HASI ACC Data Processing and Calibration Report

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1. Acronyms

ACC	Accelerometer Subsystem
COG	Center of Gravity
DDB	Data Distribution Broadcast
Piezo, PZR	ACC piezoresistive accelerometer
S/W	Software
Temp1	temperature sensor of XServo
Temp2	temperature sensor of Piezos
XServo	ACC Servo accelerometer

2. Scope of the document

Scope of the document is to report on the procedure and results of the calibration of the HASI ACC Sensors and to present guidelines for the data process and the reconstruction of the acceleration measurement.

3. Applicable and Reference documents

[AD1] Cassini Mission Huygens Probe Huygens Atmospheric Structure Instrument – **HASI Accelerometer subsystem Flight Model Acceptance Data Package** (ACC FM ADP) PY-HASI-UKC-AD-003 (II/209.B.6)

[AD2] HASI Experiment Flight User Manual Document HASI-MA-OG-002 Issue 3, 1 December 1998 (II/196.B.6)

[AD3] HASI DPU Software User Requirements Document HASI-SP-OG-004, Issue 7, 7 Sep 1995 (II/179.B.1)

[AD4] HASI Accelerometer Subsystem Conversion Relations – Flight Model (ACC-3), HASI-ACC-FM-EQ-1.0 (II/239.B.6)

[AD5] HASI DPU subsystem Proto- Flight Model Summary Report HASI-RP-OG-047 Issue 1 04/06/96 (II/188.C.4)

[RD1] Zarnecki, J.C., F. Ferri, B. Hathi, M.R. Leese, A.J. Ball, G. Colombatti, M. Fulchignoni,. **In-Flight Performance of the HASI Accelerometer and Implications For Results at Titan,** Proceedings of *International Workshop 'Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science'*, October 6 - 9, 2003 Lisbon, Portugal, *ESA-SP-**544***, February 2004.

[AD6] Huygens Probe Data for post flight analysis
HUY-ASP-MIS-TN-0006 Issue 1, 3 June 2005

4. ACC description

The Accelerometer subsystem (ACC) is placed at the centre of mass of the descent module of the Probe. It consists of one highly sensitive single axis accelerometer (**Xservo**)) and three piezoresistive accelometer (**X, Y, Z piezo**), their conditioning electronics and two temperature sensors (**Temp1** and **Temp2**) used for thermal compensation. The Xservo accelerometer output is amplified providing two channels (HIGH and LOW Gain). Each channel has a switchable range (HIGH and LOW Resolution) which is set autonomously (HIGH Range set at startup and swithched on LOW Range prior saturation or anyhow after Tdata (T0+10s)). Xservo channel selection is performed autonomously by checking the measured value against a setable threshold.

Table 1. ACC characteristics and performance.

X-axis servo accelerometer (along Probe path)
High resolution setting
Range: 2-20 mg
Resolution: 1-10 μg
Low resolution setting
Range: 1.85-18.5 g
Resolution: 0.9-9 mg
Relative accuracy: 1 % of full scale

X/Y/Z-axis piezoresistive accelerometers
Range: +- 20 g
Resolution: +- 15 mg

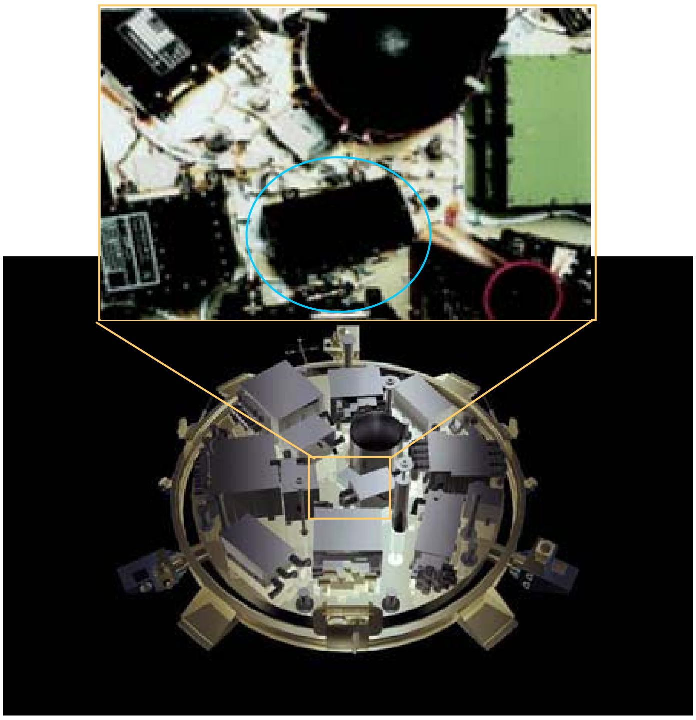


Fig. 1 ACC subsystem as accommodate on the Huygens experiment platform

4.1. ACC location and accommodation

ACC is placed as close as possible to the center of gravity (CoG) of the Huygens entry module (seismic mass of the XServo should be within a sphere of 3 mm-radius [AD2]). The ACC box is attached to Huygens' experiment platform with four cap head bolts. Its footprint, for mounting purposes, is a 60x80 mm rectangle centred on, and orthogonal, to Huygens' X-axis.
The XServo accelerometer is aligned with the Probe X axis. The three piezoresistive accelerometers are sensitive to the acceleration in one of the X/Y/Z-Probe's axes. ZPiezo accelerometer axis is antiparallel to the Huygens Z axis.

Location of ACC sensors wrt Huygens entry Probe CoG:

ACC box CoG wrt ACC reference hole [AD1] *and as reported in HASI IDS for ACC*
X_{ACC}=32 ±1 mm
Y_{ACC}=27 ±1 mm
Z_{ACC}=-33.5 ±1 mm

Position of sensor wrt ACC reference hole [AD1]

	X'	Y'	Z'	[mm]
XServo seismic mass centroid	15.64	23.5	-33.5	
XPZR seismic mass centroid	15.5	36.54	-46.54	
YPZR seismic mass centroid	15.7	9.19	-47.81	
ZPZR seismic mass centroid	15.7	9.19	-19.19	

as reported in the ACC Interface Data Sheet (drawing PY-HASI-UKC-D/AS0039)

Note: ACC as close as possible to Probe CoG in entry phase configuration. XServo seismic mass should be within a 3 mm sphere radius [AD2]. Offsets/displacements between ACC XServo seismic mass and Probe CoG (in entry configuration) should be known with an accuracy better than 10% (e.g. 0.3 mm on a 3 mm offset) also in Y and Z axes to better characterize the Probe oscillations [AD2].

Probe Mass and CoG evolution [RD2]

Event	Mass (kg)	Mass without MLI(kg)	CoG position (mm)		
			X	Y	Z
begin Entry	318,62	318,62	75,44	1,75	5,38
end Entry	309,72	305,522	82,54	2,48	5,13
Main+Front shield	287,6	285,66	65,19	2,64	5,46
Main-Front shield	206,91	206,91	81,33	3,67	1,17
Stabiliser parachute	201,51		71,83	-0,52	3,68
without Stabiliser parachute	200,48		69,22	-1,46	5,46

Position of ACC reference hole wrt Probe axes (Probe absolute reference)
X=53,8 mm
Y=-7,1 mm
Z=40,3 mm
[as from table in Aerospatiale drawing "Experiment platform layout" 6/01/94]

ACC sensors Offset/displacement from Probe CoG (in [mm])

XServo	X	Y	Z	mission time
begin Entry	-6	14,65	1,42	preT0
end entry	-13,1	13,92	1,67	T0
Main+Front shield	4,25	13,76	1,34	T0+2.5s
Main-Front shield	-11,89	12,73	5,63	T0+32.5s
Drogue+Drogue	-2,39	16,92	3,12	T0+900s
descent module	*0,22*	*17,86*	*1,34*	*N/A*

XPiezo	X	Y	Z	mission time
begin Entry	-6,14	27,69	-11,62	preT0
end entry	-13,24	26,96	-11,37	T0
Main+Front shield	4,11	26,8	-11,7	T0+2.5s
Main-Front shield	-12,03	25,77	-7,41	T0+32.5s
Drogue+Drogue	-2,53	29,96	-9,92	T0+900s
descent module	*0,08*	*30,9*	*-11,7*	*N/A*

YPiezo	X	Y	Z	mission time
begin Entry	-5,94	0,34	-12,89	preT0
end entry	-13,04	-0,39	-12,64	T0
Main+Front shield	4,31	-0,55	-12,97	T0+2.5s
Main-Front shield	-11,83	-1,58	-8,68	T0+32.5s
Drogue+Drogue	-2,33	2,61	-11,19	T0+900s
descent module	*0,28*	*3,55*	*-12,97*	*N/A*

ZPiezo	X	Y	Z	mission time
begin Entry	-5,94	0,34	15,73	preT0
end entry	-13,04	-0,39	15,98	T0
Main+Front shield	4,31	-0,55	15,65	T0+2.5s
Main-Front shield	-11,83	-1,58	19,94	T0+32.5s
Drogue+Drogue	-2,33	2,61	17,43	T0+900s
descent module	*0,28*	*3,55*	*15,65*	*N/A*

P.S. Requirement to have ACC XServo seismic mass within a 3 mm sphere centred in Probe CoG seems to not be respected.

The two ACC temperature sensors are fixed one inside the servo accelerometer case (Temp 1) and one attached to the aluminium alloy accelerometer mounting block (Temp 2).

