

# MAUS SUNSENSOR

## PRODUCT SPECIFICATION

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**DOCUMENT CHANGE RECORD**

Issue	Date	Total pages	Pages affected	Brief description of change
1	17-08-2020	15	All	New document
1a	04-12-2020	15	7	Clarification update of equations
1b	11-01-2020	15	10	Requirement on resistance sapphire to housing deleted
1c	12-04-2021	15	15	Suggestion for acceptance testing added
2	30-12-21	15	10 10 12..14	Update due to use of different photodiode, Output currents redefined Reg 5.4 added. Note on attachment hardware added Update of vibration and shock levels

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## Abbreviations

AD	Applicable Document
ADC	Analogue to Digital Converter
BOL	Begin of Life
COTS	Commercial Off The Shelf
CTE	Coefficient of Thermal Expansion
EMC	Electro Magnetic Compatibility
EOL	End of Life
FOV	Field of View
ICD	Interface Control Document
LOS	Line Of Sight
MAIT	Manufacturing Assembly Integration and Test
NTC	Negative Temperature Coefficient resistor (thermistor)
PIND	Particle Induced Noise Detection
PSD	Power Spectral Density
RD	Reference Document
Req	Requirement



## Applicable documents

Nr	Document name	Document number	Issue
[AD-01]	MAUS interface control document	20-LRD-ICD-0003	1
[AD-02]	MAUS interface control drawing	114T701	01
[AD-03]	Precision fastener	500M085	01
[AD-04]	Washer vented	500M086	01
[AD-05]	Delivery, Packing, Storage, Handling, and Transportation procedure.	19-LRD-PR-0052	1

## Reference documents

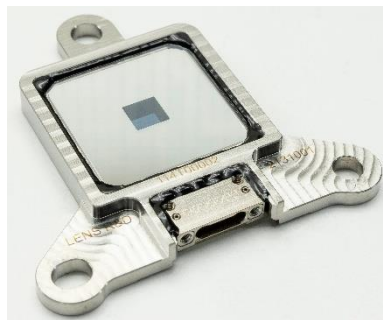
Nr	Document number	Document name	Issue



## 1 Introduction

The MAUS Sun sensor, see [Figure 1](#) is a radiation hardened Cubesat Sun sensor with a nominal field of view of >64 degrees in diagonal which is specifically designed for highly demanding satellite applications.

This document specifies the performance of the sensor and shall be read in conjunction with the interface control document [AD-01] and the interface control drawing [AD-02].

