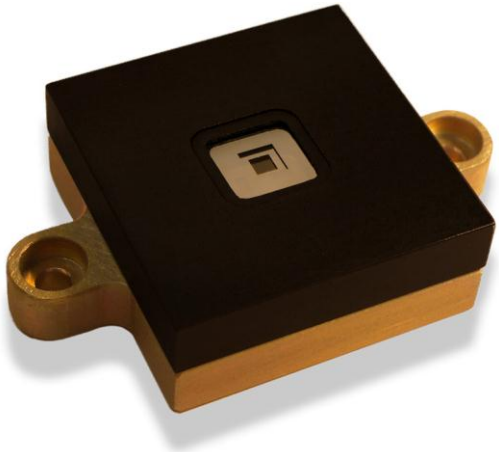

Sun Sensor on a Chip

SSOC-A60 - Analog interface

Technical Specification, Interfaces & Operation

Specifications

Two orthogonal axes sun sensor
Wide field of view (FOV): ±60º
High accuracy: <0.3º
Precision: <0.05º
Power supply: 5.00 V
Low power consumption: <36 mW
Reduced size: 30 × 30 × 12 mm
Low weight: 25 g
Temperature sensing

Qualification

Extended temperature range: - 45° to 85°C
Random vibration: 14g @ 2KHz
Mechanical shock: 3000g 1-100ms
TID radiation: > 100 kRads
LET threshold: 6MeV/mg/cm^2
Thermal cycling and vacuum tests

Applications

Low cost satellite attitude determination
Accurate Sun position determination
Satellite solar panel positioning
Attitude Failure Alarm
Satellite positioning in specific trajectory points
Balloons and UAVs control

Sun Sensor on a Chip (SSOC) is a two-axis, low cost sun sensor for high accurate sun-tracking and attitude determination. The device measures the incident angle of a sun ray in both orthogonal axes, providing a high sensitivity based on the geometrical dimensions of the design.

SSOC sun sensor is based on MEMS fabrication processes to achieve high integrated sensing structures.

Every sensor is characterized and calibrated for its application. It includes an internal thermistor. The use of materials as aluminum and cover glass minimizes the ageing of the device under high energy particle radiation.

SSOC-A60 sun sensor has reduced dimension, minimum weight and low power consumption. It provides a flexible solution for space programs.

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Contents

Responsibility exemption:

Solar MEMS has checked the concordance of this document with the described software and hardware. However, as it is impossible to exclude deviations, Solar MEMS is not liable for full concordance. Solar MEMS reviews this document periodically. If necessary, possible corrections will be included in the next version.

Solar MEMS is not liable for the correct operation of the system if the user does not follow the instructions of this document or use replacement parts that are not covered by this guarantee.

Figures

Tables

1. Introduction

This user manual presents a brief description to enable customers to correctly use SSOC-A60 sun sensor, and provides information about the operating principle, design, interfaces, communications protocol and operations of the device. Instructions and recommendations are also included for operator handling and other relevant activities with the sun sensor.

The sun sensor is available in two different versions: flight model (SSOC-A60) and engineering model (SSOC-A60LC), which presents the same performances as SSOC-A60 flight model, but without including some specific qualification tests.

Besides this specification document, the sun sensor is delivered with a certificate of conformance and an acceptance test report. For further assistance in design, interfacing, or sensor operation, Solar MEMS Technologies can make a dedicated quotation for product support based on each customer specific requirements.

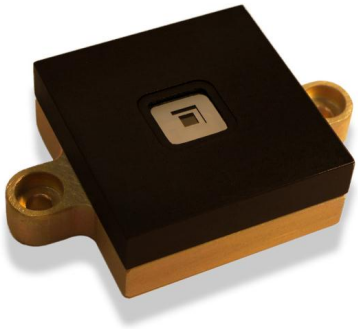

Fig 1. Photograph of SSOC-A60 sun sensor device.

2. Design review

The sun sensor uses four silicon photodiodes monolithically integrated, including a transparent cover glass on the same silicon die to act as a shield to prevent space radiation damage. Device fabrication combines microelectronics technology with a high efficiency solar cell fabrication process, leading to small area and low weight device. All materials used in the silicon sensor fabrication process are compatible with space requirements in terms of thermal and vibration resistance, and low degasification.