4.2. Measurement principle and data sampling

The **servo accelerometer** (Sundstrand QA-2000-030) senses the displacement of a seismic mass and drives it back to a null position. The required current is a direct measurement of the acceleration.
The X-axis servo accelerometer's output is conditioned and amplified by two non-inverting amplifiers, one with a gain of 1 and the other with 10. They provide the two X-axis servo channel outputs.
Besides these two channels, the servo's range is switchable between high resolution and low resolution ranges, achieved by switching the output of the servo accelerometer (a current) between two load resistors by using a single analogue switch.
The **piezoresistive accelerometer** (ENDEVCO 7264A-2000T) consists of a suspended silicon seismic mass supported by two strain-dependent resistances. The accelerometer is incorporated in a Wheatstone bridge; a small output voltage dependent on acceleration is produced when an external voltage is applied. Temperature is measured by an AD 590 sensor included in the servo package. Temperature variations are measured by an AD 590 sensors (**Temp1** and **Temp2**), respectively monitoring XServo and Piezos temperature for compensation.

ACC has in total 7 channels, each channel is sampled at 400 Hz. The data are processed with a lower rate by extracting one every 'n' samples.
The ACC channels and their sampling rate:

- Xservo LOW gain	at 100 Hz
- Xservo HIGH gain	at 100 Hz
- Xpiezo	at 50 Hz
- Ypiezo	at 50 Hz
- Zpiezo	at 50 Hz
- Temp 1 (Tservo)	at 1.5625 Hz
- Temp 2 (Tpiezo)	at 1.5625 Hz

Values are arithmetically averaged by the HASI onboard S/W to produce lower sampling rates.
For acceleration there are two types of data: 'raw' and statistic data. Statistic data are obtaining by integrating over a statistic time period (0.1 Hz) taking one sample every 32 from the 400 Hz samples.

4.3. Operational modes

HASI starts to sample ACC sensors during entry at TACC= -0:21:30 preT0 (DDB time, since probe ON). ACC data are stored in a telemetry queue for later transmission, till when the Probe relay link is set (TdataH=T0+0:02:30).
ACC data are continuously sampled and transmitted till impact detection state.
IMPACT state devoted to Probe impact detection and starts at 1 km latitude (triggered by DDB information). No ACC data transmitted until SURFACE state. During this state the 400 Hz XServo

low gain values are quadratic filtered to compare to a threshold value in order to detect the impact (threshold value in HASI S/W set to 2.3 V corresponding to ~3.99 g= 39 m/s2).
The impact trace is constructed from the 200Hz Piezos data corresponding to a period of .5 s before impact and 5.5 s after detection.

ACC channels readouts are summed in order to get the following sampling rate:

ACC Xservo	3.125 Hz	in ENTRY; from Tacc till T0+10 s
	4.167 Hz	till T0+32 min (=Tradar) DESCENT 1&2 states
	1.754 Hz	till last km (~132 min) Impact detection DESCENT 3& SURFACE state
ACC X, Y, Z piezo	1.6129 Hz	in ENTRY and last km and in Surface state
Startistics	0.1 Hz	always, except in impact detection
ACC Servo & piezo Temperature	0.097 Hz	always, except in impact detection

Impact trace (0.5 s before & 5.5 s after impact)
X piezo 200 Hz
Y piezo 200 Hz transmitted after Timpact
Z piezo 200 Hz
p.s. NO ACC data are transmitted during impact phase

4.4. Telemetry output

ACC telemetry data are organized in telemetry (TM) packets per sensor, mode and data type:

Data format	Format name	Content
#32	ACC XServo ENTRY (3.125 Hz)	sum of 32 samples at 100 Hz ENTRY
#33	ACC XServo DESCENT (4.167 Hz)	sum of 24 samples at 100 Hz DESCENT1&2
#34	ACC XServo RADAR (1.754 Hz)	sum of 57 samples at 100 Hz DESCENT3 & SURFACE
#35	ACC X Piezo (1.6129 Hz)	sum of 31 samples at 50 Hz only in ENTRY
#36	ACC Y Piezo (1.6129 Hz)	sum of 31 samples at 50 Hz only in ENTRY
#37	ACC Z Piezo (1.6129 Hz)	sum of 31 samples at 50 Hz only in ENTRY
#38	ACC XServo T (Temp1) (0.098 Hz)	sum of 16 samples; always except in IMPACT
#39	ACC Piezo T (Temp2) (0.098 Hz)	sum of 16 samples; always except in IMPACT
#40	ACC XServo Statistics (0.1 Hz)	sum of 128 samples @ 12.5 Hz, except in IMPACT
#41	ACC XPiezo Statistics (0.1 Hz)	sum of 128 samples @ 12.5 Hz, except in IMPACT
#42	ACC YPiezo Statistics (0.1 Hz)	sum of 128 samples @ 12.5 Hz, except in IMPACT
#43	ACC ZPiezo Statistics (0.1 Hz)	sum of 128 samples @ 12.5 Hz, except in IMPACT
#48	ACC X Piezo impact trace	200 Hz impact trace data of X Piezo
#49	ACC Y Piezo impact trace	200 Hz impact trace data of Y Piezo
#50	ACC Z Piezo impact trace	200 Hz impact trace data of Z Piezo

Each TM packet is time stamped with mission time (=DDB time) when the first data is written in Time relevant to each data value is derived from the packet time stamp and the ACC sampling rate of the relevant data format.

5. Pre-flight calibration

5.1. Static calibration

For ACC sensor data sheet and calibration data refer to ANNEX 1 and ANNEX 2.
At subsystem level:

- ACC calibration at ±1 g by rotation of 180° performed at UKC
  (ref. PY-HASI-UKC-FMQFS-036 15/05/1995 contained into HASI ACC FM APD PY-HASI-UKC-AD-003, II/209.B.6)

5.2. Dynamic calibration

Tests performed at subsystem level and system level at ground (AIV-AIT):

At subsystem level:

- ACC PZR calibration by pendulum motion UKC
  (ref to M. Patel's Master Thesis HASI_ACC_Manish_MPhysproject.pdf)
- Impact tests UKC
- ACC displacement tests at UPD

At System level:

- HASI ACC FM Special Test (SET) rotating the Probe dolly
  - DASA 1/08/1995 (HASI-RP-OG-034 II/169.B.6)
  - DASA 31/10/1996 rotation around Z-axis only during DPU reintegration
  - DASA 3-4/03/1997 after ACC box moved closer to Probe CoG (HASI-RP-UPD-?)

6. In-flight Calibration

During the cruise phase HASI experiment and the Huygens probe have been switched on regularly for performing in-flight CheckOut (CO). These COs have been performed approximately every 6 months since launch, to test the probe and its subsystems during simulated entry, descent and surface proximity phases and also to upload S/W patches.
These in-flight checkouts were useful for checking the ACC performance and monitoring any drift in the accelerometer outputs due to ageing or any degradation. Specifically in-flight data have been used in order to monitor the offset at zero g of the ACC sensor and estimate the long-term stability in the zero offset [RD1]. Analysis of the In-flight CO data has demonstrated that the offset in zero g of the XServo in high resolution range has varied within a range of 4 µg (~39 m/s^2) [RD1]. The zero offset of the XServo will be estimated from the first measurements (at ~ 1900 km) recorded during the mission at Titan (when the Probe will be still outside Titan's atmosphere).
Comparison with similar instrumentation flown on probes and landers of other missions shows that ACC XServo is the one of the most sensitive and stable sensor launched to date.

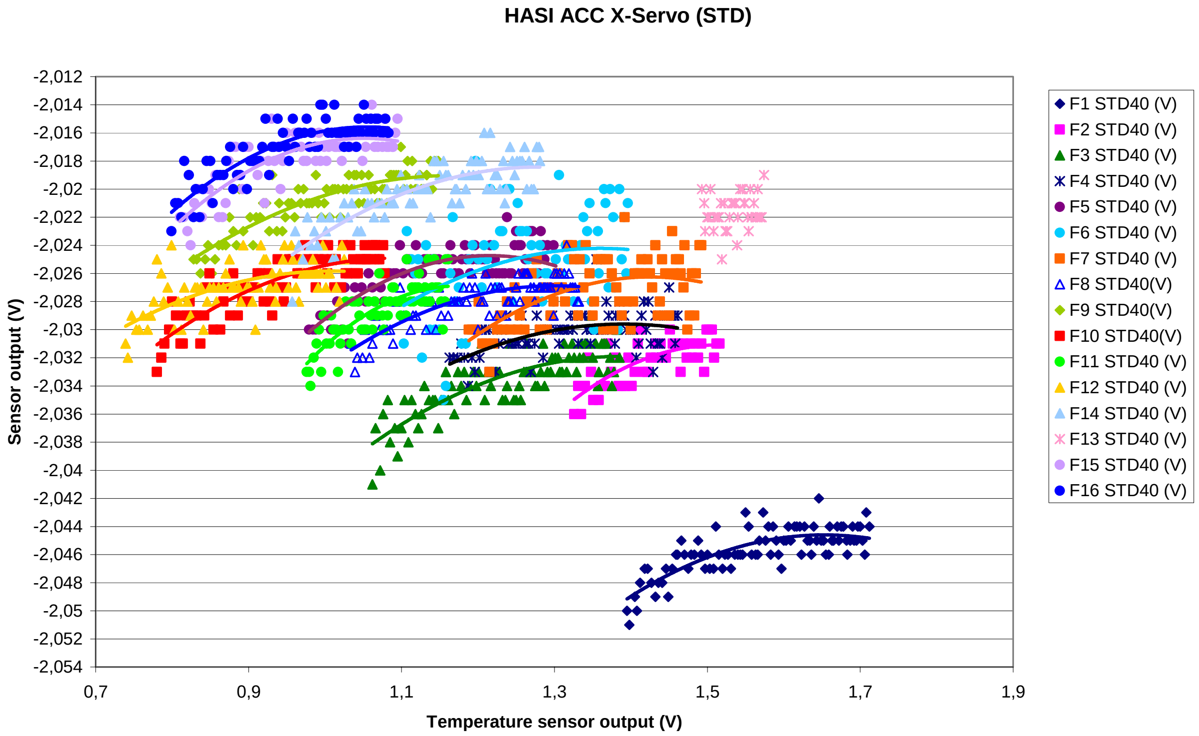


Fig. 2 ACC Servo output vs. temperature (in engineering units) for all the in-flight checkouts, plus second-order polynomial fits.