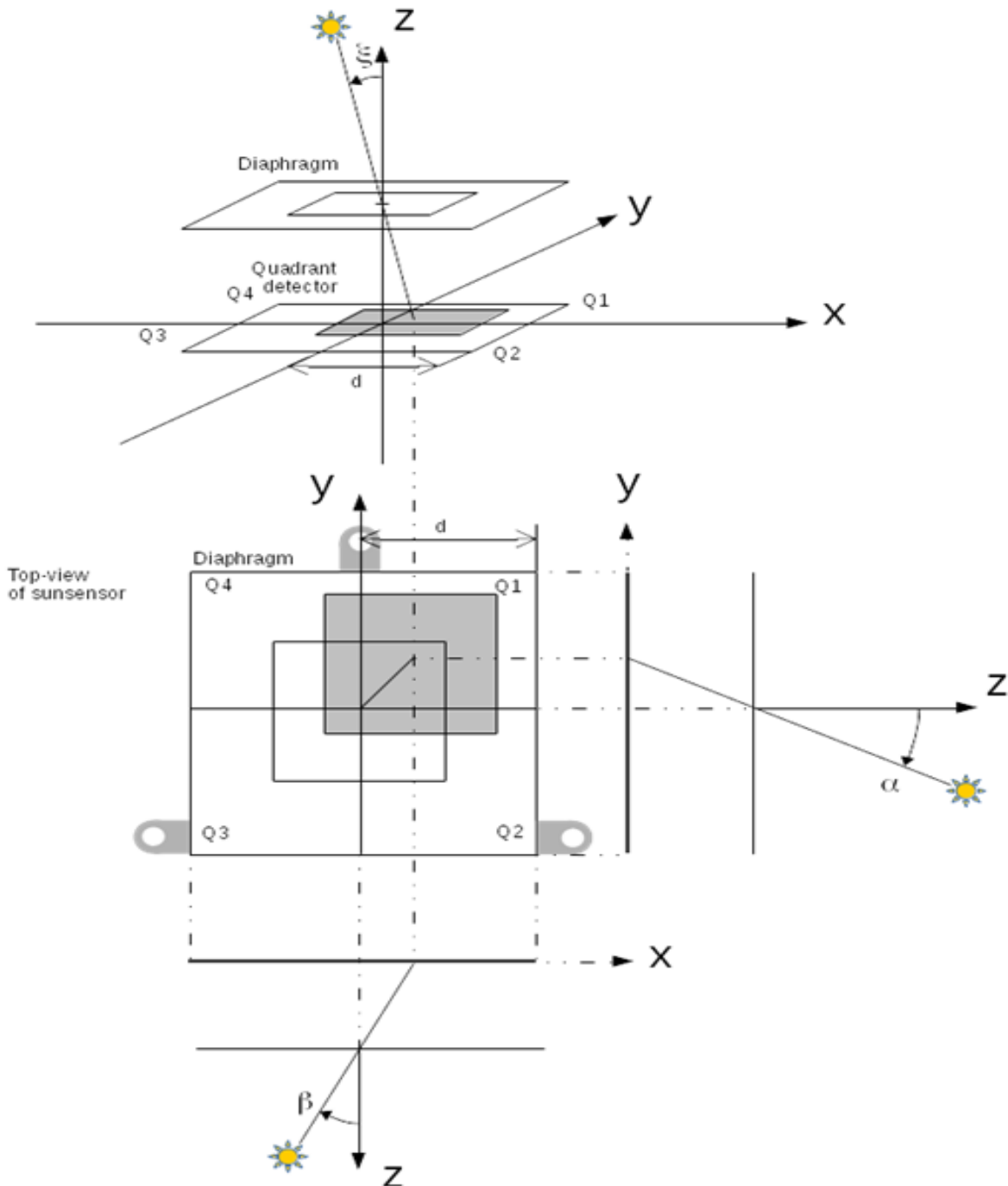


**Figure 1 MAUS Sunsensor V02**



## 2 Solar direction angles

Apart from the quadrant definition as given in [AD-02] it is necessary to define the reference frame of the Sun sensors in order to avoid sign errors in the attitude control subsystem. All MAUS Sun sensors use the reference definition given below.



**Figure 2  $\alpha$  and  $\beta$  reference frame and angle visualization**



These diagrams provide the definition of the angles  $\alpha$  and  $\beta$  to be calculated by means of the formulas given in Equation 1. It can be deduced that a negative  $\alpha$  means that the sun is to the top of the Sun sensor and that a negative  $\beta$  means that the sun is to the right of the Sun sensor (both when viewed from the top side). The illumination given in Figure 2 is for positive  $\alpha$  and positive  $\beta$  of the MAUS Sun sensor

All MAUS Sun sensors use the reference definition given in Equation 1. The definition is applicable for the non-compensated utilization. In order to improve the accuracy further the sensor can be implemented with standard calibration tables or using a simplified compensation formula, see Equation 2.

$$S_a = \frac{Q_1 + Q_4 - Q_2 - Q_3}{Q_1 + Q_2 + Q_3 + Q_4} = \frac{\tan(\alpha)}{\tan(\alpha_{max})}$$

$$S_b = \frac{Q_1 + Q_2 - Q_3 - Q_4}{Q_1 + Q_2 + Q_3 + Q_4} = \frac{\tan(\beta)}{\tan(\beta_{max})}$$

**Equation 1 BiSon64-ET  $\alpha$  and  $\beta$  formulas**

$$S_{a\_compensated} = S_a - C_a = \frac{Q_1 + Q_4 - Q_2 - Q_3}{Q_1 + Q_2 + Q_3 + Q_4} - C_a = \frac{\tan(\alpha)}{\tan(\alpha_{max})}$$

$$S_{b\_compensated} = S_b - C_b = \frac{Q_1 + Q_2 - Q_3 - Q_4}{Q_1 + Q_2 + Q_3 + Q_4} - C_b = \frac{\tan(\beta)}{\tan(\beta_{max})}$$

**Equation 2  $\alpha$  and  $\beta$  formulas with correction in radian**

$C_a$  is the offset correction parameter used to compensate zenith offset in the  $\alpha$  direction.  
 $C_b$  is the offset correction parameter used to compensate zenith offset in the  $\beta$  direction.

### 3 Mechanical interfaces

The dimensions of the mechanical interfaces are given in interface control drawing [AD-02]. The counterpart on which the Sun sensor will be mounted shall have at least the same accuracies as the sensor as defined in the IC-drawing.

The X axis of the right-hand Cartesian reference system is defined by the line through the center of the lower right and lower left mounting points. The Z axis is fixed by means of the plane running through the three mounting feet.

