

**ETM/ITM Quad Suspension**

**Details of OSEMs, Magnets, ESDs and DC control ranges at each stage**

T1100595-v4  
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<b>Max DAC Voltage</b>	(Differential voltage across the Plus and Minus legs)
<b>[V<sub>p</sub>]</b>	
10	

Suspension Stage	OSEM Type	Magnet Type	Magnet Size diameter x thickness	Coil Magnet Actuation Strength	Coil Magnet Actuation Strength
Units	[ ]	[ ]	[mm]	[N/A]	[N/mA]
Main and Reaction Chain Top (TOP)	BOSEM	NdFeB	10 x 10	1.694	0.001694
Upper-Intermediate Mass (UIM)	BOSEM	SmCo	10 x 10	1.694	0.001694
Penultimate Mass (PUM)	AOSEM	SmCo	2 x 6	0.0309	0.0000309

Coil Driver	DC Transconductance	DC Max Current Output	DC Current Range	DC Current Range Requirement	Frequency Range
Units	[mA/V]	[mA <sub>p</sub> ]	[mA <sub>pp</sub> ]	[(mA <sub>pp</sub> ) or (mA <sub>rms</sub> )]	[Hz]
TOP (D0902747-v4)	9.943	99.43	198.86	200 (pp)	continuous
UIM (D070481-v4)	0.1535	1.535	3.07	2 (rms)	< 1
MODUIM (T1400223-v1)	0.6154	6.154	12.308	2 (rms)	< 1
PUM (D070483-v5)	0.2685	2.685	5.37	16 (rms)	200 - 5000

Degree of Freedom (DOF)	Stage	DC Compliance at Mass	Lever Arm	# of OSEMs	DC Compliance at Coil Driver Output	DC Max Disp. from Coil Drive	DC Max Disp. from Coil Drive	DC Disp. Range from Coil Drive	DC Disp. Range from Coil Drive
Units	[ ]	[(m/N) or (rad/N.m)]	[m]	[ ]	[(m/mA) or (rad/p)]	[(m <sub>pp</sub> ) or (rad <sub>p</sub> )]	[(m <sub>pp</sub> ) or (rad <sub>p</sub> )]	[(m <sub>pp</sub> ) or (rad <sub>pp</sub> )]	[(m <sub>pp</sub> ) or (rad <sub>pp</sub> )]
Longitudinal	TOP	0.000348	1	2	1.179E-06	1.172E-04	117.23	2.345E-04	234.461
Pitch	TOP	0.033500	0.078	1	4.426E-06	4.401E-04	440.12	8.802E-04	880.238
Yaw	TOP	0.015100	0.12	2	6.139E-06	6.104E-04	610.41	1.221E-03	1220.813
Longitudinal	UIM	0.000630	1	4	4.269E-06	6.553E-06	6.55	1.311E-05	13.105
Pitch	UIM	0.047200	0.065	4	2.079E-05	3.191E-05	31.91	6.382E-05	63.822
Yaw	UIM	0.036500	0.065	4	1.608E-05	2.468E-05	24.68	4.935E-05	49.354
Longitudinal	MODUIM	0.000630	1	4	4.269E-06	6.272E-05	26.27	5.254E-05	52.541
Pitch	MODUIM	0.047200	0.065	4	2.079E-05	1.279E-04	127.93	2.559E-04	255.868
Yaw	MODUIM	0.036500	0.065	4	1.608E-05	9.893E-05	98.93	1.979E-04	197.864
Longitudinal	PUM	0.001060	1	4	1.310E-07	3.518E-07	0.35	7.036E-07	0.704
Pitch	PUM	0.078600	0.0707	4	6.868E-07	1.844E-06	1.84	3.688E-06	3.688
Yaw	PUM	0.053500	0.0707	4	4.675E-07	1.255E-06	1.26	2.511E-06	2.511

ESD Driver	DC Gain (Differential In to Single-ended Out)	DC Max Voltage Output	DC Voltage Range	DC Voltage Range Requirement	Frequency Range
Units	[V/V]	[V <sub>p</sub> ]	[V <sub>pp</sub> ]	[V <sub>pp</sub> ]	[Hz]
Acquisition Driver (T1000220-v1)	40	400	800	800	< 2000
Low Noise Driver (T0900567, see above)	1.1	11	22	30	< 2000

