#### LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY - LIGO -CALIFORNIA INSTITUTE OF TECHNOLOGY MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Technical Note	LIGO-T1100595-v4-	2014/03/26
ETM/ITM	Quad Suspension Cont	trol Ranges
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### 1 Introduction

This document defines the maximum range of the actuators on an Advanced LIGO (aLIGO) Quadruple (QUAD) suspension, used for input and end test masses (ITM and ETMs, respectively), given the final design of their respective signal chains. The range is calculated explicitly at DC in tabular form in section 3. Because the range depends on the actuator driver's frequency response which are different at each stage, the single actuator force as a function of frequency in section 4. The mechanical response to force longitudinal, pitch, and yaw are shown in 5. Finally, the magnitude of test mass displacement as a function of frequency for high(est)-range and low(set)-noise configurations is shown in section 6.

### 2 Calculating the Maximum Force

The maximum (peak) differential drive voltage,  $V_{max}$ , from an aLIGO Digital-to-Analog Converter (DAC), a General Standards PCIe66-18AO8, 18-bit, DAC card, is 10  $[V_p]$ .

For the top three stages (TOP, UIM, and PUM), the force is calculated by multiplying the linear signal chain,

$$F = \eta T_{CD} G_{AI} V_{DAC} \tag{1}$$

where  $V_{DAC}$  is the applied DAC voltage,  $G_{AI}$  is the gain of the anti-aliasing chassis (assumed to be unity),  $T_{CD}$  is the transconductance of the coil driver (in [A/V]), and  $\eta$  is the OSEM arrangement's coil-magnet force coefficient (in [N/A]). Each isolation stage's driver circuit transconductance produces frequency-dependent current, and this frequency dependence is switchable such that the driver can meet both actuation range and output noise requirements. Table 1 summarizes the frequency response of each driver configuration for each stage. The assumed-frequency-independent, force-per-current coefficient for a given OSEM arrangement is then applied to determine the force produced in the actuator basis.

The test mass stage's, non-linear ESD's force is calculated as

$$F = \alpha \left( V_{bias} - V_{control} \right)^2 \tag{2}$$

where  $\alpha$  is the non-linear force coefficient of the ESD pattern (in  $[N/V^2]$ ),  $V_{bias} = G_{ED}V_{DAC}$  (the product of the ESD driver voltage gain,  $G_{ED}$  and the applied DAC voltage) is the voltage on the bias pattern, and  $V_{control} = G_{ED}V_{DAC}$  is the voltage on the control pattern. The ESD driver, as currently designed, has a single, non-switchable pole at 2 [kHz]. As higher bias voltage means a smaller degree of non-linearity, the bias voltage is always operated at the maximum possible voltage for a given ESD driver. If the control voltage were equal, but opposite in sign, we could achieve a maximum force of

$$|F_{max}^{(ESD)}| = 4\alpha (G_{ED}V_{max})^2.$$
(3)

However, the ESD is inherently attractive and we wish to have both attractive and repulsive forces. We have therefore assumed that the control voltage is operated with a force offset of half the maximum possible, leaving the operational maximum force to be

$$|F_{op.\ max}^{(ESD)}| = 2\alpha (G_{ED}V_{max})^2.$$
 (4)

For all stages, the frequency-dependent, single-actuator, maximum force is converted to the Euler basis using the number of actuators and lever arm for each degree of freedom, which is then propagated through the aLIGO production QUAD matlab model transfer functions between each stage's degree of freedom excitation and test mass displacement in the same degree of freedom.

	Driver	Drawing #	State Name	(zeros):(poles) [Hz]
ſ	TOP	D0902747-v4	$acq^{\dagger}$	(31):(0.9)
			$^{ m lp}$	(10, 31): $(0.9, 1)$
	UIM	D070481-v4	acq <sup>†</sup>	(50): $(300)$
			lp1	(10.5,  50): $(1,  300)$
			lp2	(10.5, 10.5, 50): $(1, 1, 300)$
			$ m lp3~\diamond$	(10.5, 10.5, 10.5, 50):(1, 1, 1, 300)
	MODUIM	T1400223-v1	$acq^{\dagger}$	(85):(300)
			lp1	(10.5, 85): $(1, 300)$
			lp2	(10.5, 10.5, 85):(1, 1, 300)
			$ m lp3~\diamond$	(10.5, 10.5, 10.5, 85):(1, 1, 1, 300)
	PUM	D070483-v5	acqOff lpOff	(12):(110)
			acqOn lpOff $^\dagger$	(1.35): $(80.5)$
			acqOff lpOn $\diamond$	(6, 12, 20): $(0.5, 110, 250)$
			acqOn lpOn	(1.35, 6, 20): $(0.5, 80.5, 250)$

Table 1: Frequency response for each state of the three upper-stage QUAD actuator driver types. Maximum range states are marked with  $\dagger$ , low-noise states are marked with  $\diamondsuit$ .

Table 2: Configurations of the test-mass stage electro-static drive.

Duirron	Driver	State	Driver Gain	Gap Size	Pattern	
Driver	Drawing $\#$	Name	[V/V]	[mm]	Type	
ESD	T1000220-v1	acq5mm $^{\dagger}$	40	5.0	ETM (D0900949-v2)	
		ln5mm $\diamond$	1.1	5.0	ETM (D0900949-v2)	
		acq20mm $^{\dagger}$	40	20.0	ITM (D080177-v4)	
		$\ln 20 \mathrm{mm}^{\diamond}$	1.1	20.0	ITM (D080177-v4)	