#### 3.1 Repeatability of mounting

**Req. 3.1** The repeatability of mounting will be better than 0.06 degrees, when using the prescribed mounting hardware (special fasteners with washers, [AD-03] and [AD-04]). Also the dimensions and accuracies of the counterpart on which the Sun sensor will be mounted shall be in line with the Sun sensor specifications as stated on the IC-drw [AD-02] and assembly is according to the prescribed procedure as given in paragraph 6.3 of [AD-05].

#### 3.2 Fastening torque

The special fasteners defined in [AD-03] shall be fastened with a torque of  $1\text{Nm} \pm 10\%$ .

#### 3.3 Mass

**Req. 3.3** The mass of the unit is  $\leq 16$  grams.

#### 3.4 Centre of gravity

The center of gravity is given on sheet 1 of [AD-02] (no requirement)

### 4 Optical interfaces

The optical interfaces are defined on sheet 2 of [AD-02]. For optimal functioning of the sensor there must be no obstruction visible within the given FOV.

**Req. 4-1** The field of view of the sensors is  $>62^\circ$  in both diagonals.

The actual angles and associated limits on the FOV are given on sheet 2 of [AD-02].

## 5 Electrical interfaces

The electrical connections are given on sheet 3 of [AD-02].

The sensor will generate 4 analogue currents the value of which is a function of sunlight intensity and direction.

**Req. 5-1** The generated currents shall be  $-2.00 \text{ mA} \pm 10\%$  at normal incidence and  $20^\circ\text{C}$

**Req. 5-2** The generated currents shall be  $-2.80 \text{ mA} \pm 10\%$  maximum at  $20^\circ\text{C}$

**Req.5-4** The temperature coefficient of the current generated will be between 0 and  $+0.1 \text{ } \%/^\circ\text{C}$

### NOTE:

These values are at  $1 \text{ AM}(0)$  sun illumination and 0 bias (measured with a transimpedance amplifier) over the full temperature range and without albedo signal. In orbit measurements have shown that the collected albedo signal can be significant and might lead to saturation in the acquisition chain if not accounted for. Albedo signals however are non-deterministic and both altitude and local node time dependent. As a result they cannot be unambiguously specified. Based on currently available in-orbit data a full-scale range including a margin of  $+25\%$  is expected to cover all orbits above 600km at all inclinations. It should however be noted that all specifications presume the signal is albedo free.

**Req. 5-3** The internal thermistor has a nominal value of  $10\text{k}\Omega \pm 10\%$  @  $25^\circ\text{C}$ .

### 5.1 Grounding and isolation

**Req. 5.1-1** The resistance between common ground and case will be  $1\text{M}\Omega < R < 10\text{M}\Omega$ .

**Req. 5.1-2** The capacitance between the sensor and ground will be  $< 100\text{pF}$ .

**Req. 5.1-3** Deleted

### 5.2 Specified accuracy

**Req. 5.2-1** The non-corrected angular accuracy is better than 3.5 degrees .

**Req. 5.2-2** The specified angular accuracy is better than 2 degrees if a sensor specific offset and gain correction is implemented.

**Req. 5.2-3** The specified angular accuracy is better than 0.5 degree  $3\sigma$  if calibration tables are used.

NOTE: these accuracies can only be guaranteed when the mounting hardware as specified in [AD-03] and [AD-04] is used.

## 6 Environmental specifications

### 6.1 Storage conditions

**Req. 6.1** The sensor shall be stored in a dust-free, dry and temperature-controlled environment within a temperature range of 0°C to +30 °C and a relative humidity of <60%. Storage lifetime under these conditions is longer than 5 years when kept in the original packaging.

### 6.2 Operating temperature range

**Req. 6.2** The sensors will perform within specifications when operated in the range of -40°C to +80°C.

### 6.3 Non-operating temperature range

**Req. 6.3** The sensors will survive a non-operating temperature range of -45°C to +85°C.

### 6.4 Temperature cycling

The sensors have been qualified by temperature cycling as specified in [Table 1](#).

Req.	Conditions	Temperature range	Number of cycles
6.4	Thermal vacuum cycling (qualification)	-40°C..... +80°C	1000
		-45°C...+105°C	1000

**Table 1 Thermal cycling specification**

### 6.5 Vibration specifications

Vibration specifications for the sensors as used during qualification testing are given below. The sine and random qualifications have been performed using the in [AD-03] and [AD-04] defined hardware and torqued to the level specified in chapter 3.2.