<u>ACC XServo offset at zero g</u>

CO	**(V)**	**(µg)**	**(m/s2)**
F1	-2,04567	9,09	8,9146E-05
F2	-2,03229	11	0,00010788
F3	-2,03371	9,56	9,3756E-05
F4	-2,03363	10,8	0,00010592
F5	-2,03359	10,7	0,00010494
F6	-2,03351	11,4	0,0001118
F7	-2,03348	11,6	0,00011376
F8	-2,03346	10,5	0,00010297
F9	-2,03341	10,8	0,00010592
F10	-2,03337	9,32	9,1402E-05
F11	-2,0333	9,68	9,4933E-05
F12	-2,03325	9,06	8,8852E-05
F13	-2,03323	10,1	9,9052E-05
F14	-2,03317	11,7	0,00011474
F15	-2,03314	11,2	0,00010984
F16	-2,03311	11,3	0,00011082

(values reported are averages of standard data in High range, High gain).

7. Post Flight calibration

The **zero offset** of the ACC sensors has been estimated looking at the first measurements recorded during the mission at Titan (before the atmospheric entry).
The ACC **Xservo** zero offset has been calculated averaging the values (256) recorded during the first 81s of measurements (when the Probe was still outside the atmosphere). This value is -**2.2654E-5 m s^{-}2** (corresponding to -2.045 V) and has been subtracted to the ACC Xservo measurements.
The high sensitivity of the Xservo allowed detecting pre-entry oscillations due to the coning of the Probe. The pre-entry oscillations observed in the Xservo data can be fitted by:

a_XServo(t)=Acos(2πf(t-t_0)+ε)
where A = 1.8E-5 m s^{-2}, f = 0.085 Hz a and ε ≈ 1 radiant. 1/f is the period of the oscillation that corresponds to 38 Xservo measurements.

The zero offsets of the **Xpiezo**, **Ypiezo**, and **Zpiezo** sensors, based on analysis of their measurements before atmospheric entry (values derived as average on the first 60 s of sampling) are **0.1967 m s-2** (3.980 V), **0.1286 m s-2** (-1.453 V), and **1.2282 m s-2** (2.876 V), respectively.

8. ACC total error budget

Absolute accuracy:
Temp ±0.5 K
XServo ±35 μg (in high resolution, high gain)
Piezos= ±0.4 g

Resolution
Xservo 1-10 μg depending on mode
Piezo 0.1 g

ACC uncertainty is 1% of full scale.

ACC XServo uncertainty

Ranges	*Acceleration limits (m/s2)*	*Uncertainty (m/s2)*
High Resolution / High Gain	20 E-3	20 E-5
High Resolution / Low Gain	200 E-3	200 E-5
Low Resolution / High Gain	20	0.2
Low Resolution / Low Gain	200	2

9. ACC data processing: Engineering value reconstruction

In every packet for every data format are contained:

Data Format:	Sensor	Data Field Content:
# 32	Xservo Entry	52 XServo subfields of 16 bit (1 word) each 2 FLAG subfields of 1 bit each
# 33	Xservo Descent	52 XServo subfields of 16 bit (1 word) each

		2 FLAG subfields of 1 bit each
#34	Xservo Radar	52 XServo subfields of 16 bit (1 word) each 2 FLAG subfields of 1 bit each
#35	XPiezo	56 XPiezo subfields of 16 bit (1 word) each
# 36	YPiezo	56 YPiezo subfields of 16 bit (1 word) each
#37	ZPiezo	56 ZPiezo subfields of 16 bit (1 word) each
#38	Temp1 (HKD1)	56 Temp1 subfields of 16 bit (1 word) each
#39	Temp2 (HKD2)	56 Temp2 subfields of 16 bit (1 word) each
#40	Xservo statistics	37 Xservo statistics subfields of 24 bit each
#41	XPiezo statistics	37 XPiezo statistics subfields of 24 bit each
#42	YPiezo statistics	37 YPiezo statistics subfields of 24 bit each
#43	ZPiezo statistics	37 ZPiezo statistics subfields of 24 bit each
#48	Impact trace XPiezo	56 XPiezo subfields of 16 bit (1 word) each
#49	Impact trace YPiezo	56 YPiezo subfields of 16 bit (1 word) each
#50	Impact trace ZPiezo	56 ZPiezo subfields of 16 bit (1 word) each

The packet data field layout are:

For data formats #32 (SCDS.E) , #33 (SCDS.R), #34 (SCDS.R)

word 0	SCDS.E #0		
word 1	….		
….			
word 51	SCDS.E #51		
word 52	#15	#0	
word 53	#31	#16	SCDS.E FLAG
word 54	#47	#32	
word 55	UNUSED	#51 #48	

For data formats #35 (SCDP.X) , #36 (SCDP.Y), #37 (SCDP.Z)

word 0	SCDP.X
word 1	….
….	…..
word 55	SCDP.X

For data formats #38 (HKD1) , #39 (HKD2)

word 0	HKD1
word 1	….
….	…..
word 55	HKD1

For data formats #40 , #41 , #42, #43

word 0	S1a	S0a
word 1	S0b	S2a
Word 2	S2b	S1b
…	…	…
word 55	UNUSED	S2z

For data formats #48 (ID1) , #49 (ID2), #50 (ID3)

word 0	ID1
word 1	….
….	…..
word 55	ID1

9.1. Raw values extraction

The first step is the extraction of the sub-fields from the packet for each data format.
Raw values are positive or negative (16 bit integer signed). If the value is negative (first bit set to 1), it is necessary to apply two's complement arithmetic inverting every bit.

9.1.1. XServo acceleration raw data extraction

The first 52 words in packets in df#32, 33, 34 are raw XServo data.

XServo_RawVal bit 15-0

The following 3 words plus 4 bits (for a total of 52bit) of the last word give indication for every raw value if the gain was high (bit set to 1) or low (bit set to 0).

9.1.2. Piezo accelerometers raw data extraction

For data formats 35, 36, 37 in each packet are contained 56 words for raw PIEZO (X,Y and Z) values.

XPiezo_RawVal bit 15-0

9.1.3. XServo and Piezo temperature raw data extraction

For data formats 38, 39 (HKD1 and HKD2) in each packet are contained 56 words for raw Temp (1 and 2) values.

Temp1_RawVal bit 15-0

9.1.4. XServo and Piezo statistical raw data extraction

For data formats 40, 41 , 42, 43 in each packet are contained 56 words divided in 37 statistics subfields of 24 bit each.
Each datum is composed by S2a,S1a,S0a.

XServo_Stat_RawVal bit 21-0
XPiezo_Stat_RawVal bit 21-0

The bit#23 is the channel selection flag, 0 = LOW and 1= HIGH.
The bit#22 is a spare bit.

9.1.5. Piezo impact trace acceleration raw data extraction

For data formats 48 (ID1) , 49 (ID2), 50 (ID3) in each packet are contained 56 words for raw values of the Piezo impact trace.

XPiezo_Impact_RawVal bit 15-0

9.2. Raw values normalisation

Raw values for each sensor are normalised as follows.

9.2.1. XServo acceleration normalisation

XServo_Norm_Val= XServo_RawValue/16

9.2.2. Piezo acceleration normalisation

XPiezo_Norm_Val= 2* XPiezo_RawValue/31
YPiezo_Norm_Val= 2* YPiezo_RawValue/31
ZPiezo_Norm_Val= 2* ZPiezo_RawValue/31

9.2.3. Xservo and Piezo temperature normalisation

Temp1_Norm_Val= Temp1_RawValue/16
Temp2_Norm_Val= Temp2_RawValue/16

9.2.4. XServo and Piezo statistical data normalisation

XServo_Stat_Norm_Val= XServo_Stat_RawValue/128

9.2.5. Piezo impact trace acceleration normalisation

XPiezo_Impact_Norm_Val = XPiezo_ImpactRawVal

9.3. Engineering conversion

The normalised value with sign is converted in engineering units (volts) using the same coefficients for every sensor:

Eng_Val= 10* 2^{-11} * SF* Norm_Val

where SF is the scale factor (for the Flight Model its value is 1,02405)

10. Scientific conversion of engineering values

Hereafter are reported the formulas for the scientific conversions for each sensor [AD4].

10.1. Xservo acceleration conversion

10.2. XServo(m/s2) = (XServo_Eng_Val/(R*sf)-offset)*9.80708 Eq. 1

whereR, sf and offset are calibration data reported in appendix A.

10.3. Piezo acceleration conversions

XPiezo(g)= (XPIEZO_Eng_Val-m*Temp2_Eng_Val+offset)/sf/9.80655 Eq. 2

For the calculation of m (temperature gradient), offset (temperature offset) and sf (scale factor) values see Appendix B to this document.
These values are recalculated for every in-flight checkout and for the mission must be used the values calculated from the data of the last in-flight checkout.

