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1 Abstract

1.1 Background

Presens is currently developing its pressure sensor design and technology for space applications. The overall goal is to develop and qualify a range of sensors for commercial and scientific spacecrafts to be available off the shelf. Low pressure, high pressure and differential pressure will be covered with different pressure transmitters (fully compensated output). This effort is driven and financed with company funds with ESA support.

The primary objective of work under ESA contract “Reliability of MEMS Pressure sensors for Space” is to perform pre-qualification preparatory activities with PRESENS’ sensor technology and products.

1.2 Pressure transmitters for space

Aside from the launcher market, a considerable market for pressure transmitters exists in the satellite industry for the propulsion system in all medium to large satellites. The market is dominated by American suppliers of pressure transmitters.

Presens has developed two high pressure transmitters for space, part 1096 and part 1560.

Part 1560 HP transmitter 0-5V

Part 1096 HP transmitter 0-5V in titanium

Part 1096 is designed for aggressive space propellants with titanium housing, while part 1560 is designed for a cold gas propulsion system and will fly on the Swedish satellite “Prisma” early 2009.

Outline datasheets are appended. Note that part 1096 is not released for production yet and the datasheet is preliminary.

Both of the above described sensors have been used for the MEMS reliability for space pressure sensors study; ESA contract C18804.

1.3 MEMS element

Both of the sensors share the patented MEMS pressure sensing element developed by Presens. The sensing element is tubular with a central vacuum cavity providing reference pressure for the absolute pressure sensing. Pressure is applied externally, compressing the MEMS tube. Thus the sensing element suffers limited tensile stress and is inherently robust against overpressure damage. Crystalline silicon provides an almost perfectly elastic material minimising hysteresis and shift from plastic deformation. The MEMS sensing element is small, silicon processing allows reproduction in high quantities with high repeatability and virtually no batch variations.

The MEMS sensing element compared to a pencil tip

1.4 Market survey

A market survey was carried out in March to June 2006. The survey report gives an overview of the space market, possible applications and the market potential for Presens Space Pressure Sensors. The survey was based on literature and web search with subsequent interviews of contacts within the industry (European space industry, ESA, NASA, local space agencies, universities etc)

The basic requirements for a standard accuracy pressure sensors in satellite propulsion applications are listed in the table below.

	LP-Xe	HP-Xe	LP	HP	Unit
Calibrated pressure range (FS)	5	150	25	310	bar
Proof pressure (Acceptance)	7.5	225	37.5	465	bar
Burst pressure (Qualification)	20	600	100	1240	bar
Calibrated temperature range	-20 to 85		0to50	-30to45	°C
Qualification temperature	-30 to 95		-10to60	-40to55	°C
Static error band, standard accuracy sensors	± 0.5				%FS
Temperature effect on pressure output	2				%FS
Output pressure signal	0 – 5				V
Supply voltage	28 ± 4 42 ± 4				VDC
Current consumption	20				mA
Total radiation dose	10				Mrad
Weight	Low as possible (< 300 grams)				g

1.5 Qualification of part 1560

The work performed under this contract has followed the development of pressure sensors for space. Qualification of a sensor (Part 1560) to requirements for the Swedish satellite "Prisma" was successfully done, the qualification includes environmental testing for a 1year mission in low earth orbit. Even though the electronic readout and conditioning circuit was designed with commercial electronics and integrated circuits, the sensor passed total ionising dose (TID) tests by a factor 3, TID testing was stopped at 10krad without any measurable degradation of the circuitry.

The screening and qualification levels for "Prisma" have been compared to requirements for a typical 15years GEO mission (eg. telecom platform) and a delta test matrix is made. Prisma requirements are notably less demanding than typical 15years GEO requirements. Two key requirements which can probably not be met with part 1560 remains to be proven with Presens technology: radiation hardness (TID and particle) to 15years GEO and material compatibility to hydrazine and dinitrogen tetroxide. Presens has a development programme running to become fully compatible with these requirements and become a qualified supplier to the space industry.

