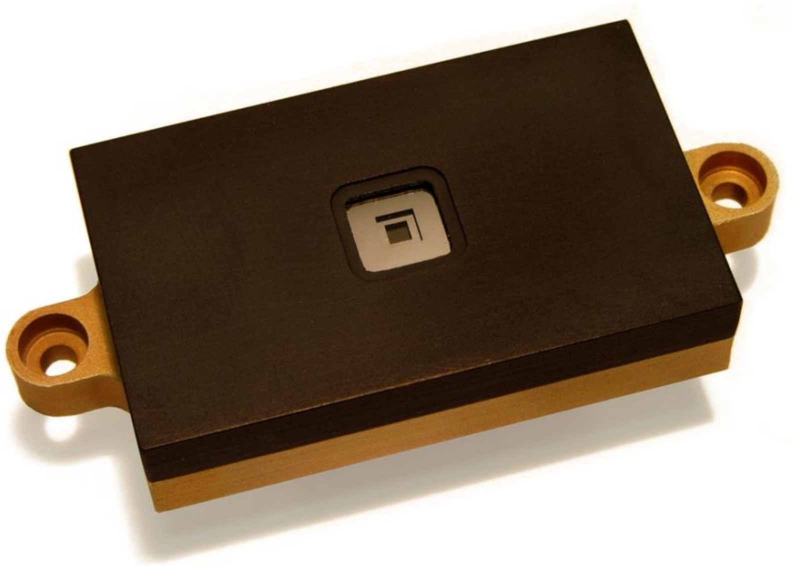


SSOC-D60

INTERFACE CONTROL DOCUMENT

Identifier:	SSOCD60-16-MAN
Title:	Interface Control Document
Entity:	Solar MEMS Technologies S.L.
Authors:	Manuel Rodríguez, J. Miguel Moreno
Date:	10th October 2016
Security:	Confidential

Page intentionally left blank

Approval

	Name	Position	Date	Signature
Prepared by:	Manuel Rodriguez	Project Manager	10.06.2021	
Approved by:	José M. Moreno	General Manager	10.06.2021	

Document history

Revision	Date	Change	Authors
100	10.10.2016	Initial version	JMML
101	09.04.2018	Section 6.1: Negative vs Positive bit correction	MRH
102	06.02.2019	Table 17: list updated	MRH
103	09.03.2020	Section 5.6 command 02 removed, command 04 updated. Section 6 and 7 added	MRH
104	28.04.2020	Table 16 reviewed: length value corrected	MRH
105	20.07.2020	Table 2 updated: exclusion fov added	MRH
106	29.03.2021	Section 1. RS485 reference removed Section 4.1.2. RS422 bus correction Section 4.2. balanced signals based on RS422 standard Section 5. UART mention removed. RS485 replaced by RS422, because full-duplex RS485 is RS422.	MRH
107	10.06.2021	Table 2: cable side connector reference corrected from 222S20M11 to 222S20M16 Section 4.2: cable side connector reference corrected	MRH

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

Contents

List of Figures

List of Tables

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
TC	Telecommand
TM	Telemetry

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		
AD-02		

Table 1. Applicable Documents

1. INTRODUCTION

The scope of this document is to define the Mechanical, Thermal, Electrical and Communications interfaces for SSOC-D60 Sun Sensors.

This document presents a brief description to enable customers to correctly use SSOC-D60 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.

1.1. Design Review

SSOC-D60 sun sensor has been designed to withstand space conditions. It includes 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.

1.2. Principles of Operation

SSOC-D60 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 Figure 1.

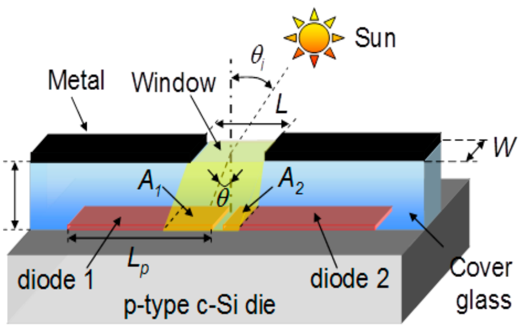


Figure 1. Operating principle

1.3. Spectral Responsivity

SSOC-D60 spectral responsivity range is from 380 nm to about 1200 nm. The light transmittance through the glass windows present an optical transmittance greater than 85% in the visible and near infrared. The electrical behavior of the sensor photodiodes has been measured using AM0 filter with solar light spectrum of 1366 W/m2 at ambient temperature (25ºC) and normal incidence.

