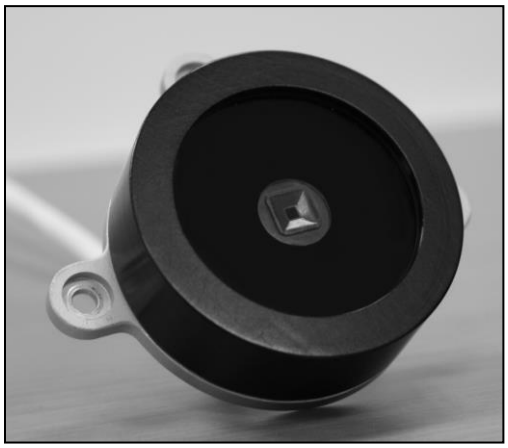
Solar MEMS Technologies S.L.

Sun Sensor ISS-TX

Digital sensor for Tracking Systems
RS485 communication

Technical Specifications



Features

Two orthogonal axes sun sensor
Wide or narrow field of view
High accuracy
1 UART module based on RS - 485
Low power consumption: 33 mA
Wide operating voltage range: 5÷12 V
Industrial temperature range: - 40° to 85°
Reduced size
Low weight
IP65 protection
Reverse polarity protection

Applications

Sun tracking/pointing systems
Heliostats
Attitude control using light sources
Determination of sun radiation

ISS-TX sun sensor measures the incident angle of a sun ray in both orthogonal axes and the solar radiation. The high sensitivity reached is based on the geometrical dimensions of the design.

Its characteristics make it a suitable tool for high accurate sun-tracking, with low power consumption and high reliability.

ISS-TX sun sensor has been designed with a unique and novel own technology based on MEMS fabrication processes to achieve high integrated sensing structures at low cost.

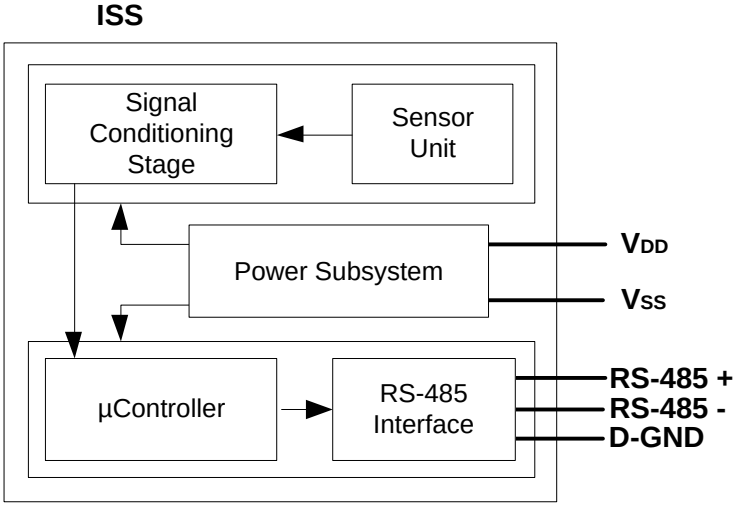


Fig 1. Block Diagram

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1. Sun Sensor ISS-TX

ISS-TX measures the incidence angle of a sun ray in both azimuth and elevation based on a quadrant photo-detector device. The sunlight is guided to the detector through a window above the sensor. Dependent of the angle of incidence, the sunlight induces photocurrents in the four quadrants of the detector.

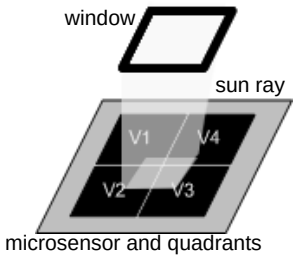

Fig 2. Microsensor of ISS-TX

Different models of the ISS-TX are offered, depending on the field of view (FOV) of the sensor. The accuracy of the sensor is inversely proportional to this field of view.