### 3 Maximum Displacement at DC

ETM/ITM Out of Output stations									
Details of OSEMS Magnete ESDs and	DC control ranges	at each etage							
T1100595-v4	20 cond of ranges	at such staye							
Norna A Robertson and Jeff Kissel									
26th May 2014									
Max DAC Voltage		acrose the Plue a	nd Minue leas)						
[V p]	(Differential voltage	across the r rus a	na minas iega)						
10									
10	2								
			Magnet Size	Coil Magnet	Coil Magnet				
Suspension Stage	OSEM Type	Magnet Type	diameter x	Actuation	Actuation				
Unite	r1	[]	Imm1	Strength N/A1	Strength [N/mA]	1			
	L								
Main and Reaction Chain Top (TOP)	BOSEM	NOFEB	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				
				DC Current		1			
Coil Driver	DC	DC Max	DC Current	Range	Frequency				
	Transconducance	Current Output	Range	Requirement	Range				
				[(mA_pp) or					
Units	[mA/V]	[mA_p]	[mA_pp]	(mA_rms)]	[Hz]				
TOP (D0902747-v4)	9.943	99.43	198.86	200 (pp)	continuous				
UIM (D070481-v4)	0 1535	1 5 3 5	3.07	2 (rms)	< 1				
MODUIN (74400000	0.0454	0.454	40.000	2 (		1			
MODUIM (11400223-V1	0.0154	0.104	12.306	2 (ms)	<1 <1				
PUM (D070483-v5	0.2685	2.685	5.37	16 (rms)	200 - 5000	]			
					DC Compliance				
Degree of Freedom (DOF)	Stage	DC Compliance	Lever Arm	# of OSEMs	at Coil Driver	DC Max Disp.	DC Max Disp. from	DC Disp. Range	DC Disp. Range
		at Mass			Output	from Coll Drive	Coll Drive	from Coll Drive	from Coll Drive
		[(m/N) or			[(m/mA) or	[(m_p) or	[(um_p) or	[(m_pp) or	[(um_pp) or
Units	μ	(rad/N.m)]	[m]	U	(rad/mA)	(rad_p)]	(urad_p)]	(rad_pp)]	(urad_pp)]
Longitudina	TOP	0.000348	1	2	1.179E-06	1.172E-04	117.23	2.345E-04	234.46
Pitch	TOP	0.033500	0.078	1	4.426E-06	4.401E-04	440 12	8.802E-04	880.23
	TOD	0.015100	0.40		6 1205 00	6 1045 04	640.44	1 2245 02	4000.044
Yaw	100	0.015100	0.12	2	0.139E-06	0.104E-04	010.41	1.22 IE-03	1220.81
Longitudina	UIM	0.000630	1	4	4.269E-06	6.553E-06	6.55	1.311E-05	13.10
Pitch	UIM	0.047200	0.065	4	2.079E-05	3.191E-05	31.91	6.382E-05	63.82
Yaw	UIM	0.036500	0.065	4	1 608E-05	2 468E-05	24.68	4 935E-05	49 354
L an aite ation	MODUIN	0.0000000			4 0005 00	0.0075.05	00.07	5 0545 05	50.54
Longitudina	MODUIM	0.000630	1	4	4.269E-06	2.62/E-05	26.27	5.254E-05	52.54
Pitch	MODUIM	0.047200	0.065	4	2.079E-05	1.279E-04	127.93	2.559E-04	255.86
Yaw	MODUIM	0.036500	0.065	4	1.608E-05	9.893E-05	98.93	1.979E-04	197.864
Longitudina	PLIM	0.001060	1	4	1 310E-07	3 518E-07	0.35	7.036E-07	0.70
Longitadina	1000	0.001000			1.5102-07	3.3102-01	0.00	1.0302-07	0.70
Pitcr	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	2.51
FOD Delves	DC Gain	DC Max	DC Voltage	DC Voltage	Frequency	1			
ESD Driver	DC Gain (Differential In to Single-ended Out)	DC Max Voltage Output	DC Voltage Range	DC Voltage Range Requirement	Frequency Range				
ESD Driver	DC Gain (Differential In to Single-ended Out)	DC Max Voltage Output [V p]	DC Voltage Range	DC Voltage Range Requirement [V pp]	Frequency Range [Hz]				
ESD Driver	DC Gain (Differential In to Single-ended Out) [V/V]	DC Max Voltage Output [V_p]	DC Voltage Range [V_pp]	DC Voltage Range Requirement [V_pp]	Frequency Range [Hz]				
ESD Driver Units Acquisition Driver (T1000220-v1)	DC Gain (Differential In to Single-ended Out) [V/V] 40	DC Max Voltage Output [V_p] 400	DC Voltage Range [V_pp] 800	DC Voltage Range Requirement [V_pp] 800	Frequency Range [Hz] < 2000				
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above)	DC Gain (Differential In to Single-ended Out) [V/V] 40 1.1	DC Max Voltage Output [V_p] 400 11	DC Voltage Range [V_pp] 800 22	DC Voltage Range Requirement [V_pp] 800 30	Frequency Range [Hz] < 2000 < 2000				
ESD Driver Units Acquisition Driver (T1000220-v1 Low Noise Driver (T0900567, see above	DC Gain (Differential In to Single-ended Out) [V/V] 40 1.1	DC Max Voltage Output [V_p] 400 11	DC Voltage Range [V_pp] 800 22	DC Voltage Range Requirement [V_pp] 800 30	Frequency Range [Hz] < 2000 < 2000		1		
ESD Driver Units Acquisition Driver (T1000220-v1 Low Noise Driver (T0900567, see above)	DC Gain (Differential In to Single-ended Out) (V/V) 40 1.1 RM to TST Gap	DC Max Voltage Output [V_p] 400 11 Actuation	DC Voltage Range [V_pp] 800 22 Max BIAS	DC Voltage Range Requirement [V_pp] 800 30 Max QUAD	Frequency Range [Hz] < 2000 < 2000	Max Force w/			
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver	DC Gain (Differential In to Single-ended Out) [V/V] 40 1.1 RM to TST Gap Size	DC Max Voltage Output [V_p] 400 11 Actuation Strength (all four quadrants)	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage	DC Voltage Range Requirement [V_pp] 800 30 Max QUAD Voltage	Frequency Range [Hz] < 2000 < 2000 Max Force	Max Force w/ Bias Offset ***			
ESD Driver Units Acquisition Driver (T1000220-v1 Low Noise Driver (T0900567, see above) ESD Pattern / Driver	DC Gain (Differential In to Single-ended Out) (V/V) 40 1.1 RM to TST Gap Size	DC Max Voltage Output [V_P] 400 11 Actuation Strength (all four quadrants)	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage	DC Voltage Range Requirement [V_pp] 800 30 Max QUAD Voltage	Frequency Range [Hz] < 2000 < 2000 Max Force	Max Force w/ Bias Offset ***			
ESD Driver Units Acquisition Driver (T1000220-v1 Low Noise Driver (T0900567, see above ESD Pattern / Driver Units	DC Gain (Differential In to Single-ended Out) IV/V 40 1.1 RM to TST Gap Size [mm]	DC Max Voltage Output [V_p] 400 11 Actuation Strength (all four quadrants) [N/V^2]	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p]	DC Voltage Range Requirement [V_pp] 800 30 Max QUAD Voltage [V_p]	Frequency Range [Hz] < 2000 < 2000 Max Force [N_p]	Max Force w/ Blas Offset *** [N_p]			
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire	DC Gain (Differential In to Single-ended Out) V/V 40 1.1 RM to TST Gap Size [mm] 5	DC Max Voltage Output (V_p) 400 11 Actuation Strength (all four quadrants) [NV^2] 4.20E-10	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400	DC Voltage Requirement IV_pp] 800 30 Max QUAD Voltage IV_p] 400	Frequency Range [Hz] < 2000 < 2000 Max Force [N p] 2.69E-04	Max Force w/ Bias Offset *** [N p] 1.34E-04			
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire ITM / Acquire	DC Gain (Differential In to Single-ended Out) IV/V 40 1.1 RM to TST Gap Size [mm] 5 20	DC Max Voltage Output [V_p] 400 11 Actuation Strength (all four quadrants) [NV*2] 4.20E-10 7.50E-12	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400 400	DC Voltage Range Requirement V pp 800 30 Max QUAD Voltage Voltage Voltage 400 400	Frequency Range [Hz] < 2000 < 2000 Max Force [N_p] 2.69E-04 4.80E-06	Max Force w/ Bias Offset *** [N p] 1.34E.04 2.40E-06			
ESD Driver Units Acquisition Driver (T1000220-v1 Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Low Noise	DC Gain (Differential In to Single-ended Out) VV 40 1.1 RM to TST Gap Size [mm] 5 20	DC Max Voltage Output [V_p] 400 11 Actuation four quadrants) [NVV^2] 4.20E-10 7.50E-12 4.20E-10	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400 400	DC Voltage Range Requirement [V_pp] 800 300 Max QUAD Voltage [V_p] 400 400 411	Frequency Range [Hz] < 2000 < 2000 Max Force [N p] 2.69E-04 4.80E-06 2.03E-07	Max Force w/ Bias Offset *** [N p] 1.34E-06 2.40E-06 1.02E-02			
ESD Driver Units Acquisition Driver (T1000220-v1 Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Low Noise	DC Gain (Differential In to Single-ended Out) (V/V) 40 1.1 RM to TST Gap Size [mm] 5 20 5	DC Max Voltage Output IV_p] 400 111 Actuation Strength (all four quadrants) [N/V^2] 4.20E-10 7.50E-12 4.20E-10	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400 400	DC Voltage Range Requirement V_pp] 800 30 30 Max QUAD Voltage V_p] 400 400	Max         Force           [Hz]         < 2000	Max Force w/ Bias Offset *** [N_p] 1.34E-04 2.40E-06 1.02E-07 			