In the following figure, it can be understood the different layers that sun rays have to cross until reaching the photodiodes.

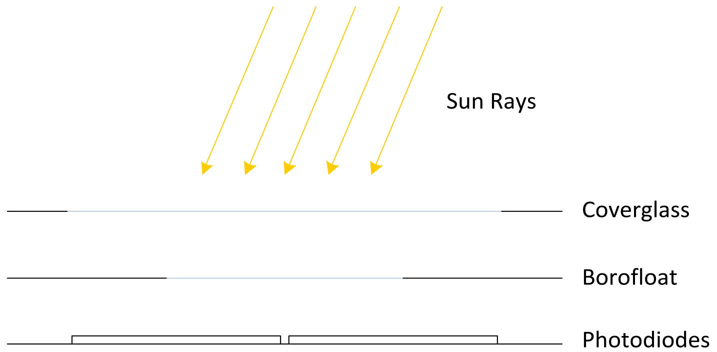


Figure 2. Optical layers

Photodiodes have the following spectral responsivity in the 380-1200nm range:

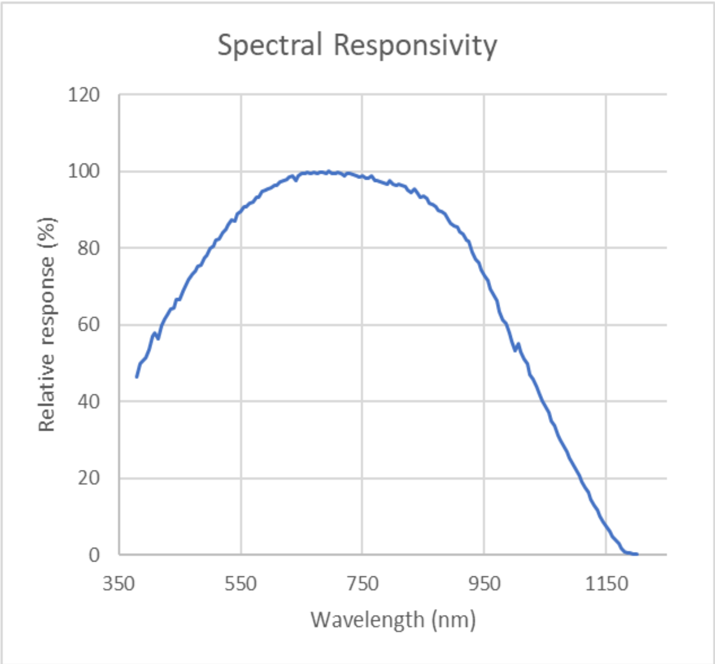


Figure 3. Spectral Responsivity

1.4. Specifications summary

ACCURACY		
Parameter	**Value**	**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	3σ error
Sensitivity	0.05 º	
Calibration conditions: Tª = 25ºC, Vdd = 5.00V, Radiation = 1366 W/m2 (AM0 standard)		
ELECTRICAL SPECIFICATIONS		
Parameter	**Value**	**Comments**
Supply voltage	5.00 V	
Max current consumption	63 mA	
Connector (Cable side)	222S20M16	From Nicomatic
Connector (Sensor side)	221T20F22	From Nicomatic
MECHANICAL SPECIFICATIONS		
Parameter	**Value**	**Comments**
Dimensions (L × W × H)	50 × 30 × 12 mm	68 x 30 x 12.61 mm including mounting feet and connector
Weight	35.5 ± 0.2g	
Mount holes Ø	Ø3.2 x2	
Mount holes separation	60 mm	
Mounting screws	M3	Recommended M3 Allen screws A2-70 s/UNE – EN-ISO 4762 -2005
Recommended torque	1.1 - 1.4 Nm	
Housing	Aluminum 6082	Alodine 1200S (ECSS-Q-70-71) Black anodized (ECSS-Q-ST-70-03C)
THERMAL SPECIFICATIONS		
Parameter	**Value**	**Comments**
Temperature range	-40 to +85 ºC	
Temperature value accuracy	1 ºC	Internal thermistor
FILTERING OF SIGNALS		
Parameter	**Value**	**Comments**
Sampling frequency	50 Hz	
Butterworth filtering stage	3th order	
Cutting frequency	1 Hz	
LIFETIME		
Parameter	**Value**	**Comments**
Expected life time	3+ years	