2. General Specifications

Parameter	**T60**	**T25**	**T15**	**T5**	**Unit**	**Comments**
Sensor type	2 axes	2 axes	2 axes	2 axes	-	Orthogonal
Field of view (FOV)	120	50	30	10	º	Aperture of the cone of view
Accuracy	< 10	< 10	< 10	< 10	%	3σ
Precision	< 0,06	< 0,04	< 0,02	< 0,005	º	Sensitivity
Average consumption	33	33	33	33	mA	
Dimensions						
Diameter	80	80	80	80	mm	
Height	27	27	27	27	mm	
Weight	100	100	100	100	g	
Level of protection	IP65	IP65	IP65	IP65		CEI 60529 Standard
Pressure	Tested at 0,05 mbar and 25ºC					

Table 1. General Specifications

3. Absolute maximum ratings

Symbol	Parameter	Minimum value	Maximum value	Unit
V_{DD}	Supply voltage	0	16	V
T_{OP}	Operating temperature	-40	85	ºC
V_{RS485}	RS-485 input voltage	-10	10	V

Table 2. Absolute maximum ratings

4. Recommended operating conditions

Symbol	Parameter	Minimum value	Maximum value	Unit
V_{DD}	Supply voltage	5	12	V
V_r	Supply voltage ripple	0	100	mVpp
T_{OP}	Operating temperature	-40	85	ºC
V_{RS485}	RS-485 input voltage	-10	10	V

Table 3. Recommended operation conditions

5. Electrical characteristics

Symbol	Parameter	Min	Typical	Max	Unit
V_{DD}	Supply voltage	5	5	12	V
I_{DD}	Feed current	-	33	-	mA
RS-485					
V_{IH}	Voltage *input high*	2			V
V_{IL}	Voltage *input low*			0.8	V
V_{OH}	Voltage *output high*	3.5			V
V_{OL}	Voltage *output low*			0.4	V

Table 4. Electrical characteristics

Reverse polarity protection.
120Ω RS-485 termination resistors included (see figs. 10 to 12):
Please, refer to the manufacturer for any other configuration.

6. Characteristics of the ISS-TX

Parameter	T60	T25	T15	T5	Unit	Comments
Sensor type	2 axes	2 axes	2 axes	2 axes	-	Orthogonal
Field of view (FOV)	120	50	30	10	º	Aperture of the cone of view
Accuracy	< 10	< 10	< 10	< 10	%	3σ
Precision	< 0,06	< 0,04	< 0,02	< 0,005	º	Sensitivity
Angle resolution	0,01	0,001	0,001	0,001	º	
Radiation accuracy	< 10	< 10	< 10	< 10	%	As accurate as close to normal vector
Radiation resolution	1	1	1	1	W/m^2	
Max. radiation	1200	1200	1200	1200	W/m^2	
Temperature accuracy	2	2	2	2	ºC	
Temperature resolution	1	1	1	1	ºC	
Sampling frequency	50	50	50	50	Hz	
Bandwidth	0,4	0,4	0,4	0,4	Hz	
T^a 25ºC, V_{DD} 5V, Radiation 900 W/m^2						
Expected lifetime: 10 years +						

Table 5. Characteristics of the sensor

Sun sensor ISS-TX is specifically designed and made for Tracking Systems, as CPV trackers, Weather Stations, PV trackers, Dish-stirling trackers, etc, any system using a tracking controller, for Sun or other light sources.

Different models of the ISS-TX are offered, differing in the field of view (FOV) of the sensor. The accuracy of the sensor is inversely proportional to the field of view. All these models have been tested on solar trackers with Solar MEMS Helios Controller in our facilities.

Depending on the application of the Sun Sensor ISS-TX, we recommend the use of the following models:

- Solar Tracker with Photovoltaic:
  The accuracy requirements are not demanding, so it's recommended to **use the ISS-T25** model, **to get a wide field of view**.
- Solar Tracker with CPV or similar:
  The accuracy requirements are very demanding, so it's recommended to **use the ISS-T5** model, **to get high accuracy and narrow field of view**, because a wide field of view increases the effects of the **environmental conditions** on the accuracy of the sun sensor: clouds effect and seeing of the ground.
- Other applications:
  It depends on the demanding of the field of view and the accuracy.