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Low Noise ITM / Low Noise	DC Gain           (Differential in to Single-ended Out)           (VV)           40           1.1           RM to TST Gap Size           [mm]           5           200           5           200           5           200           6	DC Max Voltage Output IV_p] 400 11 Actuation Strength (all four quadrants) [N/V*2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400 400 400 111	DC Voltage Range Reguirement IV_pp] 800 30 Max QUAD Voltage IV_p] 400 400 400 111	Frequency Range           (Hz)           < 2000	Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Emay see reference	na <u>91000032 kalou</u> u		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Acquire ETM / Low Noise	DC Gain (Differential in to Single-ended Out) (VV) 40 1.1 RM to TST Gap Size [mm] 5 20 5 20 1 order to get both a	DC Max Voitage Output [V p] 400 111 Actuation Strength (all four quadrants) [NV^2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 attractive and repu	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400 400 111 111	DC Voltage Range Requirement [V_pp] 800 30 Max QUAD Voltage [V_p] 400 400 111 11]	King         King           < 2000         < 2000           < 2000         < 2000           Max Force            100         2.69E-04           4.80E-06         2.03E-07           2.63E-09         036E-09           000000000000000000000000000000000000	Max Force w/ Bias Offset *** [N_p] 1.34E-04 2.40E-06 1.02E-07 1.02E-07 Fmax, see referen	ce P100032 below		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Low Noise ITM / Low Noise	DC Gain (Differential in to Single-ended Out) (VV) 40 1.1 RM to TST Gap Size [mm] 5 20 5 0.20 10 order to get both a	DC Max Voltage Output [V p] 400 11 Actuation Strength (all four quadrants) four quadrants four q	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400 400 400 111 111 ulsive forces, we	DC Voltage Range Requirement V_pp] 800 30 Max QUAD Voltage V_p] 400 400 400 111 11 10 operate with a 1 DC Max Disp.	Frequency Range           < 2000           < 2000           Max Force           IN_p1           2.69E-04           4.80E-06           2.03E-07           3.63E-09           orce offset of -1/2           DC Max Disp.	Max Force w/ Bias Offset *** [N_p] 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Fmax, see referen DC Disp Range	ce P1000032 below DC Disp. Range		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Low Noise ITM / Low Noise UTM / Low Noise	DC Gain (Differential in to Single-ended Out) (VV) 40 1.1 RM to TST Gap Size (mm) 5 20 5 20 1 n order to get both a Stage / Driver	DC Max Voltage Output [V p] 400 111 Actuation Strongth (all four quadrants) INV^22 4.20E-10 7.50E-12 4.20E-10 7.50E-12 attractive and repi DC Compliance at Mass	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400 400 400 111 11 11 Usive forces, we	DC Voltage Range Requirement V-pp] 800 30 Max QUAD Voltage Voltage Voltage Voltage IV-p] 400 400 400 111 11 10 operate with a 1 DC Max Disp.	Frequency Range           < 2000           < 2000           Max Force           [N-p]           2.69E-04           4.80E-06           2.03E-07           3.63E-09           orce offset of -1/2           DC Max Disp.           from ESD w/	Max Force w/ Bias Offset ***           IN_pi           1.34E-04           2.40E-06           1.02E-07           1.82E-09           Fmax, see referen           DC Disp Range from ESD w/	ce P1000032 below DC Disp. Range from ESD w/ Force		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Acquire ITM / Low Noise ITM / Low Noise	DC Gain (Differential in to Single-ended Out) (VV) 40 1.1 RM to TST Gap Size [mm] 5 20 5 20 1 n order to get both Stage / Driver	DC Max Voltage Output [V_p] 400 11 Actuation Strength (all four quadrants) [NVV*2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 dtactive and results DC Compliance at Mass	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400 400 111 111 Usive forces, we'	DC Voltage Range Requirement Vpp] 800 30 Woltage Voltage Voltage Voltage IV_p] 400 400 111 11 I operate with a 1 DC Max Disp. from ESD wi	Max         Frequency Range           < 2000         < 2000           Max         Force           IN_p1         2.09E-04           2.03E-07         3.63E-09           7.63E-09         ordified of -1/2           DC Max Disp.         from ESD w/           Force Offset         offset	Max Force w/ Bias Offset ***           [N_p]           1.34E-04           2.40E-06           1.02E-07           1.82E-09           Frmax, see referen           DC Disp Range from ESD w/ Force Offset	ce P1000032 below DC Disp. Range from EDS wf Force irron Offset		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Acquire ITM / Acquire ITM / Low Noise ITM / Low Noise ITM / Low Noise ITM / Low Noise	DC Gain (Differential in to Single-ended Out) IVV 40 1.1 RM to TST Gap Size (mm) 5 20 5 20 10 order to get both Stage / Driver	DC Max Voltage Output V_p] 400 111 Actuation Strongth (all four quadrants) [NV/v2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 attractive and repi DC Compliance at Mass [(m/N) or (rea/N) m)	DC Voltage Range [V_pp] 800 22 Max BIAS Voltage [V_p] 400 400 111 111 111 Ulsive forces, we <sup>1</sup> Lever Arm	DC Voltage Range Requirement           Requirement           New           Max QUAD           Voltage           Voltage           IV           PI           400           400           400           111           1           Operate with a I           DC Max Disp.           Form SD w/           Forme SD w/           Forme SD first           (mp.p) offset	Frequency Range           [Hz]         < 2000	Max Force w/ Bias Offset ***           In j           1.34E.04           2.40E.06           1.02E.07           1.82E.09           Frank, see referen           DC Disp Range from ESD w/ from ESD w/ from po) or	ce P1000032 below DC Disp. Range from ESD wi Force (rom. pp) or		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Acquire ITM / Acquire Obegree of Freedom (DOF) Units	DC Gain (Differential in to Single-ended Out) (VV) 40 1.1 RM to TST Gap Size [mm] 5 20 5 20 1 n order to get both Stage / Driver []	DC Max Voltage Output V_p] 400 11 Actuation Strongth (all four quadrants) (N/V^2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 attractive and rep DC Compliance at Mass (m/N) or (rad/N.m)]	CC Voltage Range [V. pp] 222 Max BIAS Voltage [V.p] 400 400 400 400 400 400 400 (III) 111 Usive forces, wr	DC Voltage Range Requirement           Requirement           Requirement           Max QUAD Voltage           V.p]           4000           4000           4000           10 perste with a 10           Tom ESD W           Force Offset (m p) or (rad p)]	Frequency Range           [Hz]         < 2000	Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Fmax, see referen DC Disp Range from ESD w/ Force Offset ((m, pp) or (red_pp)]	ce P1000032 below DC Disp. Range from ESD w Force (orred pp) or (nrad pp)		
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ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Low Noise ITM / Low Noise Obgree of Freedom (DOF) Units Longitudina Pitcf	DC Gain (Differential in to Single-ended Out) (VV) 40 1.1 RM to TST Gap Size [mm] 5 20 5 20 1 order to get both 1 Stage / Driver [] ETM / Acq. ETM / Acq.	DC Max Voltage Output [V_p] 400 111 Actuation Strength (all four quadrants) [N/V^2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10 7.50E-12 attractive and rep DC Compliance at Mass [(m/N) or (rad/N.m)] 0.0026 0.116	UC Voltage Range           [V. pp]           8000           222           Max BIAS Voltage           4000           4000           4000           4000           400           400           400           400           400           111           111           111           111           111           0.14	DC Voltage Range Requirement/ Poltage           Requirement/ Poltage           Max QUAD Voltage           Vp1           4000           4000           4000           400           50           60           70           2.183	Frequency Range           [Hz]           < 2000	Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 Fmax, see referen DC Disp Range From ESD w/ Force Offset ((m,pp) or (rad_pp)] 6.939E-07 4.365E-06	ce P1000032 below DC Disp. Range from ESD w Force Offset (nm.pp) or (nrad_pp)] 698.880 4985.312		
