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EoM Analysis
Full Car A-Arm Pushrod

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Chapter 1

Introduction

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1.1 System Description

The properties of the bodies are given in Tables 1.1 and 1.2. The properties of the connecctions are given in Tables 1.3, 1.4, and 1.5.

Table 1.1: Body CG Locations and Mass

No.	Body Name	Location [m]	Mass [kg]
1	Chassis	0.000, 0.000, 0.500	1,400.000
2	LF Upright	1.200, 0.800, 0.300	5.000
3	LF Lower A-arm	1.200, 0.600, 0.150	5.000
4	LF Upper A-arm	1.200, 0.600, 0.400	5.000
5	LF Bell-crank	1.140, 0.340, 0.460	1.000
6	LF Anti-roll arm	1.300, 0.300, 0.400	1.000
7	LF Push-rod	1.200, 0.550, 0.300	1.000
8	LF Tie-rod	1.040, 0.550, 0.280	1.000
9	LF Wheel+hub	1.200, 0.900, 0.300	10.000
10	LR Upright	−1.300, 0.800, 0.300	5.000
11	LR Lower A-arm	−1.300, 0.600, 0.150	5.000
12	LR Upper A-arm	−1.300, 0.600, 0.400	5.000
13	LR Bell-crank	−1.250, 0.350, 0.450	1.000
14	LR Push-rod	−1.300, 0.550, 0.300	1.000
15	LR Tie-rod	−1.140, 0.450, 0.125	1.000
16	LR Wheel+hub	−1.300, 0.900, 0.300	10.000
17	LF Contact patch	1.200, 0.900, 0.000	0.000
18	LR Contact patch	−1.300, 0.900, 0.000	0.000
19	RF Upright	1.200, −0.800, 0.300	5.000
20	RF Lower A-arm	1.200, −0.600, 0.150	5.000
21	RF Upper A-arm	1.200, −0.600, 0.400	5.000
22	RF Bell-crank	1.140, −0.340, 0.460	1.000
23	RF Anti-roll arm	1.300, −0.300, 0.400	1.000
24	RF Push-rod	1.200, −0.550, 0.300	1.000
25	RF Tie-rod	1.040, −0.550, 0.280	1.000

26	RF Wheel+hub	1.200, −0.900, 0.300	10.000
27	RR Upright	−1.300, −0.800, 0.300	5.000
28	RR Lower A-arm	−1.300, −0.600, 0.150	5.000
29	RR Upper A-arm	−1.300, −0.600, 0.400	5.000
30	RR Bell-crank	−1.250, −0.350, 0.450	1.000
31	RR Push-rod	−1.300, −0.550, 0.300	1.000
32	RR Tie-rod	−1.140, −0.450, 0.125	1.000
33	RR Wheel+hub	−1.300, −0.900, 0.300	10.000
34	RF Contact patch	1.200, −0.900, 0.000	0.000
35	RR Contact patch	−1.300, −0.900, 0.000	0.000

Table 1.2: Body Inertia Properties

No.	Body Name	Inertia† [kg m^2] (I_{xx}, I_{yy}, I_{zz}; I_{xy}, I_{yz}, I_{zx})					
1	Chassis	800.000,	2,000.000,	2,200.000;	0.000,	0.000,	0.000
2	LF Upright	0.100,	0.100,	0.100;	0.000,	0.000,	0.000
3	LF Lower A-arm	1.000,	1.000,	2.000;	0.000,	0.000,	0.000
4	LF Upper A-arm	1.000,	1.000,	2.000;	0.000,	0.000,	0.000
5	LF Bell-crank	0.050,	0.050,	0.050;	0.000,	0.000,	0.000
6	LF Anti-roll arm	0.050,	0.050,	0.050;	0.000,	0.000,	0.000
7	LF Push-rod	0.011,	0.003,	0.008;	0.000,	−0.005,	0.000
8	LF Tie-rod	0.021,	0.003,	0.024;	0.008,	0.002,	0.001
9	LF Wheel+hub	2.000,	4.000,	2.000;	0.000,	0.000,	0.000
10	LR Upright	0.100,	0.100,	0.100;	0.000,	0.000,	0.000
11	LR Lower A-arm	1.000,	1.000,	2.000;	0.000,	0.000,	0.000
12	LR Upper A-arm	1.000,	1.000,	2.000;	0.000,	0.000,	0.000
13	LR Bell-crank	0.050,	0.050,	0.050;	0.000,	0.000,	0.000
14	LR Push-rod	0.011,	0.003,	0.008;	0.000,	−0.005,	0.000
15	LR Tie-rod	0.041,	0.003,	0.044;	−0.011,	0.003,	−0.001
16	LR Wheel+hub	2.000,	4.000,	2.000;	0.000,	0.000,	0.000
17	LF Contact patch	0.000,	0.000,	0.000;	0.000,	0.000,	0.000
18	LR Contact patch	0.000,	0.000,	0.000;	0.000,	0.000,	0.000
19	RF Upright	0.100,	0.100,	0.100;	0.000,	0.000,	0.000
20	RF Lower A-arm	1.000,	1.000,	2.000;	0.000,	0.000,	0.000
21	RF Upper A-arm	1.000,	1.000,	2.000;	0.000,	0.000,	0.000
22	RF Bell-crank	0.050,	0.050,	0.050;	0.000,	0.000,	0.000
23	RF Anti-roll arm	0.050,	0.050,	0.050;	0.000,	0.000,	0.000
24	RF Push-rod	0.011,	0.003,	0.008;	0.000,	0.005,	0.000
25	RF Tie-rod	0.021,	0.003,	0.024;	−0.008,	−0.002,	0.001
26	RF Wheel+hub	2.000,	4.000,	2.000;	0.000,	0.000,	0.000
27	RR Upright	0.100,	0.100,	0.100;	0.000,	0.000,	0.000
28	RR Lower A-arm	1.000,	1.000,	2.000;	0.000,	0.000,	0.000
29	RR Upper A-arm	1.000,	1.000,	2.000;	0.000,	0.000,	0.000
30	RR Bell-crank	0.050,	0.050,	0.050;	0.000,	0.000,	0.000
31	RR Push-rod	0.011,	0.003,	0.008;	0.000,	0.005,	0.000
32	RR Tie-rod	0.041,	0.003,	0.044;	0.011,	−0.003,	−0.001
33	RR Wheel+hub	2.000,	4.000,	2.000;	0.000,	0.000,	0.000
34	RF Contact patch	0.000,	0.000,	0.000;	0.000,	0.000,	0.000
35	RR Contact patch	0.000,	0.000,	0.000;	0.000,	0.000,	0.000

†Inertias are defined as the positive integral over the body, e.g., $I_{xy} = +\int r_x r_y \, dm$.

Table 1.3: Connection Location and Direction

No.	Connection Name	Location [m]	Unit Axis
1	LF Wheel bearing	1.200, 0.900, 0.300	0.000, 1.000, 0.000
2	LF Lower ball joint	1.200, 0.800, 0.150	0.000, 1.000, 0.000
3	LF Lower A-arm pivot, rear	1.000, 0.100, 0.150	0.000, 1.000, 0.000
4	LF Lower A-arm pivot, front	1.400, 0.100, 0.100	1.000, 0.000, 0.000
5	LF Bell-crank pivot	1.100, 0.400, 0.400	0.000, 0.707, 0.707
6	LF Upper A-arm pivot, front	1.400, 0.300, 0.350	1.000, 0.000, 0.000
7	LF Upper A-arm pivot, rear	1.000, 0.300, 0.350	1.000, 0.000, 0.000
8	LF Upper ball joint	1.200, 0.750, 0.450	1.000, 0.000, 0.000
9	LF Lower push-rod end	1.200, 0.700, 0.200	0.000, −0.832, 0.555
10	LF Upper push-rod end	1.200, 0.400, 0.400	0.000, −0.832, 0.555
11	LF Inner tie-rod end	0.950, 0.300, 0.260	0.000, −0.832, 0.555
12	LF Outer tie-rod end	1.130, 0.800, 0.300	0.338, 0.938, 0.075
13	LF Anti-roll mount	1.300, 0.300, 0.350	0.000, 1.000, 0.000
14	LR Wheel bearing	−1.300, 0.900, 0.300	0.000, 1.000, 0.000
15	LR Lower ball joint	−1.300, 0.800, 0.150	0.000, 1.000, 0.000
16	LR Lower A-arm pivot, front	−1.100, 0.100, 0.100	0.000, 1.000, 0.000
17	LR Lower A-arm pivot, rear	−1.500, 0.100, 0.100	1.000, 0.000, 0.000
18	LR Bell-crank pivot	−1.200, 0.400, 0.400	0.000, 0.707, 0.707
19	LR Upper A-arm pivot, rear	−1.500, 0.300, 0.350	1.000, 0.000, 0.000
20	LR Upper A-arm pivot, front	−1.100, 0.300, 0.350	1.000, 0.000, 0.000
21	LR Upper ball joint	−1.300, 0.750, 0.450	1.000, 0.000, 0.000
22	LR Lower push-rod end	−1.300, 0.700, 0.200	0.000, −0.832, 0.555
23	LR Upper push-rod end	−1.300, 0.400, 0.400	0.000, −0.832, 0.555
24	LR Inner tie-rod end	−1.050, 0.100, 0.100	0.000, −0.832, 0.555
25	LR Outer tie-rod end	−1.230, 0.800, 0.150	−0.248, 0.966, 0.069
26	LF Contact patch constraint	1.200, 0.900, 0.000	0.000, 1.000, 0.000
27	LR Contact patch constraint	−1.300, 0.900, 0.000	0.000, 1.000, 0.000
28	RF Wheel bearing	1.200, −0.900, 0.300	0.000, −1.000, 0.000
29	RF Lower ball joint	1.200, −0.800, 0.150	0.000, −1.000, 0.000
30	RF Lower A-arm pivot, rear	1.000, −0.100, 0.150	0.000, −1.000, 0.000
31	RF Lower A-arm pivot, front	1.400, −0.100, 0.100	1.000, 0.000, 0.000
32	RF Bell-crank pivot	1.100, −0.400, 0.400	0.000, −0.707, 0.707
33	RF Upper A-arm pivot, front	1.400, −0.300, 0.350	1.000, 0.000, 0.000
34	RF Upper A-arm pivot, rear	1.000, −0.300, 0.350	1.000, 0.000, 0.000
35	RF Upper ball joint	1.200, −0.750, 0.450	1.000, 0.000, 0.000
36	RF Lower push-rod end	1.200, −0.700, 0.200	0.000, 0.832, 0.555
37	RF Upper push-rod end	1.200, −0.400, 0.400	0.000, 0.832, 0.555
38	RF Inner tie-rod end	0.950, −0.300, 0.260	0.000, 0.832, 0.555
39	RF Outer tie-rod end	1.130, −0.800, 0.300	0.338, −0.938, 0.075
40	RF Anti-roll mount	1.300, −0.300, 0.350	0.000, −1.000, 0.000
41	RR Wheel bearing	−1.300, −0.900, 0.300	0.000, −1.000, 0.000
42	RR Lower ball joint	−1.300, −0.800, 0.150	0.000, −1.000, 0.000
43	RR Lower A-arm pivot, front	−1.100, −0.100, 0.100	0.000, −1.000, 0.000
44	RR Lower A-arm pivot, rear	−1.500, −0.100, 0.100	1.000, 0.000, 0.000
45	RR Bell-crank pivot	−1.200, −0.400, 0.400	0.000, −0.707, 0.707
46	RR Upper A-arm pivot, rear	−1.500, −0.300, 0.350	1.000, 0.000, 0.000
47	RR Upper A-arm pivot, front	−1.100, −0.300, 0.350	1.000, 0.000, 0.000
48	RR Upper ball joint	−1.300, −0.750, 0.450	1.000, 0.000, 0.000
49	RR Lower push-rod end	−1.300, −0.700, 0.200	0.000, 0.832, 0.555
50	RR Upper push-rod end	−1.300, −0.400, 0.400	0.000, 0.832, 0.555
51	RR Inner tie-rod end	−1.050, −0.100, 0.100	0.000, 0.832, 0.555
52	RR Outer tie-rod end	−1.230, −0.800, 0.150	−0.248, −0.966, 0.069
53	RF Contact patch constraint	1.200, −0.900, 0.000	0.000, −1.000, 0.000
54	RR Contact patch constraint	−1.300, −0.900, 0.000	0.000, −1.000, 0.000
55	LF Tire, vertical	1.200, 0.900, 0.000	0.000, 0.000, 1.000

