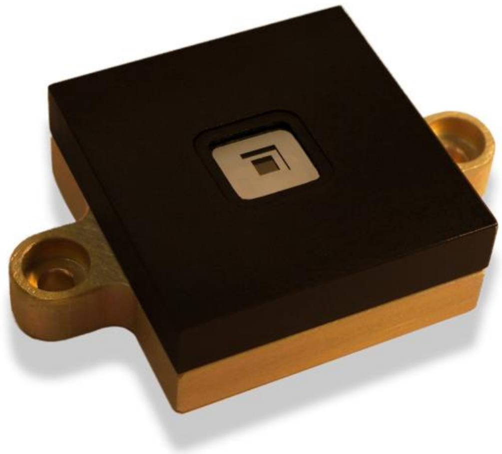

SSOC-A60

INTERFACE CONTROL DOCUMENT

Identifier:	SSOCA60-15-MAN
Title:	Interface Control Document SSOC-A60
Entity:	Solar MEMS Technologies S.L.
Authors:	Manuel Rodríguez, J. Miguel Moreno
Date:	17th September 2018
Security:	Confidential

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Approval

	Name	Position	Date	Signature
Prepared by:	Manuel Rodriguez	Project Manager	27.04.2022	
Approved by:	José M. Moreno	General Manager	27.04.2022	

Document history

Revision	Date	Change	Authors
100	17.09.2018	Initial version	MRH, JMML
101	24.10.2018	Degradation added: table 7 Formula corrected: section 2.9	MRH
102	26.09.2019	Table 2 connector updated to DLMM Figure 4 updated with connector DLMM	MRH
103	31.10.2019	Table 2: connector changed to DMM	MRH
104	22.11.2019	Section 2.5: all VCC_RTN are the same.	MRH
105	27.03.2020	Two options included 5 or 12V Table 2 updated Table 3 updated Section 2.8 updated	MRH
106	20.07.2020	Table 2 updated: exclusion fov added	MRH
107	25.08.2021	Table 3: specification “output voltage rise/fall time” corrected.	MRH
108R	27.04.2022	Fig 2 removed Supply voltage at 12V: removed Table 3 updated to model R Section 2.8 updated Section 5 updated Annex added	MRH
109R	18.01.2023	Section 5.4: radiation detected, added Section 5.5: updated to show “radiation detected” parameter.	MRH
110R	03.02.2023	Table 4: 12V removed	MRH
111R	01.03.2023	Table 2: updated	NMP

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ABBREVIATIONS

AIT	Assembly, Integration and Test
AR	Acceptance Review
CDR	Critical Design Review
DCL	Declared Component List
DDV	Design, Development and Verification
DR	Design Review
ECSS	European Cooperation for Space Standardization
EEE	Electronic, Electromagnetic and Electrical Part
EM	Engineering Model
FM	Flight Model
FOV	Field Of View
HAAPS	High-Accurate Angular Positioning System
ICD	Interface Control Document
LUT	Look-up-table
MEMS	Micro Electro Mechanical Systems
MoC	Matrix of Compliance
PA	Product Assurance
PCB	Printed Circuit Board
PDR	Preliminary Design Review
QA	Quality Assurance
QM	Qualification Model
SMT	Solar MEMS Technologies
SS	Sun Sensor
SSOC	Sun Sensor On a Chip
TBC	To be confirmed
TBD	To be defined

Solar MEMS Technologies S.L. CIF. B-91794131. C/ Early Ovington 24, nv 01, 41309 La Rinconada (Sevilla) Spain
Phone : +34-95-4460113 E-Mail : smt@solar-mems.com

APPLICABLE DOCUMENTS

The next documents contain supporting and background information to be taken into account during the activities specified within this document.

Ref.	Document Number	Title
AD-01	SSOCA60-55-ICD	Mechanical Interface Control Document
AD-02		
AD-03	ECSS-E-ST-10-02C	Space engineering: Verification
AD-04	ECSS-E-ST-10-03C	Space engineering: Testing
AD-05	ECSS-E-ST-10-24C	Space engineering: Interface management
AD-06	ECSS-E-ST-50-14C	Space engineering: Spacecraft discrete interfaces
AD-07	MIL-STD-461C	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment

Table 1. Applicable Documents

1. INTRODUCTION

The scope of this ICD is to explain the Mechanical, Thermal and Electrical interfaces of the Sun Sensor SSOC-A60-R.

SSOC-A60 is a miniaturized two axis sun sensor capable of measuring the incidence angle of a sun ray accurately in both azimuth and elevation. The sensor consists of four photodiodes fabricated monolithically in the same silicon substrate and placed orthogonally. The sunlight is guided to the detector through a window above the sensor, inducing photocurrents on each diode that depends on the angle of incidence.