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ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Low Noise ITM / Low Noise Units Degree of Freedom (DOF) Units Longitudina Pitci Yaw	DC Gain (Differential in to Single-ended Out) (VV) 40 1.1 RM to TST Gap Size [mm] 5 20 5 20 1 5 20 1 5 20 5 20 1 0 5 20 1 1 5 20 5 20	DC Max Voltage Output Voltage Output Voltage Output 11 Actuation four quadrants) Inuv×21 4_20E-10 7.50E-12 4_20E-10 7.50E-12 4_20E-10 7.50E-12 4_20E-10 7.50E-12 4_20E-10 7.50E-12 0.0026 0.0026 0.0026	UC Voltage Range           (V. pp)           8000           222           Max BIAS Voltage           Voltage           4000	DC Voltage Range Requirement           Requirement           No           300           Max QUAD Voltage           V pl           4000           500           500           600           500           610           610           610           610           610           610           610           610           610           610           610           610           610	Frequency Range           [Hz]           < 2000	Max Force w/ Bias Offset ***           [N p]           1.34E-04           2.40E-06           1.02E-07           1.82E-09           Franz, see referen           DC Disp Range from ESD w/ Force Offset           (m_pp) or (red pp)           6.999E-07           4.365E-06           3.951E-06           1.248E-06	ce P1000032 below DC Disp. Ranger fom ESD w Port (inrag pp) (inrag pp) (inrag pp) (inrag 1098.880 4365.312 3951380 12 Ann		
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ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ETM / Low Noise ITM / Low Noise Degree of Freedom (DOF) Units Longitudina Pitch Yaw Longitudina	DC Gain (Differential in to Single-ended Out) (VV) 40 1.1 RM to TST Gap Size [mm] 5 20 5 20 1 0 order to get both Stage / Driver [] ETM / Acq. ETM / Acq. ITM / Acq.	DC Max Voltage Output Voltage Output (1) Actuation four quadrants) (NUV*2) 4_20E-10 7.50E-12 4_20E-10 7.50E-12 4_20E-10 7.50E-12 4_20E-10 0.0026 0.0116 0.0026 0.0126 0.0116	DC Voltage Range           V. pp]           800           222           Max BIAS Voltage           Voltage           400           400           400           111           111           111           0.14           0.14           1           0.15	DC Voltage Range Requirement           Requirement           Nax QUAD Voltage           V pl           4000           500           500           500           500           500           500           500           500           500           500           500           500           500           500 <t< td=""><td>Frequency Range           [Hz]           &lt; 2000</td>           &lt; 2000</t<>	Frequency Range           [Hz]           < 2000	Max Force w/ Bias Offset *** 1.02E-07 1.02E-07 1.02E-07 Fmax, see referen DC Disp Range from ESD w/ Force Offset ((m,pp) or (red.pp)) 6.999E-07 4.365E-06 3.951E-06 1.244E-08 8.352E-08	ze P1000032 below <b>DC Disp. Range</b> from ESD w Force <b>Offset</b> (imm.pp) or (imm.pp) or (imm.pl.) 698.880 4365.312 3351.360 12.480 83.520		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ITM / Acquire ITM / Acquire ITM / Low Noise ITM / Low Noise Obegree of Freedom (DOF) Units Longitudina Pitch Yaw	DC Gain (Differential in to Single-ended Out) (VV) 40 1.1 RM to TST Gap Size [mm] 5 20 5 20 5 20 5 20 1 in order to get both Stage / Driver [] ETM / Acq. ETM / Acq. ITM / Acq. ITM / Acq.	DC Max Voltage Output V p] 400 11 Actuation Strength (aii four quadrants) [NVV*2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10 7.50E-12 (m/N) or (rad/N.m)] 0.0026 0.116 0.105 0.0026	UC Voltage Range           [V. p]           8000           222           Max BIAS Voltage           [V. p]           400           400           400           11           11           ulsive forces, we's           [m]           1           0.141           0.15           0.15	DC Voltage Range Requirement.           Requirement.           Requirement.           Max QUAD Voltage           V.pl           400           50           10           11           11           12           13.85           13.780           3.780	Frequency Range           (Hz)           < 2000	Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Fmax, see referen DC Disp Range Form SD w/ Force Offset (m_pp) or 6.989E-07 4.365E-06 3.951E-06 1.248E-08 8.352E-08 7.560E-08	ce P1000032 below DC Disp. Range from ESD wi Force (mm.pp) 0 (mm.pp) 0 4385.312 3951.360 12.480 83.520 75.6000 75.600 75.60000 75.60000 75.60000 75.60000 75.60000 75.60000 75.60000 75.60000 75.600000 75.600000 75.600000 75.6000000000 75.6000000000000000000000000000000000000		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ETM / Acquire ETM / Acquire ETM / Low Noise ITM / Low Noise ITM / Low Noise ITM / Low Noise Low Noise Low Noise ITM / Low No	DC Gain           (Differential in to Single-ended Out)           (VV)         40           1.1         RM to TST Gap Size           (mm)         5           20         5           20         5           20         5           20         5           20         5           20         5           20         5           20         20           In order to get both         1           Stage / Driver         1           ETM / Acq.         ETM / Acq.           ITM / Acq.         ITM / Acq.           ETM / Low Noise         ETM / Low Noise	DC Max Voltage Output Voltage Output (1) Actuation Strongth (all four quadrants) (NV/*2) 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10 7.50E-12 (m/N) or (rad/N.m)] 0.0026 0.0116 0.0026 0.0126 0.0026	DC Voltage Range           V. pp]           800           222           Max BIAS Voltage           Voltage           400           400           400           11           11           11           11           0.14           0.14           0.15           0.15	DC Voltage Range           Requirement           Requirement           Max QUAD           Voltage           W pl           4000           4000           4000           4000           4000           4000           400           50           50           50           50           50           60           50           60           50           60           60           60           60           60           60	Frequency Range           [Hz]           < 2000	Max Force w/ Bias Offset *** 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Fmax, see referen DC Disp Range from ESD w/ Force Offset (m.pp) or (red.pp) 6.999E-07 4.365E-06 3.951E-06 8.352E-08 7.560E-08 8.352E-08 7.560E-08 5.282E-10	ce P1000032 below DC Disp. Range from ESD w/ Force (Inm.gp) of (mad.pp) 698.880 4385.312 3951.360 12.480 83.520 75.600 0.529		
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ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ETM / Acquire ITM / Acquire ETM / Low Noise ITM / Low Noise ITM / Low Noise ITM / Low Noise Longitudina Pitch Quits Longitudina Pitch Yaw Longitudina Pitch Yaw	DC Gain           (Differential in to Single-ended Out)           (Winde-ended Out)           (WV)           40           1.1           RM to TST Gap Size           [mm]           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           10           11           11           12           13           14           14 <td>DC Max Voltage Output V_p] 400 11 Actuation Strongth (all four quadrants) [NV^2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10 0.05E-12 1.20E-10 0.0026 0.116 0.105 0.0026 0.016 0.105 0.0026 0.016 0.116 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.0026 0.0026 0.016 0.0026 0.0</td> <td>DC Voltage Range           V. pp]           800           222           Max BIAS Voltage           400           400           11           11           11           11           11           11           11           0.14           0.14           1           0.15           0.16           0.14</td> <td>DC Voltage Range Requirement (V pp) 8000 300 Max QUAD Voltage (V p) 4000 4000 4000 4000 4000 4000 4000 40</td> <td>Content         Content         <t< td=""><td>Max Force w/ Bias Offset *** 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Frax, see referen DC Disp Range from ESD w/ Force Offset ((n-pp)) 6.989E-07 4.365E-06 3.951E-06 1.248E-08 8.352E-09 7.560E-08 5.265E-10 3.301E-09 0.0007 =7</td><td>ce P1000032 below DC Disp. Range from ESD w/ Force (mm pp) 0 (mad pp) 698.880 4.365.312 3.951.360 12.480 8.520 7.5600 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529</td><td></td><td></td></t<></td>	DC Max Voltage Output V_p] 400 11 Actuation Strongth (all four