56	LR Tire, vertical	−1.300, 0.900, 0.000	0.000, 0.000, 1.000
57	LF Tire, sidewall	1.200, 0.900, 0.000	0.000, 1.000, 0.000
58	LR Tire, sidewall	−1.300, 0.900, 0.000	0.000, 1.000, 0.000
59	LF Tire, horizontal	1.200, 0.900, 0.000	0.000, 0.000, 1.000
60	LR Tire, horizontal	−1.300, 0.900, 0.000	0.000, 0.000, 1.000
61	RF Tire, vertical	1.200, −0.900, 0.000	0.000, 0.000, 1.000
62	RR Tire, vertical	−1.300, −0.900, 0.000	0.000, 0.000, 1.000
63	RF Tire, sidewall	1.200, −0.900, 0.000	0.000, −1.000, 0.000
64	RR Tire, sidewall	−1.300, −0.900, 0.000	0.000, −1.000, 0.000
65	RF Tire, horizontal	1.200, −0.900, 0.000	0.000, 0.000, 1.000
66	RR Tire, horizontal	−1.300, −0.900, 0.000	0.000, 0.000, 1.000

Table 1.4: Connection Locations

No.	Connection Name	Location [m]	Location [m]
1	LF Suspension spring	1.100, 0.300, 0.500	0.700, 0.300, 0.500
2	LR Suspension spring	−1.200, 0.300, 0.500	−0.800, 0.300, 0.500
3	Anti-roll bar	1.300, 0.300, 0.350	1.300, −0.300, 0.350
4	RF Suspension spring	1.100, −0.300, 0.500	0.700, −0.300, 0.500
5	RR Suspension spring	−1.200, −0.300, 0.500	−0.800, −0.300, 0.500
6	LF Drop link	1.140, 0.300, 0.500	1.300, 0.300, 0.500
7	RF Drop link	1.140, −0.300, 0.500	1.300, −0.300, 0.500

Table 1.5: Connection Properties

No.	Connection Name	Stiffness [N/m]	Damping [Ns/m]
1	LF Tire, vertical	150,000	0
2	LR Tire, vertical	150,000	0
3	LF Tire, sidewall	135,000	0
4	LR Tire, sidewall	135,000	0
5	LF Tire, horizontal	0	2,000
6	LR Tire, horizontal	0	2,000
7	RF Tire, vertical	150,000	0
8	RR Tire, vertical	150,000	0
9	RF Tire, sidewall	135,000	0
10	RR Tire, sidewall	135,000	0
11	RF Tire, horizontal	0	2,000
12	RR Tire, horizontal	0	2,000
1	LF Suspension spring	20,000	2,000
2	LR Suspension spring	20,000	2,000
3	Anti-roll bar	100	0
4	RF Suspension spring	20,000	2,000
5	RR Suspension spring	20,000	2,000

Chapter 2

Analysis

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2.1 Eigenvalue Analysis

The eigenvalue properties are given in Tables 2.1 and 2.2.

Table 2.1: Eigenvalues

No.	Real [rad/s]	Imaginary [rad/s]	Real [Hz]	Imaginary [Hz]
1	$-1.9946974394 \times 10^{1}$	$7.1626908222 \times 10^{1}$	$-3.1746595745 \times 10^{0}$	$1.1399776502 \times 10^{1}$
2	$-1.9946974394 \times 10^{1}$	$-7.1626908222 \times 10^{1}$	$-3.1746595745 \times 10^{0}$	$-1.1399776502 \times 10^{1}$
3	$-1.9617503256 \times 10^{1}$	$7.0244101281 \times 10^{1}$	$-3.1222226144 \times 10^{0}$	$1.1179695942 \times 10^{1}$
4	$-1.9617503256 \times 10^{1}$	$-7.0244101281 \times 10^{1}$	$-3.1222226144 \times 10^{0}$	$-1.1179695942 \times 10^{1}$
5	$-2.3209251356 \times 10^{1}$	$7.1608798939 \times 10^{1}$	$-3.6938670788 \times 10^{0}$	$1.1396894320 \times 10^{1}$
6	$-2.3209251356 \times 10^{1}$	$-7.1608798939 \times 10^{1}$	$-3.6938670788 \times 10^{0}$	$-1.1396894320 \times 10^{1}$
7	$-2.3042944844 \times 10^{1}$	$7.1215876379 \times 10^{1}$	$-3.6673985754 \times 10^{0}$	$1.1334358752 \times 10^{1}$
8	$-2.3042944844 \times 10^{1}$	$-7.1215876379 \times 10^{1}$	$-3.6673985754 \times 10^{0}$	$-1.1334358752 \times 10^{1}$
9	$-6.7367456050 \times 10^{1}$	$0.0000000000 \times 10^{0}$	$-1.0721863634 \times 10^{1}$	$0.0000000000 \times 10^{0}$
10	$-6.7499918828 \times 10^{1}$	$0.0000000000 \times 10^{0}$	$-1.0742945740 \times 10^{1}$	$0.0000000000 \times 10^{0}$
11	$-6.0749792877 \times 10^{1}$	$0.0000000000 \times 10^{0}$	$-9.6686298282 \times 10^{0}$	$0.0000000000 \times 10^{0}$
12	$-5.8879263207 \times 10^{1}$	$0.0000000000 \times 10^{0}$	$-9.3709257850 \times 10^{0}$	$0.0000000000 \times 10^{0}$
13	$-4.9325080292 \times 10^{1}$	$0.0000000000 \times 10^{0}$	$-7.8503303469 \times 10^{0}$	$0.0000000000 \times 10^{0}$
14	$-5.0487891009 \times 10^{1}$	$0.0000000000 \times 10^{0}$	$-8.0353974204 \times 10^{0}$	$0.0000000000 \times 10^{0}$
15	$-4.5148544470 \times 10^{1}$	$0.0000000000 \times 10^{0}$	$-7.1856140258 \times 10^{0}$	$0.0000000000 \times 10^{0}$
16	$-4.5137904498 \times 10^{1}$	$0.0000000000 \times 10^{0}$	$-7.1839206216 \times 10^{0}$	$0.0000000000 \times 10^{0}$
17	$-7.9421879648 \times 10^{0}$	$0.0000000000 \times 10^{0}$	$-1.2640384736 \times 10^{0}$	$0.0000000000 \times 10^{0}$
18	$-5.1152563711 \times 10^{0}$	$0.0000000000 \times 10^{0}$	$-8.1411833664 \times 10^{-1}$	$0.0000000000 \times 10^{0}$
19	$-2.4505439258 \times 10^{0}$	$5.5691811908 \times 10^{0}$	$-3.9001617906 \times 10^{-1}$	$8.8636271549 \times 10^{-1}$
20	$-2.4505439258 \times 10^{0}$	$-5.5691811908 \times 10^{0}$	$-3.9001617906 \times 10^{-1}$	$-8.8636271549 \times 10^{-1}$
21	$-1.4249822445 \times 10^{0}$	$5.3175149963 \times 10^{0}$	$-2.2679296803 \times 10^{-1}$	$8.4630879663 \times 10^{-1}$
22	$-1.4249822445 \times 10^{0}$	$-5.3175149963 \times 10^{0}$	$-2.2679296803 \times 10^{-1}$	$-8.4630879663 \times 10^{-1}$
23	$-1.7474333976 \times 10^{0}$	$5.9324407384 \times 10^{0}$	$-2.7811266295 \times 10^{-1}$	$9.4417726811 \times 10^{-1}$
24	$-1.7474333976 \times 10^{0}$	$-5.9324407384 \times 10^{0}$	$-2.7811266295 \times 10^{-1}$	$-9.4417726811 \times 10^{-1}$
25	$-1.6344445159 \times 10^{-5}$	$0.0000000000 \times 10^{0}$	$-2.6012992392 \times 10^{-6}$	$0.0000000000 \times 10^{0}$
26	$1.6344453575 \times 10^{-5}$	$0.0000000000 \times 10^{0}$	$2.6013005787 \times 10^{-6}$	$0.0000000000 \times 10^{0}$

27	$8.0555269999 \times 10^{-12}$	$0.0000000000 \times 10^{0}$	$1.2820769413 \times 10^{-12}$	$0.0000000000 \times 10^{0}$
28	$7.4419793112 \times 10^{-12}$	$0.0000000000 \times 10^{0}$	$1.1844277938 \times 10^{-12}$	$0.0000000000 \times 10^{0}$
29	$1.3962862844 \times 10^{-11}$	$0.0000000000 \times 10^{0}$	$2.2222586413 \times 10^{-12}$	$0.0000000000 \times 10^{0}$
30	$1.1062557531 \times 10^{-11}$	$0.0000000000 \times 10^{0}$	$1.7606607142 \times 10^{-12}$	$0.0000000000 \times 10^{0}$
31	$-6.6716242596 \times 10^{-12}$	$0.0000000000 \times 10^{0}$	$-1.0618219794 \times 10^{-12}$	$0.0000000000 \times 10^{0}$
32	$-5.3916400269 \times 10^{-12}$	$0.0000000000 \times 10^{0}$	$-8.5810616165 \times 10^{-13}$	$0.0000000000 \times 10^{0}$

Note: oscillatory roots appear as complex conjugates.