A printed circuit board with the EEE parts and the solar sensor is packaged in a mechanical case to attenuate the influence of the outer-space radiation effect. The sensor is also protected with an additional cover-glass placed on the package. The external window of the aluminum structure has been designed to avoid light reflections inside the active area of the sensor. The following figure illustrate the SSOC-A60 sensor.

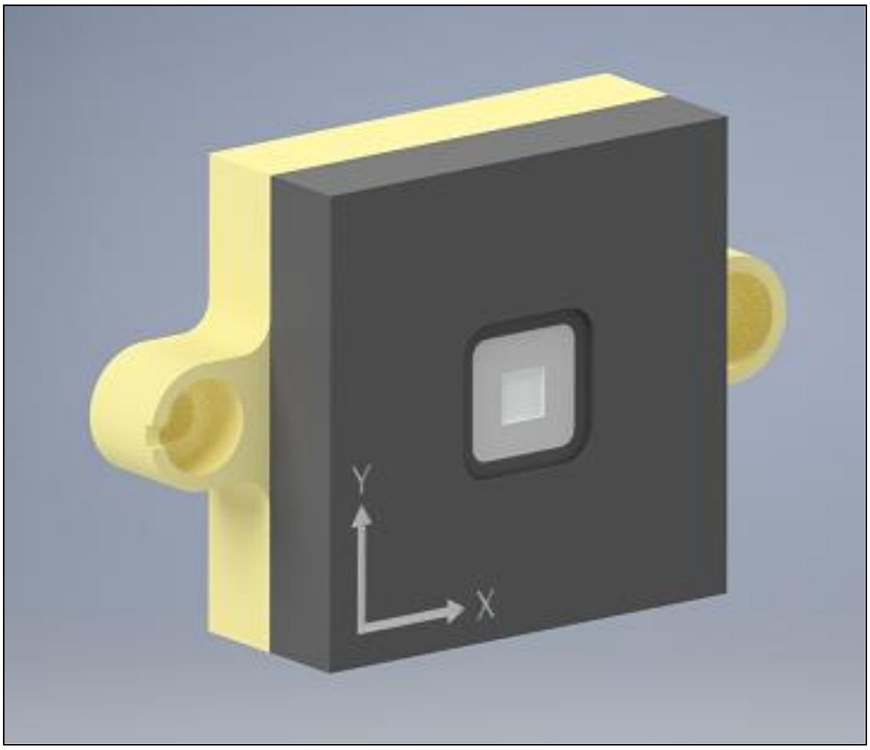


Fig 1. SSOC-A60

1.1. General characteristics

SPECIFICATIONS	Value	Unit	Comments
Sensor type	2	axes	Orthogonal
Performance field of view	+/- 60	º	Cone shaped, performance field
Exclusion Field of View	+/- 75	º	It must be clear of obstacles or reflective surfaces (recommended)
Accuracy	0.3	º	3sigma error
Precision	0.05	º	
Supply voltage	5	V	Vcc must be regulated
Average consumption	< 25	mA	< 15 mA when illuminated
Connector	10	Pins	D221T10D51 Nicomatic
Analog outputs	5	Signals	4 sun sensor outputs + 1 temperature
Temperature range	-45 to 85	ºC	Operation
Dimensions	30x30x12	mm	
Mass	25	g	
Mounting holes	2	Holes	Diameter 3.2 mm
Housing	Al. 6082		Alodine + Black coating

Table 2. General Characteristics.

2. ELECTRICAL INTERFACE

2.1. Specifications

Electrical characteristics of the SSOC-A60 are summarized in the following table:

SPECIFICATIONS	Min	Typical	Max	Unit	Comments
Global specs					
Supply voltage at 5v	4.5	5	5.5	V	
Supply voltage ripple	0	-	100	mV_{pp}	
Current consumption when illuminated	-	9	-	mA	Light: AM0 1360 W/m^2
Current consumption when dark	-	21	-	mA	No light inside FoV
Output signals					
Nº of signals	-	5	-		4 sensor + 1 thermistor
Output voltage range	0	-	5	V	Max/Min output voltage
Output capabilities	-	-	-	-	Voltage follower included
Output voltage rise/fall time	-	0,8	-	ms	Internal RC per output
Inrush current	-	-	1,15	A	First peak
Inrush duration	-	3	-	us	First cross-zero
ADC converter conditions					
ADC bits	-	10	-	Bits	Recommended
Voltage range	0	-	5	V	
Sun sensors are calibrated using an ADC of 10 bits.					

Table 3. Electrical Characteristics.