7. Main operations

ISS-TX sensor measures the incidence angles of a solar radiation respect to its perpendicular. This information is provided through a RS485 UART channel (master-slave configuration).

7.1. ISS-TX parameters

7.1.1. Reference Axes

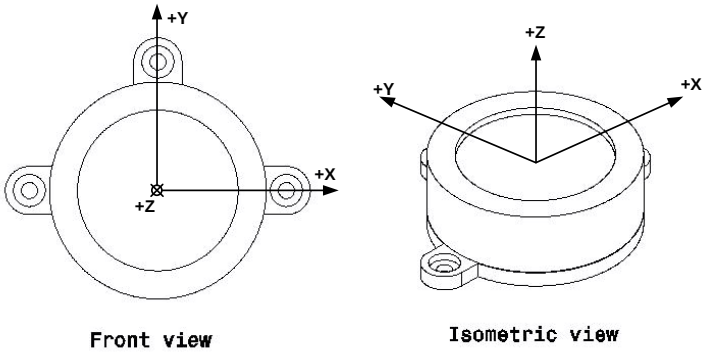

Fig 3. ISS-TX reference system

Z axis is perpendicular to the sensor base plane.

7.1.2. Angles

The *angle x and angle y* specify the angular position of the incident sun ray inside the field of view of the ISS-TX sensor. The accuracy of the sensor increases close to zero degrees (perpendicular). Both angles are provided in degrees.

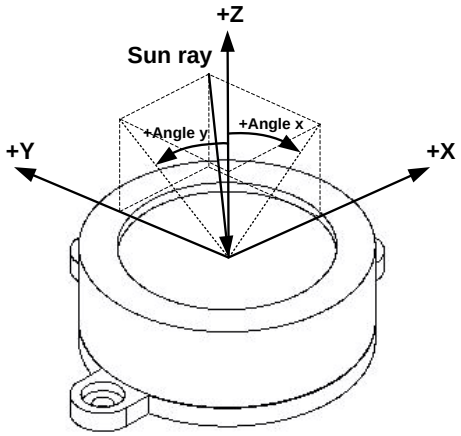

Fig 4. Reference for measured angles

The ISS-TX does an internal filtering processing to the angle measurements with the following features: third-order Butterworth filter with sampling frequency of 50 Hz and cut-off frequency of 0.4 Hz.

7.1.3. Solar Radiation DNI

Radiation is an estimation value of the atmospheric solar radiation, according to the measurements inside FOV. In sunny day conditions, this radiation is equivalent to the direct solar radiation. Radiation is provided in W/m^2.

The user can utilize this information, in addition to the sensor data, to estimate the atmospheric conditions at the time of measurement, i.e. clouds, fog, dust, etc.

7.1.4. Temperature

This parameter is an estimation of the internal ISS-TX sun sensor temperature. Thermal data is provided in ºC.

7.1.5. Additional information

This information is a data packet to validate the measurements: indicates if the sun sensor receives enough radiation, or if it detects the Sun out of its field of view (FOV). See 8.4.5 section for more information.

8. ISS-TX Protocol

ISS-TX communication protocol is based on UART over RS-485 master/slave configuration. ISS-TX always acts as slave. Up to 15 sensors can be connected to the same communication bus.

8.1. Communication channel parameters

Parameter	Value	Unit	Comments
Bit rate	115200 (default) 38400 19200	bps	Bit rate is modifiable by message. *Please, refer to the manufacturer for any other configuration.*
Data Bits	8	Bits	
Stop Bits	1	Bit	
Parity	No	-	

Table 6. UART link parameters

8.2. Master – Slave Operation

The master/slave operation allows the master of the system to request information to one (or more) ISS-TX. The fields of each message are described in Section 8.4.

