Appendix-1

Specifications – Types 4394 and 4397-A

Type No.			4394*	4397-A*
General				
Weight (excluding cable, wherever applicable)		gram	2.9	2.4
		oz	0.102	0.085
Voltage Sensitivity (at 159.2 Hz and 4 mA supply current)		mV/ms^{-2}	1 ±2%	
		mV/g	9.8 ±2%	
Frequency Range	Amplitude (±10%)	Hz	1 to 25000	
	Amplitude (±5%)	Hz	1 to 10000	
	Phase (±5°)	Hz	4 to 2500	
Mounted Resonance Frequency		kHz	52	53
Max. Transverse Sensitivity (at 30 Hz, 100 ms^{-2})		%	<4	
Transverse Resonance Frequency		kHz	15	17
Measuring range (± peak)		kms^{-2}	5 (7.5 when T <100 °C)	
		g	500 (750 when T <100 °C)	
TEDS			No	
Electrical				
Bias Voltage	at 25 °C and 4 mA	V	12 ±0.5	
	at full temp. and curr. range		8 to 15	
Power Supply	Constant current	mA	2 to 10 (2 to 20 mA if T <100 °C)	
	Unloaded supply voltage	V	24 to 30	
Output Impedance		Ω	100	
Start-up time (to final bias ±10%)		s	<5	
Residual Noise (inherent RMS broadband noise in the specified frequency range)		µV	<25	<15
		µg	<2500	<1500
Noise Spectral	10 Hz	$mms^{-2}/\sqrt{Hz}$ (µg/√Hz)	1.3 (130)	0.79 (79)
	100 Hz		0.45 (45)	0.21 (21)
	1000 Hz		0.17 (17)	0.14 (14)
Environmental				
Operating Temperature Range		°C	−50 to +125	
		°F	−58 to +257	
Temperature Coefficient of Sensitivity		%/°C	0.04	0.05
Temperature Transient Sensitivity (3 Hz Lower Limiting Freq. (−3 dB, 6 dB/oct))		ms^{-2}/°C	2	
		g/°F	0.11	
Magnetic Sensitivity (50 Hz, 0.038 T)		ms^{-2}/T	10	50
		g/kGauss	0.1	0.5
Base Strain Sensitivity (at 250 µε in base plane)		$ms^{-2}/\mu\varepsilon$	0.005	
		g/µε	0.0005	
Max. Non-destructive Shock (± peak)		kms^{-2}	100 (axial), 50 (transverse)	
		g	10000 (axial) 5000 (transverse)	
Mechanical				
Case Material			Titanium ASTM Grade 2	
Piezoelectric Sensing Element			PZ 23	
Construction			DeltaShear	
Sealing			Welded	
Electrical Connector			Coaxial M3	
Mounting			M3 × 2 mm threaded hole	M3 × 2.4 mm threaded hole
Mounting Torque		Nm (lbf-in)	Max. 0.6 (5.3), Min. 0.2 (1.8)	

* All values are typical at 25 °C (77 °F) unless otherwise specified

COMPLIANCE WITH STANDARDS

Ordering Information

Type 4394
includes the following accessories:
- Carrying Box
- Calibration Chart
- AO-1381-D-012: Cable M3 (M) to 10−32 UNF (M), 1.2 m, 250 °C (482 °F)
- 3×YS-8321: Steel stud with flange, M3/M3, 3.5 mm

Type 4397
includes the following accessories:
- Carrying Box
- Calibration Chart
- AO-1381-D-012: Cable M3 (M) to 10−32 UNF (M), 1.2 m, 250 °C (482 °F)
- 4×YS-8321: Steel stud with flange, M3/M3, 3.5 mm

Type 4397-A
includes the following accessories:
- Carrying Box
- Calibration Chart
- 1×YS-8321: Steel stud with flange, M3/M3, 3.5 mm

Optional Accessories	
AO-0283	Super low-noise coaxial cable, M3 to 10−32 UNF, 250 °C (482 °F)
AO-0339	Flexible low-noise coaxial cable, M3 to 10−32 UNF, 250 °C (482 °F)
AO-1381	Flexible double-screened low-noise coaxial cable, M3 to 10−32 UNF, 250 °C (482 °F)
AO-0641	Low-cost coaxial cable, M3 to BNC, 90 °C (194 °F)
AO-0698	Super low-noise coaxial cable, M3 to SMB, 250 °C (482 °F)
UA-0867	25 × cement stud, M3, 8.0 mm dia.
UA-0186	25 × extension connector 10−32 UNF
UA-1075	5 × mounting magnet
UA-1221	25 × steel stud with flange, M3/M3, 3.5 mm
WA-0224	Mechanical filter
JP-0145	Plug adaptor, BNC/10−32 UNF
QA-0041	Tap for M3 thread
QA-0042	Hexagonal key for M3 studs
QS-0007	Tube of cyanoacrylate adhesive
YJ-0216	Beeswax for mounting
Type 4397-A only	
UA-1193	10 × insulated stud, M3/M3, 2.4 mm
YQ-2003	M3 threaded steel stud, 5 mm
YQ-2007	M3 threaded steel stud, 8 mm
Calibration Services*	
439x-CAF	Accredited calibration
439x-CAI	Accredited initial calibration
439x-CFF	Factory standard calibration
439x-CTF	Traceable calibration