A printed circuit board with the electronics and the solar sensor is packaged in an anodized and alodined 3 mm thickness aluminum box to attenuate the influence of the outer-space radiation effect. The layout of the electronic components has been determined according to its functionality and maximizing their protection against high energy particle radiation. The electronics assembly has been done considering the special requirements demanded by space applications.

The sensor is also protected with an additional external cover-glass placed on the package. The steps in the input window of the aluminum structure are designed to avoid light reflections inside the active area of the sensor. CAD sketches of SSOC-A60 are illustrated in Fig 2.

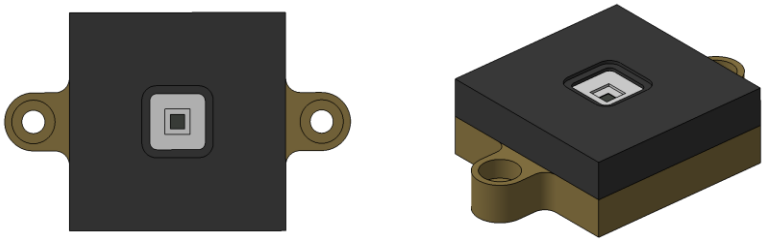

Fig 2. CAD Sketches of the sun sensor package.

3. General specifications

Parameter	SSOC-A60	Comments
Sensor type	2 axes	Orthogonal
Field of view (FOV)	± 60 º	Angular size of the view cone
Accuracy	< 0.3 º	3σ error
Precision	< 0.05 º	
Electrical specs.		
Supply voltage	5.00 V	Configurable up to 12V (Factory set)
Average consumption	< 12 mW	Dark
Average consumption	< 36 mW	Light: 1360 W/m^2, AM0
Connector (Cable side)	M80-4611042	From HARWIN
Thermal specs.		
Temperature range	- 45 to +85 ºC	
Temperature value accuracy	0.5 ºC	Internal thermistor
Mechanical specs.		
Dimensions (L × W × H)	30 × 30 × 12 mm	
Weight	25 g	
Mount holes	Ø3.2 x2	
Housing	Aluminum 6082	Alodine 1200S (ECSS-Q-70-71) Black anodized (ECSS-Q-ST-70-03C)
Calibration conditions: Tª = 25ºC, Vdd = 5V, Radiation = 1366 W/m2 (AM0 standard) Expected life time: 10 years +		

Table 1. General specifications

4. Operation

This section describes SSOC-A60 operational aspects, such as the sensor reference angles, calibration and main characteristics.

4.1. Principles of Operation

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 crystalline 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 simplified scheme of a pair of photodiodes to measure one particular sun incidence angle is illustrated in Fig. 3.

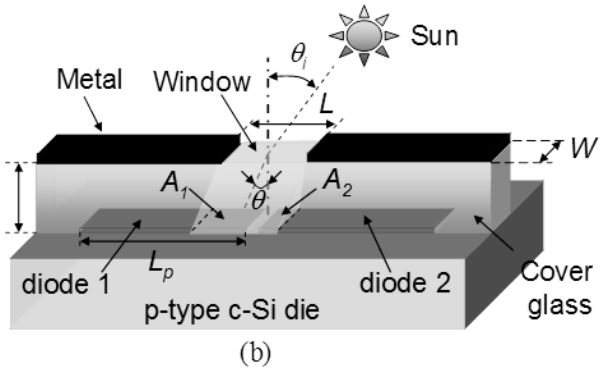

Fig 3. Operating principle of SSOC-A60 sun sensor

These photocurrents are detected and processed according to simple algorithms and a calibration table which will be provided to customer.

4.2. Reference system

With the X_A, Y_A, Z_A coordinate system as the sensor angles references, the angle α and angle β specify the angular position of the incident sun ray inside the field of view of SSOC-A60 (Fig. 4).

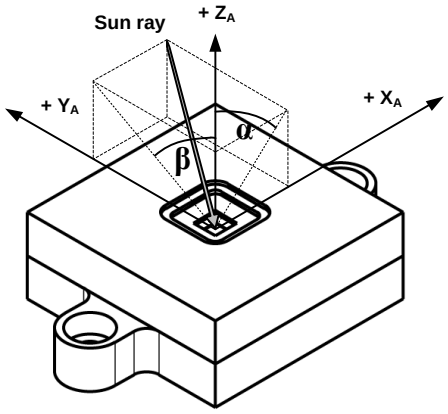

Fig 4. SSOC-A60 reference for measured angles

4.3. Temperature calculation

SSOC-A60 has an integrated thermistor that produces an output voltage proportional to absolute temperature. To obtain the current temperature the following expression must be used:

$$Temperature\ (^{o}C) = ((Thermistor\ voltage/2200)\ x\ 10^{6}) - 273.15$$

4.4. Characteristics

The characteristics of the sensor are summarized in table 1. In order to guarantee a high accuracy every sun sensor is individually tested and characterized, and customer is provided with unique look-up table. A ground calibration of the sensor is carried out to compensate all manufacturing tolerances and misalignment respect to the sensor positional reference.