Recommended maximum sampling frequencies are 20 Hz for 115200 bps, and 10 Hz for 38400 bps and 19200 bps.

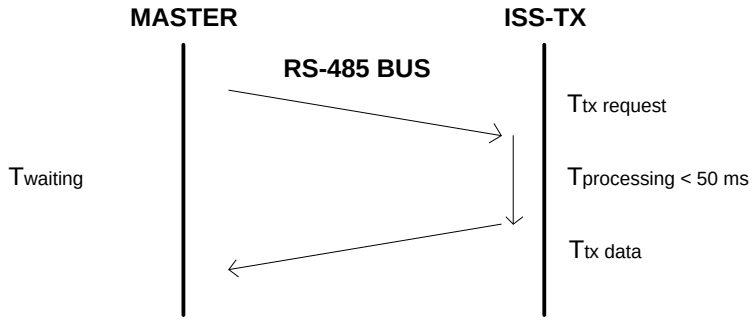

Fig 5. Communication timeouts.

8.3. RS-485 bus configurations

8.3.1. Point to Point configuration

ISS-TX sun sensors include a 120 ohm terminator resistor for point to point configuration.

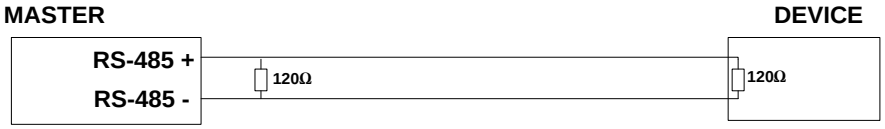

Fig 6. Recommended point to point configuration

8.3.2. Bus configuration

According to *TIA/EIA-485 standard, the termination resistors are modifiable and depend on the bus configuration.*

Please refer to the manufacturer for ISS-TX sun sensors without terminator resistor, or any other value for this element.