Table 2.2: Eigenvalue Analysis

No.	Frequency (ω_n) [Hz]	Damping Ratio (ζ)	Time Constant (τ) [s]	Wavelength (λ) [s]
1	$1.1833569525 \times 10^{1}$	$2.6827573605 \times 10^{-1}$	$5.0132916414 \times 10^{-2}$	$8.7721018025 \times 10^{-2}$
2	$1.1833569525 \times 10^{1}$	$2.6827573605 \times 10^{-1}$	$5.0132916414 \times 10^{-2}$	$8.7721018025 \times 10^{-2}$
3	$1.1607492210 \times 10^{1}$	$2.6898339089 \times 10^{-1}$	$5.0974886403 \times 10^{-2}$	$8.9447870961 \times 10^{-2}$
4	$1.1607492210 \times 10^{1}$	$2.6898339089 \times 10^{-1}$	$5.0974886403 \times 10^{-2}$	$8.9447870961 \times 10^{-2}$
5	$1.1980561512 \times 10^{1}$	$3.0832169888 \times 10^{-1}$	$4.3086266965 \times 10^{-2}$	$8.7743201956 \times 10^{-2}$
6	$1.1980561512 \times 10^{1}$	$3.0832169888 \times 10^{-1}$	$4.3086266965 \times 10^{-2}$	$8.7743201956 \times 10^{-2}$
7	$1.1912913189 \times 10^{1}$	$3.0785069255 \times 10^{-1}$	$4.3397230986 \times 10^{-2}$	$8.8227311474 \times 10^{-2}$
8	$1.1912913189 \times 10^{1}$	$3.0785069255 \times 10^{-1}$	$4.3397230986 \times 10^{-2}$	$8.8227311474 \times 10^{-2}$
9	–	–	$1.4843962629 \times 10^{-2}$	–
10	–	–	$1.4814832630 \times 10^{-2}$	–
11	–	–	$1.6460961472 \times 10^{-2}$	–
12	–	–	$1.6983908180 \times 10^{-2}$	–
13	–	–	$2.0273661879 \times 10^{-2}$	–
14	–	–	$1.9806729495 \times 10^{-2}$	–
15	–	–	$2.2149108277 \times 10^{-2}$	–
16	–	–	$2.2154329297 \times 10^{-2}$	–
17	–	–	$1.2590988836 \times 10^{-1}$	–
18	–	–	$1.9549362289 \times 10^{-1}$	–
19	$9.6837569328 \times 10^{-1}$	$4.0275296227 \times 10^{-1}$	$4.0807266887 \times 10^{-1}$	$1.1282063003 \times 10^{0}$
20	$9.6837569328 \times 10^{-1}$	$4.0275296227 \times 10^{-1}$	$4.0807266887 \times 10^{-1}$	$1.1282063003 \times 10^{0}$
21	$8.7616986344 \times 10^{-1}$	$2.5884588993 \times 10^{-1}$	$7.0176312992 \times 10^{-1}$	$1.1816018030 \times 10^{0}$
22	$8.7616986344 \times 10^{-1}$	$2.5884588993 \times 10^{-1}$	$7.0176312992 \times 10^{-1}$	$1.1816018030 \times 10^{0}$
23	$9.8428520608 \times 10^{-1}$	$2.8255292392 \times 10^{-1}$	$5.7226787663 \times 10^{-1}$	$1.0591231475 \times 10^{0}$
24	$9.8428520608 \times 10^{-1}$	$2.8255292392 \times 10^{-1}$	$5.7226787663 \times 10^{-1}$	$1.0591231475 \times 10^{0}$
25	–	–	$6.1182866120 \times 10^{4}$	–
26	–	–	$-6.1182834616 \times 10^{4}$	–
27	–	–	$-1.2413837108 \times 10^{11}$	–
28	–	–	$-1.3437285407 \times 10^{11}$	–
29	–	–	$-7.1618550664 \times 10^{10}$	–
30	–	–	$-9.0395010126 \times 10^{10}$	–
31	–	–	$1.4988853705 \times 10^{11}$	–
32	–	–	$1.8547232290 \times 10^{11}$	–

Notes: a) oscillatory roots are listed twice, b) negative time constants denote unstable roots.

There are 18 degrees of freedom. There are 7 oscillatory modes, 20 damped modes, 5 unstable modes, and 0 rigid body modes.

2.2 Frequency Response Plots

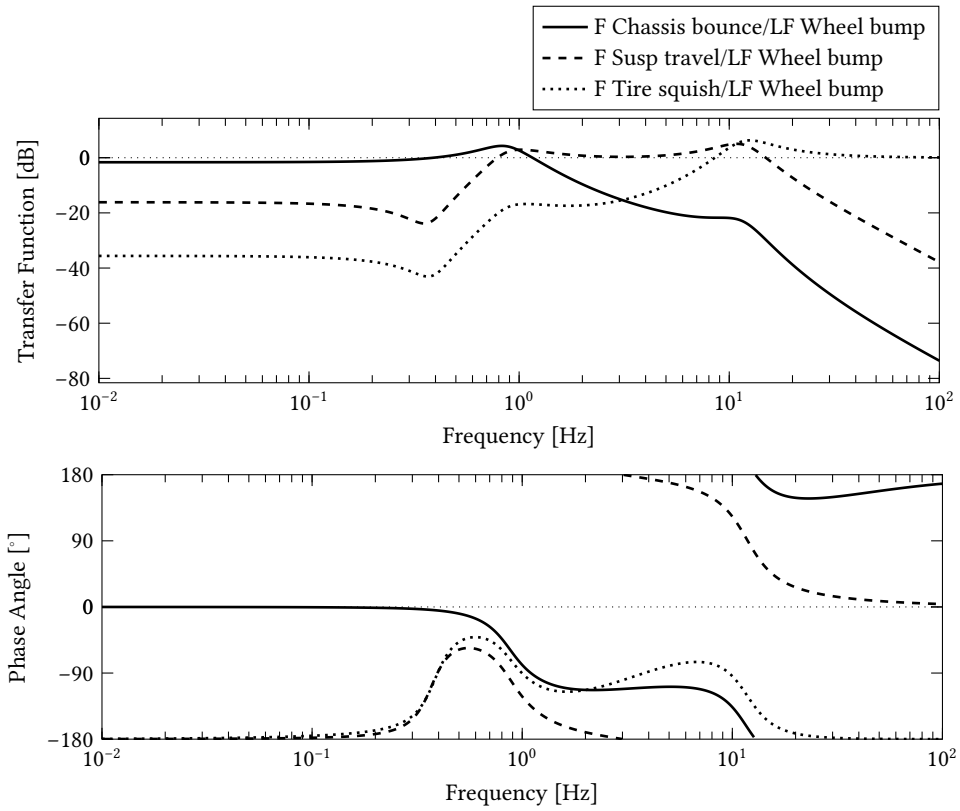

Figure 2.1: Frequency response: LF Wheel bump

2.3 Steady State Gains

The steady state gains are given in Table 2.3.

Table 2.3: Steady State Gains

No.	Output/Input	Gain
1	F Chassis bounce/LF Wheel bump	$8.2744599000 \times 10^{-1}$
2	F Susp travel/LF Wheel bump	$-1.5595645000 \times 10^{-1}$
3	F Tire squish/LF Wheel bump	$-1.6597560000 \times 10^{-2}$

2.4 Hankel Singular Value Analysis

The Hankel singular values are given in Table 2.4.

2.5 Equilibrium Analysis

The results of the equilibrium load analysis are given in Tables 2.5 and 2.6.