The calibration procedure consists in the use of a high-accurate Angular Positioning System (APS), which is necessary to achieve high precision calibration curves. The APS, specifically developed by Solar MEMS for this purpose, has a certificate of calibration carried out by the Andalusian Metrology Center (CAM), with certificate Nº 22969. The calibration process is carried out with the standard AM0 irradiance (1366 W/m^2). As an example of the obtained data, the surface resulting from the amplified voltages corresponding to each photodiode cell for each defined angular position in azimuth and elevation within the sensor cone of vision (±60º) is shown in Fig. 5:

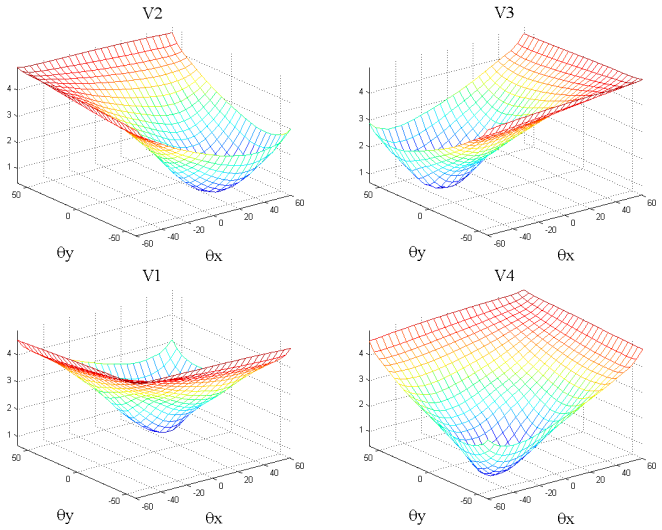

Fig 5. Photodiodes voltages obtained from the sun sensor calibration

Proprietary software characterizes and post-processes the response of the unit and generates the corresponding calibration tables. Fig. 6 illustrates an example of a sun sensor calibration function obtained in the calibration process. Sensor calibration is performed at the Solar MEMS facilities.

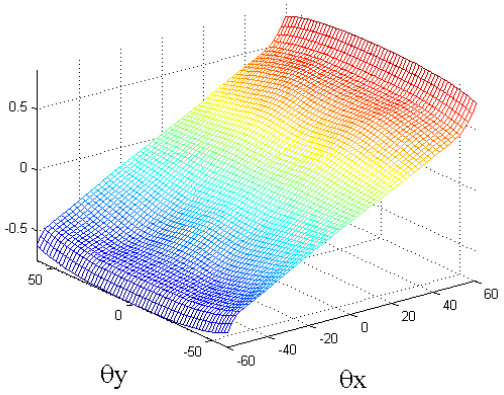

Fig 6. SSOC-A60 Calibration function

5. Mechanical interfaces

SSOC-A60 is packaged in an alodined aluminum box with dimensions of 30 x 30 x 12 mm, including a staircase-shaped aperture to collect the light with an angle of 120º (±60º). The aluminum package has been black-anodized according to the ECSS-Q-ST-70-03C, excepting the contact surface of the back which is subjected to alodine 1200S for space applications (ECSS-Q-70-71). The aluminum package has two mounting feet with holes to fasten the sensor by means of 3 mm diameter Allen screws.

The mechanical reference axes for sensor assembling are shown in Fig. 7, where the origin of the coordinate system is located in the center of the left mounting hole (front view). The optical line of sight is perpendicular to the sensor base plane, which is called Z_M-axis. The centerline of the two sensor mounting holes is by definition the X_M axis, and the Y_M axis is the third one of a right-handed orthogonal coordinate system.