quadrants) [NV^2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10 0.05E-12 1.20E-10 0.0026 0.116 0.105 0.0026 0.016 0.105 0.0026 0.016 0.116 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.016 0.0026 0.0026 0.0026 0.016 0.0026 0.0	DC Voltage Range           V. pp]           800           222           Max BIAS Voltage           400           400           11           11           11           11           11           11           11           0.14           0.14           1           0.15           0.16           0.14	DC Voltage Range Requirement (V pp) 8000 300 Max QUAD Voltage (V p) 4000 4000 4000 4000 4000 4000 4000 40	Content         Content <t< td=""><td>Max Force w/ Bias Offset *** 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Frax, see referen DC Disp Range from ESD w/ Force Offset ((n-pp)) 6.989E-07 4.365E-06 3.951E-06 1.248E-08 8.352E-09 7.560E-08 5.265E-10 3.301E-09 0.0007 =7</td><td>ce P1000032 below DC Disp. Range from ESD w/ Force (mm pp) 0 (mad pp) 698.880 4.365.312 3.951.360 12.480 8.520 7.5600 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529</td><td></td><td></td></t<>	Max Force w/ Bias Offset *** 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Frax, see referen DC Disp Range from ESD w/ Force Offset ((n-pp)) 6.989E-07 4.365E-06 3.951E-06 1.248E-08 8.352E-09 7.560E-08 5.265E-10 3.301E-09 0.0007 =7	ce P1000032 below DC Disp. Range from ESD w/ Force (mm pp) 0 (mad pp) 698.880 4.365.312 3.951.360 12.480 8.520 7.5600 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529 3.301 0.529		
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ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Low Noise ITM / Acquire ETM / Low Noise ITM / Low Noise ITM / Low Noise ITM / Low Noise Units Degree of Freedom (DOF) Units Longitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Quant Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Congitudina Pitter Congitudina Pitter Congitudina Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Pitter Congitudina Congitudina Pitter Congitudina Pitter Congitudina Congitudina Pitter Congitudina Congitudina Pitter Congitudina Pitter Congitudina Congitudina Pitter Congitudina Pitter Congitudina Congitudina Congitudina Pitter Congitudina Congitudina Pitter Congitudina Congitudina Pitter Congitudina Congitudina Congitudina Pitter Congitudina Cong	DC Gain (DF Gain (DF Grant and the top of the second of	DC Max Voltage Output Voltage Output (V p) 400 11 Actuation Strongth (all four quadrants) (NV^2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 attractive and rep DC Compliance at Mass [(m/N) or (rad/N.m)] 0.0026 0.116 0.105 0.0026 0.116 0.105	DC Voltage Range           IV.ppl           800           22           Max BIAS Voltage           400           400           11           usive forces, we'           Lever Arm           In           0.14           0.15           0.14           0.15           0.15           0.15           0.15	DC Voltage Range Requirement. [V p] 8000 800 800 800 800 800 800 800 800 8	Frequency Range           [Hz]         < 2000	Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Fmax, see referen DC Disp Range from E5D w/ Force Offset (m_p.p) or (rad_p.p)] 6.989E-07 4.365E-06 3.951E-06 1.248E-08 8.8352E-08 5.285E-10 3.301E-09 2.988E-09 2.988E-09 9.438E-12 6.316E-11 5.717E-11	ce P1000032 below <b>DC Disp. Rango</b> <b>Ofsat</b> [(m.pp) or (nrad pp)] 698.880 4.936.312 3.951.360 1.2.480 8.5.522 7.5.600 0.529 3.301 2.988 0.009 0.063 0.057		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire ETM / Acquire ETM / Low Noise ITM / Low Noise ITM / Low Noise ITM / Low Noise Comparison of Preedom (DOF) Units Degree of Freedom (DOF) Units Longitudina Pitch Yaw Longitudina Pitch Yaw Longitudina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Stronget Actuation Strengths	DC Gain           (Differential in to Single-ended Out)           (Differential in to Single-ended Out)           (IVV)         40           1.1           RM to TST Gap Size           [Imm]         5           20         5           20         5           20         5           20         5           20         10           Stage / Driver         11           Stage / Driver         11           ETM / Acq.         ETM / Acq.           ITM / Acq.         ITM / Acq.           ITM / Low Noise         ETM / Low Noise           ITM / Low Noise         ITM / Low Noise           ITM / Low Noise         ITM / Low Noise           T1200311-v1         M090034-v4           T1200314-v1         M090034-v4	DC Max Voltage Output Voltage Output 11 Actuation four quadrants) four quadrants) fwv*2 4_20E-10 7.50E-12 6_20E-10 7.50E-12 7.50E-12 7.50E	DC Voltage Range           VP.pp1           800           222           Max BIAS Voltage           400           400           400           11           111           11           0.14           0.14           0.15           1           0.15           1           0.15           0.15           0.15	DC Voltage Range Requirement (V pp) 8000 300 Max QUAD Voltage (V p) 4000 4000 4000 4000 4000 4000 4000 40	Frequency Range           [Hz]           < 2000	Max Force w/ Bias Offset ***           IN p]         1.34E-04           2.40E-06         1.02E-07           1.02E-07         1.82E-09           Franx, see referen         500 France           DC Disp Range         7           from ESD w/ Force Offset         1099E-07           4.365E-06         3.951E-06           3.3951E-06         5.285E-10           3.301E-09         2.988E-09           9.438E-12         6.316E-11           5.717E-11         5.717E-11	ze P1000032 below <b>DC Disp. Range</b> <b>forn ESD w Porce</b> <b>offset</b> <b>(imr.gp) or</b> <b>(imr.gp) or</b>		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire ETM / Acquire ETM / Acquire ETM / Acquire ETM / Acquire ETM / Acquire TTM / Acquire ETM / Acquire TTM / Acquire ETM / Acquire Noise Degree of Freedom (DOF) Units Longitudina Pitch Quality Acquires Congitudina Pitch Congitudina Pitch Yaw References Doc Mongen Acquires Strengths OSEM for angent Acquires Strengths OSEM for angent Acquires Strengths OSEM for angent Acquires Strengths	DC Gain           OFG Gain           Single-ended Out)           VV           40           1.1           RM to TST Gap           Size           Imm]           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           10           11           12           11           12           11           11	DC Max Voltage Output Voltage Output 11 Actuation Strength (all four quadrants) (N/V^2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10 7.50E-12 (m/N) or (rad/N.m)] 0.0026 0.116 0.0026 0.116 0.105 0.0026 0.116 0.105	UC Voltage Range           [V. p]           8000           222           Max BIAS Voltage           4000           4000           4000           4000           400           400           400           400           400           400           400           400           400           400           400           400           400           400           400           11           0.14           0.15           0.15           0.15           0.15	DC Voltage Range Requirement [V p] 8000 300 Max QUAD Voltage (V p] 400 400 400 400 400 400 400 400 400 40	Frequency Range           [Hz]         < 2000	Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 Fmax, see referen DC Disp Range from SD w/ Force Offset [(m,pp) or (rad_pp)] 6.989E-07 1.248E-08 8.352E-00 3.301E-09 2.298E-09 9.438E-12 6.316E-11 5.717E-11	ce P1000032 below <b>DC Disp. Range</b> <b>from ESD w Force</b> <b>from ESD w Force</b> <b>from 25D w Force</b> <b>from 25D w Force</b> <b>from 200 of</b> <b>12 480</b> <b>4365 312</b> <b>3951 360</b> <b>12 480</b> <b>3951 360</b> <b>12 480</b> <b>3955 362</b> <b>75 600</b> <b>0 529</b> <b>3 3001</b> <b>2 988</b> <b>0 0.099</b> <b>0 0.063</b> <b>0 0.057</b> <b>09-06 mat</b>		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ITM / Acquire ITM / Acquire ETM / Acquire ETM / Acquire ITM / Acquire ETM / Acquire ITM / Acquire ITM / Acquire ETM / Acquire ITM	DC Gain           (Differential in to Single-ended Out)           (Differential in to Single-ended Out)           (IVV)         40           1.1           RM to TST Gap Size           [mm]         5           20         5           20         5           20         5           20         5           20         5           20         5           20         5           20         5           20         10           Stage / Driver         11           ETM / Acq.         