Table 2.5: System Static Deflections

No.	Body Name	Type	Deflection [m] or [rad]
1	Chassis	translation	3.7738×10^{-3}, 1.8000×10^{-7}, -3.0526×10^{-1}
–	–	rotation	-3.3000×10^{-7}, 2.3772×10^{-2}, 5.0000×10^{-8}
2	LF Upright	translation	1.9500×10^{-2}, -3.6517×10^{-2}, -4.3129×10^{-2}
–	–	rotation	1.7425×10^{-1}, -8.1895×10^{-2}, -9.2622×10^{-2}
3	LF Lower A-arm	translation	2.1404×10^{-2}, -1.0381×10^{-2}, -1.2617×10^{-1}
–	–	rotation	4.1522×10^{-1}, 2.3772×10^{-2}, -5.1902×10^{-2}
4	LF Upper A-arm	translation	1.3965×10^{-3}, -3.1327×10^{-2}, -1.4582×10^{-1}
–	–	rotation	6.2654×10^{-1}, 2.3772×10^{-2}, 1.9000×10^{-7}
5	LF Bell-crank	translation	-1.3918×10^{-1}, -4.7336×10^{-2}, -2.8502×10^{-1}
–	–	rotation	-3.2000×10^{-7}, -1.1596×10^{0} , -1.1834×10^{0}
6	LF Anti-roll arm	translation	-7.7496×10^{-2}, 2.1000×10^{-7}, -3.3616×10^{-1}
–	–	rotation	-3.3000×10^{-7}, -1.5541×10^{0} , 5.0000×10^{-8}
7	LF Push-rod	translation	1.4590×10^{-2}, -7.4740×10^{-2}, -1.5005×10^{-1}
–	–	rotation	4.3599×10^{-1}, -1.8146×10^{-4}, -8.7833×10^{-2}
8	LF Tie-rod	translation	8.7844×10^{-3}, -1.5017×10^{-2}, -1.8835×10^{-1}
–	–	rotation	4.8697×10^{-1}, -1.9720×10^{-1}, -5.8640×10^{-2}
9	LF Wheel+hub	translation	2.8763×10^{-2}, -3.6517×10^{-2}, -2.5705×10^{-2}
–	–	rotation	1.7425×10^{-1}, 4.1286×10^{-3}, -9.2622×10^{-2}
10	LR Upright	translation	-9.8073×10^{-4}, -3.4443×10^{-2}, -3.5386×10^{-2}
–	–	rotation	1.1583×10^{-1}, 2.3772×10^{-2}, 5.0000×10^{-8}
11	LR Lower A-arm	translation	-4.5466×10^{-3}, -1.7069×10^{-2}, -1.0366×10^{-1}
–	–	rotation	3.4138×10^{-1}, 2.3772×10^{-2}, 5.0000×10^{-8}
12	LR Upper A-arm	translation	1.3965×10^{-3}, -2.5909×10^{-2}, -1.1890×10^{-1}
–	–	rotation	5.1817×10^{-1}, 2.3772×10^{-2}, 5.0000×10^{-8}
13	LR Bell-crank	translation	1.0500×10^{-1}, -5.1208×10^{-2}, -2.2434×10^{-1}
–	–	rotation	-3.3000×10^{-7}, 1.0479×10^{0} , 1.0242×10^{0}
14	LR Push-rod	translation	-9.8072×10^{-4}, -6.8277×10^{-2}, -1.2073×10^{-1}
–	–	rotation	3.4138×10^{-1}, 2.3772×10^{-2}, 5.0000×10^{-8}
15	LR Tie-rod	translation	-5.1409×10^{-3}, -8.5346×10^{-3}, -1.5867×10^{-1}

–	–	rotation	3.2746×10^{-1}, 7.7917×10^{-2}, 3.8675×10^{-3}
16	LR Wheel+hub	translation	-9.8074×10^{-4}, -3.4443×10^{-2}, -2.3803×10^{-2}
–	–	rotation	1.1583×10^{-1}, -1.4078×10^{-4}, 5.0000×10^{-8}
17	LF Contact patch	translation	2.7524×10^{-2}, 1.5756×10^{-2}, -2.5705×10^{-2}
–	–	rotation	1.7425×10^{-1}, 4.1286×10^{-3}, -9.2622×10^{-2}
18	LR Contact patch	translation	-9.3850×10^{-4}, 3.0476×10^{-4}, -2.3803×10^{-2}
–	–	rotation	1.1583×10^{-1}, -1.4078×10^{-4}, 5.0000×10^{-8}
19	RF Upright	translation	1.9501×10^{-2}, 3.6518×10^{-2}, -4.3129×10^{-2}
–	–	rotation	-1.7425×10^{-1}, -8.1898×10^{-2}, 9.2619×10^{-2}
20	RF Lower A-arm	translation	2.1405×10^{-2}, 1.0381×10^{-2}, -1.2617×10^{-1}
–	–	rotation	-4.1522×10^{-1}, 2.3772×10^{-2}, 5.1903×10^{-2}
21	RF Upper A-arm	translation	1.3966×10^{-3}, 3.1327×10^{-2}, -1.4582×10^{-1}
–	–	rotation	-6.2654×10^{-1}, 2.3772×10^{-2}, 5.0000×10^{-8}
22	RF Bell-crank	translation	-1.3918×10^{-1}, 4.7336×10^{-2}, -2.8502×10^{-1}
–	–	rotation	-3.3000×10^{-7}, -1.1596×10^{0}, 1.1834×10^{0}
23	RF Anti-roll arm	translation	-7.7496×10^{-2}, 2.1000×10^{-7}, -3.3616×10^{-1}
–	–	rotation	-3.3000×10^{-7}, -1.5541×10^{0}, 5.0000×10^{-8}
24	RF Push-rod	translation	1.4590×10^{-2}, 7.4740×10^{-2}, -1.5005×10^{-1}
–	–	rotation	-4.3599×10^{-1}, -1.8281×10^{-4}, 8.7836×10^{-2}
25	RF Tie-rod	translation	8.7847×10^{-3}, 1.5017×10^{-2}, -1.8835×10^{-1}
–	–	rotation	-4.8697×10^{-1}, -1.9720×10^{-1}, 5.8641×10^{-2}
26	RF Wheel+hub	translation	2.8763×10^{-2}, 3.6518×10^{-2}, -2.5705×10^{-2}
–	–	rotation	-1.7425×10^{-1}, 4.1286×10^{-3}, 9.2619×10^{-2}
27	RR Upright	translation	-9.8065×10^{-4}, 3.4443×10^{-2}, -3.5386×10^{-2}
–	–	rotation	-1.1583×10^{-1}, 2.3772×10^{-2}, 5.0000×10^{-8}
28	RR Lower A-arm	translation	-4.5465×10^{-3}, 1.7069×10^{-2}, -1.0366×10^{-1}
–	–	rotation	-3.4138×10^{-1}, 2.3772×10^{-2}, 5.0000×10^{-8}
29	RR Upper A-arm	translation	1.3966×10^{-3}, 2.5909×10^{-2}, -1.1890×10^{-1}
–	–	rotation	-5.1817×10^{-1}, 2.3772×10^{-2}, 5.0000×10^{-8}
30	RR Bell-crank	translation	1.0500×10^{-1}, 5.1208×10^{-2}, -2.2434×10^{-1}
–	–	rotation	-3.3000×10^{-7}, 1.0479×10^{0}, -1.0242×10^{0}
31	RR Push-rod	translation	-9.8066×10^{-4}, 6.8277×10^{-2}, -1.2073×10^{-1}
–	–	rotation	-3.4138×10^{-1}, 2.3772×10^{-2}, 5.0000×10^{-8}
32	RR Tie-rod	translation	-5.1408×10^{-3}, 8.5346×10^{-3}, -1.5867×10^{-1}
–	–	rotation	-3.2746×10^{-1}, 7.7917×10^{-2}, -3.8674×10^{-3}
33	RR Wheel+hub	translation	-9.8064×10^{-4}, 3.4443×10^{-2}, -2.3803×10^{-2}
–	–	rotation	-1.1583×10^{-1}, -1.4076×10^{-4}, 5.0000×10^{-8}
34	RF Contact patch	translation	2.7524×10^{-2}, -1.5756×10^{-2}, -2.5705×10^{-2}
–	–	rotation	-1.7425×10^{-1}, 4.1286×10^{-3}, 9.2619×10^{-2}
35	RR Contact patch	translation	-9.3842×10^{-4}, -3.0486×10^{-4}, -2.3803×10^{-2}
–	–	rotation	-1.1583×10^{-1}, -1.4076×10^{-4}, 5.0000×10^{-8}

Table 2.6: System Preloads

No.	Connector Name	Type	Load [N] or [Nm] (Components; Magnitude)
1	LF Wheel bearing	force	0.0000×10^{0}, 0.0000×10^{0}, -3.7576×10^{3}; 3.7576×10^{3}
2	LF Lower ball joint	force	-1.2600×10^{0}, -1.2134×10^{3}, -3.9405×10^{3}; 4.1231×10^{3}
3	LF Lower A-arm pivot, rear	force	-1.2600×10^{0}, -3.4517×10^{3}, -4.8075×10^{1}; 3.4520×10^{3}
4	LF Lower A-arm pivot, front	force	0.0000×10^{0}, -3.4473×10^{3}, -4.8075×10^{1}; 3.4476×10^{3}
5	LF Bell-crank pivot	force	-4.7335×10^{3}, 5.6856×10^{3}, -3.7757×10^{3}; 8.3059×10^{3}
–	–	moment	-5.8860×10^{-1}, -9.5201×10^{1}, 9.5201×10^{1}; 1.3464×10^{2}
6	LF Upper A-arm pivot, front	force	0.0000×10^{0}, 6.0522×10^{2}, 1.4267×10^{2}; 6.2181×10^{2}
7	LF Upper A-arm pivot, rear	force	1.0023×10^{0}, 6.0748×10^{2}, 1.4317×10^{2}; 6.2412×10^{2}
8	LF Upper ball joint	force	-1.0023×10^{0}, -1.2127×10^{3}, -2.3679×10^{2}; 1.2356×10^{3}
9	LF Lower push-rod end	force	0.0000×10^{0}, 5.6856×10^{3}, -3.7953×10^{3}; 6.8359×10^{3}