10.4. Xservo and Piezo Temperature conversions

Temp1(K)= 109,23 (0,1Temp1_Eng_Val+2,5) Eq. 3
Temp2(K)= 109,71 (0,1Temp2_Eng_Val+2,5)

10.5. Xservo and Piezo statistical data conversions.

For XServo, Piezo statistical and piezo impact trace the scientific conversions uses the same formulas reported in par. 6.1 and 6.2.

The XServo statistic data resulting from the integration executed while a range change occurred should be discarded, since the values are meaningless.
After a range change, X Servo outputs (high and low gain) need about 1 s to stabilize.

11. Higher level products derivation

ACC measurements will be performed during the entry, descent and landing phases in order to characterize the atmosphere and surface of Titan.
In particular, vertical profiles of atmospheric **density**, pressure and temperature will be derived during entry using accelerometric data considering the drag force exerted by the atmosphere on the Probe and using the assumption of hydrostatic equilibrium and the perfect gas law (refer to ZARNECKIETAL2001 [RD1] and FULCHIGNONIETAL2002).
The probe **trajectory** and **attitude** can be reconstructed by analysing vehicle acceleration. The profile of axial and normal accelerations during the Huygens entry and descent in Titan's atmosphere will be used in order to retrieve the probe entry track, velocity and altitude profiles, and attitude, during the high-speed entry phase (ref. FULCHIGNONIETAL2002).
The auxiliary data necessary to for post flight analysis are reported in Appendix C as from [RD2].

12. Appendixes

12.1. Appendix A: ACC XServo Calibration Data

XServo data conversion parameters

Xservo acceleration conversion

XServo(m/s2) = (XServo_Eng_Val/(R*sf)-offset)*9.80708 Eq. 1

sf=1.30675E-03-1.35046E-07*(T(K))+4.02821E-10*(T(K))^2 (A.1)

offset = -8.9642327E-04+3.83652E-06*(T(K))-0.00761E-06*(T(K))^2 g (A.2)

obtained as polynomial fit of the value reported in table, page 5 of [AD4]

where T(K)= temperature sensor is Temp1 [K]:

Temp1(K)= 109,23 (0,1Temp1_Eng_Val+2,5) Eq. 3

R	Gain	Resolution
453 Ω	Low	Low
4.294718 E03Ω	High	Low
411109 Ω	Low	High
3.897566E06 Ω	High	High

As from [AD4]

g is the terrestrial acceleration of gravity: 9.80708 m/s^2 (as provided by manufacturer [AD4])

12.2. Appendix B: ACC Piezo Calibration Data

Piezo parameters calculation

Piezo acceleration conversions

XPiezo(g)= ((XPIEZO_Eng_Val-m*Temp2_Eng_Val-offset)/sf)*9.80655 Eq. 2

g is the terrestrial acceleration of gravity: 9.80665 m/s^2 (as provided by [AD4])

The values of m (temperature gradient) and offset (temperature offset) are calculated as the slope and the intercept of the line (passing for the points corresponding to readings at 21:39preT0, 45:51postT0, 1:56:49 postT0) in the graphic reporting the piezo reading on the X axis and the corresponding Temp2 value on the Y axis during the most recent inflight CO.

ACC Piezo m (temperature gradient) offset (temperature offset) as derived during In-Flight CO (at 0 gravity)

	XPZR		**YPZR**		**ZPZR**	
	m	**offset**	**m**	**offset**	**m**	**offset**
FCO1	-0,388	4,315	-0,279	-0,957	-0,441	3,850
FCO2	-0,389	4,406	-0,281	-0,939	-0,443	3,833
FCO3	-0,400	4,488	-0,286	-0,920	-0,433	3,806
FCO4	-0,395	4,508	-0,284	-0,920	-0,437	3,810
FCO5	-0,399	4,548	-0,286	-0,912	-0,432	3,794
FCO6	-0,398	4,562	-0,285	-0,912	-0,437	3,804
FCO7	-0,393	4,574	-0,285	-0,914	-0,439	3,809
FCO8	-0,401	4,618	-0,287	-0,906	-0,434	3,790
FCO9	-0,407	4,663	-0,289	-0,900	-0,420	3,762
FCO10	-0,406	4,681	-0,290	-0,898	-0,416	3,747
FCO11	-0,409	4,707	-0,293	-0,894	-0,413	3,735
FCO12	-0,410	4,723	-0,291	-0,897	-0,412	3,730
FCO13	-0,403	4,721	-0,289	-0,899	-0,434	3,778
FCO14	-0,403	4,740	-0,288	-0,899	-0,429	3,757
FCO15	-0,407	4,752	-0,289	-0,896	-0,419	3,721
FCO16	-0,408	4,764	-0,288	-0,892	-0,416	3,705

The value of sf (scale factor) for each sensor (X,Y,Z) is calculated as follow [AD4] from calibration data:

sfx= 0,3122-0,0007(Temp2(K)-300) (B.1)
sfy= 0,2395-0,0007(Temp2(K)-300) (B.2)
sfz= 0,1826-0,0007(Temp2(K)-300) (B.3)
where
Temp2(K)= 109,71 (0,1Temp2_Eng_Val+2,5) Eq. 3

For the EGSE software for Titan encounter values for m (temperature gradient) and offset (temperature offset) have been taken from F16.

Piezo calibration data *as from Calibration data sheet in [AD4]*

Sensor	*Sensitivity (@100Hz, 10 g pk)*	*Transverse sensitivity*
X PIEZO	0.3122 mV/g	0.7%
YPIEZO	0.2395 mV/g	0.4%
ZPIEZO	0.1826 mV/g	0.6%

Thermal sensitivity shift -0.07% °C typical

12.3. Appendix C: Huygens Probe auxiliary data

Probe Mass, CoG & products of Inertia evolution

Probe Mass, CoG and products of Inertia evolution [RD2]

Phase	*Mass (kg)*		*CoG (mm)*		*Inertia (m2kg)*			*Mission time*
		X	Y	Z	XX	YY	ZZ	
Cruise*	330.23	75.65	1.69	5.50				N/A
Begin Entry	318,62	75,44	1,75	5,38	126,17	74,63	71,57	preT0
End Entry	309,72	82,54	2,48	5,13	126,11	74,3	71,3	T0
Under Main with FRSS	287,6	65,19	2,64	5,46	113,2	66	63,19	T0+2.5s
Under Main without FRSS**	206,91	81,33	3,67	1,17	38,6	25,62	23,61	T0+32.5s
Under Stabiliser parachute	201,51	71,83	-0,52	3,68	38,23	24,71	22,7	T0+900s
Without Stabiliser parachute	200,48	69,22	-1,46	5,46	38,49	24,51	22,93	N/A

*values as from Huygens User Manual [R1] *] (HUY.AS/c.100.OP.0201 page 54)*
** including DISR cover ejection
FRSS= Front Shield Subsystem

Uncertainties on these values are 0.5% for mass and 1% for CoG.

Frontshield mass ablation
Note that the Mass of the front shield will change due to ablation during Entry phase. The foreseen mass loss is up to 9.7 kg (from Alcatel): including 4.6 kg mass loss via pyrolisis and the aluminium radiative window plate.
The mass evolution equation can be written as:

$$M = M_0 \cdot e^{(2*\sigma*(V^2(t) - V_0^2))}$$

Where M_0 and V_0 are respectively the mass and velocity of probe at start of ablation process and σ is a mass evolution coefficient: $\sigma = \frac{\eta_{eff}}{C_X L_{abl}}$.

η_{eff} is a coefficient that characterises the efficiency of energy transfer from incident flux to probe, C_X is the aerodynamic coefficient and L_{abl} is a sort of “ablation enthalpy”. σ has been calculated as the best fit of the above formula for the experimental data given by Alcatel and is: $\sigma \approx 4.18 \cdot 10^{-10} m^{-2} s^2$

Reference cross -sectional area – Characteristic lenghts
Values provided by Alcatel/Aerospatiale in 1997. Reference: HUY-MBA-3200-RE-00013 Issue 01 and reported confirmed in [RD2].

Item	*Diameter (m)*	*Area (m2)*	
Front Shield	2.6937 (+0.9 / -4.9 mm)		ejected at T0+32.5
Descent module	1.3		*not measured*
Pilot parachute	2.59	5.27	inflated at T0+0.25s
Main parachute	8.30	54.06	inflated at T0+2.5s
Stabiliser/drogue chute	3.03	7.23	inflated at T0+15 min

These values correspond to the characteristic lengths of the items

Parachute physical characteristics
Three parachute systems are used in the descent phase (ref §4):

Pilot parachute	inflated at T0+0.25s
Main parachute	inflated at T0+2.5s
Stabilizing drogue chute	inflated at T0+15 min

Only the latter two parachute systems are used for mission analysis. Both are Disk Gap Band (DGB) parachutes.

Parachute parameters values have been derived from [R2].
Reference:
Huygens DCSS descent control design report HUY-MBA-3200-RE-00001 8/06/1992 Issue 01

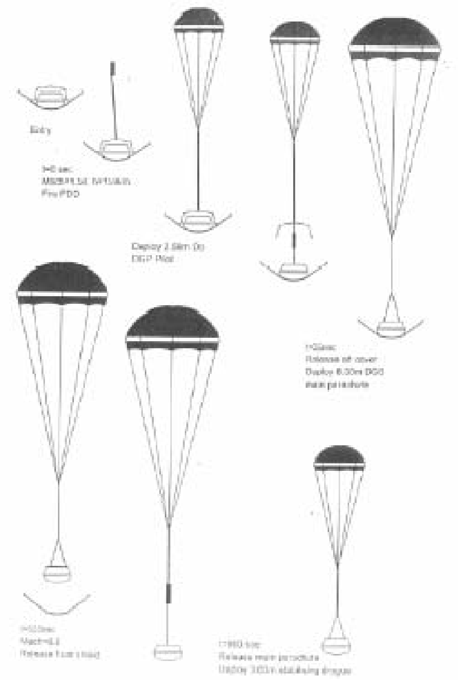


Fig. 1 Huygens entry and descent scenario

Aerodynamical Coefficients

The complete Huygens aerodynamical data base has been provided by Alcatel [RD2] and is archived within the Huygens HK data.