Table 2. Specifications Summary

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. MECHANICAL INTERFACE

2.1. Material and Surface Treatments

SSOC-D60 sun sensor package is made of 3 mm aluminum 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 back which is subjected to alodine 1200S for space applications (ECSS-Q-70-71). It includes a staircase-shaped aperture to collect the light with an angle of 120º (±60º).

2.2. Labeling

Each sensor is labeled with a unique serial number. It can be seen in the following picture:

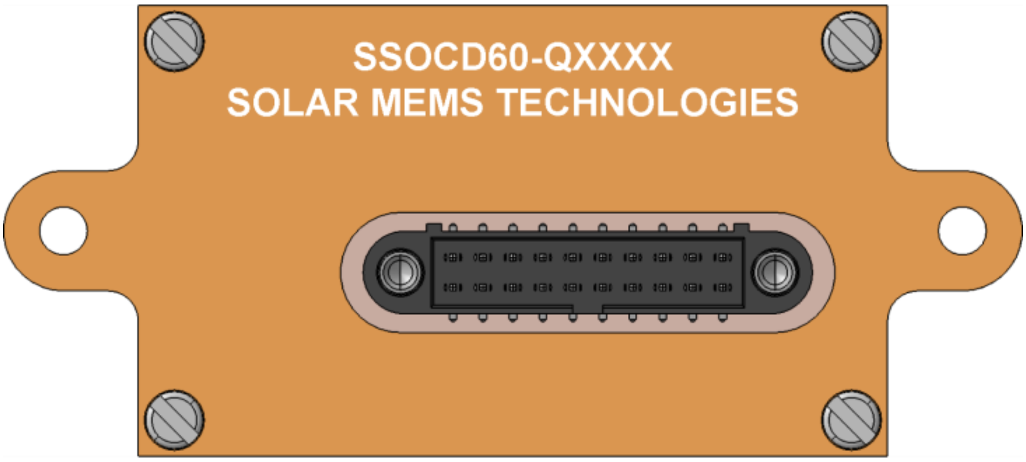


Figure 4. Sensors labeling

2.3. Venting Holes

Adequate venting is provided to preserve the structural integrity of the units during launch depressurization.

2.4. Mass

Mass of SSOC-D60 is 35.5 ± 0.2g.

2.5. Dimensions

SSOC-D60 dimensions are 50 x 30 x 12 mm (68 x 30 x 12.61 mm including mounting feet and connector). The following figure shows all the relevant dimensions of SSOC-D60. All dimensions are in mm.