2.2. Inrush current

Power on peak current is showed in the following figure:

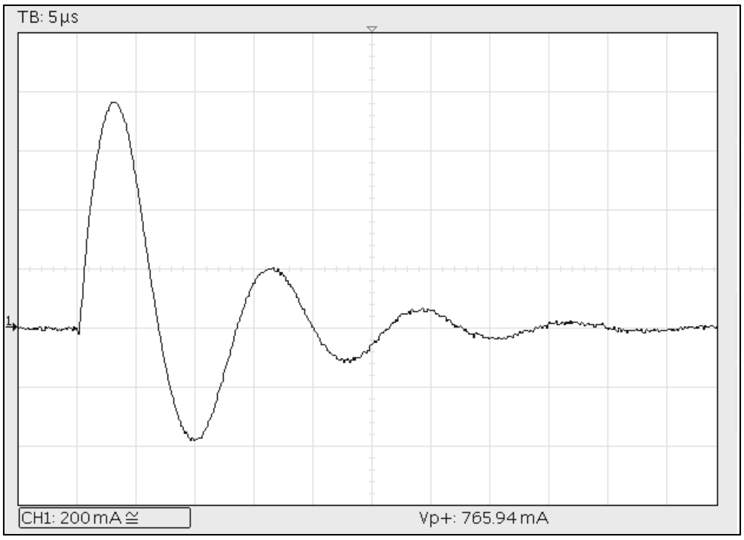


Fig 2. Inrush current

2.3. Electrical protections

SSOC-A60 does not include the following electrical protection: insulation switch, fuses, reverse polarity.

2.4. Grounding and isolation

Grounding has been performed to be done at one point only:

- Case: mounting interface of the chassis.
- Connector: chassis pin.

Pin 9 of connector is connected to mechanical case (chassis).
The internal photodiodes are electrically isolated from chassis.
The sensor has no direct connection between the power zero and the chassis (electrically isolated).

2.5. Connector pin numbering

The following table shows the pinout list.

Pin number	Signal	Description	Type	Output range (Typ.)
3	µSSB1	Photodetector 1	Analog output	0-5 V
8	µSSB2	Photodetector 2	Analog output	0-5 V
7	µSSB3	Photodetector 3	Analog output	0-5 V
2	µSSB4	Photodetector 4	Analog output	0-5 V
4	VCC_RTN	Supply return	Analog output	0 V
10	VCC	Supply voltage	Power	Vcc
5	VCC_RTN	Supply return	Power	0 V
1	THD	Thermistor output	Analog output	0-5 V
6	VCC_RTN	Supply return	Analog output	0 V
9	Chassis	Connection to chassis	-	-

Table 4. Connector pinout

All VCC_RTN signals are internally connected to the same point inside the sun sensor.

2.6. Signal electrical interface data

The electrical signals of the sun sensor are detailed as follows:

- Supply voltage: two inputs (VCC and VCC_RTN), corresponding to signal line and return line, respectively.
- Analog signals: five lines.
    - 4 analog output signals of the sun sensor.
    - 1 analog output signal of the thermistor.
- Chassis: One signal to connect the ground reference plane of the circuit to the spacecraft/satellite structure.
- Supply return signals: all of them are internally interconnected (pins 4,5,6).

Solar MEMS Technologies S.L. CIF. B-91794131. C/ Early Ovington 24, nv 01, 41309 La Rinconada (Sevilla) Spain
Phone : +34-95-4460113 E-Mail : smt@solar-mems.com

2.7. Hardware interfaces

Electrical connection with SSOC-A60 uses a male micro-connector with 10 pins. This connector is installed through the bottom face of the mechanical case.

The connector is a NICOMATIC D221T10D51, 2-row male connector straight SMT with fixing. The recommended connector for connection cable side is a NICOMATIC D222SP10D53, 2-row female connector with fixing crimp gauge AWG 24-28, 10 contacts.

The pin numbering of connector is described in the following figure:

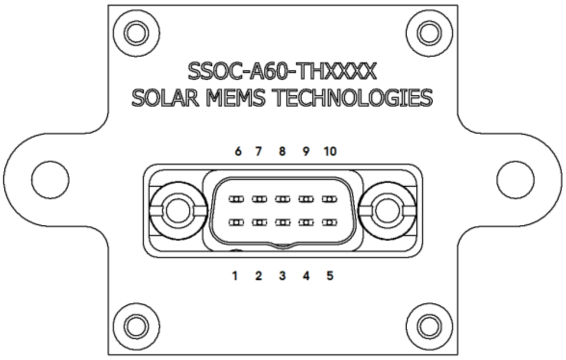


Fig 3. Connector pin numbering

For the interface cable, Solar MEMS recommends the use of a cable harness composed of AWG-24 wire gauge for the individual wires, twisted, and shielded for best reduction of magnetic field and EMI. The recommended cable length shall be shorter than 1.5 m.