The aerodynamical database includes:
- Entry phase:
  1) Free Molecular Flow (FMF) regime: $Kn=1.25\cdot\gamma^{0.5}\cdot Ma/Re>5 \Rightarrow H>780$ km
  2) Transitional flow regime $5>Kn>0.001 \Rightarrow 780$ km>H>360 km
  3) hypersonic and supersonic Continuum flow regime:
     360 km>H>159 km ⇒ 21.8>Ma>1.5, 3.4·104>Re>1.8·105

Entry Module aerodynamic coefficients:
CA and CN, Cm and Cmq values as function of AoA and Mach
0°<AoA<90° [0-28° (with 1° step), 30-90° (with 10° step)]
0<Ma<99 [0, 0.5, 0.8, 1, 1.19, 1.42, 1.71, 2.03, 4, 7.15, 10, 30, 99]
- Descent phase

    Descent Module
    CA and CN, Cm and Cmq values as function of AoA and Mach
    Parachutes
    Drag coefficient as function of Mach and Reynold numbers.

AoA, α Angle of attack
CA axial force coefficient
CN normal force coefficient
CD drag coefficient $CD=CA\cos\alpha + CN\sin\alpha$
CL lift coefficient $CL=-CA\sin\alpha+CN\cos\alpha$
Cm pitching moment coefficient
Cmq dynamic pitching coefficient = $\partial Cm/\partial (qL/V)$
q dynamic pressure
L characteristic length
H altitude,
FPA flight path angle
V Probe velocity
Ma Mach number, $Ma=v/sqr(\gamma*R*T)$, $\gamma=cp/cv$
Re Reynolds number, $Re=rho*V*L/\eta$
Kn Knudsen number, Kn=l/L with l mean free molecular path
η dynamic viscosity

Entry state
Nominally Huygens **entry** phase begins at reference altitude 1270 km. The **Entry state vector** at reference altitude will be provided by the Cassini Navigation team and will be archived within the DTWG (Descent Trajectory Working Group) data set.

Flight path angle FPA=-65.4°±0.3 * *from technical note by Jeremy Jones: IOM-343J-05-08_CassiniHuygens_Trajectory_7March2005*

ANNEX 1

ACC XSERVO Data Sheet and Calibration Data
(as provided by the manufacturer)

QA-2000 Accelerometer

The Sundstrand QA-2000 inertial grade accelerometer evolved from the time-proven Q-Flex® accelerometer to meet a single objective — volume production of a precise accelerometer that can satisfy the demands of the strapdown inertial navigation market.

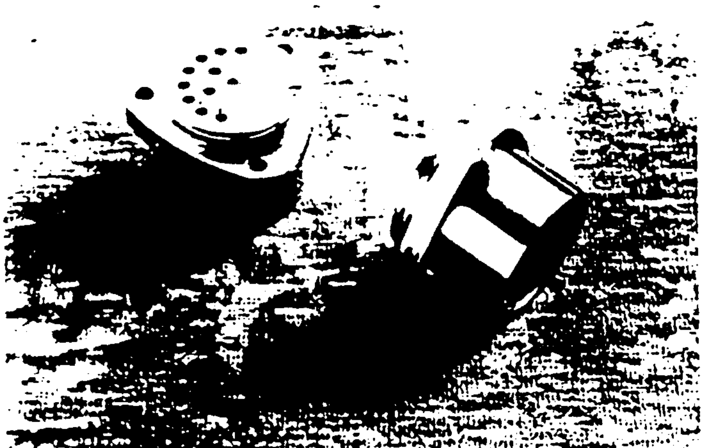
The objective was met and surpassed, as indicated by installations in inertial reference systems in the 737-300, 747-400, 757, 767, JAS-39, F-20, A310, A320, F-15, F-16, F-18 and the standard Form, Fit, Function (F^3) military system. The users of these systems have enjoyed the superior reliability of the QA-2000. One customer reported a mean-time-between-failures of over 580,000 hours taken from actual system operation.

Repeatability is paramount to the QA-2000's performance characteristics. The parameters listed in this brochure include three optional one-year repeatability performance levels.

The specifications that follow allow a user to select the standard model closest to his requirements. Specifications may be modified to meet the demands of a particular application. Please contact Sundstrand Data Control for further details.

Features

- Quartz elastic seismic suspension (flexure) ensures long-term repeatability
- Precision three-point mounting flange creates stable alignment and mount-to-mount repeatability
- Advanced hybrid electronics provide current output, where the scale factor and full scale range are determined by an external resistor
- Internal temperature sensor output allows precise temperature modeling of bias, scale factor and axis alignment
- Laser-welded hermetic package meets stringent military and space environments
- Dual self-test capability provides flexible accelerometer performance verification
- Self-contained seismic system and servo electronics allow compact packaging



QA-2000 Accelerometer Specifications

Applications

- Gimbal and strapdown inertial reference systems
- Precision leveling and inclination measurement system
- High performance autopilot and flight control functions

Temperature Modeling

Maximization of accelerometer accuracy is achieved through temperature modeling (the derivation of coefficients used in fourth-order equations, applied as correction to the accelerometer output). Measurements of accelerometer performance, with temperature as the only variable, yield the performance constants and coefficients. These are furnished with the accelerometer. In a typical computer-based system (in which modeling algorithms are used), the accelerometer operating temperature is measured, the temperature-related correction values are calculated, the accelerometer output is measured, and the measured output is combined with correction values to derive input acceleration.

Extensive accelerometer testing, at temperature, yields not only the coefficients but figures that describe temperature sensitivity (the change of a parameter per unit of temperature change), residual error and composite repeatability.

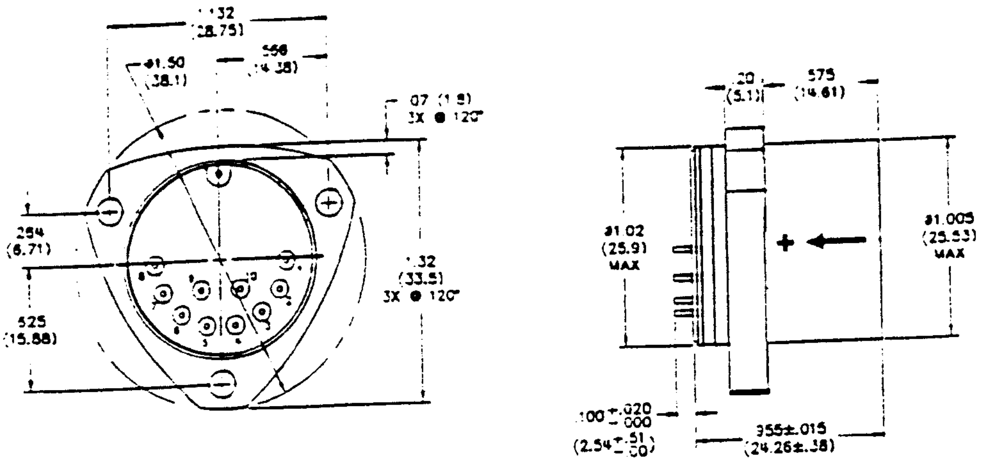
QA-2000 Technical Data

Environmental	
Temperature *	-55°C to +95°C
Shock	250g, half-sine, 6ms
Vibration	MIL-E-5400 Curve IV (A)
Leakage	<1x10⁻⁸ cc/s

* Note: Accelerometer can be operated to 125°C, but with wider performance values.

Electrical	
Power Supply Voltage	±13.0 to 18.0 Vdc
Quiescent Current	<20 mA
Insulation Resistance (electronics to case)	>50 Mohm @ 50 VDC
Regulated Output @ 1.5 ma max	±8.5 to 10.1V
Physical	
Weight	<80 grams
Case Material	Stainless steel
Functional Charateristics (24°C; Maximum Values)	
Output Range	±25g
Scale Factor	1.20 to 1.46 mA/g
Bias	4000 μg
Axis Misalignment	
Output Axis	2000 μrad
Pendulous Axis	2000 μrad
Frequency Response	
0 to 10 Hz	0.01 dB
10 to 300 Hz	0.45 dB
Above 300 Hz	5 dB peaking
Natural Frequency	Above 800 Hz
Damping Ratio	0.3 to 0.8
Threshold and Resolution	<1 μg
Noise	
0 to 10 Hz	10 nA rms
10 to 500 Hz	100 nA rms
500 to 10 kHz	2 μA rms
Temperature Sensor	
Output at 20°C, nominal	293μA
Scaling	1.0μA/°C
Load	11 Kohms, max