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

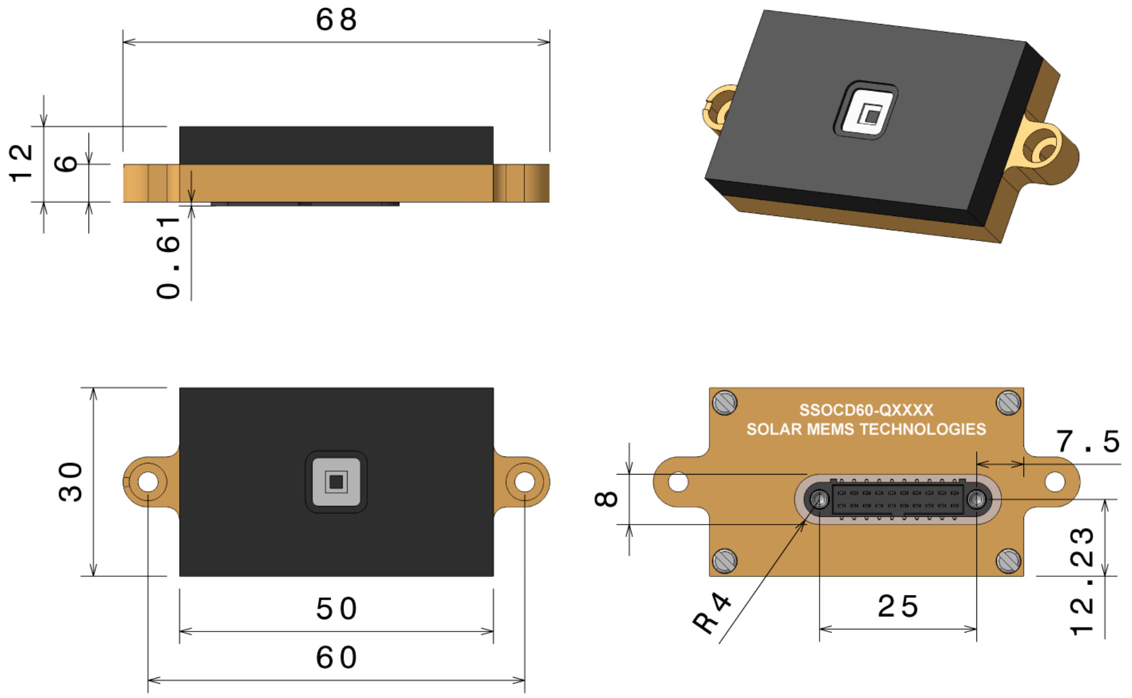


Figure 5. Dimensions

2.6. Reference System

The mechanical reference axes for sensor assembling are shown in Figure 6, 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.

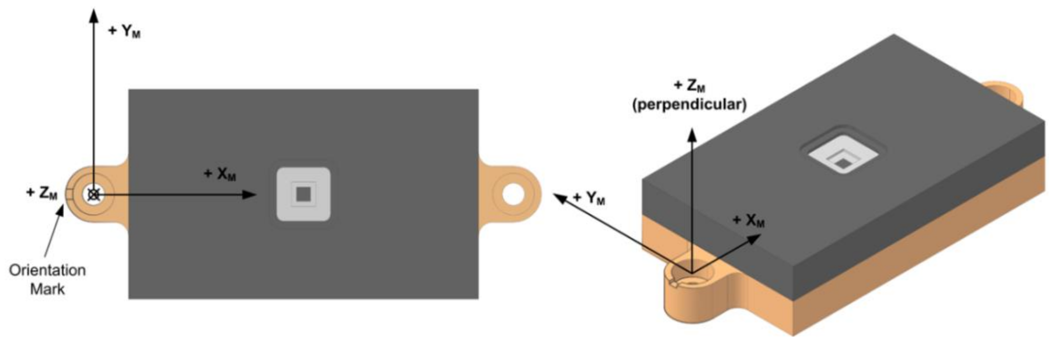


Figure 6. Mounting reference system

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-D60 (See Figure 7).

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

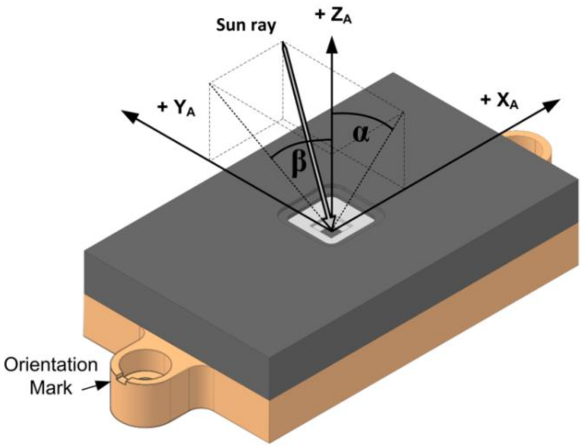


Figure 7. Reference for measured angles

2.7. Mounting Holes

The sensor package has two mounting feet for M3 screws. Both feet have precision holes with a diameter of 3.2 mm. The two mounting feet have interface planes which are co-planar to better than 0.01 mm. The distance between the centers of the two holes is 60 +0.02/-0.02 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. The choice of recommended fasteners as well as torque levels ensures appropriate sensor alignment.

2.8. Remove Before Flight Items

SSOC-D60 precision can be affected by dust particles. For that reason, they have a protective film with an attached red ‘REMOVE BEFORE FLIGHT’ label.

Figure 8. Remove before Flight label

3. THERMAL INTERFACE

3.1. Material Characteristics

The aluminum housing 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).