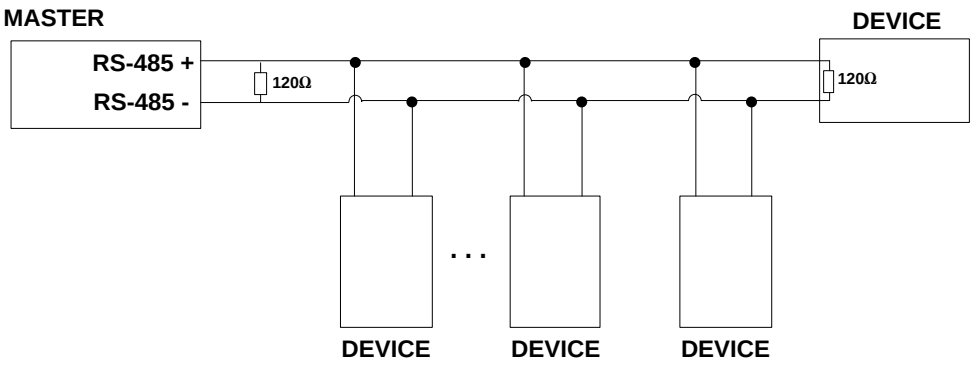

Fig 7. Optional bus configuration for more than one ISS-TX

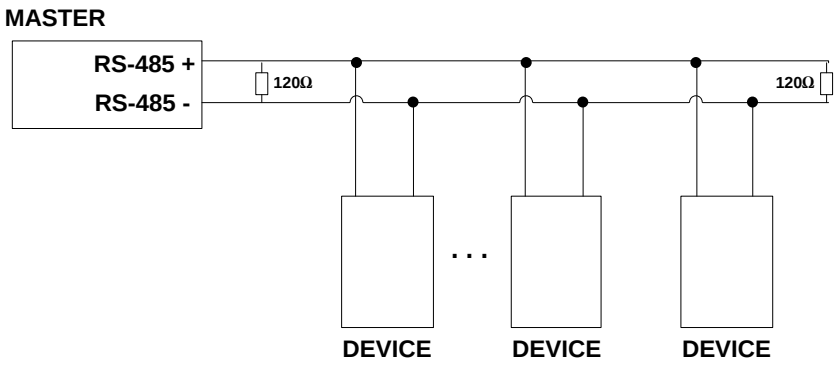

Fig 8. Optional bus configuration for more than one ISS-TX

8.4. Protocol messages

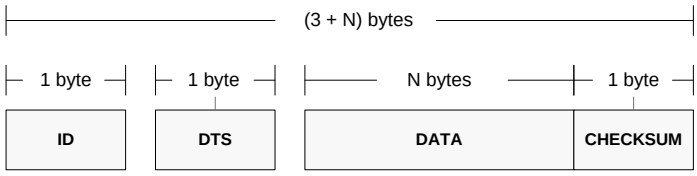

Fig 9. Message syntax

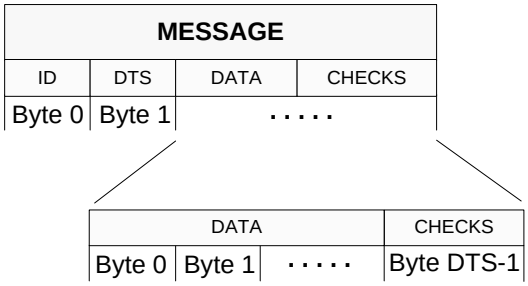

Fig 10. Byte order

See Annex 1 for Bits/Bytes Numbering Convention.

Acronyms	Parameter	Size	Comments
ID	Identifier	1 byte	See Table 9
DTS	Size	1 byte	DTS = DATA bytes + CHECK8 byte
DATA	Data	(DTS-1) bytes	Data of the sensor
CHECK8	Checksum	1 byte	8 bits checksum, without carry, of only DATA bytes.

Table 7. Description of the ISS-TX message fields

Identifier (bits)								Type	Name	Message
7	6	5	4	3	2	1	0			
0	0	0	1	ID of ISS-TX				Master -> Slave	REQUEST	To request information to the sensor
0	0	1	0	ID of ISS-TX				Master -> Slave	CONFIG	To modify identifier of the ISS-TX
0	0	1	1	ID of ISS-TX				Master -> Slave	BIT RATE	To modify the bit rate
0	1	0	1	ID of ISS-TX				Master <- Slave	CONFIG ACK	Modified ID confirmation
0	1	1	0	ID of ISS-TX				Master <- Slave	ANGLES	Information: angles
0	1	0	0	ID of ISS-TX				Master <- Slave	TEMPERATURE	Information: temperature
Note 1: data radiation is provided additionally to the angle information *Note2: the ID of the ISS-TX are the 4 bits LSB of the ID byte, and identifies the destination ISS-TX of the message*										

Table 8. ISS-TX identifiers

Identifier Example 1:
REQUEST message addressed to an ISS-DX with ID 6:
Binary identifier *0b00010110*
Hexadecimal identifier *0x16*

Identifier Example 2:
ANGLES message addressed to an ISS-DX with ID 14
Binary identifier *0b01101110*
Hexadecimal identifier *0x6D*

8.4.1. CONFIG

CONFIG: message for configure the ID of the sensor

	Bytes	**Value (hex) / Comment**
ID	1	0x20 + destination ISS-TX ID
DTS	1	0x02
DATA		
New ID	1	The new ISS-TX value to configure
CHECKSUM	1	Checksum

Table 9. The CONFIG message semantics

All ISS-TX are configured from manufacturer to ID 1. If there are several units connected to the same bus it is recommended to configure them with different identifiers.

The ID of an ISS-TX must be from 1 to 15 (0x01 until 0x0F).
Please, refer to the manufacturer for a particular configuration.