Outline Drawing



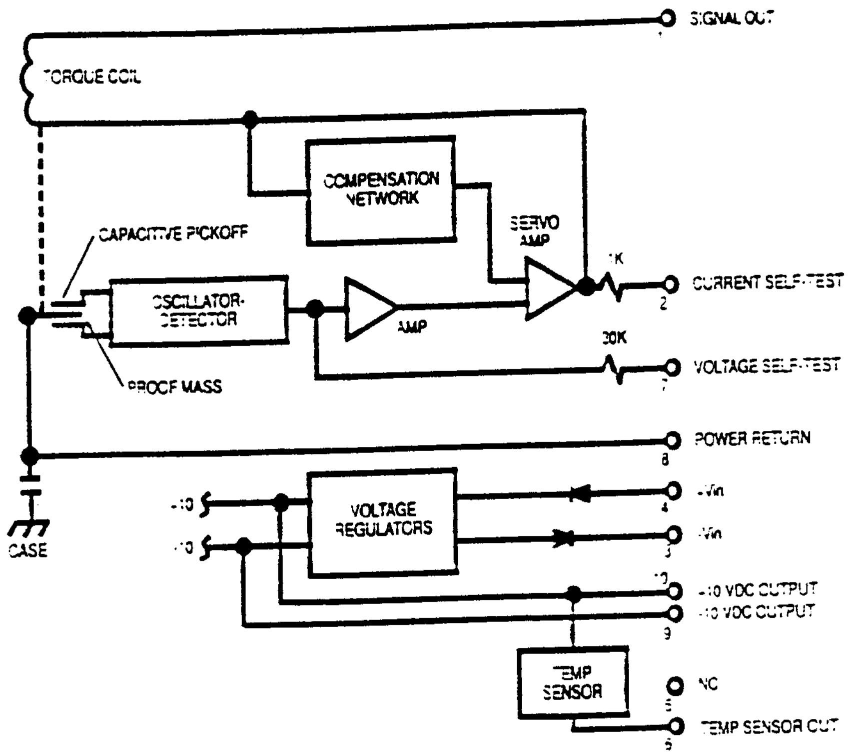
QA-2000 Performance Comparison

	QA-2000-010	QA-2000-020	QA-2000-030
Scale Factor			
Temperature Sensitivity	180 ppm/°C	180 ppm/°C	180 ppm/°C
Temperature Modeling Residual	200 ppm	125 ppm	100 ppm
Composite Repeatability	600 ppm	500 ppm	310 ppm
Nonlinearity	40 $\mu g/g^2$	40 $\mu g/g^2$	20 $\mu g/g^2$
Bias			
Temperature Sensitivity	30 μg/°C	30 μg/°C	30 μg/°C
Temperature Modeling Residual	100 μg	60 μg	60 μg
Composite Repeatability	550 μg	220 μg	160 μg
Axis Misalignment			
Temperature Sensitivity	5 μrad/°C	4 μrad/°C	3 μrad/°C
Temperature Modeling Residual	50 μrad	40 μrad	40 μrad
Composite Repeatability	105 μrad	105 μrad	100 μrad
Vibration Rectification			
50 to 500 Hz	40 $\mu g/g^2$rms	40 $\mu g/g^2$rms	20 $\mu g/g^2$rms
500 to 2000 Hz	150 $\mu g/g^2$rms	60 $\mu g/g^2$rms	60 $\mu g/g^2$rms

Notes:

- The temperature sensitivity figures are useful for determining maximum magnitude of temperature-related errors to be expected when modeling is not accomplished.
- The modeling residual describes the net error (which remains after modeling). This number includes the temperature hysteresis error.
- The composite repeatability is the root-sum-square characterization of the maximum error to be expected over a period of one year through all operating [en]vironmental conditions. Bias composite repeatability includes both bias and output axis misalignment. The composite repeatability figure under Axis Misalignment is for the pendulous axis.

Block Diagram



For more information please call (206) 885-8010 or FAX (206) 883-2104.
Specifications subject to change without notice.

Sundstrand Data Control
SUNDSTRAND AEROSPACE
REDMOND, WASHINGTON 98073 Sundstrand Corporation

FM

ACCEPTANCE TEST DATA

SUNDSTRAND DATA CONTROL

Acc's

P/N 979-2000-003 T/A S/N: 725

SENSOR S/N: TJRVW HYBRID S/N: 14657 PRINT DATE: 2/26/93

PARAMETER	UNITS	LIMITS	ACTUAL	QA STAMP
BIAS:				
BIAS	ug	max 4000	-425	ACCEPT
BTC	ug/degC	max 30	-1	ACCEPT
RSS Bias & Hinge (stab incl @ 80)	ug	max 160	80	ACCEPT
SCALE FACTOR:				
SCALE FACTOR	mA/g	1.20 to 1.46	1.301569	ACCEPT
SFTC	ppm/degC	max 120	77	ACCEPT
RSS SF error (stab incl @ 200)	ppm	max 310	200	ACCEPT
AXIS ALIGNMENT:				
MIP	urad	max 1000	248	ACCEPT
MIH	urad	max 1000	35	ACCEPT
MIPTC	urad/degC	max 3	1	ACCEPT
MIHTC	urad/degC	max 3	-0	ACCEPT
PA error (stab incl @ 65)	urad	max 105	71	ACCEPT

For this and subsequent sheets from Sundstrand, it would be very good to have a description of test procedures measurement set-up etc, as it is not totally clear (especially for sheet A3). I presume we don't have such a thing - we should get it from Sundstrand.

(050-1776-003 REV B) 979-2000-701 SHEET A1

MAR 02 1993

FLIGHT ACC 3

Q-FLEX MODEL DATA SHEET

T/A S/N: 725

SENSOR S/N: TJRVW RUN DATE: 1/13/93 LOCAL g: 980.708 cm/sec-sec

TEMPERATURE (degrees-C)		BIAS (ug)	SCALE FACTOR (mA/g)	TEMP. SENSOR (u-amp)
T 1	94.95	-519	1.311624	370.497
T 2	65.15	-474	1.307132	340.448
T 3	34.93	-445	1.303387	310.196
T 4	4.88	-420	1.300347	280.087
T 5	-25.28	-417	1.297980	249.782
T 6	-55.22	-423	1.296463	219.685
T 7	-25.42	-408	1.298003	249.696
T 8	4.72	-412	1.300342	279.958
T 9	34.92	-435	1.303387	310.254
T10	64.87	-458	1.307091	340.257
T11	94.95	-514	1.311629	370.497
T12	35.01	-441	1.303399	310.261

	COEFFICIENTS (@293u-amps)		COEFFICIENTS (@293u-amps)		COEFFICIENTS (20degrees-C)	
CONSTANT :	B0 =	-425	C0 =	1.301569	A0 =	295.236
1ST ORDER:	B1 =	-.60	C1 =	99.21E-06	A1 =	1.00370
2ND ORDER:	B2 =	-5.3E-03	C2 =	368.1E-09		
3RD ORDER:	B3 =	5E-06	C3 =	-82E-12		
4TH ORDER:	B4 =	-40E-08	C4 =	542E-14		

TEMPERATURE (degrees-C)		RESIDUALS (ug)	RESIDUALS (ppm)	RESIDUALS (u-amp)
T 1	94.95	-3	-2	.0
T 2	65.15	-7	6	-.1
T 3	34.93	-8	2	-.0
T 4	4.88	-1	-2	.0
T 5	-25.28	-6	-11	-.0
T 6	-55.22	0	0	-.1
T	-25.42	3	11	.0
T 8	4.72	7	3	.1
T 9	34.92	2	-3	.0
T10	64.87	9	-5	-.0
T11	94.95	2	2	.0
SHIFT:		4	4	-.0
HYSTERESIS(p-p):				
TEMP =	65.01	12	-15	.1
TEMP =	34.93	7	-7	.1
TEMP =	4.80	6	3	.0
TEMP =	-25.35	8	21	.1

(050-1776-003 REV B) 979-2000-701 SHEET A2

Q-FLEX AXIS ALIGNMENT DATA SUMMARY T/A S/N: 725

[SE]NSOR S/N: TJRVW RUN DATE: 2/03/93 BLOCK POSITION: 09 STATION NUMBER: 04

----------- PENDULUM AXIS --------------------- HINGE AXIS -----------***

	Pendulum OVEN TEMP (deg-C)	Pendulum ALIGN-MENT (urad)	Pendulum TEMP SENSOR (u-amp)	Hinge OVEN TEMP (deg-C)	Hinge ALIGN-MENT (urad)	Hinge TEMP SENSOR (u-amp)
T 1	94.37	351	369.530	94.37	20	369.540
T 2	65.03	282	339.890	65.03	23	339.890
T 3	35.30	236	310.020	35.30	30	310.010
T 4	6.04	208	280.740	6.04	39	280.700
T 5	-23.81	187	250.750	-23.81	44	250.710
T 6	-53.68	192	220.700	-53.68	36	220.660
T 7	-24.62	254	249.800	-24.62	41	249.800
T 8	5.01	269	279.530	5.01	40	279.540
T 9	34.86	291	309.500	34.86	31	309.520
T 10	64.56	318	339.400	64.56	29	339.420
T 11	94.37	349	369.530	94.37	22	369.540
T 12	35.33	234	310.050	35.33	31	310.040

------------------------ MODEL COEFFICIENTS ------------------------

	PENDULUM AXIS (@293u-amps)		HINGE AXIS (@293u-amps)		TEMP SENSOR (@20deg-C)	
CONSTANT :	P0 =	248	H0 =	35	A0 =	294.689
1ST ORDER:	P1 =	.775	H1 =	-.249	A1 =	1.00505
2ND ORDER:	P2 =	5.9E-03	H2 =	-.1E-03		
3RD ORDER:	P3 =	51E-06	H3 =	29E-06		
4TH ORDER:	P4 =	-43E-08	H4 =	-23E-08		

