			
51	987.0	−620.0	76.5	89.72D	81.89D	0.0D			
52	984.2	−562.3	113.9						
53	945.9	−480.4	607.7						
54	965.5	−547.4	354.1						
55	945.9	−480.4	607.7						
56	954.4	−509.6	497.3						
57	945.9	−480.4	607.7						
58	987.0	−620.7	76.5						
61	966.1	−693.1	165.9						
62	965.3	−547.4	354.1						
63	945.9	−480.4	607.7	−343.66D	164.61D	180D			

[a] *The ZP orientation is only applied to the marker which belongs to the rack part and is used for the universal joint connecting the rack to the tie rod.*

Table A.12 Rear Right Suspension Geometry

Point Id.	Coordinates (mm)			Euler Angles (deg)			ZP (mm)		
	X	Y	Z	ψ	θ	ϕ	X	Y	Z
7100	3732	725	167						
7200	3743	493	112	0D	4.55D	0D			
7300	3701.02	525.66	606.36	163.46D	166.09D	0D			
7400	3630	587	70						
70	3732	725	167	0D	90D	0D			
71	703.6	534.4	569.6	163.46D	166.09D	0D			
72	3732	725	167						
73	3747	706	109.5	88.809D	90D	−4.3376D			
74	3701	525.7	606.4	163.46D	166.09D	−195D			
75	3695.4	684.6	48.1	56.715D	97.334D	0.0D			
76	3803.4	613.7	34.2	56.716D	97.334D	0.0D			
77	3743	496	84.0						
78	3743	475	265.8						
79	3737	225	146	88.809D	90D	−4.3376D			
80	3203	600	144.5	75.0491D	98.3D	0D			
81	3703.5	533	573						
82	3693	499	714						
83	3693.3	499.7	715.9						
84	3729.7	622.2	200						
85	3701	525.7	606.4	163.46D	166.09D	0D			
86	3703.6	534.4	569.6						
91	3732	684.6	167						

Table A.13 Rear Left Suspension Geometry

Point Id.	Coordinates (mm)			Euler Angles (deg)			ZP (mm)		
	X	Y	Z	Ψ	θ	ϕ	X	Y	Z
10100	3732	−725	167						
10200	3743	−493	112	−180D	4.55D	−180D			
10300	3701.02	−525.66	606.36	−343.46D	166.09D	−180D			
10400	3630	−587	70						
100	3732	−725	167	0D	90D	0D			
101	3703.6	−534.4	569.6	163.46D	166.09D	0D			
102	3732	−725	167						
103	3747	−706	109.5	91.191D	90D	−175.6624D			
104	3701	−525.7	606.4	−343.46D	166.09D	15D			
105	3695.4	−684.6	48.1	123.284D	97.334D	180D			
106	3803.4	−613.7	34.2	123.284D	97.334D	180D			
107	3743	−496	84.0						
108	3743	−475	265.8						
109	3737	−225	146	91.191D	90D	−175.634D			
110	3203	−600	144.5	−255.049D	98.3D	180D			
111	3703.5	−533	573						
112	3693	−499	714						
113	3693.3	−499.7	715.9						
114	3729.7	−622.2	200						
115	3701	−525.7	606.4	−343.46D	166.09D	180D			
116	3703.6	−534.4	569.6						
121	3732	−684.6	167						

Table A.14 Body, Rollbars and Steering Geometry

Point Id.	Coordinates (mm)			Euler Angles (deg)			ZP (mm)		
	X	Y	Z	ψ	θ	ϕ	X	Y	Z
20000	2150.4	0.0	452.0						
20100	1264	263	87	0D	90D	0D			
201	1264	263	87	0D	90D	0D			
203	1264	0.0 87	0D	90D	0D				
204	966.1	743.9	165.9						
20200	1264	−263	87	0D	90D	0D			
202	1264	−263	87	0D	90D	0D			
203	1264	0.0	87	0D	90D	0D			
205	966.1	−743.9	165.9						
20300	4142	508	268	0D	90D	0D			
206	4142	508	268	0D	90D	0D			
208	4142	0	268	0D	90D	0D			
209	3732	725	167						
20400	4142	−508	268	0D	90D	0D			
207	4142	−508	268	0D	90D	0D			
208	4142	0	268	0D	90D	0D			
210	3732	−725	167						
50000	1145	0	196						
501	1145	0	196	180D	90D	0D			
51000	1964	353	787.6				1698.6	348.6	604.4
502	1964	353	787.6				1698.6	348.6	604.4
5101	2072	353	631						
5102	1961	543	788						
5103	1967	163	788						
5104	1145	338	222						

Table A.15 Lumped Mass Model Geometry

Point Id.	Coordinates (mm)			Euler Angles (deg)			ZP (mm)		
	X	Y	Z	ψ	θ	ϕ	X	Y	Z
1100	966.1	743.9	165.9						
1200	966.1	500	165.9						
4100	966.1	−743.9	165.9						
4200	966.1	−500	165.9						
7100	3732	500	167						
10100	3732	−500	167						
11	966.1	500	165.9						
41	966.1	−500	165.9						
39	966.1	743.9	165.9						
69	966.1	−743.9	165.9						
99	3732	500	167						
129	3732	−500	167						