2.8. Thermistor transfer function

For thermistor reading, the output voltage (pin 1, THD) must be measured and then apply the following formula to get a measurement of the resistance value of the thermistor, which is equivalent to a temperature value, based on its performance curves (see annex):

$$R_{NTC} = 8250 \times THD / (Vcc - THD)\ [Ohm]$$

THD: Thermistor_Output

SPECIFICATIONS	Min	Typical	Max	Unit	Comments
Thermistor type	-	-	-	-	TE 44907 GSFC S311-P18-07S7R6
Beta value 25/85	-	3694	-	K	
Tolerance on beta value	-	0.8	-	%	
Temperature range	-55	-	90	ºC	
Voltage range	0	-	5	V	
Precision	-	27	-	mV/ºC	From 0 to 90 ºC

Table 5. Thermistor Characteristics.

For best accuracy and precision, input impedance of the ADC for reading the thermistor signal should be high, to minimize current draw.

3. MECHANICAL INTERFACE

3.1. Mechanical case

Mechanical case is made of aluminum 6082 type, with black coating to mitigate straylight into the sun sensor and homogenize heat due to solar radiation, and with alodine 1200S to avoid oxidation and ensure electrical and thermal conduction through mounting interface.

The walls of the case have a thickness of 3 mm to mitigate radiation impact inside, due to TID and TNID sources.

3.2. Mechanical interface

SSOC-A60 dimensions of main body are 30 x 30 x 12 mm (48 x 30 x 12 mm including mounting feet and connector). The following figures show the relevant dimensions of the unit and the centre of gravity. All dimensions are in mm. The maximum geometrical tolerance of the mechanical housing is 0.05 mm.

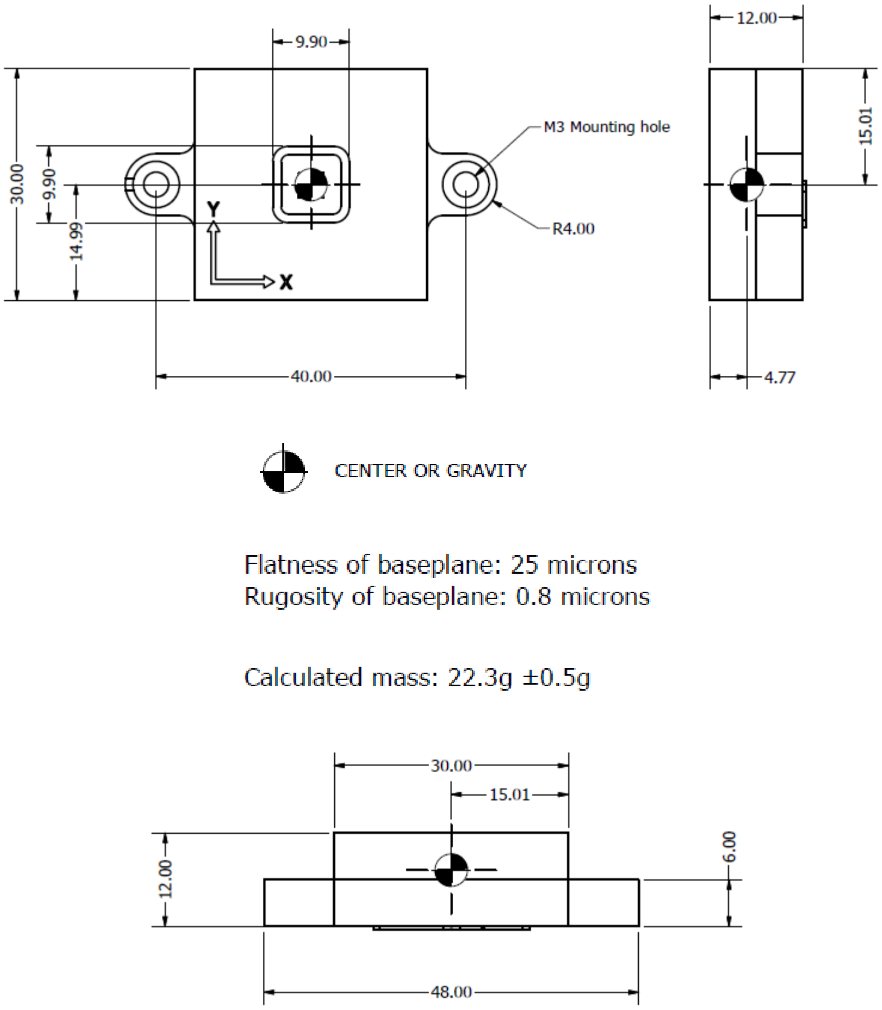


Fig 4. Mechanical layout and interface dimensions of SS

3.3. Mounting interface and holes

The sensor package has two mounting feet for M3 bolts. Both feet have precision holes with a diameter of 3.2 mm. The contact surface flatness is 25 microns, the roughness of baseplate is better that 0.8 microns and the contact area coplanarity is better than 10 microns. The distance between the centres of the two holes is 40 +0.02/-0.02 mm.

