USER MANUAL

1U Solar Panel

SOLAR PANEL – 1U

USER MANUAL

This user manual details the applications, features and operation of EnduroSat's 1U Solar Panel.

Please read carefully the manual before unpacking the solar panels in order to ensure safe and proper use.

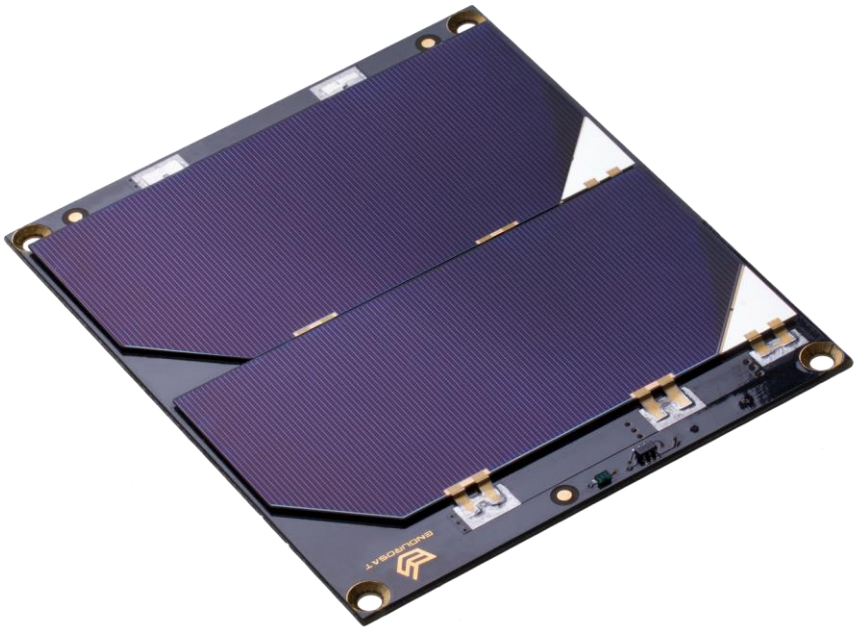


Figure 1: 1U Solar Panel X/Y

1 CHANGE LOG

Date	Version	Note
10/04/2016	Rev 1	
15/12/2016	Rev 1.2	Added Solar Panel X/Y with RBF (paragraph 5.3)
01/08/2017	Rev 1.3	Magnetic dipole measurement updated
23/11/2017	Rev 1.4	Minor text enhancements
22/10/2018	Rev 1.5	Technical writing enhancements.

2 ACRONYMS LIST

ADCS	Attitude Determination and Control System
CIE	International Commission on Illumination
ECSS	European Cooperation Space Standardization
ESA	European Space Agency
GEO	Geostationary Earth Orbit
GEVS	General Environmental Verification Standard
GND	Ground
LEO	Low Earth Orbit
MTQ	Magnetorquer
PCB	Printed Circuit Board
RBF	Remove Before Flight
RH	Relative humidity
SCA	Solar Cell Assembly
SCIC	Satellite Communication Interface Connector
SPI	Serial Peripheral Interface

3 DESCRIPTION

EnduroSat's 1U Solar Panels are equipped with 2 CESI Solar cells of type CTJ30 with up to a 29.5% efficiency. The wide effective cell area is the largest possible for solar panels suitable for 1U CubeSats and provides up to 2.4 Watts per panel in a LEO. The 1U Solar Panels are also compatible with EnduroSat's 3U and 6U structures.

On the PCB, a network of sensors and a magnetorquer can be interfaced to an Attitude Determination and Control System(ADCS). The network can be all or a combination of the following: temperature sensor, Sun sensor, magnetorquer, and gyroscope. The temperature sensor and Sun sensor (photodiode) are positioned on the top surface of the solar panel whereas the magnetorquer and gyroscope are positioned within the solar panel and not visible. The magnetorquer is a series of large electrical coils positioned over several layers of a multi-layer PCB. Furthermore, the PCB is equipped with a connector for an external magnetorquer.