8.4.2. CONFIG ACK

CONFIG ACK: acknowledge of the new ID configuration

	Bytes	**Value (hex) / Comment**
ID	1	0x50 + source ISS-TX ID
DTS	1	0x02
DATA		
New ID	1	The new ID ISS-TX value stored
CHECKSUM	1	Checksum

Table 10. The CONFIG ACK message semantics

8.4.3. BIT RATE

BIT RATE: message for change the communication bit rate

	Bytes	**Valor (hexadecimal) / Comentario**
ID	1	0x30 + destination ISS-TX ID
DTS	1	0x02
DATA		
Nuevo ID	1	0x01: change to 115200 bps 0x02: change to 38400 bps 0x03: change to 19200 bps
CHECKSUM	1	Checksum

Tabla 11. The BIT RATE message semantics

All ISS-TX are configured from manufacturer to 115200 bps, but you can use BIT RATE message to change to 38400 bps or 19200 bps.

This message doesn't generate response.

Please, refer to the manufacturer for a particular configuration.

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8.4.4. REQUEST

REQUEST: message for requesting information to the sensor (angles)

	Bytes	**Value (hex) / Comment**
ID	1	0x10 + destination ISS-TX ID
DTS	1	0x02
DATA		
Request Message	1	0x63: message ANGLES requested 0x0B: message TEMPERATURE requested
CHECKSUM	1	Checksum

Table 12. The REQUEST message semantics

8.4.5. ANGLES

ANGLES: message including measured angles and radiation, sent by the ISS-TX

	Bytes	**Value (hex) / Comment**
ID	1	0x60 + ID source ISS-TX
DTS	1	0x0E
DATA		
Angle X [º]	4	Floating 32 bits (IEEE 754 standard)
Angle Y [º]	4	Floating 32 bits (IEEE 754 standard)
Radiation [W/m^2]	4	Floating 32 bits (IEEE 754 standard)
Additional info:	1	See next table
CHECKSUM	1	Checksum

Table 13. The ANGLES message semantics

Value (hexadecimal)	**Information**	**Comments**
0x00	No information	
0xFF	Zero radiation	Angles values set to 0º Radiation not enough: less than 300 W/m^2
0x33	Sun out of FOV	Angles values set to 0º
0x01	Sun out of FOV	Angles values set to 0º Sun is to X positive reference
0x02	Sun out of FOV	Angles values set to 0º Sun is to X negative reference
0x10	Sun out of FOV	Angles values set to 0º Sun is to Y positive reference
0x20	Sun out of FOV	Angles values set to 0º Sun is to Y negative reference
0x11	Sun out of FOV	Angles values set to 0º Sun is to X positive and Y positive reference
0x12	Sun out of FOV	Angles values set to 0º Sun is to X negative and Y positive reference
0x21	Sun out of FOV	Angles values set to 0º Sun is to X positive and Y negative reference
0x22	Sun out of FOV	Angles values set to 0º Sun is to X negative and Y negative reference