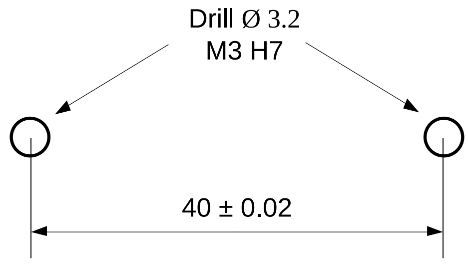


Fig 5. Assembly pattern of mounting holes

For fastening the sensor at the two precision holes, it is recommended using M3 threaded screws A2-70 s/UNE – EN-ISO 4762 -2005, A2 stainless steel, 20mm length, minimum and maximum torque levels of 1.1 to 1.4 Nm and including stainless steel washers to increase mechanical robustness. It is important to use the same torque in both bolts. The choice of recommended fasteners as well as torque levels ensures appropriate sensor alignment.

Sun Sensor alignment during installation into the satellite should be ensured using an alignment procedure and/or checking, like laser pointing, reference optical cubes, etc. This procedure shall be carried out by the AIT responsible of the satellite, although SMT can provide technical support if necessary.

3.4. Reference coordinate system

The mechanical reference axes for sensor assembling are shown in the following figure, where the origin of the coordinate system is the centre of the left mounting hole (front view). The optical line of sight (Z_M-axis) is perpendicular to the sensor base plane. The centreline of the two sensor mounting holes is X_M axis, and the Y_M axis is the third one of a right-handed orthogonal coordinate system.

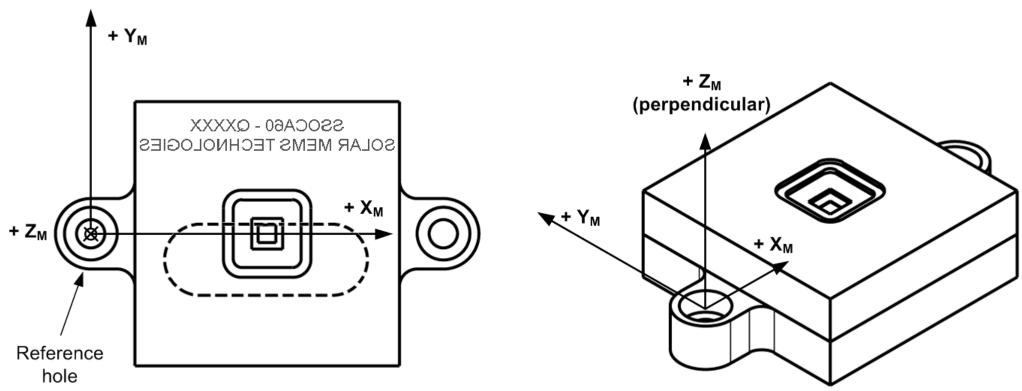


Fig 6. SSOC-A60 mounting reference system

With the X_A, Y_A, Z_A coordinate system as the sensor angles references, the angle α (angle X) and angle β (angle Y) specify the angular position of the incident sun ray inside the field of view of the sun sensor.

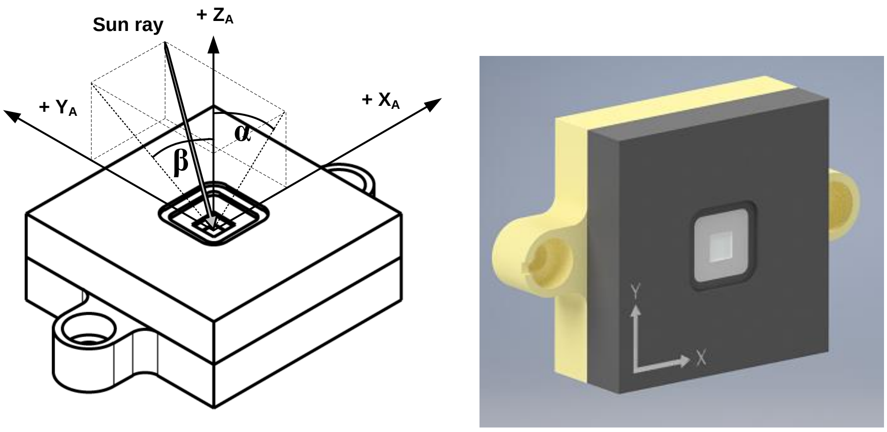


Fig 7. SSOC-A60 reference for measured angles

Reference axes X and Y have been indicated in the front face of the sun sensor.

3.5. Materials and surface treatments

SSOC-A60 package is made of 3 mm aluminium 6082 to attenuate the influence of the outer-space radiation. It is black-anodized according to the ECSS-Q-ST-70-03C (MIL-A-8625 type II class 2, hard black anodize), excepting the contact surface of the bottom side which is treated with alodine 1200S for space applications (ECSS-Q-70-71) to ensure electrical and thermal contact with the spacecraft baseplate.