Solar panel configurations on the outside of the satellite can be simple or complex. Therefore, using our connector system on the PCB, multiple solar panels can be easily connected in an electrical series or parallel configuration. The solar panels are then typically connected to an Electrical Power System (EPS) module.

Also, customization of the panel for additional external connectors (e.g. an RBF pin) and interfaces to access the satellite can be provided upon request.

4 PRODUCT PERFORMANCE AND PROPERTIES

4.1 Solar Panel Features and Characteristics

- Two CESI Solar Cells CTJ30, space qualified triple junction (specs in the following paragraph)
- 60.30cm^2 effective cell area (2 solar cells)
- Temperature Sensor with SPI Interface (Accuracy: ±1.5°C from -25°C to 85°C (max), ±2.0°C from -55°C to 125°C (max))
- Up to 2.4 Watt in LEO
- Gold plated invar interconnectors
- Space-grade silicone adhesive with minimum outgassing behavior
- Gyroscope
- Sun Sensor
- Multiple panels can be connected in series or parallel
- Two internal 70 µm copper layers
- Plated, countersink mounting holes with ground connection
- Connector for external magnetorquer
- Max Voltage: up to 4.66V (for 2 cells)
- Max Current: up to 517mA
- Thickness 2.2 mm ±150 µm

4.2 Solar Cell Features and Characteristics

- Efficiency up to 29.5%
- Triple Junction Solar Cells InGaP/GaAs/Ge
- Very low solar cell mass (81-89 mg/cm2)
- Thickness 155 µm ±15 µm
- Fully qualified under ESA Standard ECSS E ST20-08C for LEO and GEO
- Internal by-pass diode for optimized output power
- Size 30.15 cm^2
- High radiation resistance
- Coverglass CMG (150 µm thick)
- Good mechanical strength

5 AVAILABLE CONFIGURATIONS

EnduroSat's 1U Solar Panels are available in 5 configurations.

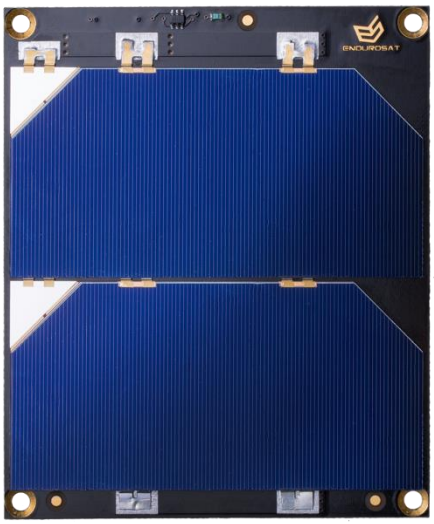
- Solar Panel X/Y
- Solar Panel X/Y RBF (i.e. with Remove Before Flight Pin)
- Solar Panel X/Y MTQ (i.e. with Magnetorquer)
- Solar Panel Z
- Solar Panel Z MTQ (i.e. with Magnetorquer)

Where:

i) X/Y indicates the panel can be used on the side panels of the CubeSat.
ii) Z indicates the panel can be used on the top and bottom of the CubeSat.

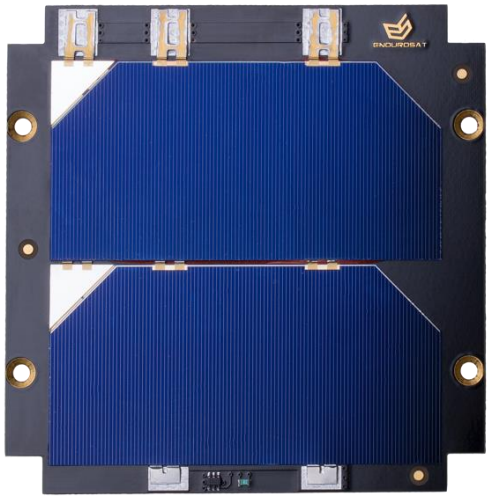
All configurations can be ordered with a white or black solder mask.