10	LF Upper push-rod end	force	0.0000×10^{0} , -5.6856×10^{3} , 3.7855×10^{3}; 6.8305×10^{3}
11	LF Inner tie-rod end	force	-2.5773×10^{-1}, -7.1591×10^{-1}, -4.9623×10^{0}; 5.0203×10^{0}
12	LF Outer tie-rod end	force	2.5773×10^{-1}, 7.1591×10^{-1}, -4.8477×10^{0}; 4.9071×10^{0}
13	LF Anti-roll mount	force	-1.4500×10^{-3}, 0.0000×10^{0} , 9.8100×10^{0}; 9.8100×10^{0}
14	LR Wheel bearing	force	0.0000×10^{0} , 0.0000×10^{0} , -3.4724×10^{3}; 3.4724×10^{3}
15	LR Lower ball joint	force	1.3388×10^{0} , -1.1222×10^{3} , -3.6350×10^{3}; 3.8043×10^{3}
16	LR Lower A-arm pivot, front	force	1.3388×10^{0} , -3.0244×10^{3} , -1.5007×10^{2}; 3.0281×10^{3}
17	LR Lower A-arm pivot, rear	force	0.0000×10^{0} , -3.0197×10^{3} , -1.4974×10^{2}; 3.0234×10^{3}
18	LR Bell-crank pivot	force	4.0966×10^{3} , 4.9218×10^{3} , -3.2665×10^{3}; 7.1887×10^{3}
–	–	moment	-4.9050×10^{-1}, 8.2521×10^{1} , -8.2521×10^{1}; 1.1670×10^{2}
19	LR Upper A-arm pivot, rear	force	0.0000×10^{0} , 5.5942×10^{2} , 1.3249×10^{2}; 5.7489×10^{2}
20	LR Upper A-arm pivot, front	force	-1.1310×10^{0} , 5.6196×10^{2} , 1.3306×10^{2}; 5.7750×10^{2}
21	LR Upper ball joint	force	1.1310×10^{0} , -1.1214×10^{3} , -2.1650×10^{2}; 1.1421×10^{3}
22	LR Lower push-rod end	force	0.0000×10^{0} , 4.9218×10^{3} , -3.2861×10^{3}; 5.9180×10^{3}
23	LR Upper push-rod end	force	0.0000×10^{0} , -4.9218×10^{3} , 3.2763×10^{3}; 5.9126×10^{3}
24	LR Inner tie-rod end	force	2.0774×10^{-1}, -8.0788×10^{-1}, -4.9627×10^{0}; 5.0323×10^{0}
25	LR Outer tie-rod end	force	-2.0774×10^{-1}, 8.0788×10^{-1}, -4.8473×10^{0}; 4.9185×10^{0}
26	LF Contact patch constraint	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
27	LR Contact patch constraint	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
28	RF Wheel bearing	force	0.0000×10^{0} , 0.0000×10^{0} , -3.7576×10^{3}; 3.7576×10^{3}
29	RF Lower ball joint	force	-1.2600×10^{0} , 1.2134×10^{3} , -3.9405×10^{3}; 4.1231×10^{3}
30	RF Lower A-arm pivot, rear	force	-1.2600×10^{0} , 3.4517×10^{3} , -4.8075×10^{1}; 3.4520×10^{3}
31	RF Lower A-arm pivot, front	force	0.0000×10^{0} , 3.4473×10^{3} , -4.8075×10^{1}; 3.4476×10^{3}
32	RF Bell-crank pivot	force	-4.7336×10^{3} , -5.6856×10^{3} , -3.7757×10^{3}; 8.3059×10^{3}
–	–	moment	5.8860×10^{-1}, -9.5201×10^{1} , -9.5201×10^{1}; 1.3464×10^{2}
33	RF Upper A-arm pivot, front	force	0.0000×10^{0} , -6.0523×10^{2} , 1.4267×10^{2}; 6.2181×10^{2}
34	RF Upper A-arm pivot, rear	force	1.0023×10^{0} , -6.0748×10^{2} , 1.4317×10^{2}; 6.2412×10^{2}
35	RF Upper ball joint	force	-1.0023×10^{0} , 1.2127×10^{3} , -2.3679×10^{2}; 1.2356×10^{3}
36	RF Lower push-rod end	force	0.0000×10^{0} , -5.6856×10^{3} , -3.7953×10^{3}; 6.8359×10^{3}
37	RF Upper push-rod end	force	0.0000×10^{0} , 5.6856×10^{3} , 3.7855×10^{3}; 6.8305×10^{3}
38	RF Inner tie-rod end	force	-2.5773×10^{-1}, 7.1591×10^{-1}, -4.9623×10^{0}; 5.0203×10^{0}
39	RF Outer tie-rod end	force	2.5773×10^{-1}, -7.1591×10^{-1}, -4.8477×10^{0}; 4.9071×10^{0}
40	RF Anti-roll mount	force	1.4500×10^{-3}, 0.0000×10^{0} , 9.8100×10^{0}; 9.8100×10^{0}
41	RR Wheel bearing	force	0.0000×10^{0} , 0.0000×10^{0} , -3.4724×10^{3}; 3.4724×10^{3}
42	RR Lower ball joint	force	1.3388×10^{0} , 1.1222×10^{3} , -3.6350×10^{3}; 3.8043×10^{3}
43	RR Lower A-arm pivot, front	force	1.3388×10^{0} , 3.0243×10^{3} , -1.5007×10^{2}; 3.0281×10^{3}
44	RR Lower A-arm pivot, rear	force	0.0000×10^{0} , 3.0197×10^{3} , -1.4974×10^{2}; 3.0234×10^{3}
45	RR Bell-crank pivot	force	4.0966×10^{3} , -4.9218×10^{3} , -3.2665×10^{3}; 7.1886×10^{3}
–	–	moment	4.9050×10^{-1}, 8.2521×10^{1} , 8.2521×10^{1}; 1.1670×10^{2}
46	RR Upper A-arm pivot, rear	force	0.0000×10^{0} , -5.5942×10^{2} , 1.3249×10^{2}; 5.7489×10^{2}
47	RR Upper A-arm pivot, front	force	-1.1310×10^{0} , -5.6196×10^{2} , 1.3306×10^{2}; 5.7750×10^{2}
48	RR Upper ball joint	force	1.1310×10^{0} , 1.1214×10^{3} , -2.1650×10^{2}; 1.1421×10^{3}
49	RR Lower push-rod end	force	0.0000×10^{0} , -4.9218×10^{3} , -3.2861×10^{3}; 5.9180×10^{3}
50	RR Upper push-rod end	force	0.0000×10^{0} , 4.9218×10^{3} , 3.2763×10^{3}; 5.9126×10^{3}
51	RR Inner tie-rod end	force	2.0774×10^{-1}, 8.0788×10^{-1}, -4.9627×10^{0}; 5.0323×10^{0}
52	RR Outer tie-rod end	force	-2.0774×10^{-1}, -8.0788×10^{-1}, -4.8473×10^{0}; 4.9185×10^{0}
53	RF Contact patch constraint	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
54	RR Contact patch constraint	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
55	LF Tire, vertical	force	0.0000×10^{0} , 0.0000×10^{0} , 3.8557×10^{3}; 3.8557×10^{3}
56	LR Tire, vertical	force	0.0000×10^{0} , 0.0000×10^{0} , 3.5705×10^{3}; 3.5705×10^{3}
57	LF Tire, sidewall	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
58	LR Tire, sidewall	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
59	LF Tire, horizontal	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
60	LR Tire, horizontal	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
61	RF Tire, vertical	force	0.0000×10^{0} , 0.0000×10^{0} , 3.8557×10^{3}; 3.8557×10^{3}
62	RR Tire, vertical	force	0.0000×10^{0} , 0.0000×10^{0} , 3.5705×10^{3}; 3.5705×10^{3}
63	RF Tire, sidewall	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
64	RR Tire, sidewall	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}
65	RF Tire, horizontal	force	0.0000×10^{0} , 0.0000×10^{0} , 0.0000×10^{0}; 0.0000×10^{0}

66	RR Tire, horizontal	force	0.0000×10^{0} ,	0.0000×10^{0} ,	0.0000×10^{0};	0.0000×10^{0}
67	LF Suspension spring	force	4.7335×10^{3} ,	0.0000×10^{0} ,	0.0000×10^{0};	-4.7335×10^{3}
68	LR Suspension spring	force	-4.0966×10^{3} ,	0.0000×10^{0} ,	0.0000×10^{0};	-4.0966×10^{3}
69	Anti-roll bar	moment	0.0000×10^{0} ,	-2.2000×10^{-4},	0.0000×10^{0};	2.2000×10^{-4}
70	RF Suspension spring	force	4.7336×10^{3} ,	0.0000×10^{0} ,	0.0000×10^{0};	-4.7336×10^{3}
71	RR Suspension spring	force	-4.0966×10^{3} ,	0.0000×10^{0} ,	0.0000×10^{0};	-4.0966×10^{3}
72	LF Drop link	force	-1.4500×10^{-3},	0.0000×10^{0} ,	0.0000×10^{0};	-1.4500×10^{-3}
73	RF Drop link	force	1.4500×10^{-3},	0.0000×10^{0} ,	0.0000×10^{0};	1.4500×10^{-3}

Table 2.4: Hankel Singular Values

No.	Hankel SV
1	–
2	–
3	–
4	–
5	–
6	–
7	–
8	$1.6231316526 \times 10^{0}$
9	$1.2766885266 \times 10^{0}$
10	$8.9371716224 \times 10^{-1}$
11	$6.6864089737 \times 10^{-1}$
12	$1.3358992908 \times 10^{-2}$
13	$1.1692815448 \times 10^{-2}$
14	$1.9990616744 \times 10^{-3}$
15	$8.9283414651 \times 10^{-4}$
16	$3.8502854661 \times 10^{-4}$
17	$1.0475570377 \times 10^{-4}$
18	$1.3974419989 \times 10^{-5}$
19	$1.1026225267 \times 10^{-5}$
20	$5.0043380851 \times 10^{-6}$
21	$4.8880102047 \times 10^{-6}$
22	$2.6345082597 \times 10^{-6}$
23	$8.2549717760 \times 10^{-7}$
24	$1.9817843531 \times 10^{-8}$
25	$2.7837696082 \times 10^{-10}$
26	$9.3626576300 \times 10^{-13}$
27	$5.2393041340 \times 10^{-13}$
28	$3.0985981295 \times 10^{-13}$
29	$4.3810899733 \times 10^{-14}$
30	$3.2552864585 \times 10^{-15}$
31	$5.5675127928 \times 10^{-19}$
32	$6.9713344509 \times 10^{-25}$
33	$0.0000000000 \times 10^{0}$
34	$0.0000000000 \times 10^{0}$
35	$0.0000000000 \times 10^{0}$
36	$0.0000000000 \times 10^{0}$
37	$0.0000000000 \times 10^{0}$

Chapter 3

Conclusion

Replace this text with the conclusion to your report.