ETM / Acq.           ETM / Low Noise         ETM / Low Noise           ITM / Low Noise         ITM / Low Noise           T1200311-v1         Mid9044-v3           Model:         Model:	DC Max Voltage Output Voltage Output (1) Actuation Strongth (all four quadrants) (mV×2) 4.20E-10 7.50E-12 6.20E-10 7.50E-12 6.20E-10 7.50E-12 6.20E-10 7.50E-12 6.20E-10 7.50E-12 8.20E-10 7.50E-12 7.50E	DC Voltage Range           V. ppl           800           222           Max BIAS Voltage           400           11           0.14           0.15           0.15           0.15           0.15           turk/CommenSus           rev/777	DC Voltage Range Requirement (V pp) 8000 300 Max QUAD Voltage (V p) 4000 4000 4000 4000 4000 4000 4000 40	Content         Content <t< td=""><td>Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 from ESD w/ Force Offset [(m,pp) or 6.999E-07 4.365E-06 3.951E-06 8.352E-08 7.560E-08 8.352E-08 7.560E-08 9.298E-09 9.4.38E-12 6.3.01E-09 2.988E-09 9.4.38E-12 6.3.16E-11 5.717E-11 5.717E-11</td><td>ce P1000032 below <b>DC Disp. Range</b> <b>from ESD wiferce</b> <b>(inrag pp) or</b> <b>(inrag pp)</b> <b>698.880</b> <b>4365.312</b> <b>3951.360</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>13.520</b> <b>13.520</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13</b></td><td></td><td></td></t<>	Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 from ESD w/ Force Offset [(m,pp) or 6.999E-07 4.365E-06 3.951E-06 8.352E-08 7.560E-08 8.352E-08 7.560E-08 9.298E-09 9.4.38E-12 6.3.01E-09 2.988E-09 9.4.38E-12 6.3.16E-11 5.717E-11 5.717E-11	ce P1000032 below <b>DC Disp. Range</b> <b>from ESD wiferce</b> <b>(inrag pp) or</b> <b>(inrag pp)</b> <b>698.880</b> <b>4365.312</b> <b>3951.360</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>12.480</b> <b>13.520</b> <b>13.520</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13.521</b> <b>13</b>		
ESD Driver Units Acquisition Driver (T 1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire ETM / Acquire ETM / Low Noise ITM / Low Noise ITM / Low Noise ITM / Low Noise Units Degree of Freedom (DOF) Units Longitudina Pitct Yaw Longitudina Pitct Yaw Longitudina Pitct Yaw References DAC Weigee OSEM and magnet details OSEM coliMagnet Actuation Strengths DC Compliances for longipticitysw	DC Gain           (Differential in to Single-ended Out)           (Differential in to Single-ended Out)           (IVV)           40           1.1           RM to TST Gap Size           [Imm]           5           200           5           201           5           202           6           7           8           7           10           ETM / Acq.           ETM / Acq.           ITM / Acq.           ETM / Low Noise           ITM / Colubra           Information           I Low Noise           ITM / Colubra           ID0014-3           ITM / Colubra           ID014-3           ID02014-3           ID0404-3           ID0504-3           ID0504-3	DC Max Voltage Output Voltage Output Voltage Output Strength (all four quadrants) [NV/v2] 4 20E-10 7.50E-12 4 20E-10 7.50E-12 4 20E-10 7.50E-12 4 20E-10 7.50E-12 4 20E-10 7.50E-12 4 20E-10 7.50E-12 4 20E-10 7.50E-12 4 20E-10 7.50E-12 0 0.026 0.0026 0.016 0.0026 0.	UC Voltage Range           IV. pp]           8000           222           Max BIAS Voltage           V. pl           4000           400           11           0.14           0.15           1           0.15           0.15           1           0.15           1           0.15           1           0.15           1           0.15           1           1           0.15	DC Voltage Range Requirement/ Ppp           Requirement/ Ppp           300           Max QUAD Voltage           400           50           400           400           51           52           52           52           62           62           62           62           62           62           62           62           62           62           62	Frequency Range           [Hz]           < 2000	Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 Fmax, see referen DC Disp Range from SD w/ Force Offset [(m,pp) or (rad_pp)] 6.989E-07 4.365E-06 3.951E-06 1.248E-08 8.352E-08 7.560E-08 5.255E-10 3.301E-09 2.988E-09 9.438E-12 6.316E-11 5.717E-11 rev3311 fiber 2012	ce P1000032 below DC Disp. Range from ESD w Force (mm_pp) or (mm_pp) or (		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above) ESD Pattern / Driver Units ETM / Acquire ETM / Acquire ETM / Low Noise ITM / Low Noise Longitudina Pitch Yaw Longitudina Pitch Yaw Longitudina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Yaw Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Congludina Pitch Congludina Congludina Pitch Congludina Congludina Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Pitch Congludina Congludina Pitch Congludina Congludina Congludina Pitch Congludina Congludina Pitch Congludina Conglu	DC Gain           (Differential in to Single-ended Out)           (Differential in to Single-ended Out)           (W)         40           1.1           RM to TST Gap Size           (mm)         5           20         5           20         5           20         5           20         5           20         20           In order to get both         5           ETM / Acq.         ETM / Acq.           ITM / Acq.         ITM / Acq.           ITM / Low Noise         ETM / Low Noise           ITM / Low Noise         ITM / Low Noise           T1200311-v1         M000034-v4           T1000164-16 - Wax         Noise:           Compliance =:         DC compliance =:	DC Max Voltage Output Voltage Output Voltage Output Voltage Output Voltage Output Voltage Output Voltage Volta	DC Voltage Range           V. ppl           8000           222           Max BIAS Voltage           4000           11           0.15           track CommonState           track CommonState           track CommonState           track CommonState           track CommonState           track CommonState	DC Voltage Range Requirement (V pp) 8000 300 Max QUAD Voltage (V p) 4000 4000 4000 4000 4000 4000 4000 40	Characterize           Frequency Range           [Hz]           < 2000	Max Force w/ Bias Offset *** 1.34E-04 2.40E-06 1.02E-07 from ESD w/ From ESD w	ce P1000032 below DC Disp. Range from ESD wire Porce (Inm. pp) or (Inma pp) (1988 880 43963 312 3961 360 12 480 13 480 0.529 3.301 2.988 0.009 0.063 0.057 09-06 mat		
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire ETM / Acquire ETM / Acquire ITM / Acquire ETM / Low Noise ITM / Low Noise ITM / Low Noise ITM / Low Noise Units Degree of Freedom (DOF) Units Longitudina Pitch Yaw Longitudina Pitch Yaw ColdMage details OEM and magnet details OEM and ma	DC Gain           (Differential in to Single-ended Out)           (Differential in to Single-ended Out)           (IVV)           40           1.1           RM to TST Gap Size           [Imm]           5           20           5           20           6           20           6           20           1           Stage / Driver           11           ETM / Acq.           ETM / Acq.           ITM / Acq.           ETM / Low Noise           ITM / Low Noise           ITM / Low Noise           ITM / Low Noise           ITM / Low Noise           T1200311-v1           Modeit           Parameters:           DC compliance ==           T06005/v1           Informed by response	DC Max Voltage Output	DC Voltage Range           V. ppl           8000           222           Max BIAS Voltage           V. ppl           4000	DC Voltage Range Requirement/ Ppp           Requirement/ Ppp           Max QUAD Voltage           V PJ           4000           3.494E-00           4.176E-00           3.168E-11           2.859E-11           ModelTageMattabe/           to best mass, L to I           /massborg Mm	Frequency Range           [Hz]         < 2000	Max Force w/ Bias Offset *** [N p] 1.34E-04 2.40E-06 1.02E-07 1.82E-09 Fmax, see referen DC Disp Range from ESD w/ Force Offset (m_pp) of (red_pp)] 6.999E-07 4.365E-06 3.951E-06 1.248E-08 8.352E-08 7.560E-08 5.285E-10 3.301E-09 2.988E-09 9.438E-12 5.717E-11 5.717E-11	ce P1000032 below DC Disp. Range from ESD w Porce (nrad_pp)] 0 6988.880 4365.312 3951.360 12.480 0.529 3.301 2.988 0.009 0.067 0.057 0.057 0.057 0.057		