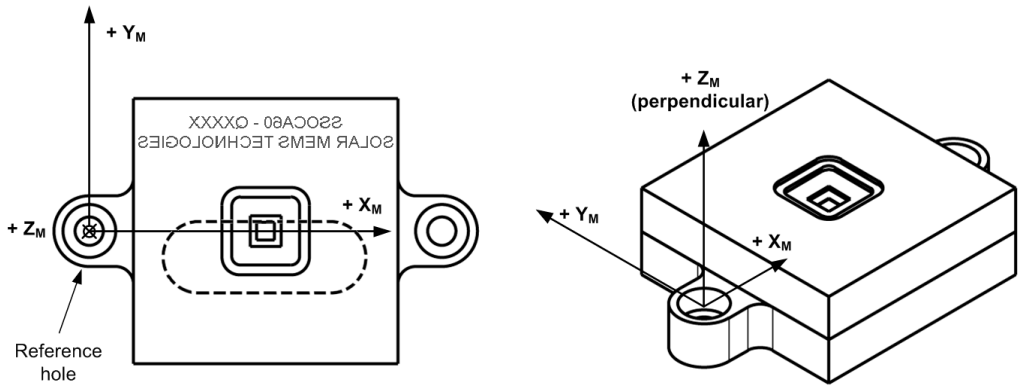

Fig 7. SSOC-A60 mounting reference system

The detailed mechanical outline of SSOC-A60 is presented in Fig. 8, following the reference axes described before. All dimensions are in millimeters.

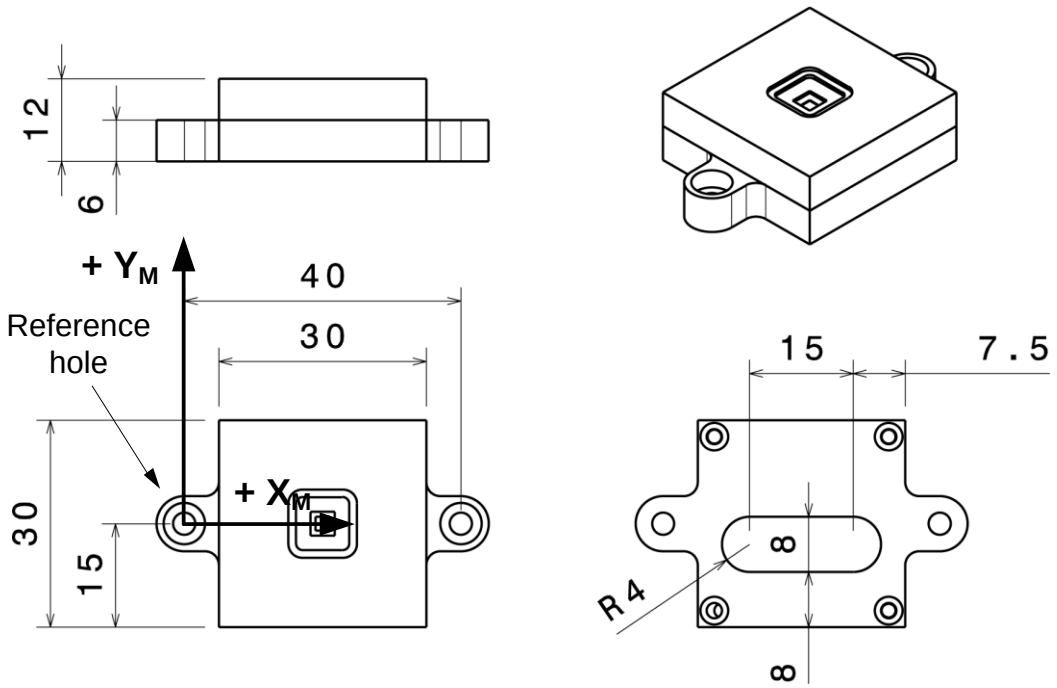

Fig 8. Mechanical layout and interface dimensions of SSOC-A60

The sun sensor package is made of aluminum 6082 to attenuate the influence of the outer-space radiation and its surface has been processed with a protective coating of chromic anodizing. The sensor is identified with a unique serial number, printed on the bottom cover of the package. The sensor package has two mounting feet for M3 threaded Allen screws. Both feet have precision holes with a diameter of 3.2 H7.