Table 14. Additional information

8.4.6. TEMPERATURE

TEMPERATURE: message including internal sensor temperature, sent by the ISS-TX

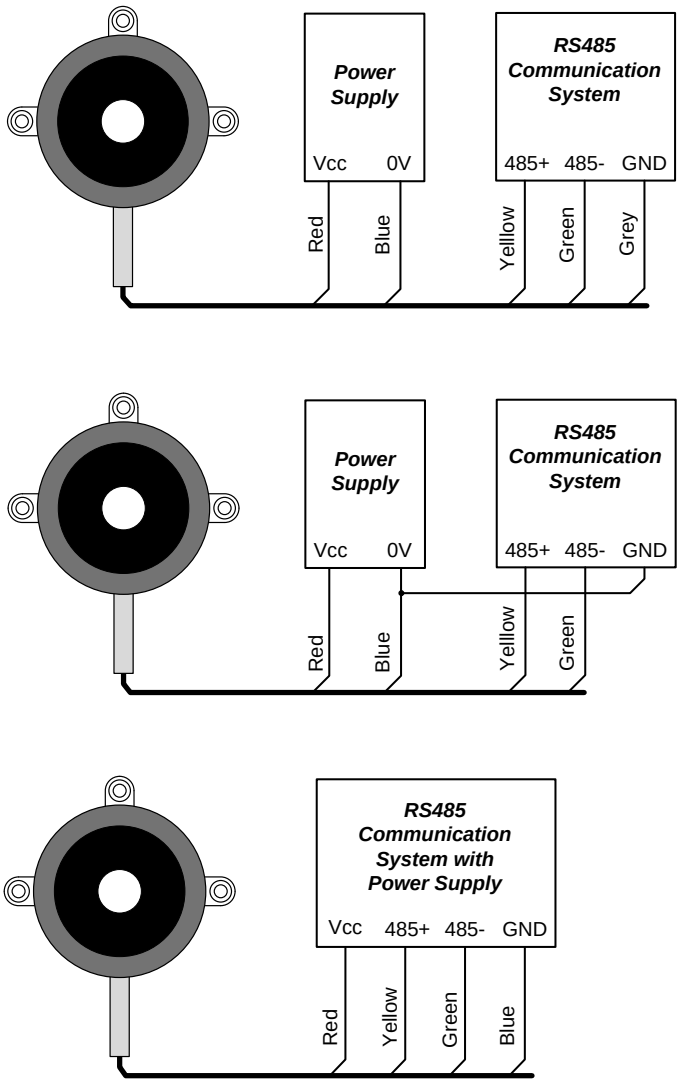
	Bytes	**Value (hex) / Comment**
ID	1	0x40 + ID source ISS-TX
DTS	1	0x05
DATA		
Temperature [ºC]	4	Floating 32 bits (IEEE 754 standard)
CHECKSUM	1	Checksum

Table 15. The TEMPERATURE message semantics

9. Electrical interface

Colour	Terminal	Type	Comments
Red	V_{DD}	Power	Power Supply
Blue	V_{SS}	Power	Ground
Yellow	RS-485 +	I/O	Terminal + RS-485
Green	RS-485 -	I/O	Terminal - RS-485
Grey	D-GND	Communications	Digital Ground
White	-	-	Do Not connect
Brown	-	-	Do Not connect
Pink	-	-	Do Not connect
Shield	-	-	See fig. 15

Table 16. Electrical interface



In any configuration we recommend
connecting the shield to the blue wire

Fig 11. Recommended wiring diagram

The housing of the sun sensor ISS-TX is isolated electrically.