Black anodized has the following characteristics:

- $\alpha \geq 0.930$
- $\varepsilon \geq 0.853$

3.2. Contact Area

Contact area of SSOC-D60 is 13.17 cm^2. This is the main dissipation way for the unit

3.3. Unit Temperature Range

SSOC-D60 temperature range is -45° to 85°C.

3.4. Power Dissipation

The unit power dissipation is <0.32W.

4. ELECTRICAL INTERFACE

4.1. Electrical Characteristics

4.1.1. Power supply

SSOC-D60 electrical characteristics are shown in the following table:

Symbol	Parameter	Min	Typical	Max	Unit
V_{DD}	Supply voltage				
	Absolute Maximums	4.50	-	5.50	V
	Recommended	4.95	5.00*	5.05	V
I	Current Consumption	-	-	63	mA

Table 3. Electrical Characteristics

*SSOC-D60 0.3º 3-sigma precision is guaranteed for a supply voltage range from 4.50V to 5.50V. However, supply voltage should be precisely tuned to 5.00 V to achieve best precision results.

4.1.2. RS-422 bus

SSOC-D60 integrates separate driver and receiver for RS422 communication for increased distances and baud rate than RS232. By defect, driver and receiver do not include parallel termination resistors. 120 ohm resistors can be added under customer request.

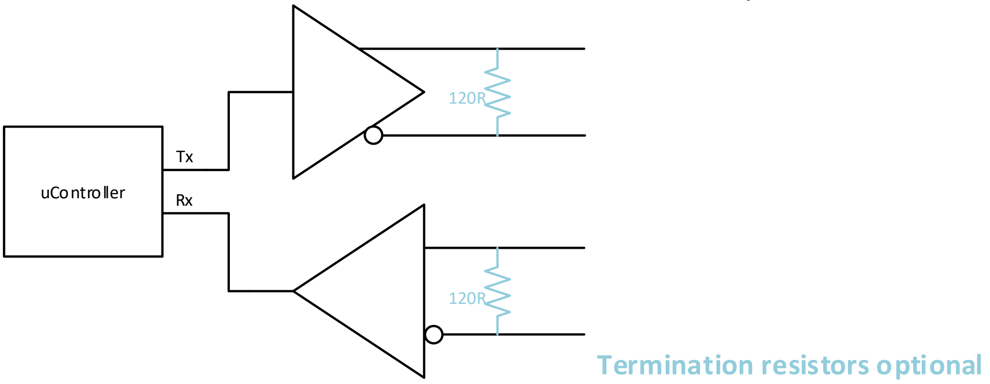


Figure 9. Termination resistors

4.2. Pin Description

The electrical interface with SSOC-D60 lies in a male micro-connector with 20 contacts installed through the bottom cover of the sensor package. This connector is a Nicomatic 221T20F22, 2-row male connector straight SMT with fixing. The recommended connector for connection cable side is a Nicomatic 222S20M16, 2-row female connector with fixing crimp gauge AWG 24-28, 20 contacts (1 piece is included with the purchase of a SSOC-D60).