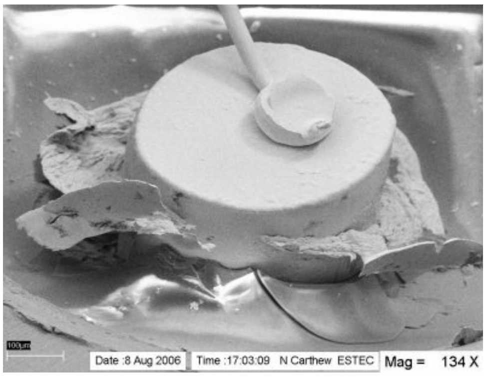
1.6 Destructive physical analyses

Contract "Reliability of MEMS Pressure sensors for Space" included destructive analysis of Presens sensors at ESTEC, two important findings were made and these have been thoroughly investigated by Presens:

Offset between wafers bonded during MEMS processing. The microsectioning of a MEMS sensing element showed an offset of 20-30μm between two wafer-to-wafer bonded chips. No further mechanical defects were found. Chips from the same wafer, exhibiting the same offset, were thoroughly tested under pressure and temperature at Presens and found OK. Even though the bonding mismatch exceeded allowed mechanical tolerances with a significant factor, chips from the wafer showed no performance reduction and no reduction in life/drift. Burst pressure was also tested and found comparable to chips bonded within mechanical tolerances. In conclusion, chips from the offset wafer bonding are rejects based on mechanical non conformance during optical inspection at foundry, nevertheless the same chips qualify performance requirements without signs of reduced performance. Inspection routines at foundry were revised as result of the offset finding.

Compromising of glass to metal seal during assembly. The disassembly and microsectioning of a complete pressure transmitter at ESTEC showed the pulling of four pins, compromising the high pressure glass to metal seal. The pins had probably been slightly pulled during assembly and screening. The pressure transmitter is assembled with a standard construction where the glass to metal sealed pins are soldered directly to the electronics PCB, if the PCB is stressed during assembly before it is secured to housing or similar, high stress can translate to the pins and possibly pull these out of position.

Compromised glass to metal seal



SEM picture of same pin

Analysis concluded that pulling of pins may cause catastrophic failure from three main effects: possible leak, shaving of plated metal causing loose metal particles, possible pulling of wire-bond too close to chip edge. A review of designs, processes and jigs was performed as a mitigating action.

1.7 PA/QA

Process Identification Documents (PID) for part 1096 and 1560 were compiled in accordance to ESA/SCC Basic Specification 22700. The PID basically includes all QA and PA documentation required to manufacture/screen/qualify the part, the overall documents being:

- Declared material list (bill of material)
- List of process specifications and inspection procedures + flow diagrams

1.8 Follow up activities

Part 1096 was not finalised and not qualified. The programme was stopped after prototyping due to the harmonisation of Presens activities with a Greek ASIC development activity to develop a digital pressure transmitter. No working ASIC was produced by the developers. European space industry has shown interest in part 1096, this pressure transmitter will therefore be finalised and qualified to the requirements of a commercial GEO platform.

Part 1560 was qualified, but only for short space missions. Thorough reviews reveal potential for improvement of the sensor. This is being considered but relies on customer requirements, heritage will be lost upon a redesign. Qualification to longer space missions is planned.

Successful qualification to typical 15years GEO requirements will benefice space applications with pressure sensors of extreme accuracy and the extreme low drift made available from using MEMS technology. Saving in mass and volume is already an obvious benefit.

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0-5V pressure sensor for space applications (Preliminary)