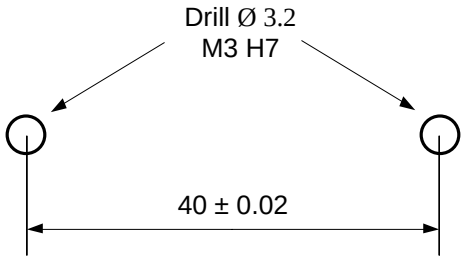

Fig 9. Drilling pattern for sun sensor fastening. All dimensions are in mm.

For fastening the sensor at the two precision holes, it is recommended the use of M3 threaded Allen screws A2-70 s/UNE – EN-ISO 4762 -2005, A2 stainless steel, 20mm length, and minimum and maximum torque levels of 1.1 Nm and 1.4 Nm (they are not deliverables). The choice of recommended fasteners as well as torque levels ensures appropriate sensor alignment.

6. Electrical interfaces

The electrical interface with SSOC-A60 uses a male micro-connector with 10 contacts installed through the bottom cover of the sensor package. The connector is a HARWIN M80-5121042, 2-row male connector straight SMT with fixing. The recommended connector for connection cable side is a HARWIN M80-4611042, 2-row female connector with fixing crimp gauge AWG 24-28, 10 contacts (1 piece is included with the purchase of a SSOC-A60).

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

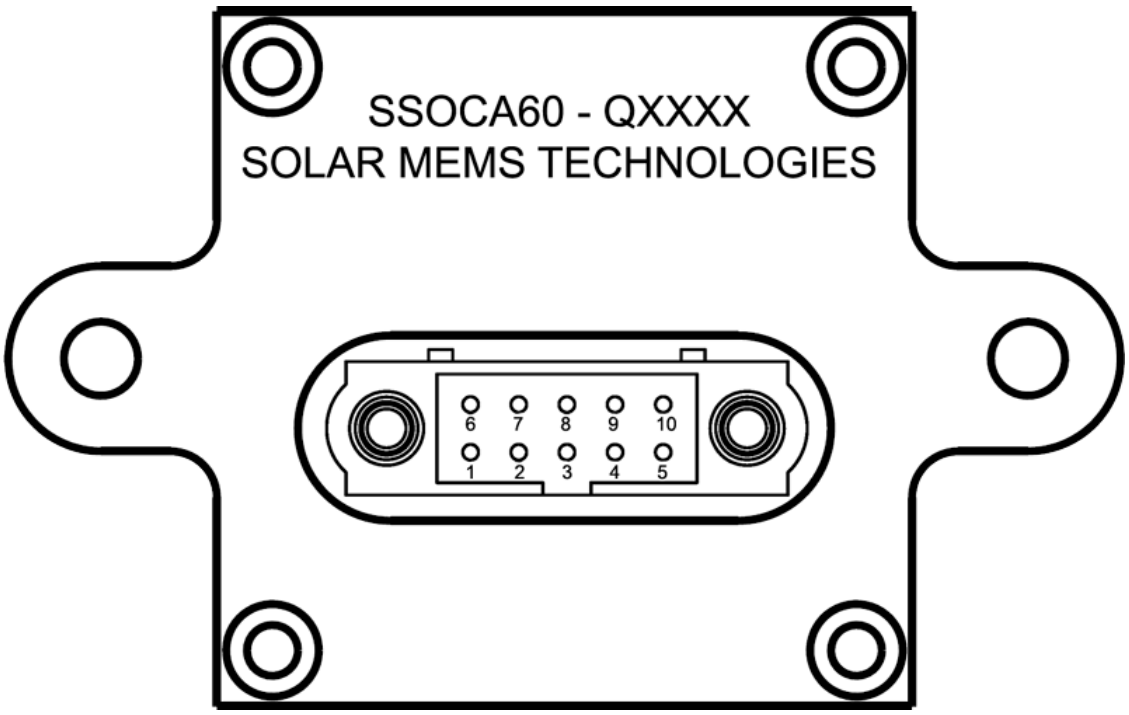

Fig 10. SSOC-A60 connector pin numbering

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

- Supply voltage: Two inputs (5V and 5V_RTN), corresponding to signal line and return line, respectively.
- Analog signals: Five lines, out of which four are the analog output signals of the four photodetector cells of the sun sensor, which are monolithically integrated in the chip (µSSA1, µSSA2, µSSA3 and µSSA4).
- Chassis: One signal to connect the ground reference plane of the circuit to the spacecraft/satellite structure.