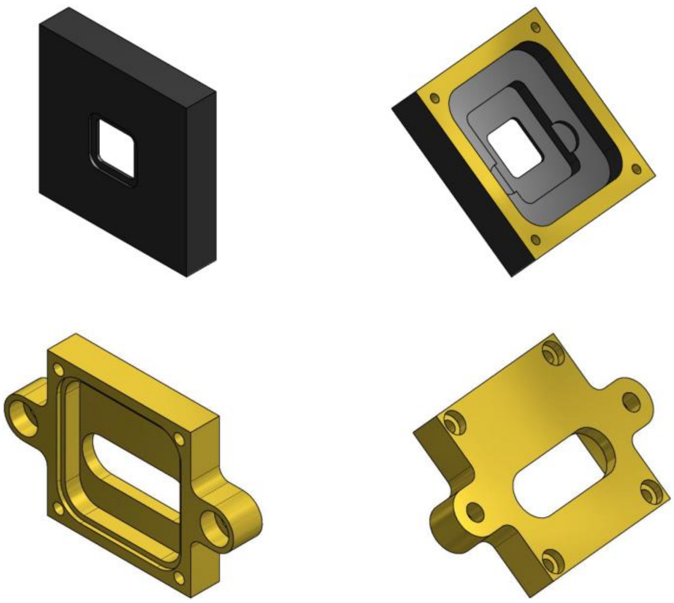


Fig 8. Surface treatment of SSOC-A60
(Black areas are black anodized and yellow areas alodined)

3.6. Venting holes

Adequate venting is provided to preserve the structural integrity of the units during launch depressurization. Venting holes are in the bottom cover of the sensor package (area surrounding the SS connector) and in the top cover of the package (area surrounding the sensor cover glass). The total area for venting is 66 mm^2.

3.7. Labeling

SSOC-A60 is laser labelled on the bottom face with a unique serial number for each sensor according to the following picture, where XXXX is a number between 0000 and 9999:

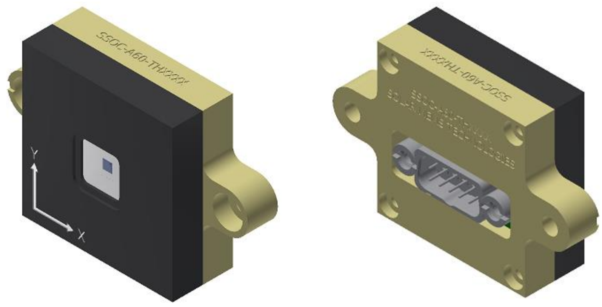


Fig 9. Sensor labeling

There a second label in the top face indicating the reference axes (Y and X). AIT responsible can use this indicator to ensure that the sensor is correctly installed in the satellite and according to the spacecraft reference system.

3.8. Remove before flight label

SSOC-A60 precision can be affected by dust particles. For that reason, FM models are delivered with a protective film (Kapton) with an attached red 'Remove Before Flight' label.

Fig 10. Remove before flight label with polyimide kapton

4. THERMAL SPECIFICATIONS

4.1. Specifications

Thermal characteristics of the SSOC-A60 are according to AD-08 and summarized in the following table:

SPECIFICATIONS	Min	Typical	Max	Unit	Comments
Global specs					
Acceptance thermal range	-40	-	+75	ºC	
Qualification thermal range	-45	-	+85	ºC	
Survival thermal range	-55		+105	ºC	
Dissipation					
Contact area (conduction)	-	7.97	-	cm^2	Mounting interface
Roughness of contact area	-	0.8	-	um	
Coplanarity of contact area	-	-	10	um	
Solar absorptance (α)	0.930	-	-	-	Black coating
Normal emittance (ε)	0.853	-	-	-	Black coating
Power dissipation	-	50	100	mW	

Table 6. Thermal Characteristics.

Main dissipation path of the SSOC-A60 is conductive through the mounting interface to the Spacecraft. It should be respected and ensure a good contact surface-surface, without any heater.

The part which is the most sensitive to temperature is the photodiode. Its dissipation is ensured by conduction:

- From photodiode to PCB through copper layer.
- A second copper layer in PCB to dissipate heat from photodiode position to the borders of the PCB.
- Dissipation from PCB borders to mechanical case through stainless steel bolts and copper layer.
- Dissipation from aluminium mechanical case to mounting interface and finally to Spacecraft baseplate.

4.2. Thermistor

Thermistor included is installed inside mechanical case, onto the PCB, to measure its temperature. This thermal point is representative of the temperature of the photodiode, which is the part most exposed and most sensitive to heating due to solar radiation.
The temperature measurement is only used for monitoring.