Appendix A

Equations of Motion

The equations of motion are of the form

$$\begin{bmatrix} \mathbf{I} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{M} & -\mathbf{G} \\ \mathbf{0} & \mathbf{0} & \mathbf{0} \end{bmatrix} \begin{Bmatrix} \dot{\boldsymbol{p}} \\ \dot{\boldsymbol{w}} \\ \dot{\boldsymbol{u}} \end{Bmatrix} + \begin{bmatrix} \mathbf{V} & -\mathbf{I} & \mathbf{0} \\ \mathbf{K} & \mathbf{L} & -\mathbf{F} \\ \mathbf{0} & \mathbf{0} & \mathbf{I} \end{bmatrix} \begin{Bmatrix} \boldsymbol{p} \\ \boldsymbol{w} \\ \boldsymbol{u} \end{Bmatrix} = \begin{bmatrix} \mathbf{0} \\ \mathbf{0} \\ \mathbf{I} \end{bmatrix} \{ \boldsymbol{u} \}$$

The system is subject to constraints

$$\begin{bmatrix} \mathbf{J}_\mathrm{h} & \mathbf{0} & \mathbf{0} \\ -\mathbf{J}_\mathrm{h}\mathbf{V} & \mathbf{J}_\mathrm{h} & \mathbf{0} \\ \mathbf{0} & \mathbf{J}_\mathrm{nh} & \mathbf{0} \end{bmatrix} \begin{bmatrix} \dot{\boldsymbol{p}} & \boldsymbol{p} \\ \dot{\boldsymbol{w}} & \boldsymbol{w} \\ \dot{\boldsymbol{u}} & \boldsymbol{u} \end{bmatrix} = \begin{bmatrix} \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} \end{bmatrix}$$

The full state space equations:

$$\begin{bmatrix} \mathbf{E} & \mathbf{0} \\ \mathbf{0} & \mathbf{I} \end{bmatrix} \begin{Bmatrix} \dot{\boldsymbol{x}} \\ \boldsymbol{y} \end{Bmatrix} = \begin{bmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{C} & \mathbf{D} \end{bmatrix} \begin{Bmatrix} \boldsymbol{x} \\ \boldsymbol{u} \end{Bmatrix}$$

$$\begin{bmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{C} & \mathbf{D} \end{bmatrix} = \left[\begin{array}{cccccccc}
-5.53013967 \times 10^{3} & -4.07750499 \times 10^{3} & -3.72017913 \times 10^{3} & 6.66326815 \times 10^{3} & 2.63160974 \times 10^{3} & -8.10715489 \times 10^{2} & -3.02002858 \times 10^{3} & - \\
2.57518804 \times 10^{3} & 4.23923436 \times 10^{3} & 7.96022610 \times 10^{3} & -1.70055868 \times 10^{3} & -6.03946561 \times 10^{2} & 4.68164817 \times 10^{2} & 1.02605854 \times 10^{4} & \\
4.59861428 \times 10^{3} & 2.01372315 \times 10^{3} & 9.68744518 \times 10^{2} & -3.30421364 \times 10^{3} & -2.30259507 \times 10^{3} & 8.77365229 \times 10^{2} & -4.77978466 \times 10^{3} & \\
2.02816041 \times 10^{3} & 2.03032734 \times 10^{3} & 5.96744268 \times 10^{3} & 1.10647044 \times 10^{2} & -5.25185456 \times 10^{2} & -8.86183731 \times 10^{2} & 8.08874251 \times 10^{3} & - \\
-2.36641506 \times 10^{3} & -1.15052403 \times 10^{3} & 1.72708565 \times 10^{3} & 3.06343127 \times 10^{3} & 1.03628594 \times 10^{3} & -3.66303915 \times 10^{2} & 7.27078622 \times 10^{2} & - \\
-1.90857828 \times 10^{3} & -1.12419993 \times 10^{3} & 7.64028047 \times 10^{2} & 1.51248557 \times 10^{2} & 2.63351189 \times 10^{2} & -4.19077211 \times 10^{2} & 2.18081325 \times 10^{3} & - \\
6.54266329 \times 10^{2} & 3.36722137 \times 10^{2} & 1.18805790 \times 10^{3} & 5.41075228 \times 10^{3} & 1.16862084 \times 10^{3} & 9.81705740 \times 10^{1} & 1.50665155 \times 10^{3} & - \\
-4.78691914 \times 10^{3} & -3.00188331 \times 10^{3} & -5.02018598 \times 10^{3} & 1.10547362 \times 10^{2} & 2.00004968 \times 10^{3} & 2.35500607 \times 10^{3} & -5.51539485 \times 10^{3} & - \\
-2.38565835 \times 10^{3} & -6.90769428 \times 10^{2} & -2.07334791 \times 10^{3} & -6.79850025 \times 10^{3} & -8.54014731 \times 10^{2} & 1.33803500 \times 10^{3} & -3.72069966 \times 10^{3} & \\
4.81051958 \times 10^{3} & 9.57169873 \times 10^{3} & 1.20297421 \times 10^{4} & -5.20220496 \times 10^{3} & -3.12641209 \times 10^{3} & -4.90378977 \times 10^{1} & 1.41172023 \times 10^{4} & \\
-4.01874437 \times 10^{3} & -3.21759095 \times 10^{3} & 2.36037662 \times 10^{3} & 2.73492365 \times 10^{3} & 1.93484854 \times 10^{3} & -7.11810517 \times 10^{2} & 4.81073197 \times 10^{3} & - \\
1.97089136 \times 10^{3} & 2.93769191 \times 10^{3} & 1.37724708 \times 10^{4} & -2.68406771 \times 10^{3} & -1.12119985 \times 10^{3} & -2.88493160 \times 10^{3} & 2.02937216 \times 10^{4} & \\
1.13828824 \times 10^{3} & -6.65278193 \times 10^{2} & -1.76407967 \times 10^{3} & -4.93051790 \times 10^{3} & -1.18512770 \times 10^{3} & -4.78426321 \times 10^{2} & -2.48875075 \times 10^{3} & \\
-4.29631498 \times 10^{3} & 2.26586884 \times 10^{3} & 9.68430329 \times 10^{3} & 1.95743073 \times 10^{3} & 6.82228554 \times 10^{2} & -2.67644850 \times 10^{3} & 1.59064881 \times 10^{4} & - \\
-7.58404357 \times 10^{2} & -2.92278449 \times 10^{3} & -1.07861427 \times 10^{4} & 3.39805963 \times 10^{3} & 8.07502106 \times 10^{2} & 1.24624571 \times 10^{3} & -1.67888540 \times 10^{4} & - \\
-1.83614320 \times 10^{3} & -1.47773847 \times 10^{3} & 7.35802722 \times 10^{1} & 4.11345731 \times 10^{3} & 1.21722958 \times 10^{3} & 1.80966240 \times 10^{0} & -6.18945190 \times 10^{2} & - \\
-1.14978226 \times 10^{3} & 4.12215211 \times 10^{2} & 6.37728220 \times 10^{3} & -2.51031696 \times 10^{3} & -7.27675348 \times 10^{2} & -2.63566742 \times 10^{3} & 1.03955436 \times 10^{4} & \\
2.90992981 \times 10^{3} & 2.66423362 \times 10^{3} & 3.54840927 \times 10^{3} & 7.68068904 \times 10^{2} & -6.30377037 \times 10^{2} & -1.30462629 \times 10^{2} & 3.51821469 \times 10^{3} & - \\
2.09104455 \times 10^{3} & -1.74808106 \times 10^{3} & -3.52705660 \times 10^{3} & -8.07531293 \times 10^{2} & -1.12283732 \times 10^{2} & 1.21488368 \times 10^{3} & -5.95478702 \times 10^{3} & - \\
-3.45372051 \times 10^{3} & -4.55455000 \times 10^{2} & 3.16681824 \times 10^{3} & 8.14904911 \times 10^{2} & 1.48382393 \times 10^{3} & -3.52931287 \times 10^{2} & 7.28517737 \times 10^{3} & - \\
7.35425110 \times 10^{3} & 8.58538647 \times 10^{3} & 1.66718200 \times 10^{4} & -9.51815431 \times 10^{3} & -5.22502374 \times 10^{3} & -2.44297762 \times 10^{3} & 1.88063470 \times 10^{4} & \\
-1.64782272 \times 10^{3} & 3.38487932 \times 10^{3} & 9.22243070 \times 10^{3} & -6.80211597 \times 10^{2} & -2.73536683 \times 10^{2} & -1.90273158 \times 10^{3} & 1.50963316 \times 10^{4} & \\
1.51122741 \times 10^{3} & 3.79715098 \times 10^{2} & 4.64299080 \times 10^{3} & 4.81391360 \times 10^{3} & 6.90858042 \times 10^{2} & -1.29574750 \times 10^{3} & 6.56045688 \times 10^{3} & - \\
-4.09137313 \times 10^{3} & -3.04586124 \times 10^{3} & 1.33507976 \times 10^{3} & 5.23048745 \times 10^{3} & 2.87700110 \times 10^{3} & -6.97243444 \times 10^{2} & 4.91421557 \times 10^{3} & - \\
7.41648904 \times 10^{2} & 5.19205707 \times 10^{3} & 9.39965086 \times 10^{3} & -1.05087245 \times 10^{3} & -1.02411716 \times 10^{3} & -5.76284117 \times 10^{2} & 1.24175062 \times 10^{4} & \\
6.56204971 \times 10^{4} & 4.76391218 \times 10^{4} & 5.35116470 \times 10^{3} & -4.09121967 \times 10^{2} & -2.10679124 \times 10^{4} & 1.03811867 \times 10^{4} & -3.56891006 \times 10^{4} & \\
1.22069143 \times 10^{3} & -2.93723142 \times 10^{2} & -2.59662391 \times 10^{3} & 9.90026366 \times 10^{3} & 1.37310013 \times 10^{3} & -4.10140859 \times 10^{2} & -4.32754534 \times 10^{3} & - \\
-7.02288075 \times 10^{2} & -9.23872053 \times 10^{2} & -5.73068668 \times 10^{3} & 7.71910003 \times 10^{3} & 7.44238562 \times 10^{2} & -1.55945646 \times 10^{3} & -7.35900889 \times 10^{3} & - \\
3.09018773 \times 10^{3} & 3.00184244 \times 10^{3} & 7.09120220 \times 10^{3} & 3.29507784 \times 10^{3} & -5.11161320 \times 10^{2} & -1.40380231 \times 10^{3} & 8.58928644 \times 10^{3} & - \\
-1.90675321 \times 10^{3} & -2.47231413 \times 10^{3} & -5.07140216 \times 10^{2} & 5.83120375 \times 10^{3} & 1.33901291 \times 10^{3} & -8.70697282 \times 10^{2} & -2.06296778 \times 10^{3} & - \\
3.60318827 \times 10^{3} & -3.13044323 \times 10^{2} & 4.87212835 \times 10^{3} & 4.51072159 \times 10^{1} & 4.38772884 \times 10^{2} & 5.23116119 \times 10^{1} & 6.64483494 \times 10^{3} & - \\
1.40407953 \times 10^{4} & -2.57672377 \times 10^{4} & -7.19882689 \times 10^{3} & -2.89544008 \times 10^{3} & -5.36953256 \times 10^{2} & -1.05897769 \times 10^{4} & -3.80235896 \times 10^{3} & - \\
3.94548738 \times 10^{2} & 1.29200136 \times 10^{3} & 3.65821722 \times 10^{3} & -5.89716877 \times 10^{3} & -2.26176526 \times 10^{3} & -2.05948753 \times 10^{3} & 4.77848419 \times 10^{3} & \\
2.94186907 \times 10^{3} & 2.79373226 \times 10^{3} & -1.52210510 \times 10^{3} & -3.06147700 \times 10^{3} & -1.82465789 \times 10^{3} & 3.27297308 \times 10^{1} & -1.94916118 \times 10^{3} & \\
-4.21543562 \times 10^{2} & -5.08236866 \times 10^{2} & -3.17688771 \times 10^{3} & -4.80903025 \times 10^{3} & -5.63734349 \times 10^{2} & 1.32331225 \times 10^{3} & -4.53829539 \times 10^{3} & \\
-1.02158679 \times 10^{3} & -7.13434189 \times 10^{2} & -3.40863399 \times 10^{3} & -9.00285487 \times 10^{3} & -1.37413359 \times 10^{3} & 7.92116706 \times 10^{2} & -3.15747665 \times 10^{3} & \\
0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & \\
\hline
-9.81036670 \times 10^{-3} & -4.58963541 \times 10^{-2} & 4.55286254 \times 10^{-2} & -4.24253755 \times 10^{-2} & 3.85369328 \times 10^{-2} & 4.90916905 \times 10^{-2} & 3.64980491 \times 10^{-2} & \\
2.24531240 \times 10^{-2} & 2.19022161 \times 10^{-2} & -1.34133686 \times 10^{-2} & -2.18080321 \times 10^{-2} & 2.25237518 \times 10^{-2} & 3.36016391 \times 10^{-3} & 2.73398320 \times 10^{-3} & - \\
-3.22634907 \times 10^{-2} & -6.77985702 \times 10^{-2} & 5.89419940 \times 10^{-2} & -2.06173434 \times 10^{-2} & 1.60131810 \times 10^{-2} & 4.57315266 \times 10^{-2} & 3.37640659 \times 10^{-2} &
\end{array}\right]$$