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

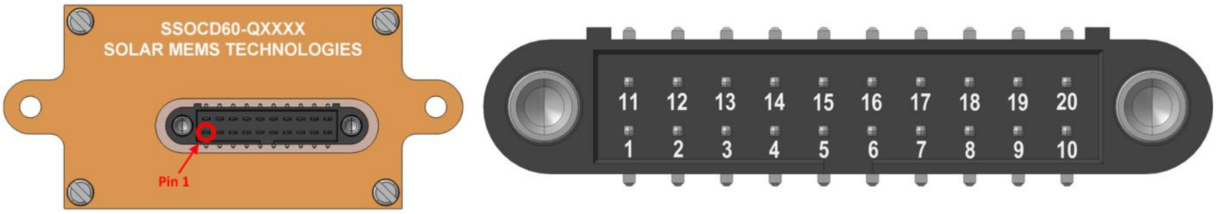


Figure 10. Pin numbering

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

- Supply voltage: 5V and 5V_RTN, corresponding to power supply and power return, respectively.
- Digital signals: Four digital input/output lines, corresponding to the two balanced signals involved in the RS422 communication protocol (TX+, TX-, RX+, RX-).
- Chassis: Two signals 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	Name	Description	Type
20	5V	5V Power supply	Power
16	5V_RTN	Power supply return	Power
10	5V_RTN	Power supply return	Power
3	TX+	Positive transmission line of RS-422	Digital output
4	TX-	Negative transmission line of RS-422	Digital output
13	RX+	Positive reception line of RS-422	Digital input
14	RX-	Negative reception line of RS-422	Digital input
9	Chassis	Chassis	-
19	Chassis	Chassis	-
5	Reserved	Reserved. Do not connect	-
6	Reserved	Reserved. Do not connect	-
15	Reserved	Reserved. Do not connect	-
1	NC	Not internally connected	-
2	NC	Not internally connected	-
7	NC	Not internally connected	-
8	NC	Not internally connected	-
11	NC	Not internally connected	-
12	NC	Not internally connected	-
17	NC	Not internally connected	-
18	NC	Not internally connected	-

Table 4. Pin description

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

4.3. Filtering Stage

The sensor includes a digital filtering stage. This filtering stage is a Butterworth Filter, 3th order, with the following data:

Parameter	Value
Sampling frequency	50 Hz
Butterworth filtering stage	3th order
Cutoff frequency	10 Hz
Coefficients B (numerator)	0.2569 0.7707 0.7707 0.2569
Coefficients A (denominator)	1.0000 0.5772 0.4218 0.0563

Table 5. Filtering parameters

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. COMMUNICATIONS

This section describes the features of the sun sensor communications interface and the different protocol messages and commands.

5.1. Main description

The protocol of the RS422 communication interface works as follows:

- Every sun sensor is a slave.
- Each sensor has a single and univocal address for identification in the same network.
- There may be only one master in the network.
- The master can communicate with a single sensor using its single address.
- Every sun sensor reads every message in the network, but only the one with the same address than the message will respond the request.
- Every sun sensor disables TX drive when there is nothing to transmit: tri-state.
- RX driver of each sun sensor is always enabled.
- If sun sensor is switched off, TX and RX drivers get into tri-state mode.
- When a sun sensor identifies its address in a request message from the master, it actives TX to transmit the response the message. After that, it deactivates TX when transmission ends.

5.2. UART Parameters

The following table summarizes the characteristics of the communications interface.

Baudrate	115200 bps
Data bits	8 bits
Parity	none
Stop bits	1
Handshaking	none

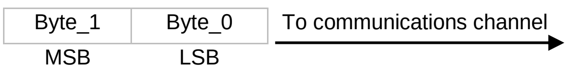
Table 6. UART Configuration

5.3. Data format

The data structure for communications transmission is explained below:

- Character transmission (*unsigned char*):

- Two byte Integer transmission (*int*):



- Floating data transmission (*float*): Float codification according to IEEE 754-1985 standard for single-precision floating 32 bits:
-

S	Exponent	Fraction		
Byte_3	Byte_2	Byte_1	Byte_0	
MSB			LSB	

To communications channel →

Floating value= $S \times 2^e \times m$.
- Sign (S): 1 bit (0=positive, 1=negative)
- Exponent: 8 bits (e = Exponent – 127)
- Fraction: 23 bits (m = 1.Fraction)

5.4. Timing

The response times of SSOC-D60 sun sensors are showed in the following table. Response time is measured as the time since the last byte of received command is read by the SS and the first byte of the response is sent to the OBC.

	Response time (ms)		
Command	**Min.**	**Typ.**	**Max.**
Unfiltered cells	-	1,10	3,00
Temperature	-	1,10	3,00
Filtered cells	-	1,10	3,00
Angular position	-	5,10	7,00
Minimum time between commands	20	50	-

Table 7. Communication timing

5.5. Frame format

Every TC sent through the RS422 link shall comply with the format described in the table below.

Address	**Command Code**	**Length**	**Checksum**
0xXX	0xXX	0x01	0xXX
1 byte	1 byte	1 byte	1 bytes
Address:	Single and univocal identification of the sun sensor		
Command Code:	It corresponds to the code of the incoming command.		
Length:	For commands it is fixed to 0x01.		
Checksum:	It is used to check the integrity of the packet. It is calculated adding all bytes in 'Address' + 'Command Code' + 'Length' fields and extracting the least significant byte of the result.		

Table 8. TC format

Answers received through the RS422 link follows the format described in the table below.