Solar MEMS Technologies S.L. CIF. B-91794131. C/ Early Ovington 24, nv 01, 41309 La Rinconada (Sevilla) Spain
Phone : +34-95-4460113 E-Mail : smt@solar-mems.com

5. OBC INTERFACE

The following algorithm and look-up-tables must be implemented in the OBC to translate output voltages of the sun sensor into angle measurement.
Algorithm and tables are delivered to the customer in ".h" files for integration.
Following sections are for description only.

5.1. Sun sensors transfer function

The four sun sensor signals (µSSB1 to 4) must be measured using an ADC of 10 bits of resolution as minimum to ensure performance.

Those values must be then used in the following formulas to get the sensor response factor, called Fx and Fy:

(1)

$$X1 = 2*Vcc - (Vph1 + Vph2)$$
$$X2 = 2*Vcc - (Vph3 + Vph4)$$
$$Y1 = 2*Vcc - (Vph1 + Vph3)$$
$$Y2 = 2*Vcc - (Vph2 + Vph4)$$

(2)

$$Fx = (X1-X2) / (X1+X2)$$
$$Fy = (Y1-Y2) / (Y1+Y2)$$

Vphx: photodetectors (µSSB1 to 4)

Values Fx and Fy must be used according to algorithm described in section 5: double interpolation and look-up-table matrixes.

5.2. Look up table

Every delivered sun sensor shall include three look-up-table as follows:

- Angle X matrix.
  Matrix of 61x61 elements: 2 bytes unsigned integer per element.
- Angle Y matrix.
  Matrix of 61x61 elements: 2 bytes unsigned integer per element.
- Albedo matrix.
  Matrix of 625 elements: 2 bytes unsigned integer per element.

Three LUT matrixes shall be delivered in a .h file.

5.3. Algorithm

Algorithm to be implemented for angle measurement is as follows:

1. Get Fx and Fy values from uSSB1 to 4 signals.
2. Ensure detection inside performance FoV:
   a. Fx and Fy are compared with side-side margins delivered in LUT.h file.
   b. If Fx or Fy are out of margins, the Sun is not inside Performance FoV.
   c. If Fx and Fy are inside margins, go to step 3.
3. Apply double interpolation algorithm using LUT of Angle X and Angle Y.
   This algorithm shall be provided in C code (.h), to be included in OBC:
4. Results of double interpolation are the angle X and Y measurements.

This full algorithm is provided in C code (library_SSOCA60.h): it is a single function which inputs and outputs are:

- In: voltages of signals uSSB1to4 of SSOC-A60, in V.
- Out: angle measured or error if any.
- Out: albedo detection comparison (see next section).

List of errors are:

- Sun out of performance FoV.
- Albedo detection: Earth and Sun+Earth.
- No Sun detected.

5.4. Radiation detected

It is possible to calculate the radiation detected based on the output voltages, as follows:

$$\textit{Radiation detected} = 4 \times V_{cc} - (V_{ph1} + V_{ph2} + V_{ph3} + V_{ph4})$$

If this value is too low (< 0.2V) then not enough radiation is measured and the angles should not be calculated because there is not enough incoming illumination, or nothing at all.

5.5. Albedo detection

Albedo can be detected comparing the radiation detected with respect to the albedo LUT matrix. The albedo LUT matrix includes the radiation detected when solar radiation is 1360 W/m2, at different positions in the performance FoV.

When comparing both values, it is possible to detect if any light source is affecting the expected measurement, as follows:

- When Earth and Sun are inside FoV, reflection of sunrays in Earth would be added to the normal solar radiation coming from the Sun. This means that the sensor would detect more voltage than expected.

- When only Earth is inside FoV, only reflection of sunrays is coming inside FoV, and this reflection will never be more than 90% of expected solar radiation.

- In case of some elements of the spacecraft go inside FoV of the sun sensor, they could reflect sunrays, generating a secondary light source and affecting measurements. This may not be detected, so it is very important to ensure that any part of the spacecraft will never be inside the FoV of the sensor.

The comparison done to detect albedo has some margins for success, because solar radiation is not constant all year, and other contributors affect to the accuracy of this comparison. The following table describes the margin for detection:

Solar MEMS Technologies S.L. CIF. B-91794131. C/ Early Ovington 24, nv 01, 41309 La Rinconada (Sevilla) Spain
Phone : +34-95-4460113 E-Mail : smt@solar-mems.com

SPECIFICATIONS	Value	Unit	Margin	Comments
Average solar radiation	1360	W/m^2	0%	AM0 spectrum
Minimum solar radiation	1320	W/m^2	-3%	June-July
Maximum solar radiation	1415		+4%	December-January
Calibration accuracy	1360 +/-5%	W/m^2	+/-5%	Solar Simulator for SSOC-A60 calibration
Degradation per year	-	-	X%	Refer to Radiation Analysis Report
Top margin	+9	%		Recommended 20%
Bottom margin	-8	%		Recommended -20%