$$\mathbf{E} = \left[\begin{array}{cccccccc}
-1.19976821 \times 10^{1} & 1.75014539 \times 10^{1} & -1.40295221 \times 10^{1} & 3.40626380 \times 10^{-1} & -1.07129199 \times 10^{1} & -1.07050792 \times 10^{1} & 1.79718425 \times 10^{1} & 8.909246 \\
5.19332478 \times 10^{0} & -2.49249397 \times 10^{1} & 1.28739074 \times 10^{1} & 8.35170447 \times 10^{0} & 3.84796720 \times 10^{0} & 5.09760197 \times 10^{0} & -2.21983588 \times 10^{1} & 4.350113 \\
-5.70350071 \times 10^{0} & 2.37678759 \times 10^{1} & -8.86960304 \times 10^{0} & -7.32196346 \times 10^{0} & 2.84708622 \times 10^{0} & 3.64980030 \times 10^{0} & 1.29907435 \times 10^{1} & -7.305111 \\
5.89904016 \times 10^{0} & -6.62715235 \times 10^{0} & 8.90021370 \times 10^{0} & -3.74095793 \times 10^{0} & 8.83925977 \times 10^{0} & 8.50898504 \times 10^{0} & -5.05654422 \times 10^{0} & -7.870575 \\
-3.30843648 \times 10^{0} & 1.70094297 \times 10^{0} & 2.24825603 \times 10^{-1} & 8.81826095 \times 10^{-1} & -1.49112782 \times 10^{-1} & -9.25425784 \times 10^{-1} & 7.06469893 \times 10^{-1} & 2.299107 \\
-1.09057292 \times 10^{1} & 6.28234307 \times 10^{0} & -7.72066608 \times 10^{0} & 4.99586200 \times 10^{0} & -8.42997411 \times 10^{0} & -5.89787076 \times 10^{0} & 4.67746767 \times 10^{0} & 1.010944 \\
5.95727582 \times 10^{0} & -9.68761070 \times 10^{0} & 5.73436617 \times 10^{0} & -1.81846552 \times 10^{0} & 5.81566196 \times 10^{0} & 7.40619779 \times 10^{0} & -3.57916534 \times 10^{0} & -3.641935 \\
-4.78596397 \times 10^{0} & -2.90992069 \times 10^{1} & 8.68759017 \times 10^{0} & 1.62880412 \times 10^{1} & -4.65302990 \times 10^{0} & -2.23109950 \times 10^{0} & -2.02954005 \times 10^{1} & 1.980710 \\
-1.10500295 \times 10^{1} & -1.97267527 \times 10^{0} & -5.40946493 \times 10^{0} & 9.13846940 \times 10^{0} & -9.18479838 \times 10^{0} & -7.42055691 \times 10^{0} & -1.03415695 \times 10^{0} & 1.539555 \\
-7.16351227 \times 10^{0} & -5.15198701 \times 10^{0} & -5.92374881 \times 10^{-1} & 6.56094824 \times 10^{0} & -1.86445445 \times 10^{0} & -1.55846913 \times 10^{0} & -2.03750157 \times 10^{0} & 1.274381 \\
-3.55903343 \times 10^{0} & -1.88460773 \times 10^{1} & 3.12090456 \times 10^{0} & 8.57305011 \times 10^{0} & -4.82383311 \times 10^{0} & 4.80957152 \times 10^{-1} & -6.05253313 \times 10^{0} & 1.255054 \\
1.28856976 \times 10^{0} & 1.03742062 \times 10^{1} & -3.40683561 \times 10^{0} & -4.33479902 \times 10^{0} & -1.91012478 \times 10^{0} & -4.26426834 \times 10^{0} & 5.62762007 \times 10^{0} & -6.347900 \\
-2.24660153 \times 10^{0} & 1.69012455 \times 10^{1} & -8.08940648 \times 10^{0} & -8.22717082 \times 10^{0} & -5.10633657 \times 10^{-1} & 3.59968435 \times 10^{-1} & 1.91266662 \times 10^{1} & -5.333922 \\
-2.02067157 \times 10^{1} & 2.73160581 \times 10^{0} & -1.08710416 \times 10^{1} & 1.37824647 \times 10^{1} & -1.74575417 \times 10^{1} & -1.67917766 \times 10^{1} & 5.10084539 \times 10^{0} & 2.681458 \\
-7.39767929 \times 10^{0} & 3.37429148 \times 10^{1} & -1.46658523 \times 10^{1} & -9.39150000 \times 10^{0} & -1.67698149 \times 10^{0} & -3.18910681 \times 10^{0} & 2.27613870 \times 10^{1} & -7.026058 \\
-6.80901922 \times 10^{0} & -5.77078242 \times 10^{0} & -1.43755386 \times 10^{0} & 4.14874376 \times 10^{0} & -2.43824431 \times 10^{0} & 2.22624690 \times 10^{0} & 1.47909341 \times 10^{0} & 9.206695 \\
-2.44000512 \times 10^{0} & -3.52025952 \times 10^{0} & -4.47119880 \times 10^{-1} & 2.22582855 \times 10^{0} & -4.05714505 \times 10^{0} & -2.53864735 \times 10^{0} & 1.21970000 \times 10^{0} & 4.357357 \\
2.45779625 \times 10^{0} & 3.37961496 \times 10^{0} & 8.49715703 \times 10^{-1} & -4.35713898 \times 10^{0} & 4.58753568 \times 10^{0} & 4.16787473 \times 10^{0} & 3.11630050 \times 10^{0} & -5.577548 \\
1.34010892 \times 10^{1} & -2.45753955 \times 10^{1} & 1.62052981 \times 10^{1} & -3.53605290 \times 10^{0} & 1.40520617 \times 10^{1} & 1.83432281 \times 10^{1} & -1.19614092 \times 10^{1} & -1.026959 \\
-3.44275625 \times 10^{0} & -2.32764900 \times 10^{1} & 5.54018348 \times 10^{0} & 1.50499280 \times 10^{1} & -7.89648103 \times 10^{0} & -7.24482717 \times 10^{0} & -1.94412683 \times 10^{1} & 1.643830 \\
-4.08624130 \times 10^{0} & 1.82024036 \times 10^{1} & -9.86586445 \times 10^{0} & -3.87435762 \times 10^{0} & -2.96679603 \times 10^{0} & -2.96884330 \times 10^{0} & 1.09995385 \times 10^{1} & -3.060963 \\
-9.71680675 \times 10^{0} & -1.75130741 \times 10^{0} & -4.31435265 \times 10^{0} & 9.37315489 \times 10^{0} & -1.02004442 \times 10^{1} & -1.12468958 \times 10^{1} & -1.03130416 \times 10^{0} & 1.585459 \\
6.40605052 \times 10^{0} & 6.57329767 \times 10^{0} & 2.82374952 \times 10^{0} & -8.91078937 \times 10^{0} & 7.16954698 \times 10^{0} & 5.76407722 \times 10^{0} & 4.27856552 \times 10^{0} & -1.316556 \\
-2.43754906 \times 10^{0} & -8.63964288 \times 10^{0} & 4.59883358 \times 10^{-1} & 5.11530715 \times 10^{0} & -5.62417509 \times 10^{0} & -3.84602421 \times 10^{0} & -3.43354612 \times 10^{0} & 7.198393 \\
-7.39738461 \times 10^{0} & -1.72882299 \times 10^{1} & 4.30983617 \times 10^{-1} & 1.22434078 \times 10^{1} & -6.71311658 \times 10^{0} & -2.93496745 \times 10^{0} & -6.18168066 \times 10^{0} & 1.864026 \\
0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.000000 \\
5.91787342 \times 10^{0} & 1.65027146 \times 10^{1} & -4.78944654 \times 10^{0} & -8.47364028 \times 10^{0} & 3.25427064 \times 10^{0} & 5.74234230 \times 10^{-1} & 6.63857409 \times 10^{0} & -1.329830 \\
-6.56033432 \times 10^{0} & 3.95995418 \times 10^{1} & -1.56515433 \times 10^{1} & -1.09172479 \times 10^{1} & -3.11281483 \times 10^{0} & -8.76245639 \times 10^{0} & 2.38803514 \times 10^{1} & -8.193333 \\
3.27634113 \times 10^{0} & 3.65217722 \times 10^{0} & -1.16912164 \times 10^{0} & -4.12792681 \times 10^{0} & 2.63042657 \times 10^{0} & 3.26670095 \times 10^{0} & 3.52534934 \times 10^{0} & -6.114341 \\
-6.72047277 \times 10^{0} & 8.41789881 \times 10^{0} & -7.13902064 \times 10^{0} & -8.12790788 \times 10^{-1} & -3.41080793 \times 10^{0} & 6.44245999 \times 10^{-1} & 1.00878128 \times 10^{1} & 2.235968 \\
2.25560605 \times 10^{1} & -3.30153987 \times 10^{1} & 2.54722609 \times 10^{1} & -7.85188110 \times 10^{0} & 2.11764552 \times 10^{1} & 2.46126984 \times 10^{1} & -1.88817459 \times 10^{1} & -1.918905 \\
0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.000000 \\
-1.20659635 \times 10^{1} & 3.24120097 \times 10^{1} & -1.80818194 \times 10^{1} & -4.48765376 \times 10^{0} & -1.03405570 \times 10^{1} & -1.26174680 \times 10^{1} & 2.41352449 \times 10^{1} & 2.676777 \\
4.71493349 \times 10^{0} & 1.30164907 \times 10^{1} & 3.93802481 \times 10^{-1} & -1.04271305 \times 10^{1} & 7.21003073 \times 10^{0} & 3.53310786 \times 10^{0} & 1.00834191 \times 10^{1} & -1.152844 \\
3.69494981 \times 10^{-1} & -1.65125258 \times 10^{1} & 4.82239334 \times 10^{0} & 6.54657623 \times 10^{0} & -8.21118585 \times 10^{-1} & 1.63160357 \times 10^{0} & -9.91437830 \times 10^{0} & 7.411212 \\
-4.42477165 \times 10^{0} & -1.76914411 \times 10^{0} & -1.00877006 \times 10^{0} & 3.66163879 \times 10^{0} & -4.29780356 \times 10^{0} & -4.88487798 \times 10^{0} & 5.71426571 \times 10^{-1} & 7.054761 \\
0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.00000000 \times 10^{0} & 0.000000
\end{array}\right]$$