---------------------------- RESIDUALS ----------------------------

	Pendulum OVEN TEMP (deg-C)	Pendulum ALIGN-MENT (urad)	Pendulum TEMP SENSOR (u-amp)	Hinge OVEN TEMP (deg-C)	Hinge ALIGN-MENT (urad)	Hinge TEMP SENSOR (u-amp)
T 1	94.37	1	.1	94.37	-0	.1
T 2	65.03	-18	-.1	65.03	-2	-.1
T 3	35.30	-27	-.0	35.30	-1	-.1
T 4	6.04	-32	.1	6.04	1	.0
T 5	-23.81	-34	.1	-23.81	1	.1
T 6	-53.68	0	.1	-53.68	0	.0
T 7	-24.62	34	-.0	-24.62	-1	-.0
T 8	5.01	31	-.1	5.01	2	-.1
T 9	34.86	28	-.1	34.86	0	-.1
T 10	64.56	18	-.1	64.56	4	-.1
T 11	94.37	-1	.1	94.37	1	.1
SHIFT		-2			1	

---------------------------- HYSTERESIS ----------------------------

Pendulum OVEN TEMP (deg-C)	Pendulum ALIGN-MENT (urad)	Pendulum TEMP SENSOR (u-amp)	Hinge OVEN TEMP (deg-C)	Hinge ALIGN-MENT (urad)	Hinge TEMP SENSOR (u-amp)
64.80	38	-.0	64.80	5	.0
35.08	57	-.1	35.08	1	-.0
5.53	63	-.2	5.53	-0	-.1
-24.22	68	-.1	-24.22	-3	-.1

050-1776-003 REV B)

979-2000-701 SHEET A3

MAR 02 1993

DATA SHEET A4
QA2000 ACCEPTANCE TEST DATA

DATE: MAR 0 2 1993

QA: 5 0 5 9

PART NO: 979-2000- 003

SENSOR S/N: TJRVW

HYBRID S/N: 14657

TEST	PARA	LIMITS	DATA	QA STAMP
LEAK RATE		$<1X10^{-6}$ cc/sec	PASS X FAIL ___	SDC 110
INSULATION RESISTANCE		50 megohms, min	PASS X FAIL ___	SDC 110
EXAMINATION OF PRODUCT:				
Dimensional	4.3.1		PASS ✓ FAIL ___	SDC 4
Workmanship	4.3.2		PASS ✓ FAIL ___	SDC 4

979-2000-701 SHEET A4

SDC 110

ANNEX 2

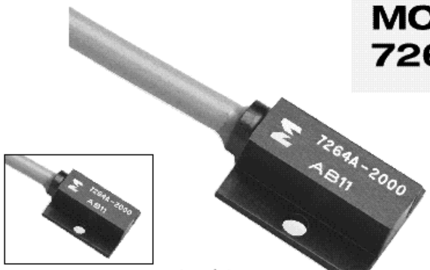
ACC PIEZO Data Sheet and Calibration Data
(as provided by the manufacturer)

Piezoresistive Accelerometer

ENDEVCO MODEL 7264A

Model 7264A

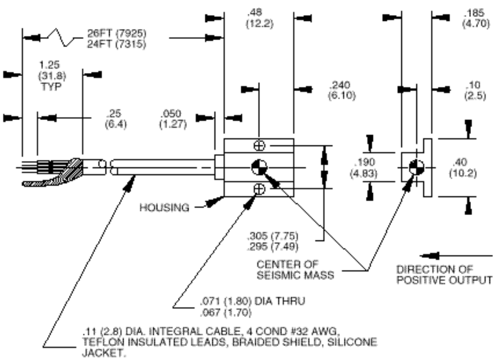
- **Small Size, Rugged**
- **2000 g Full Scale**
- **DC Response**
- **Undamped**



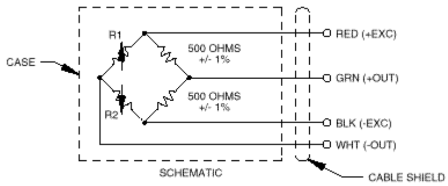
Actual size

DESCRIPTION

The ENDEVCO® Model 7264A is a very low mass piezoresistive accelerometer weighing only 1 gram. This accelerometer is designed for flutter testing, modal testing, biodynamics measurements and similar applications that require minimal mass loading and a broad frequency response. Used for shock testing of lightweight systems or structures, this accelerometer also meets SAEJ211 specifications for anthropomorphic dummy instrumentation.



The Model 7264A utilizes an advanced micromachined sensor which is etched from a single piece of silicon. This sensor offers improved ruggedness, stability and reliability over previous designs. The Model 7264A has minimum damping, thereby producing no phase shift over the useful frequency range. With a frequency response extending down to dc or steady state acceleration, this accelerometer is ideal for measuring long duration transients as well as short duration shocks.



STANDARD TOLERANCE
INCHES (MILLIMETERS)
.XX = +/- .03 (.X = +/- .8)
.XXX = +/- .010 (.XX = +/- .25)

The Model 7264A-2000 offers excellent linearity, a wide frequency response and a high resonance frequency. Further, this accelerometer offers stable performance over the temperature range of -65°F to +250°F (-54°C to +121°C) and has a full bridge circuit with fixed resistors for shunt calibration. This accelerometer has a sensitivity of 0.20 mV/g and a full scale output of 400 mV with 10 Vdc excitation. It is also available with less than 1% transverse sensitivity ("T" option) on special order.

ENDEVCO Model 136 Three-Channel System, Model 4430A or Model 68207 BCAS™ Computer Controlled System are recommended as signal conditioner and power supply.

U.S. Patents 4,498,229 and 4,605,919

SPECIFICATIONS

CERTIFIED PERFORMANCE: All values are typical at 75°F (+24°C) and 10 Vdc excitation unless otherwise specified. Calibration data, traceable to the National Institute of Standards (NIST), is supplied.

	Units	7264A-2000
RANGE	g	±2000
SENSITIVITY (at 100 Hz)	mV/g Typ	0.20
	(Min)	(0.15)
FREQUENCY RESPONSE (±5% max, ref. 100 Hz)	Hz	0 to 5000
MOUNTED RESONANCE FREQUENCY	Hz	60 000
DAMPING RATIO		0.005
NON-LINEARITY AND HYSTERESIS (% of reading, to full range)	% Max	±1

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MODEL
7264A

Piezoresistive Accelerometer

SPECIFICATIONS—continued

PERFORMANCE CHARACTERISTICS—continued

	Units	7264A-2000
TRANSVERSE SENSITIVITY [1]	% Max	3
ZERO MEASURAND OUTPUT	mV Max	±25
THERMAL ZERO SHIFT From -65°F to +250°F (-54°C to +121°C)	mV Max	±10
THERMAL SENSITIVITY SHIFT From -65°F to +250°F (-54°C to +121°C)	%/°F Typ %/°C Typ	- 0.04 -0.07
WARM-UP TIME	ms Max	1
BASE STRAIN SENSITIVITY (Per ISA 37.2 @ 250 μ strain)	Equiv. g's	< 0.1

ELECTRICAL

EXCITATION [2]	10.0 Vdc
INPUT RESISTANCE [3]	500 ±300 ohms
OUTPUT RESISTANCE [3]	1000 ±300 ohms
FIXED RESISTORS	500 ohms ±1%
INSULATION RESISTANCE	100 megohms minimum at 100 Vdc: leads to case, leads to shield, shield to case

PHYSICAL

CASE, MATERIAL	Anodized aluminum alloy
ELECTRICAL, CONNECTIONS	Integral cable, four conductor No. 32 AWG Teflon® insulated leads, braided shield, silicone jacket
MOUNTING/TORQUE	Holes for two 0-80 mounting screws/6 in-ozf (0.04 Nm)
WEIGHT	1 gram (cable weighs 9 grams/meter)

ENVIRONMENTAL

ACCELERATION LIMITS (in any direction) Static Sinusoidal Vibration Shock (half-sine pulse)	 10 000 g 1000 g pk below 5000 Hz 10 000 g, 200 μsec or longer
TEMPERATURE Operating [4]	 -65°F to +250°F (-54°C to +121°C)
HUMIDITY	Unaffected. Unit is epoxy sealed
ALTITUDE	Unaffected

CALIBRATION DATA SUPPLIED

SENSITIVITY (at 100 Hz and 10 g pk)	mV/g
FREQUENCY RESPONSE	20 Hz to 5000 Hz, % deviation reference 100 Hz; dB plot continued from 5000 to 30 000 Hz
ZERO MEASURAND OUTPUT	mV
MAXIMUM TRANSVERSE SENSITIVITY	% of sensitivity
INPUT AND OUTPUT RESISTANCE	Ohms

ACCESSORIES

EHM35	(1) ALLEN WRENCH
31033	(4) FIBER WASHERS
EH492	(2) 0-80 X 3/16 INCH SOCKET HEAD CAP SCREWS

OPTIONAL ACCESSORIES

24328	4 CONDUCTOR SHIELDED CABLE
7964A	TRIAXIAL MOUNTING BLOCK

NOTES

1. 1% transverse sensitivity available as "T" option.
2. Lower excitation voltages may be used but should be specified at time of order to obtain best calibration.
3. Measured at approximately 1 Vdc. Bridge resistance increases with applied voltage due to heat dissipation in the strain gage elements.
4. Accelerometer can operate at +275°F (+135°C) for hours with 5 Vdc excitation.
5. The safety sleeve should be kept on unit when not in use to prevent possible handling damage.

NOTE: Tighter specifications available on special order.