ESD Pattern / Driver	RM to TST Gap Size	Actuation Strength (all four quadrants)	Max BIAS Voltage	Max QUAD Voltage	Max Force	Max Force w/ Bias Offset ***
Units	[mm]	[N/V <sup>2</sup> ]	[V <sub>p</sub> ]	[V <sub>p</sub> ]	[N <sub>p</sub> ]	[N <sub>p</sub> ]
ETM / Acquire	5	4.20E-10	400	400	2.69E-04	1.34E-04
ITM / Acquire	20	7.50E-12	400	400	4.80E-06	2.40E-06
ETM / Low Noise	5	4.20E-10	11	11	2.03E-07	1.02E-07
ITM / Low Noise	20	7.50E-12	11	11	6.63E-09	1.82E-09

\*\*\* In order to get both attractive and repulsive forces, we'll operate with a force offset of -1/2 Fmax, see reference P1000032 below

Degree of Freedom (DOF)	Stage / Driver	DC Compliance at Mass	Lever Arm	DC Max Disp. from ESD w/ Force Offset	DC Max Disp. from ESD w/ Force Offset	DC Disp Range from ESD w/ Force Offset	DC Disp. Range from ESD w/ Force Offset
Units	[ ]	[(m/N) or (rad/N.m)]	[m]	[(m <sub>pp</sub> ) or (rad <sub>p</sub> )]	[(m <sub>pp</sub> ) or (rad <sub>pp</sub> )]	[(m <sub>pp</sub> ) or (rad <sub>pp</sub> )]	[(m <sub>pp</sub> ) or (rad <sub>pp</sub> )]
Longitudinal	ETM / Acq.	0.0026	1	3.494E-07	349.440	6.989E-07	698.880
Pitch	ETM / Acq.	0.116	0.14	2.183E-06	2182.656	4.365E-06	4365.312
Yaw	ETM / Acq.	0.0105	0.14	1.976E-06	1975.680	3.951E-06	3951.360
Longitudinal	ITM / Acq.	0.0026	1	6.240E-09	6.240	1.248E-08	12.480
Pitch	ITM / Acq.	0.116	0.15	4.176E-08	41.760	8.352E-08	83.520
Yaw	ITM / Acq.	0.105	0.15	3.780E-08	37.800	7.560E-08	75.600
Longitudinal	ETM / Low Noise	0.0026	1	2.643E-10	0.264	5.285E-10	0.529
Pitch	ETM / Low Noise	0.116	0.14	1.651E-09	1.651	3.301E-09	3.301
Yaw	ETM / Low Noise	0.105	0.14	1.494E-09	1.494	2.988E-09	2.988
Longitudinal	ITM / Low Noise	0.0026	1	4.719E-12	0.005	9.438E-12	0.009
Pitch	ITM / Low Noise	0.116	0.15	3.158E-11	0.032	6.316E-11	0.063
Yaw	ITM / Low Noise	0.105	0.15	2.859E-11	0.029	5.717E-11	0.057

**References**

DAC Voltage T1200311-v1  
 OSEM and magnet details M0900034-v4  
 OSEM Coil/Magnet Actuation Strengths T1000164-v3  
 DC Compliances for long/pitch/yaw [https://redout.ligo-wa.caltech.edu/svn/sus/trunk/Common/SusModelTags/Matlab/quadmodelproduction\\_rev3311\\_fiber\\_2012-09-06.mat](https://redout.ligo-wa.caltech.edu/svn/sus/trunk/Common/SusModelTags/Matlab/quadmodelproduction_rev3311_fiber_2012-09-06.mat)

Model: ssmake4pv2elMB5f\_rev1797  
 Parameters: quadopt\_fiber.m rev2731  
 DC compliance == Transfer function from given stage drive to test mass, L to LP to P, and Y to Y

T060067-v1 Informed by <http://www.its.caltech.edu/~rana/aLIGO/suselecrag.html>

Coil driver requirements T060067-v1  
 Coil Driver DC Transconductance <https://alq.ligo-la.caltech.edu/aLGO/index.php?callRep=4495> and T1400223  
 Lever Arms D0901346 for TOP, UIM, and PUM drives; D0900949 / D080177 for ETM / ITM ESD Patterns (assumes that effective lever arm for ESD is in the middle [radially] of the pattern)  
 Actuation strength for ESD drive T1000116-v1, Figure 4, 20[mm] gap, Nominal Pattern data point for ETM, G0900956-v1, pg 7 for ETM  
 Peak Voltage for High Voltage ESD Driver T1000222  
 Peak Voltage for Low Noise ESD Driver T1200479, Section 5  
 Maximum Force Used (with - 1/2 Fmax offset) P1000032-v3, Section 5.3.1.3, pg 251 (or 291 of the .pdf)