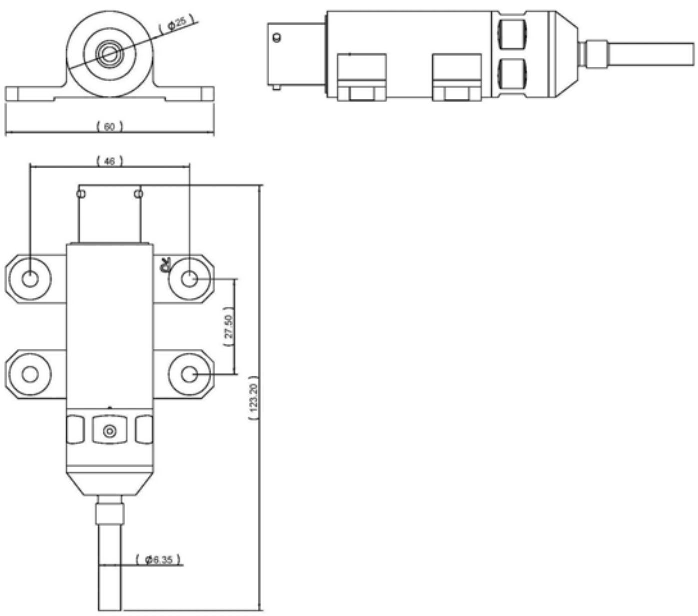
	LP	HP	Unit
Calibrated pressure range (FS)	25	170	bar
Proof pressure	40	255	bar
Burst pressure	80	800	bar
Calibrated temperature range	0/80	0/80	°C
Qualification temperature	-25/90	-25/90	°C
Static error band with internal passive compensation, i.e. measurement of pressure signal, V_S	< ± 2	< ± 2	%FS
Static error band with internal passive compensation and individual linearisation function in ground computer	< ± 0.2	< ± 0.2	%FS
Temperature error of output voltage	< ± 1.5	< ± 1.5	%FS
Thermal zero shift of output voltage	< ± 1.5	< ± 1.5	%FS
Temperature measurement accuracy	± 1		°C
Output pressure signal, V_S	0 – 5		V
Output temperature signal, V_R	0 – 5		V
Supply voltage	24 to 36		VDC
Interface (two options)	Connector or flying leads		
Material	wetted parts: Ti-6Al-4V housing: Ti-6Al-4V		- -
Mass	< 125		g
Insulation resistance between any pin and chassis at 100 V DC, TBC	> 100		MΩ

FS = Full scale

TID tested to 30krad (unshielded electronics) without performance degradation.
SEE hardness TBD.

ICs on hybrid can be interchanged to radiation hardened ICs from same manufacturer.

Pressure port
Outer diameter: 6,35mm
Inner diameter: 4,22mm



Qualification items remains, this datasheet is preliminary.

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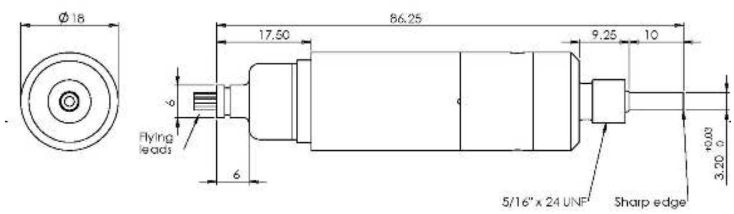
0-5V pressure sensor qualified for PRISMA space craft

Description	Level	Unit
Calibrated pressure range	250	Bar
Proof pressure	375	Bar
Burst pressure	700	Bar
Calibrated temperature range	0 to 50	°C
Acceptance temperature range	-5/55	°C
Qualification temperature	-10 to 60	°C
Total pressure accuracy including non-linearity, hysteresis and temperature effects over calibrated temperature range	< ± 0.2	%FS
Temperature measurement method	Pt-100 element, Class B	
Temperature measurement accuracy	± 1	°C
Pressure port interface	1/8 inch weldable tube and threaded connection 5/16 x 24 UNF	
Pressure port interface material	AISI316L [1)]	
Housing material	Inconel 625	
Supply voltage	5 to 12	VDC
Output signal • 1 bar • 250 bar	Analog, 0.5 V ± 0.2 % 4.5 V ± 0.2 %	V
Mass incl. flying leads	~75	g
Current consumption at 5V-12V	< 5	mA
Electrical interface	Flying leads, 1 m	
Insulation resistance between any pin and chassis at 100 V DC	> 100	M□

TID tested to 10krad (unshielded electronics) without performance degradation.
SEE hardness TBD.



Pressure port
Outer diameter: 3.2mm +0.03/-0
Inner diameter: 1.8mm (nom)

1) Optional tube materials allowed if weldable to Inconel625.