Table 7. Albedo detection margins

Annual degradation must be followed to compensate it during comparison done for albedo detection:

Comparison = Expected radiation – Radiation detected
Expected radiation: from table_albedo (matrix in C code)
Radiation detected = 4 x Vcc - (Vph1 + Vph2 + Vph3 + Vph4)

Comparison with annual degradation:

Comparison = (Expected radiation x Annual degradation) – Radiation detected
Annual degradation = 100% - degradation per year in %

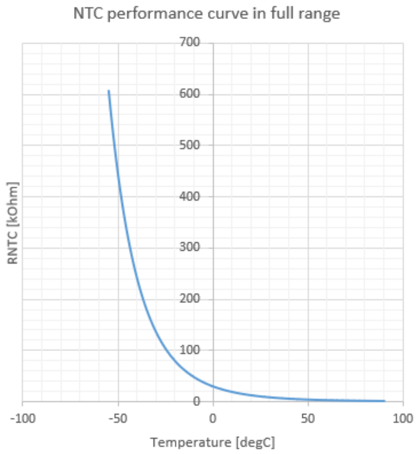
Detection capability of the algorithm depends on:

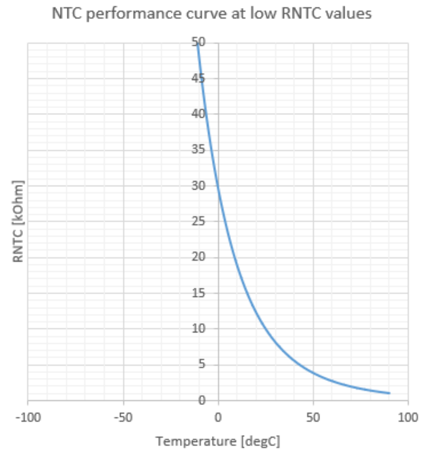
- Sun vector and Earth vector are close: Sun in the Earth Horizon.
- Earth vector coming from a surface with a very low reflectance (<10%), meaning a minor impact of albedo.
- When Sun vector is close to normal vector of the sun sensor, the detection capability is higher because any drift is more easily detected due to higher signal from the Sun.

Albedo detection algorithm does not detect 100% of albedo cases, so it is necessary to use information of other sensors of the satellite to detect some extreme cases.

This algorithm is included in the provided C codes (library_SSOCA60.h).

ANNEX: performance curve of NTC 44907





Temp °C	K-Ohms
-55	607,80
-54	569,60
-53	534,10
-52	501,00
-51	470,10
-50	441,30
-49	414,50
-48	389,40
-47	366,00
-46	344,10
-45	323,70
-44	304,60
-43	286,70
-42	270,00
-41	254,40
-40	239,80
-39	226,00
-38	213,20
-37	201,10
-36	189,80
-35	179,20
-34	169,30
-33	160,00
-32	151,20
-31	143,00
-30	135,20
-29	127,90
-28	121,10
-27	114,60
-26	108,60
-25	102,90
-24	97,49
-23	92,43
-22	87,66
-21	83,16
-20	78,91
-19	74,91

Temp °C	K-Ohms
-18	71,13
-17	67,57
-16	64,20
-15	61,02
-14	58,01
-13	55,17
-12	52,48
-11	49,94
-10	47,54
-9	45,27
-8	43,11
-7	41,07
-6	39,14
-5	37,31
-4	35,57
-3	33,93
-2	32,37
-1	30,89
0	29,49
1	28,15
2	26,89
3	25,69
4	24,55
5	23,46
6	22,43
7	21,45
8	20,52
9	19,63
10	18,79
11	17,98
12	17,22
13	16,49
14	15,79
15	15,13
16	14,50
17	13,90
18	13,33

Temp °C	K-Ohms
19	12,79
20	12,26
21	11,77
22	11,29
23	10,84
24	10,41
25	10,00
26	9,61
27	9,23
28	8,87
29	8,52
30	8,19
31	7,88
32	7,58
33	7,29
34	7,02
35	6,75
36	6,50
37	6,26
38	6,03
39	5,81
40	5,59
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48	4,18
49	4,03
50	3,89
51	3,76
52	3,63
53	3,50
54	3,39
55	3,27

Temp °C	K-Ohms
56	3,16
57	3,05
58	2,95
59	2,85
60	2,76
61	2,67
62	2,58
63	2,50
64	2,42
65	2,34
66	2,26
67	2,19
68	2,12
69	2,06
70	1,99
71	1,93
72	1,87
73	1,81
74	1,75
75	1,70
76	1,65
77	1,60
78	1,55
79	1,50
80	1,46
81	1,41
82	1,37
83	1,33
84	1,29
85	1,26
86	1,22
87	1,18
88	1,15
89	1,12
90	1,08

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