#### 6.5.1 Eigenfrequency

**Req. 6.5.1** The first eigenfrequency is >200Hz.

### 6.5.2 Sine vibration

**Req. 6.5.2** The sensors have shown to be able to function within specifications after being subject to vibration test levels specified in [Table 2](#) in all three axes.

Sine vibrations	
Frequency Hz	Level
5...44.6	10mm peak to peak 5mm zero to peak
44.6...100	40g
1 octave/minute 1 sweep up/1 sweep down	

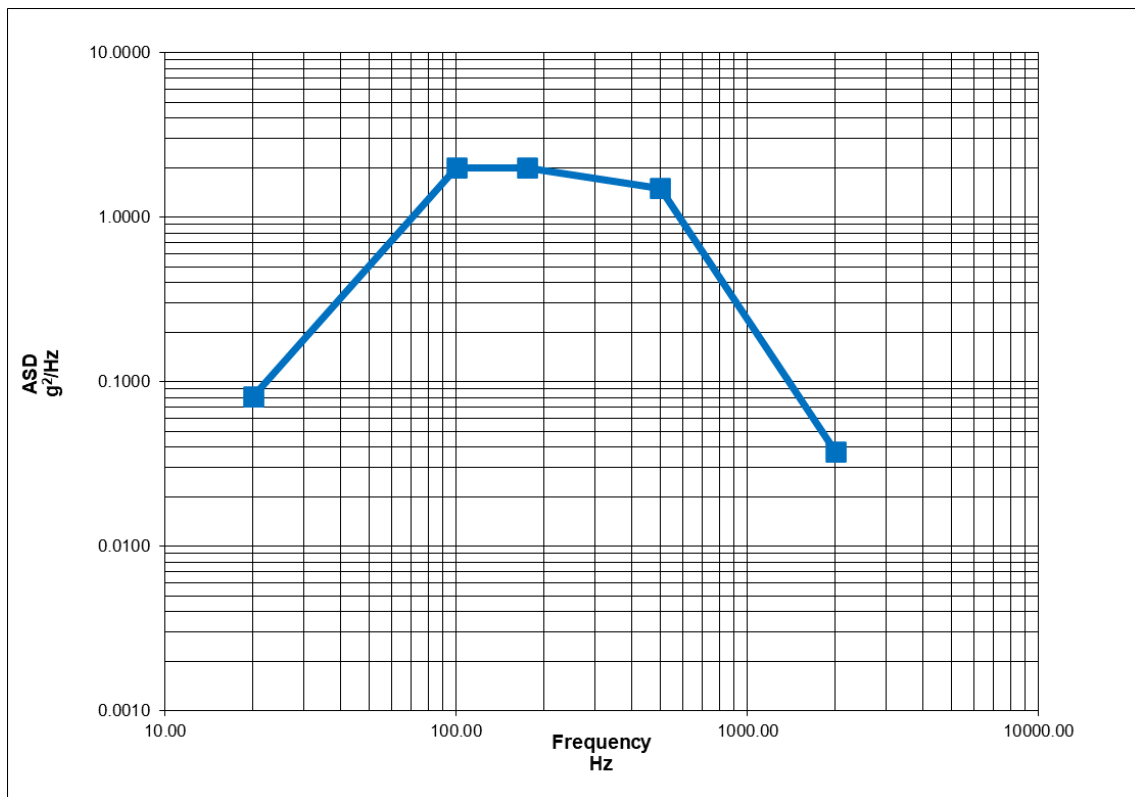
**Table 2 Sine vibrations**

### 6.5.3 Random vibrations qualification

**Req. 6.5.3** The sensors have shown to be able to function within specifications after being subjected to vibration test levels specified in [Table 3](#) and [Figure 3](#) in all three axes.

Random vibrations						
Frequency (Hz)	ASD (G <sup>2</sup> /Hz)	dB	OCT	dB/OCT	Area	Grms
20.00	0.0810	*	*	*	*	*
100.00	2.0000	13.93	2.32	6.00	66.30	8.14
175.00	2.0000	0.00	0.81	0.00	216.30	14.71
500.00	1.5000	-1.25	1.51	-0.82	767.28	27.70
2000.00	0.0376	-16.01	2.00	-8.00	1174.02	34.26
Total RMS level: 34.26g						
Duration: 180 seconds						