* x = 4 or 7

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	S1	S2			*S1 [pC/N]*	*S2 [pC/N]*

Appendix-2:

AVERAGE	12,92	12,98		Mean	12,92	12,98
STANDARD DEVIATION	0,260089	0,290512		Standard Error	0,08	0,09
SAMPLE SIZE	10	10		Median	12,97	12,98
CONFIDENCE COEFFICEINT	1,96	1,96		Standard Deviation	0,26	0,29
MARGIN OF ERROR	0,161205	0,180061		Sample Variance	0,07	0,08
UPPER BOUND	13,09	13,16		Kurtosis	4,00	2,31
LOWER BOUND	12,76	12,80		Skewness	-1,63	-0,90
MAX	13,26	13,41		Range	0,97	1,08
MIN	12,29	12,33		Minimum	12,29	12,33
RANGE	0,97	1,08		Maximum	13,26	13,41
				Sum	129,25	129,76
				Count	10,00	10,00
				Confidence Level(95.0%)	0,19	0,21

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0,863291
R Square	0,745272
Adjusted R Square	0,713431
Standard Error	16,20767
Observations	10

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6148,491	6148,491	23,40601	0,001291
Residual	8	2101,509	262,6886		
Total	9	8250			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-1243,88	268,53	-4,63	0,00	-1863,10	-624,66	-1863,10	-624,66
S1 [pC/N]	100,49	20,77	4,84	0,00	52,59	148,39	52,59	148,39

Appendix-3:

Characterization of Piezoelectric Wafer Active Sensors

Property	Unit	Symbol	APC-840	APC-841	APC-880	APC-850	APC-855	APC-856
Relative dielectric constant	1	$\varepsilon_{33}^{T}/\varepsilon_0$	1250	1350	1000	1750	3250	4100
Dissipation factor measured: C 1 kC@ low field	%	$\tan\delta$	0.4	0.35	0.35	1.4	2	2.7
Curie temperature	°C	T_c	325	320	310	360	195	150
Coupling coefficient	1	k_p	0.59	0.60	0.50	0.63	0.65	0.65
		k_{31}	0.72	0.68	0.62	0.72	0.74	0.73
		k_{33}	0.35	0.33	0.30	0.36	0.38	0.36
		k_{15}	0.70	0.67	0.55	0.68	0.66	0.65
Piezoelectric coefficient	10^{-12} C/N	d_{33}	290	275	215	400	580	620
	or	$-d_{31}$	125	109	95	175	270	260
	m/V	d_{15}	480	450	330	590	720	710
Piezoelectric coefficient	10^{-3} V-m/N	g_{33}	26.5	25.5	25	26	19.5	18.5
	or	$-g_{31}$	11	10.5	10	12.4	8.8	8.1
	m²/C	g_{15}	38	35	28	36	27	25
Young's modulus	10^{10} N/m²	Y_{11}^{E}	8	7.6	9	6.3	6.1	5.8
		Y_{11}^{D}	6.8	6.3	7.2	5.4	4.8	4.5
Frequency constants								
L = longitudinal mode	Hz-m	N_t	1524	1700	1725	1500	1475	–
T = thickness mode	or	N_t	2005	2005	2110	2032	1930	1980
R = radial mode	m/s	N_p	2130	2055	2080	1980	1980	–
Elastic compliance	10^{-12} m²/N	s_{11}^{E}	11.8	11.7	10.8	15.3	14.8	15.0
		s_{11}^{D}	17.4	17.3	15.0	17.3	16.7	17.0
Density	g/cc	ρ	7.6	7.6	7.6	7.7	7.5	7.5
Mechanical quality factor	1	Q_m	500	1400	1000	80	75	72

Table 3 Peaks of the admittance and impedance real-part plots; numerical simulation of a PZT active sensor with l = 7 mm, b = 1.68 mm, t = 0.2 mm. APC-850 piezoceramic, $\sigma = \zeta = 1\%$

Mode No.	1	2	3	4	5
Slightly damped resonance frequencies, f_r, kHz	208.059	624.17	1040.29	1456.41	1872.54
Undamped resonance frequencies, f_{r0}, kHz	208.056	624.16	1040.28	1456.39	1872.51
Error in f_r vs. f_{r0}, %	0.0014%	0.0016%	0.0010%	0.0014%	0.0016%
Slightly damped anti-resonance frequencies, f_a, kHz	219.89	628.35	1042.84	1458.26	1873.99
Undamped anti-resonance frequencies, f_{a0}, kHz	219.88	628.32	1042.78	1458.18	1873.90
Error in f_a vs. f_{a0}, %	0.0045%	0.0048%	0.0058%	0.0055%	0.0048%

Figure

Caption

Table 2 Properties of piezoelectric ceramic APC-850 (as from the company website www.americanpiezo.com)