ENDEVCO CORPORATION, 30700 RANCHO VIEJO ROAD, SAN JUAN CAPISTRANO, CA 92675 USA (949) 493-8181 fax (949) 661-7231 0298

: 4HF-91-32390

X FM

Calibration Data

Transverse Sensitivity 0.7 %

ACCELEROMETER MODEL 7264A-2000T SERIAL NO. AK4G1

Sensitivity 0.3122 mV/g @ 100 Hz, 10 g pk

Input resistance : 634 Ω
Output resistance : 1018 Ω
ZMO : 3.4 mV
Excitation : 10.00 V

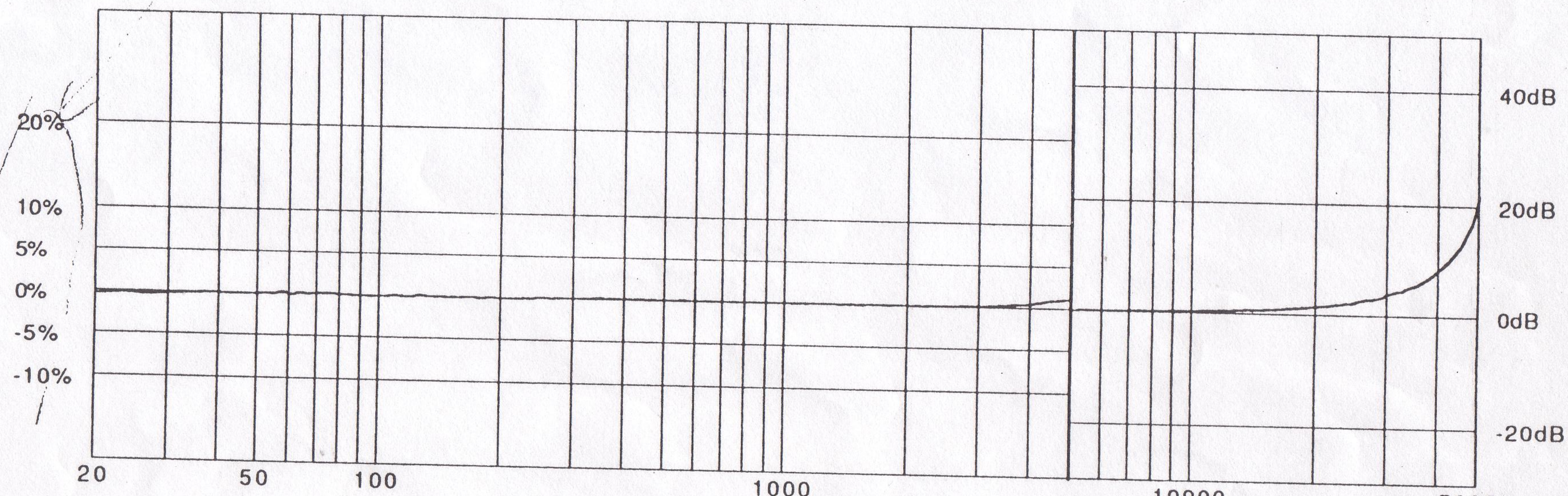
Again, do we know for sure what all these parameters mean – ? We need a detailed explanation from Endevco.

at what temp.??

What does it mean?

Any info. on temp. sensitivity?

FREQUENCY RESPONSE



FREQUENCY IN Hz

Date 2/15/95 3:28:31 PM

By

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All calibrations are traceable to the National Institute of Standards and Technology and in accordance with MIL-STD-45662.

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: 2HE-93-3347

Calibration Data

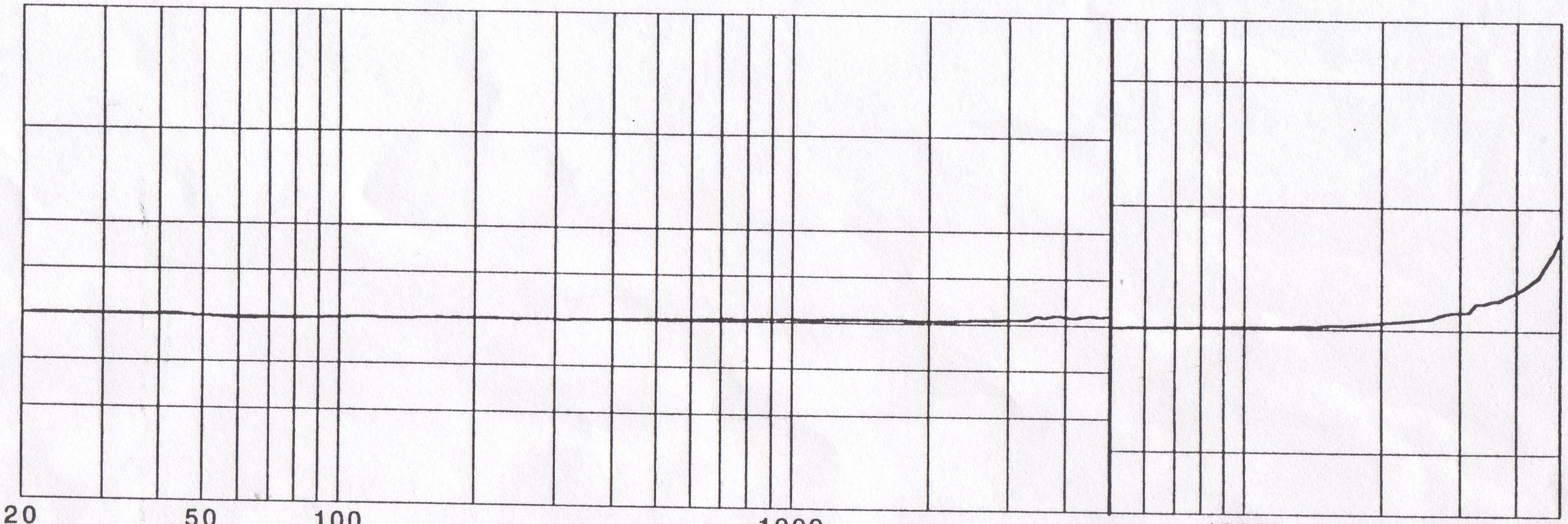
Transverse Sensitivity 0.4 %

ACCELEROMETER MODEL 7264A-2000T SERIAL NO. AFN79

Sensitivity 0.2395 mV/g @ 100 Hz, 10 g pk

Input resistance : 580 Ω
Output resistance : 934 Ω
ZMO : 9.9 mV
Excitation : 10.00 V

FREQUENCY RESPONSE



Date 4/13/94 10:35:47 AM
By

APR 14 '94

MEGGITT AEROSPACE

ENDEVCO

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V. GOOD ✓ FM-E

: 2HE-93-3352

Calibration Data

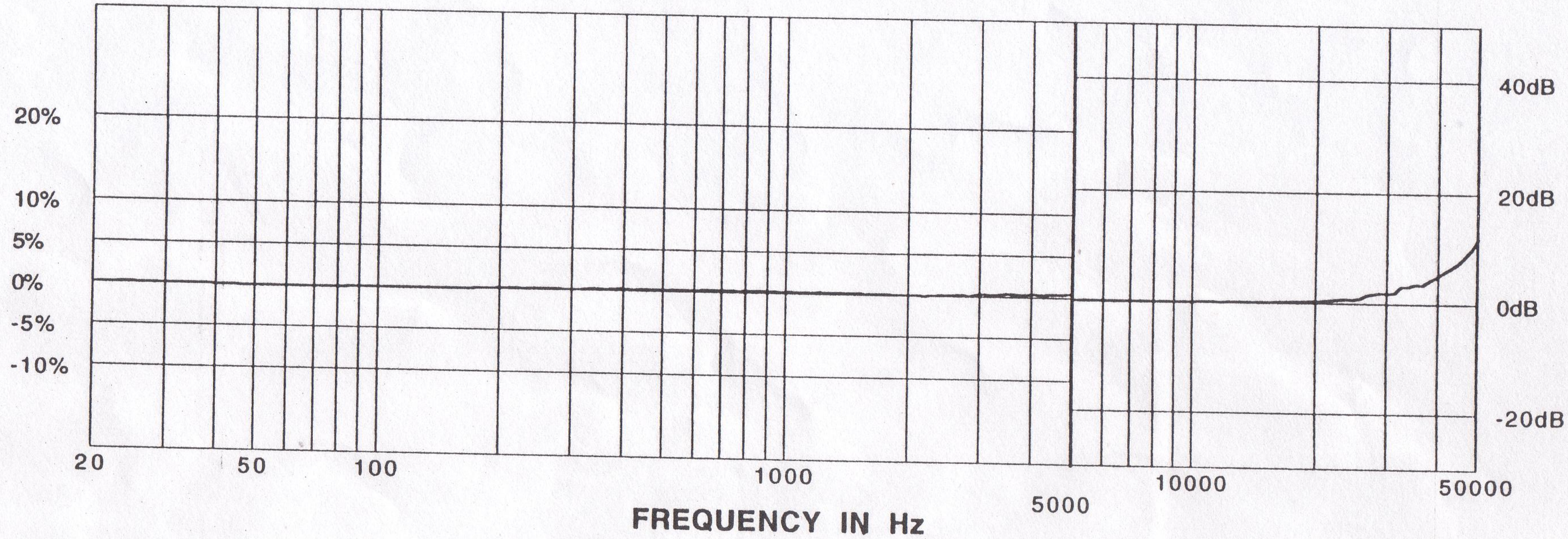
Transverse Sensitivity 0.6 %

ACCELEROMETER MODEL 7264A-2000T SERIAL NO. AJE08

Sensitivity 0.1826 mV/g @ 100 Hz, 10 g pk

Input resistance : 520 Ω
Output resistance : 865 Ω
ZMO : 4.6 mV
Excitation : 10.00 V

FREQUENCY RESPONSE



Date 4/13/94 10:59:17 AM

By

APR 14 '94

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