**Table 3 Random vibrations (qualification)**



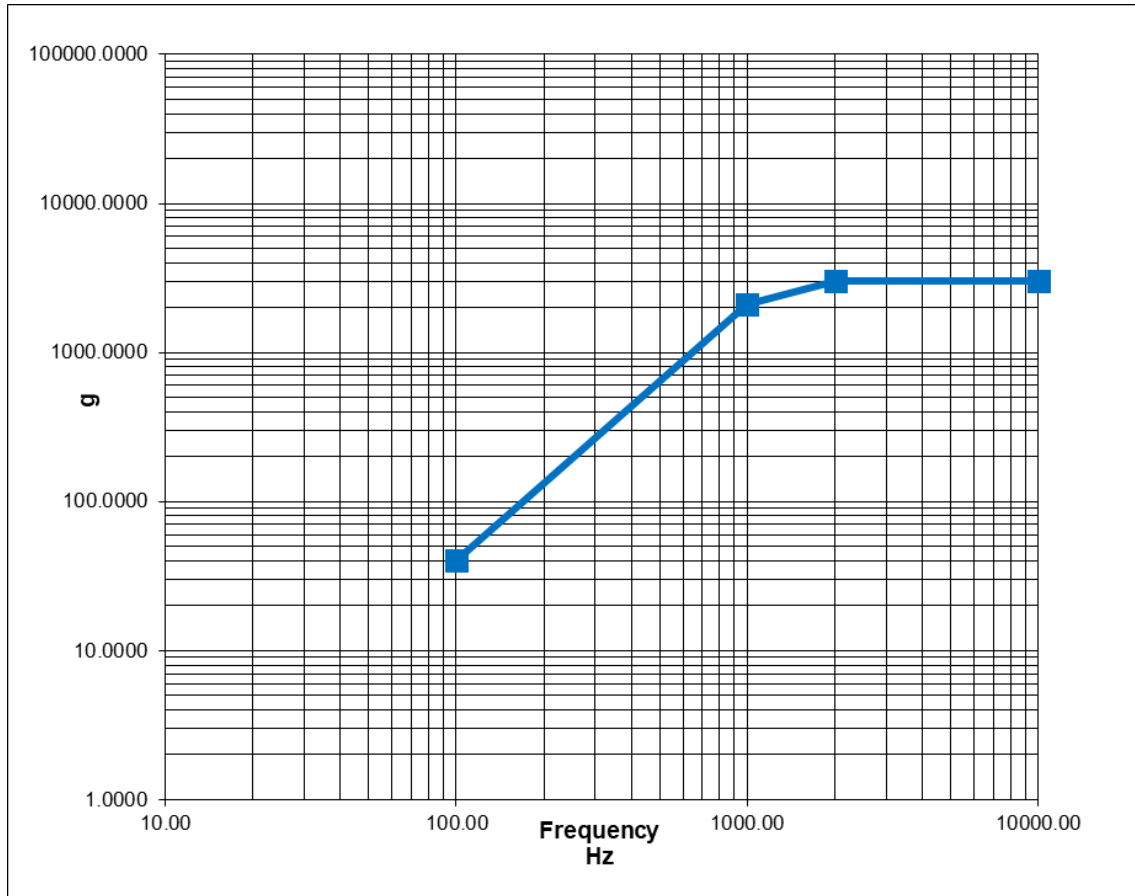
**Figure 3 Random vibration profile (qualification)**

**6.5.4 Shock specification**

**Req. 6.5.4** The sensors have shown to be able to function within specifications after being subject to vibration test levels specified in [Table 4](#) and [Figure 4](#) in all three axes.

Pyro shock	
Frequency Hz	Level g
100	40
1000	2100
2000	3000
10000	3000
3 shocks in any direction	

**Table 4 Pyro shock specifications (qualification)**



**Figure 4 Pyro shock profile (qualification)**

**6.6 Cosmic radiation resistance**

**Req. 6.6** Bare diodes shall sustain  $8E14$  1MeV electron testing without failure at a fluence of  $1E11$  electrons per second. Tolerance on radiation test parameters have been  $\pm 5\%$ .

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## 6.7 Standard acceptance testing activities

### 6.7.1 Vibration testing

**Req. 6.7.1** No acceptance vibration test is performed unless specifically agreed upon. if an acceptance vibration test is required, vibration testing in Z axis only at half of the specifications as given in par 6.5.3 is suggested

### 6.7.2 Acceptance thermal cycling

**Req. 6.7.2** No acceptance thermal cycling will be performed, unless specifically agreed upon. If acceptance thermal cycling is required, 8 thermal vacuum cycles between -40°C and +80°C is suggested. This test can be performed but at an extra cost.

### 6.7.3 Acceptance calibration

**Req. 6.7.3** As a result of standard Quality Control, the sensors will be calibrated before delivery.

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