10. Mechanical data

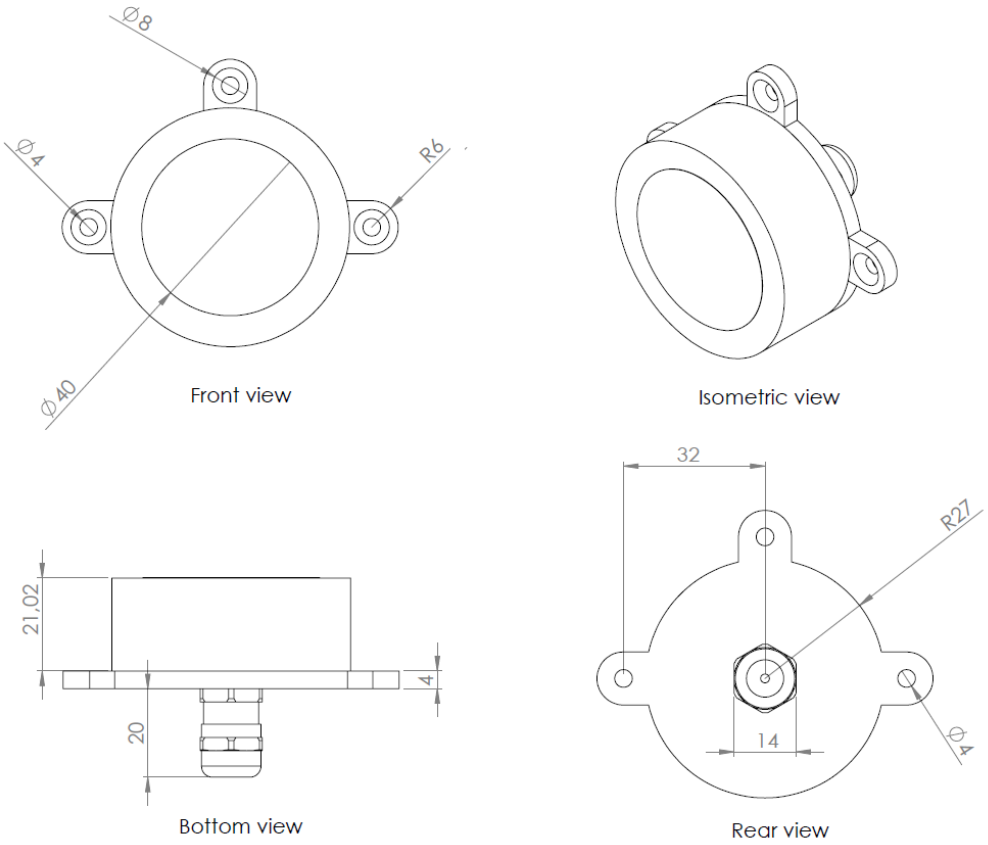


Fig 12. ISS-TX dimensions

The box of the ISS-TX sensor is composed of a top and bottom housing, both made of Aluminum 6082: it has good corrosion resistance. The top housing has a protective coating of anodizing and it is black lacquered, and the bottom housing has a protective coating of matt anodizing.

11. Warranty

Solar MEMS Technologies S.L. warrants the ISS-DX 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 the technical specifications.

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.
Solar MEMS Technologies S.L.
C/Early Ovington 24, nave 1.
41300, La Rinconada,
Seville, Spain.
E-mail: smt@solar-mems.com
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.

Annex 1: Bits/Bytes Numbering Convention

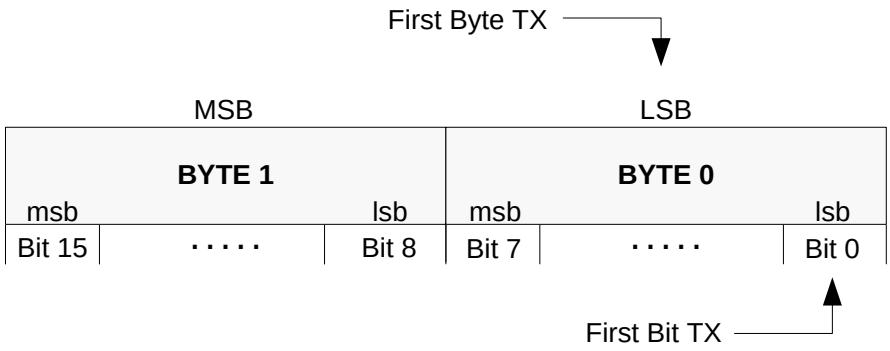


Fig 13. Bits/Bytes numbering convention

The described numbering convention (Little Endian) is applicable to transmitted and received messages.

The first byte transmitted in a string of N bytes is byte 0 (LSB) and the last byte transmitted is the byte N-1 (MSB).

The first bit transmitted in a byte is bit 0 (lsb) and the last transmitted bit is bit 7 (msb).

Annex 2: C Routines

8-bit Checksum

Considering the following structure to define a message of communications:

```
struct message
{
        unsigned char id;
        unsigned char dts;
        unsigned char data[20];
};
```

The source code proposed to calculate the 8 bits checksum is:

```
unsigned char checksum8(struct msg message)
{
        unsigned short sum = 0x0000;
        unsigned char checksum;
        int i;

        for(i=0;i<(message.dts-1);i++)
                sum = message.data[i] + sum;
        checksum = (unsigned char)(0x00FF & sum);
        return(checksum);
}
```