ESD Driver Units Acquisition Driver (T1000220-y1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Low Noise ITM / Low Noise ITM / Low Noise ITM / Low Noise ITM / Low Noise Units Degree of Freedom (DOF) Units Longitudina Pitch Quits Longitudina Pitch Yaw Longitudina Pitch Yaw Longitudina Pitch Yaw Coll driver requirements Coll driver DG Transconductance Lever Ams	DC Gain           (Differential in to Single-ended Out)           (Differential in to Single-ended Out)           (W)           40           1.1           RM to TST Gap Size           [mm]           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           11           ETM / Acq.           TTM / Acq.           TTM / Low Noise           TTM / Low Noise           TTM / Low Noise           T1200311-v1           Model           Model	DC Max Voltage Output Voltage Output Voltage Output Voltage Output Control Voltage Output Control Voltage Volt	DC Voltage Range           V. ppl           800           222           Max BIAS Voltage           V. pl           400           400           400           11           11           11           0.14           0.14           0.15           1           0.15           1           0.15           1           0.15           1           0.15           1           0.15           1           0.15           0.15           0.15           0.15           0.16           0.17           0.18           0.19           0.19           0.15           0.15           0.15           0.15           0.16           0.17           0.18           0.19           0.19           0.10           0.11           0.12           0.15           0.15           0.16 </td <td>DC Voltage Range Requirement (V pp) 8000 300 Max QUAD Voltage (V p) 4000 4000 4000 4000 4000 4000 4000 40</td> <td>Frequency Range           [Hz]         &lt; 2000</td> < 2000	DC Voltage Range Requirement (V pp) 8000 300 Max QUAD Voltage (V p) 4000 4000 4000 4000 4000 4000 4000 40	Frequency Range           [Hz]         < 2000	Max Force w/ Bias Offset ***           Il.34E.04           2.40E.06           1.02E.07           1.82E.09           Franz, see referen           DC Disp Range           (rad pp))           6.999E.07           4.365E.06           1.24E.09           6.399E.07           4.365E.06           3.3951E.06           5.265E.10           3.301E.09           9.438E.12           6.316E.11           5.717E.11           s.717E.11	ce P1000032 below <b>fcm ESD wi Force</b> <b>(mm pp) or</b> <b>(mm pp) or</b> <b>(msd pp)</b> <b>(msd pp)</b>	dde (radialiy) of the refit	211)
ESD Driver Units Acquisition Driver (T1000220-y1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Acquire TTM / Acquire TTM / Acquire ETM / Acquire TTM / Acquire ETM / Acquire TTM / Low Noise TTM / Low Noise Complete of Freedom (DOP) Units Longitudina Pitch Yaw Longitudina Pitch Yaw Longitudina Pitch Yaw Coll driver requirements Coll Driver DC Transconductance Lower Arms Actuation Strength ne ESD Area	DC Gain           (Differential in to Single-ended Out)           (Differential in to Single-ended Out)           (IVV)           40           1.1           RM to TST Gap Size           [Imm]           5           200           5           201           1           Stage / Driver           [I           ETM / Acq.           ETM / Acq.           ITM / Acq.           ITM / Acq.           ITM / Low Noise           ETM / Low Noise           ITM / Low Noise           ITM / Low Noise           T1200311-v1           Model:           Parameters:           DC compliance ==           T000019-v1, Figure 4.	DC Max Voltage Output Voltage Output Voltage Output Voltage Output Voltage Output Acoustion Acoustion Acoustion Compliance Acoustion Co	DC Voltage Range           V. ppl           8000           222           Max BIAS Voltage           V. pl           4000           0.11           0.15           0.15           0.15           0.15           0.15           0.15           0.15           0.15           0.15           0.015           0.015           0.016           0.0172           0.0172           0.016	DC Voltage Range Requirement Requirement W pp]           8000           30           Max QUAD Voltage           Y pj           4000           4000           4000           4000           4000           4000           4000           4000           4000           4000           4000           4000           4000           4000           4000           4000           4000           400           10           50           400           400           10           5206-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1498-500           1400           1400 <td>Frequency Range           [Hz]         &lt; 2000</td> < 2000	Frequency Range           [Hz]         < 2000	Max Force w/ Bias Offset ***           [N p]         1.34E-04           2.40E-06         1.02E-07           1.02E-07         1.82E-09           Fmax, see referen         90           Force Offset (Im, pp) or (red, pp))         6.999E-07           4.365E-06         3.951E-06           3.951E-06         5.285E-10           3.301E-09         2.988E-09           9.438E-12         6.316E-11           5.717E-11         5.717E-11	ce P1000032 below <b>DC Disp. Range</b> <b>fom ESD W P07</b> <b>(trad p0)</b> <b>(trad p0)</b> <b>(t</b>	ddle (radially) of the patte	em)
ESD Driver Units Acquisition Driver (T1000220-v1) Low Noise Driver (T0900567, see above ESD Pattern / Driver Units ETM / Low Noise TTM / Low Noise Units Longitudina Degree of Freedom (DOF) Units Longitudina Pitch Quarter Statement Statements Coll driver requirements Coll driver CS Transconductance Lever Arms Achation strength for ESD drive Pask Voltage to Fingh Voltage ESD Driver	DC Gain           (Differential in to Single-ended Out)           (Differential in to Single-ended Out)           (W)           40           1.1           RM to TST Gap Size           [mm]           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           5           20           10           ETM / Acq.           TTM / Acq.           TTM / Low Noise	DC Max Voltage Output Actuation Strongth (all four quadrants) (IVV^2] 4.20E-10 7.50E-12 4.20E-10 7.50E-12 4.20E-10 0.7.50E-12 4.20E-10 0.50E-12 0.0026 0.116 0.105 0.0026 0.116 0.102 0.0026 0.116 0.102 0.0026 0.116 0.102 0.0026 0.116 0.102 0.0026	DC Voltage Range           V. pp)           800           222           Max BIAS Voltage           V. p)           400           400           400           11           Using Forces, we'           Lever Arm           Im)           0.14           0.15           0.15           0.15           0.16           0.17           0.18           0.19           1           0.15           0.15           0.15           0.16           0.17           0.18           0.19           0.19           0.19           0.19           0.19           0.19           0.19           0.19           0.19           11           0.19           11           0.19           11           0.19           11           0.19           11           0.19           11           11	DC Voltage Range Requirement (V p) 8000 300 Max QUAD Voltage (V p) 4000 4000 4000 4000 4000 4000 4000 40	Frequency Range           [Hz]         < 2000	Max Force w/ Bias Offset ***           N.pl         1.34E-04           2.40E-06         1.02E-07           1.32E-09         Fmax, see referen           DC Disp Rank         See referen           DC Disp Rank         See referen           DC Jisp Rank         See referen           0.93951E-06         1.248E-08           3.351E-00         2.988E-09           2.988E-09         2.988E-09           9.9438E-12         6.316E-11           5.717E-11         5.717E-11	ce P1000032 below <b>DC Disp. Range</b> from ESD wi Force (rom_pOTset (rom_pOT (rad_pO) 0698.880 4385.312 3951.360 12.480 83.520 3.301 2.988 0.009 0.063 0.057 99-95.mat ar arm for ESD is in the mil	ddle (radially) of the patt	em)