The reduced state space equations:

$$\begin{Bmatrix} \dot{\boldsymbol{x}} \\ \boldsymbol{y} \end{Bmatrix} = \begin{bmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{C} & \mathbf{D} \end{bmatrix} \begin{Bmatrix} \boldsymbol{x} \\ \boldsymbol{u} \end{Bmatrix}$$

$$\begin{bmatrix} \mathbf{A} & \mathbf{B} \\ \mathbf{C} & \mathbf{D} \end{bmatrix} = \left[\begin{array}{cccccccc}
-1.03935745 \times 10^{2} & -4.15043235 \times 10^{2} & -1.18255207 \times 10^{2} & -1.66966760 \times 10^{2} & 3.72898600 \times 10^{1} & -1.06306375 \times 10^{2} & -8.76364759 \times 10^{1} & \\
1.01880130 \times 10^{1} & -3.55176173 \times 10^{0} & -2.63722372 \times 10^{1} & 9.99837813 \times 10^{0} & -2.23300805 \times 10^{0} & 6.36588582 \times 10^{0} & 5.24788660 \times 10^{0} & - \\
2.93562933 \times 10^{1} & -1.06314119 \times 10^{1} & -4.86137853 \times 10^{1} & 2.33833375 \times 10^{1} & 1.01009905 \times 10^{0} & -2.87960233 \times 10^{0} & -2.37387646 \times 10^{0} & \\
1.44824284 \times 10^{2} & 4.43011314 \times 10^{2} & -1.74863731 \times 10^{1} & 8.84155189 \times 10^{1} & 4.24315233 \times 10^{1} & 1.03576345 \times 10^{2} & 8.53859034 \times 10^{1} & - \\
1.82343771 \times 10^{2} & 5.98005613 \times 10^{2} & 4.74610962 \times 10^{1} & 2.25870784 \times 10^{2} & -2.51784528 \times 10^{1} & 1.67094644 \times 10^{2} & 1.16093785 \times 10^{2} & - \\
-1.64173819 \times 10^{2} & -2.35899235 \times 10^{2} & 2.61934502 \times 10^{2} & -3.76834437 \times 10^{1} & -1.07558890 \times 10^{2} & -6.70693821 \times 10^{1} & -4.14844304 \times 10^{1} & \\
-1.24688516 \times 10^{2} & -3.72778524 \times 10^{2} & 6.18788973 \times 10^{1} & -1.04541437 \times 10^{2} & -3.13674566 \times 10^{1} & -9.01606628 \times 10^{1} & -6.70988071 \times 10^{1} & \\
-2.85365576 \times 10^{2} & -1.85988971 \times 10^{3} & -3.97111178 \times 10^{2} & -4.85058368 \times 10^{2} & 1.04193183 \times 10^{2} & -6.18380987 \times 10^{2} & -3.78016724 \times 10^{2} & \\
-8.09211801 \times 10^{2} & -1.20642420 \times 10^{3} & 2.59455287 \times 10^{3} & 5.22525975 \times 10^{1} & -1.25249846 \times 10^{3} & 8.27395478 \times 10^{1} & -7.62107038 \times 10^{1} & - \\
-3.30746536 \times 10^{2} & 4.62066127 \times 10^{2} & 2.69922230 \times 10^{3} & 4.38839081 \times 10^{2} & -1.23152431 \times 10^{3} & 6.02359159 \times 10^{2} & 2.66499415 \times 10^{2} & - \\
-1.46135567 \times 10^{2} & -3.00558166 \times 10^{2} & 1.91254430 \times 10^{3} & 1.58907101 \times 10^{2} & -8.95207045 \times 10^{2} & 2.43999520 \times 10^{2} & 8.45970630 \times 10^{1} & - \\
-9.03986970 \times 10^{2} & -8.81865228 \times 10^{2} & -2.25373140 \times 10^{2} & -1.56648858 \times 10^{3} & 8.97027723 \times 10^{1} & 5.63515618 \times 10^{2} & -1.95990871 \times 10^{2} & \\
-4.43299496 \times 10^{3} & 1.12822594 \times 10^{3} & -1.21966480 \times 10^{3} & 1.71361596 \times 10^{3} & 4.60983243 \times 10^{2} & -9.89083201 \times 10^{2} & -3.27649385 \times 10^{2} & \\
7.56551121 \times 10^{2} & 1.17816773 \times 10^{3} & 1.86531173 \times 10^{3} & 4.13413012 \times 10^{3} & -9.59633398 \times 10^{2} & -1.73027696 \times 10^{3} & 2.74923573 \times 10^{2} & \\
-6.13510165 \times 10^{3} & -1.08608706 \times 10^{3} & -2.75088874 \times 10^{3} & -1.57166576 \times 10^{2} & 1.09747503 \times 10^{3} & -1.14217640 \times 10^{3} & -9.39499149 \times 10^{2} & \\
3.94067853 \times 10^{3} & 1.22185325 \times 10^{3} & -7.01883805 \times 10^{2} & 5.69454600 \times 10^{2} & 4.40760046 \times 10^{2} & 2.16260174 \times 10^{1} & 4.99029973 \times 10^{2} & - \\
-2.32311313 \times 10^{2} & -7.61545070 \times 10^{2} & -1.11729388 \times 10^{3} & -3.94636793 \times 10^{2} & 4.88825498 \times 10^{2} & -3.66844380 \times 10^{2} & -2.27807564 \times 10^{2} & \\
9.90561134 \times 10^{2} & -8.36295397 \times 10^{2} & -7.08450115 \times 10^{2} & -2.41341215 \times 10^{2} & 3.17011132 \times 10^{2} & -3.91475104 \times 10^{2} & -1.13485652 \times 10^{2} & \\
-3.72670905 \times 10^{3} & 1.55686170 \times 10^{2} & 3.00517625 \times 10^{3} & 1.56521108 \times 10^{3} & -1.50257990 \times 10^{3} & -2.22730684 \times 10^{2} & -1.09398844 \times 10^{2} & \\
7.23501752 \times 10^{2} & -4.39794492 \times 10^{2} & -2.63020149 \times 10^{3} & -1.75516711 \times 10^{3} & 1.26156382 \times 10^{3} & 2.97628471 \times 10^{2} & -1.59727164 \times 10^{2} & \\
-2.21435045 \times 10^{3} & -1.20050399 \times 10^{3} & -4.95255261 \times 10^{3} & -5.60338104 \times 10^{3} & 2.40409722 \times 10^{3} & 1.90416629 \times 10^{3} & -5.84239217 \times 10^{2} & \\
-4.58181461 \times 10^{2} & -5.34572996 \times 10^{2} & -1.52043438 \times 10^{3} & -7.11073992 \times 10^{2} & 6.77132867 \times 10^{2} & -1.71601635 \times 10^{2} & -2.32537043 \times 10^{2} & \\
9.61029177 \times 10^{2} & -1.54614804 \times 10^{2} & -1.01855206 \times 10^{3} & 1.04594813 \times 10^{1} & 4.52932420 \times 10^{2} & -3.30349217 \times 10^{2} & -2.00291200 \times 10^{1} & \\
\hline
-1.07897401 \times 10^{-1} & -1.03044812 \times 10^{-2} & -1.69058741 \times 10^{-2} & -1.66279879 \times 10^{-2} & 1.92665093 \times 10^{-2} & 3.18919643 \times 10^{-3} & 1.77525426 \times 10^{-2} & \\
3.29134703 \times 10^{-4} & -2.06158735 \times 10^{-3} & -5.40593010 \times 10^{-3} & 3.88704971 \times 10^{-2} & 1.20614973 \times 10^{-2} & -2.61079085 \times 10^{-2} & 2.41274104 \times 10^{-2} & - \\
-1.08226535 \times 10^{-1} & -8.24289384 \times 10^{-3} & -1.14999440 \times 10^{-2} & -5.54984850 \times 10^{-2} & 7.20501202 \times 10^{-3} & 2.92971049 \times 10^{-2} & -6.37486783 \times 10^{-3} &
\end{array}\right.$$