Table A.16 Swing Arm Model Geometry

Point Id.	Coordinates (mm)			Euler Angles (deg)			ZP (mm)		
	X	Y	Z	ψ	θ	ϕ	X	Y	Z
1100	966.1	743.9	165.9						
1200	966.1	500	165.9						
4100	966.1	−743.9	165.9						
4200	966.1	−500	165.9						
7100	3732	500	167						
10,100	3732	−500	167						
39	966.1	743.9	165.9						
69	966.1	−743.9	165.9						
11	966.1	−1361	358.6						
41	966.1	1361	358.6						
71	3732	−576.5	206.2						
101	3732	576.5	206.2						

Table A.17 Roll Stiffness Model Geometry

Point Id.	Coordinates (mm)			Euler Angles (deg)			ZP (mm)		
	X	Y	Z	ψ	θ	ϕ	X	Y	Z
1100	966.1	743.9	165.9						
4100	966.1	−743.9	165.9						
1300	966.1	0.0	165.9						
1400	3732	0.0	167						
39	966.1	743.9	165.9						
69	966.1	−743.9	165.9						
11	966.1	0.0	27.4						
12	3732	0.0	47.4						

Table A.18 Spring Data

The springs are defined using the SPRINGDAMPER statement.

Front Spring:	
Stiffness	K = 31.96 N/mm
Free length	L = 426 mm
Rear Spring:	
Stiffness	k = 60.8 N/mm
Free length	L = 253 mm

Table A.19 Front Damper Data

The dampers are defined using the SFORCE statement. The dampers are nonlinear. The data provided shows the variation of force in the damper with velocity.

Velocity (mm/s)	−5000, −3150, −2870, −2450, −2205, −1925, −1610, −1260, −910, −630, −470, −400, −350, −300, −250, −230, −200, −190, −160, −120, −80, −55, −40, −20, −10, −1, −0.1, 0, 0.3, 3, 30, 40, 60, 80, 100, 200, 250, 400,490, 770, 1050, 1330, 1820, 2060, 2485, 2590, 2730, 2835, 2940, 3080, 5000
Force (N)	10425, 5800, 5200, 4400, 4000, 3600, 3200, 2800, 2400, 2000, 1800, 1700, 1600, 1500, 1400, 1350, 1310, 1290, 1200, 1000, 700, 400, 210, 80, 40, 4, 0.4,0, −1, −10, −100, −123, −150, −182, −200, −260, −300, −400, −500, −800, −1200, −1600, −2400, −2800, −3400, −3500, −3600, −3700, −3800, −4000, −7840

Table A.20 Rear Damper Data

The dampers are defined using the SFORCE statement. The dampers are nonlinear. The data provided shows the variation of force in the damper with velocity.

Velocity (mm/s)	−5000, −3150, −2800, −2450, −2100, −1750, −1400, −1050, −700, −560, −500, −450, −400, −350, −300,-250, −200, −150, −100, −50, −25, −5, −1, −0.1, 0, 0.1, 1, 5, 25,50,100, 200, 300, 400, 500, 700, 1050, 1400, 1750, 2100, 2450, 2800, 3150, 5000
Force(N)	7352,3652,3120,2635,2193,1855,1518,1180,927,843,800,773,722, 686,658,596, 560,488,329,154,77,15.4,3.08,0.308,0,-0.126,-1.26, −6.3, -31.5,-63,-126,-153.25, −180.5,-208,-235,-253,-380,-675,-970, −1349, -1788,-2277,-2867,-6567

Table A.21 Roll Bar Data

Front Roll Bar:	
Torsional stiffness	Kt = 490E3 Nmm/rad
Rear roll bar:	
Torsional stiffness	Kt = 565E3 Nmm/rad

Table A.22 Front Suspension Bush Data

The following linear values are used to define the stiffness and damping in the bushes. For each bush data is listed as:

K = kx,ky,kz Stiffness (N/mm)
KT = ktx,kty,ktz Torsional stiffness (Nmm/rad)
C = cx,cy,cz Damping (Ns/mm)
CT = ctx,cty,ctz Torsional Damping (Nmms/rad)

Lower Arm Mount Bush (location 12 and 42)

K = 7825,7825,944
KT = 2.5E6,2.5E6,500
C = 35,35,480
CT = 61000,61000,40

Tie Bar Bush Mount

K = 5723,5723,6686
KT = 543000,543000,500
C = 400,400,300
CT = 18400,18400,4

Upper Damper Mount

K = 14353,14353,10000
KT = 120000,120000,400
C = 400,400,300
CT = 1200,1200,40

Lower Damper Mount

K = 6385,6385,550
KT = 355000,355000,400
C = 640,640,50
CT = 35000,35000,40

Table A.23 Rear Suspension Bush Data

The following linear values are used to define the stiffness and damping in the bushes. For each bush data is listed as:

K = kx, ky, kz Stiffness (N/mm)
KT = ktx, kty, ktz Torsional stiffness (Nmm/rad)
C = cx, cy, cz Damping (Ns/mm)
CT = ctx, cty, ctz Torsional Damping (Nmms/rad)

Rear Trailing Link to Hub Bushes
K = 10500,10500,870 KT = 2.8E5,2.8E5,67500 C = 1000,1000,100 CT = 25000,25000,40
Rear Trailing Link to Body Bush
K = 660,660,175 KT = 260300,260300,40000 C = 100,100,50 CT = 25000,25000,40
Rear Upper Damper Mount
K = 540,1300,532 KT = 58915,180750,670 C = 200,200,70 CT = 5800,5800,67
Rear Lower Arm to Body Mount
K = 10800,3420,840 KT = 790000,380000,400 C = 1000,400,100 CT = 88000,40000,40
Rear Lower Arm to Hub Bush
K = 5540,5540,515 KT = 210540,210540,400 C = 800,800,50 CT = 25000,25000,40