Figure 1: Explicit actuation range calculation at DC for aLIGO QUAD Suspension. As this calculation is prone to erroneous factors of two everywhere (differential vs. single ended, peak vs. peak-to-peak, etc.), the calculation is shown explicitly from both the maximum displacement (peak) and displacement range (peak-to-peak). Note that maximum, peak values are denoted with subscript "p," and range, peak-to-peak values are denoted with subscript "pp." Similar results from -v1 of this document should be compared against the peak-to-peak range. 3

# 4 Single-Actuator Actuation Strength

### 4.1 ITM, High-Range Configuration



### 4.2 ITM, Low-Noise Configuration



## 4.3 ETM, High-Range Configuration



#### 4.4 ETM, Low-Noise Configuration



## 5 Mechanical Transfer Functions



QUAD Transfer Function, P to P Response at Optic to Drive at Each Stage 10<sup>1</sup> M0:0.037477 [rad/N.m] @ DC MODL1 : 0.051752 [rad/N.m] @ DC 10<sup>0</sup> L2 : 0.097029 [rad/N.m] @ DC L3 : 0.14126 [rad/N.m] @ DC 10  $10^{-2}$ Magnitude [rad/N.m] 10 10 10<sup>-5</sup> 10-6 10 10 -2  $10^{-1}$ 10<sup>0</sup> 10<sup>1</sup> Frequency [Hz] 10<sup>2</sup> 10<sup>3</sup> 10<sup>4</sup> 10



# 6 Frequency-dependent Maximum Displacement

### 6.1 ETM, High-Range Configuration









6.2 ETM, Low-Noise Configuration





6.3 ITM, High-Range Configuration





6.4 ITM, Low-Noise Configuration



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