The functions of the micro-connector contacts and its internal connection to the sun sensor are summarized in the following table:

Pin number	Signal	Description	Type
3	µSSB1	Photodetector 1	Analog output
8	µSSB2	Photodetector 2	Analog output
7	µSSB3	Photodetector 3	Analog output
2	µSSB4	Photodetector 4	Analog output
4	5V_RTN	Supply return	Analog output
10	5V	Supply voltage	Power
5	5V_RTN	Supply return	Power
1	AD590	Thermistor output	Analog output
6	5V_RTN	Supply return	Analog output
9	Chassis	Connection to chassis	-

Table 2. SSOC-A60 connector pinout

Solar MEMS delivers no interface cable but 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. The four photodiode cells and the common return connections are electrically isolated from the sensor package. The spare contacts in the connector are connected to the chassis.

The grounding shall be at one point only. The sensor has no direct connection between the power zero and the chassis (electrically isolated).

The electrical behavior of the sensor has been measured using AM0 filter with solar light spectrum of 1360 W/m^2 at ambient temperature and normal incidence.

6.1. Power on peak current

SSOC-A60 needs a supply voltage according to the following table:

Symbol	Parameter	Min	Typical	Max	Unit
V_{DD}	Supply voltage	3.00	5.00	12.00	V
V_r	Supply voltage ripple	0	-	100	mV_{pp}

Table 3. Electrical characteristics

Look-up table from calibration procedure depends on the power supply level, so this value must be defined before delivery of the sun sensor.

The power on peak current can be seen in the following figure.

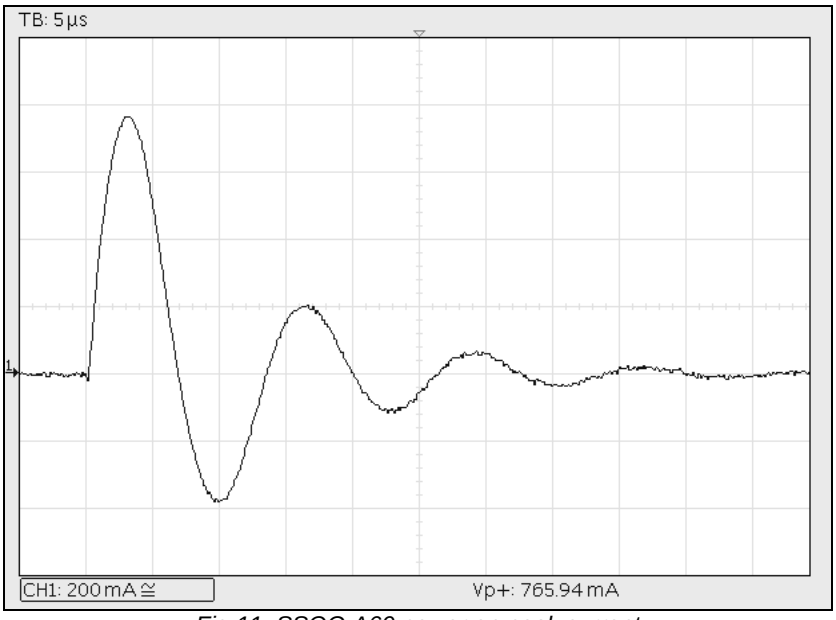

Fig 11. SSOC-A60 power on peak current

7. Environmental interfaces

The temperature range of operation should stay between -45°C and +85°C. All materials used in the sensor fabrication process are compatible with space requirements in terms of thermal and vibration resistance, and low degasification according to ECSS-70-71A standard.

Electronics and silicon sensor are packaged in an aluminum box to attenuate the influence of the radiation effect. Instead of using a conventional glass cover, the metallization has been performed directly on a space cover glass acting additionally as a shield for extraterrestrial radiation.

The sun sensor has a spectral responsivity ranging from 380 nm to about 1200 nm. The light transmittance of the cover glass presents an optical transmittance greater than 94% in the visible and near infrared.

The layout of the electronic components has been determined according to its functionality and maximizing their protection against high energy particle radiation.

8. Qualification

SSOC-A60 has been qualified in the frame of different tests.