Address	Command Code	Length	Application Data	Checksum
0xXX	0xXX	0xXX	-	0xXX
1 byte	1 byte	1 byte	2 – 16 bytes	1 bytes

Address:	It is the address of the sensor that is responding.
Command Code	It corresponds to the code of the command which this answer refers to.
Length	It is the sum of the number of bytes of the fields 'Application Data' + 'Checksum'.
Application Data	It is the answer with the data previously requested by the corresponding command.
Checksum:	It is used to check the integrity of the packet. It is calculated adding all bytes in 'Address' + 'Command Code' + 'Length' + 'Application Data' fields and extracting the least significant byte of the result. E.g.: `03 02 05 42 12 87 2B 0D` Checksum is 0D. This checksum is calculated adding 0x02 + 0x05 + 0x42 + 0x12 + 0x87 + 0x2B = 0x10D. Least significant byte of 0x10D is 0x0D.

Table 9. TM format

5.6. Commands

The following table summarizes the UART protocol commands, which are widely described below.

Command	Name	Functionality
0x01	UNFILTERED CELLS	Request for the voltages values of the four photocells without filtering.
0x03	FILTERED CELLS	Request for the voltages values of the four photocells with filtering.
0x04	ANGULAR POSITION	Request for the angular position (α,β) and error code, and additional data: temperature and sun detection parameter

Table 10. Command codes

After SSOC-D60 is turned on, a minimum timeout of 2 seconds is required before the first data request, in order to reach the stabilization of amplifiers, converters, and specifically, the digital filters. The protocol consists of data request frames sent to the sun sensor and response frames received to the attitude control subsystem (AOCS), which format is explained below.

5.6.1. Command 01: Unfiltered photocells voltages

Request for the voltages values of the four photocells without filtering: four unfiltered cells are obtained by means of an analog to digital converter (ADC) of 10 bits and 50 Hz.
The voltage of each cell is represented by a 32-bit float.

Address	Command Code	Length	Checksum
0xXX	0x01	0x01	0xXX
1 byte	1 byte	1 byte	1 byte

Table 11. Command 01 TC format

Address	Command Code	Length	Application Data				Checksum
0xXX	0x01	0x11	Float (uSSA1) [V]	Float (uSSA2) [V]	Float (uSSA3) [V]	Float (uSSA4) [V]	0xXX
1 byte	1 byte	1 byte	4 bytes	4 bytes	4 bytes	4 bytes	1 byte

Table 12. Command 01 TM format

5.6.2. Command 03: Filtered photocells voltages

Request for the voltages values of the four photocells with filtering: four filtered cells are obtained with the ADC conversion (10 bits, 50 Hz), and an internal filtering stage (Butterworth filter).
The voltage of each cell is represented by a 32-bit float.

Address	Command Code	Length	Checksum
0xXX	0x03	0x01	0xXX
1 byte	1 byte	1 byte	1 byte

Table 13. Command 03 TC format

Address	Command Code	Length	Application Data				Checksum
0xXX	0x03	0x11	Float (uSSA1F) [V]	Float (uSSA2F) [V]	Float (uSSA3F) [V]	Float (uSSA4F) [V]	0xXX
1 byte	1 byte	1 byte	4 bytes	4 bytes	4 bytes	4 bytes	1 byte

Table 14. Command 03 TM format

5.6.3. Command 04: Angular position

Request for the angular position and the corresponding error code on each axis: the estimated results are taken from the ADC converted values (10 bits and 50 Hz) of both sensor direction angles, the internal Butterworth filter, and from the obtained error code calculations.
The two angles which determine the angular position (α and β, see Figure 7. Reference for measured angles) are represented by a floating format. The error code (see Table 17) format is represented in a char.

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

Address	Command Code	Length	Checksum
0xXX	0x04	0x01	0xXX
1 byte	1 byte	1 byte	1 byte

Table 15. Command 04 TC format

Address	Command Code	Length	Application Data					Checksum
0xXX	0x04	0x12	Float (Angle X or Alpha) [º]	Float (Angle Y or Beta) [º]	Float Temperature [ºC]	Float SunDetection [%]	Char (error code)	0xXX
1 byte	1 byte	1 byte	4 bytes	4 bytes	4 bytes	4 bytes	1 byte	1 byte

Table 16. Command 04 TM format

5.7. Temperature measurement

Temperature data is linked to an NTC sensor inside SSOC-D60.
This information is delivered in Celsius degrees.

5.8. Sun Detection parameter

This parameter is calculated internally dividing the amount of radiation measured by the amount of radiation expected at the measured sun vector (Angles X and Y). This parameter allows the spacecraft to decide if Sun of Albedo have been detected.
See section about “albedo and sun detection”.

5.9. Error codes

The error code byte will always inform if angles calculation operation was done successfully or if it was any problem detected.

Error Code	Information
0	No error. Angles were calculated successfully
10	Not enough radiation detected. Angle measurements should not be considered.
11	Albedo: Earth; Sun sensor does not see the Sun, but Earth, and the reflected sun-light is affecting measurement of the sensor.
12	Albedo: Earth + Sun; Sun sensor sees the Sun and the Earth, because received solar radiation level is higher than 1360 W/m2, with a tolerance of 20%, so a reflected sun-light is affecting measurement.
13	Detected light source, but out of FoV. Check sign of angle measurement to know the direction.

Table 17. Error codes

These codes are just informative and do not affect angles calculation.
This algorithm depends on a tolerance of 20% around the solar radiation during calibration of the sun sensor, this is 1366+/-5% W/m2. When the measured radiation is lower or higher than this value considering the tolerance, the algorithm detects code 11 or 12.

6. ALBEDO AND SUN DETECTION

Sun Sensor SSOC-D60 includes some parameters to detect when Sun is inside FoV and if any albedo is affecting measurement. Albedo affects sun detection because it introduces a drift into angle measurement that may reach several to dozens of degrees, depending on its intensity. Some albedo cases are:

- Earth inside FoV reflecting sun vector into the sun sensor.
- Earth inside FoV affecting the sun vector detected.
- Any obstacle or part of the satellite affecting measurements by reflections or light generation, like thrusters.

Albedo can be detected comparing the amount of radiation detected (by summation of four sun sensor signals) with the amount of radiation expected, at a specific sun vector and according to calibration data collected on ground.

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

- When Earth (or any other albedo) 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 reflected sunrays are 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, it can 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 (thresholds), 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:

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%	Depending on expected degradation, typically 0% in a 500 km mission of 3 years.
Top margin	+9	%		Recommended 20%
Bottom margin	-8	%		Recommended -20%

Table 18. Albedo detection margins

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 possible albedo cases.

6.1. Albedo detection by error code

Albedo can be detected using the error code delivered by sun sensor and checking its value: see table 17. In this case, threshold considered is 20%.

6.2. Sun detection managed by spacecraft

Sun sensor delivers a specific parameter called SunDetection, in %, that is calculated dividing amount of radiation detected by the expected value. This parameter allows spacecraft to apply its own threshold. However, it is not recommended to apply less than 10%.

On the other hand, this parameter could be calibrated to make the threshold more and more accurate:

1. Ensure a Sun vector measurement with no albedo, using other sensors or by positioning.
2. Check SunDetection value, and consider an offset to make this new value as the center of the algorithm
3. Apply thresholds to the new calibrated value.

This way, some contributors to the sun detection algorithm can be removed:

- Degradation, if any.
- Calibration tolerance can be removed.
- Solar annual variation can be removed if calibration is done every month.

7. Packing, Handling and Storage

SSOC-D60 packing to the end customer will be carried out by skilled operators of Solar MEMS Technologies in the cleanroom complex (class 8, temp 22 ± 2°C). Operators shall follow the standard environment and handling precautions.

Devices are individually packed in antistatic plastic bags ESD protected. These bags have the serial number labeled and are hermetically sealed. The sealed bags (vacuum) 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-D60 Technical Specification, Interfaces & Operation document for each individual serial numbered device.
- A functional test report.

Unpacking of SSOC-D60 should take place in a controlled environment by skilled operators. The items under treatment are delicate and include 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 20 ºC. The relative humidity shall be between 45% and 65% if vacuum bag is removed.

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 SSOC-D60 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 surface may be wiped with a wetted nylon woven cloth with isopropyl alcohol (IPA), or a cotton wool stick.

------------------------- END OF DOCUMENT -------------------------

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