Qualification test	Value	Comments
Temperature		
Non-operational	-50 to 90 ºC	Vacuum, 8 cycles
Operational	-45 to 85 ºC	Vacuum, 8 cycles
Mechanical		
Sine vibration	0.5 g	5-2000 Hz
Random vibration	14.1 g	1 minute, 20-2000 Hz
Shock	3000 g	1-100 ms
Radiation		
Total ionizing dose	> 100 kRad	Gamma radiation
Beam energy	6 MeV	Protons beam
Lifetime		
Estimated	> 5 years	LEO orbit

Table 4. Qualification status

SSOC-A60 is a fully passive DC operating current source. As a current source it is not susceptible to EMC. This sensor will not interfere with other equipment correct operation through spurious emission and absorption of EMI.

SSOC has been tested by ALTER TECHNOLOGY TÜV NORD, CNA (National Center of Accelerators, Spain) and INTA (National Institute of Aerospace Technology, Spain).

9. Flight and Engineering models

The following sections show the differences between both versions of SSOC-A60 sensor.

- **EM: engineering model**
  Called SSOC-A60LC, this unit has commercial electronic components.
  MEMS sensor is space-qualified.
- **FM: flight model**
  Called SSOC-A60, this unit has space-grade electronic components.
  MEMS sensor is space-qualified.

10. Packing, Handling and Storage

SSOC-A60 packing to the end customer will be carried out by skilled operators of Solar MEMS Technologies in the cleanroom complex (class 10000, temp 20 ± 5 °C). Operators involved with packing shall follow the standard environment and handling precautions. Devices are individually packed in antistatic plastic bags protected from ESD. These bags carry the serial number of each product, and are hermetically sealed. The sealed bags are further packed in an appropriate box, surrounded by shock-absorbing soft foam, correctly labeled and suitable for air and road transport. The delivery will be associated with the following documents:

- Certificate of Conformity with respect to SSOC-A60 Technical Specification, Interfaces & Operation document for each individual serial numbered device.
- A functional test report.
- Look-up table file.

It is recommended that the unpacking of SSOC-A60 shall take place in a controlled environment by skilled operators. The items under treatment are delicate and high-reliability optical and electronic instruments, which require handling with the most care.

Storage of the device may take place in an anti-static plastic bag. For long-term periods, it shall be stored in a controlled cleanroom environment. The package shall be maintained in a controlled environment with a temperature in the range of 25 to 15 ºC. The relative humidity shall be between 40% and 65%.

During device handling gloves shall be worn by the personnel, as well as the clothing required for the environment. The operator shall be grounded by an electrically conductive wrist-strap to minimize the risk of damage by electro-static discharges. The total allowable number of connects / disconnects on the connector itself shall be limited to 50. The sensor window surface shall never be touched.

If in spite of the precautions SSOC-A60 package requires cleaning, the operator can use dry nitrogen gas to remove particle contamination. The maximum allowable pressure of the dry nitrogen gas flow leaving the pistol is 1 bar. If blowing is insufficient, the particular surface may be wiped with a wetted nylon woven cloth with isopropyl alcohol (IPA), or a cotton wool stick.

11. Warranty

Solar MEMS Technologies S.L. warrants SSOC-A60 sun sensor to the original consumer purchaser any product that is determined to be defective for the following terms will be repaired, or replaced.

The warranty is one year from date of purchase.

The product in question must be sent to Solar MEMS Technologies S.L. (address is shown below) within the warranty period and the original consumer purchaser must comply with the following conditions, to be eligible for repair or replacement under this warranty:

- The product must not have been modified or altered in any way by an unauthorized source.
- The product must have been installed in accordance with the installation instructions and handled and stored following the technical specification interfaces & operation document recommendations.

This limited warranty does not cover:

- Damage due to improper installation;
- Accidental or intentional damages;
- Misuse, abuse, corrosion, or neglect;
- Product impaired by severe conditions, such as excessive wind, ice, storms, lightning strikes or other natural occurrences;
- Damage due to improper packaging on return shipment.

Any and all labor charges for troubleshooting, removal or replacement of the product are not covered by this warranty and will not be honored by Solar MEMS Technologies S.L.

Return shipping to Solar MEMS Technologies S.L. must be pre-paid by the original consumer purchaser. Solar MEMS Technologies S.L. will pay the normal return shipping charges to original consumer purchaser within the European Union countries only.

Address of Solar MEMS Technologies S.L.
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Tecnoincubadora Marie Curie.
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Phone: (+34) 954 460 113

Solar MEMS has a system of quality and environment according to the ISO 9001 and ISO 14001 standards, provided by the certification company Applus CTC.

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