5.1 1U Solar Panel X/Y and X/Y MTQ



1U Solar Panel X/Y (i.e. without magnetorquer)	1U Solar Panel X/Y MTQ (i.e. with magnetorquer)
• 2 CTJ30 SCA CESI • Temperature sensor • Gyroscope (optional) • Sun sensor • Multiple panels can be connected in series or parallel • Internal by-pass diode for optimized output power • Weight: 44 g	• 2 CTJ30 SCA CESI • Magnetorquer • Temperature sensor • Gyroscope • Sun sensor • Multiple panels can be connected in series or parallel • Internal by-pass diode for optimized output power • Weight: 53 g

5.2 1U Solar Panel Z and Z MTQ



1U Solar Panel Z (i.e. without magnetorquer)	Solar Panels Z MTQ (i.e. with magnetorquer)
• 2 CTJ30 SCA CESI • Temperature sensor • Gyroscope (optional) • Sun sensor • Multiple panels can be connected in series or parallel • Internal by-pass diode for optimized output power. • Weight: 48 g	• 2 CTJ30 SCA CESI • Magnetorquer • Temperature sensor • Gyroscope • Sun sensor • Multiple panels can be connected in series or parallel • Internal by-pass diode for optimized output power. • Weight: 57.5 g

5.3 1U Solar Panel X/Y RBF

The 1U Solar Panel X/Y RBF has a Remove Before Flight (RBF) pin on the top right corner of the panel. The RBF ensures that the satellite cannot be switched on while the RBF pin is inserted. The RBF connector on the bottom side of the solar panel should be connected to the RBF connector of the power module with a cable.

Moreover, a 5-pin connector socket (which is designed to prevent incorrect orientation of the plug) provides a general purpose input/output communication interface. In the EnduroSat platform for instance, this interface is used to access the USB port of the OBC, or for charging the batteries of the EnduroSat power module.

Solar Panels X/Y RBF
(i.e. with RBF, and without magnetorquer)

- 2 CTJ30 SCA CESI
- Temperature sensor
- Gyroscope (optional)
- Sun sensor
- Multiple panels can be connected in series or parallel
- Internal by-pass diode for optimized output power.
- Remove Before Flight (RBF) pin
- 5 pin connector for communication interface (prevents incorrect orientation of the plug)
- Weight: 45 g

Figure 2 shows the front part of the 1U Solar Panel X/Y RBF and the location of the RBF pin and 5-pin connector.

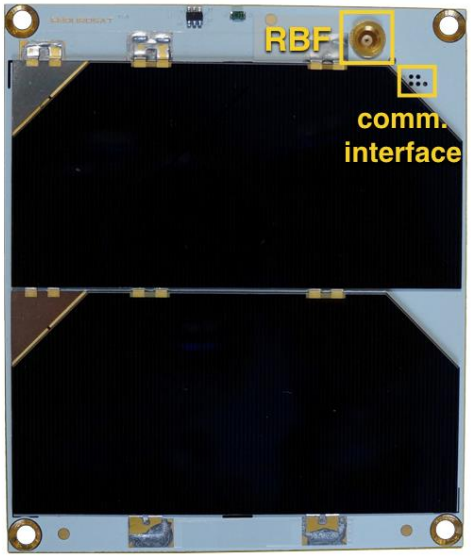


Figure 2: 1U Solar Panel X/Y RBF -Top Side

6 CONNECTORS

6.1 Power Output, and Sensors and Magnetorquer (MTQ) Connectors

EnduroSat's 1U solar panels provide three connectors for power output from the solar cells, sensor communication and magnetorquer control:

- H1 - Output Power Bus Connector
- H2 - Output Power Bus Connector
- H3 - Sensor & Magnetorquer

The H1 and H2 connectors are connected on to the same power bus and are electrically identical. Having the two connectors (H1 and H2) allows other solar panels to be easily connected in either an electrical series or parallel configuration.

The H1,H2, and H3 connectors are in the same position for all 1U, 1.5U and 3U solar panels.

6.1.1 H1, H2, and H3 Location

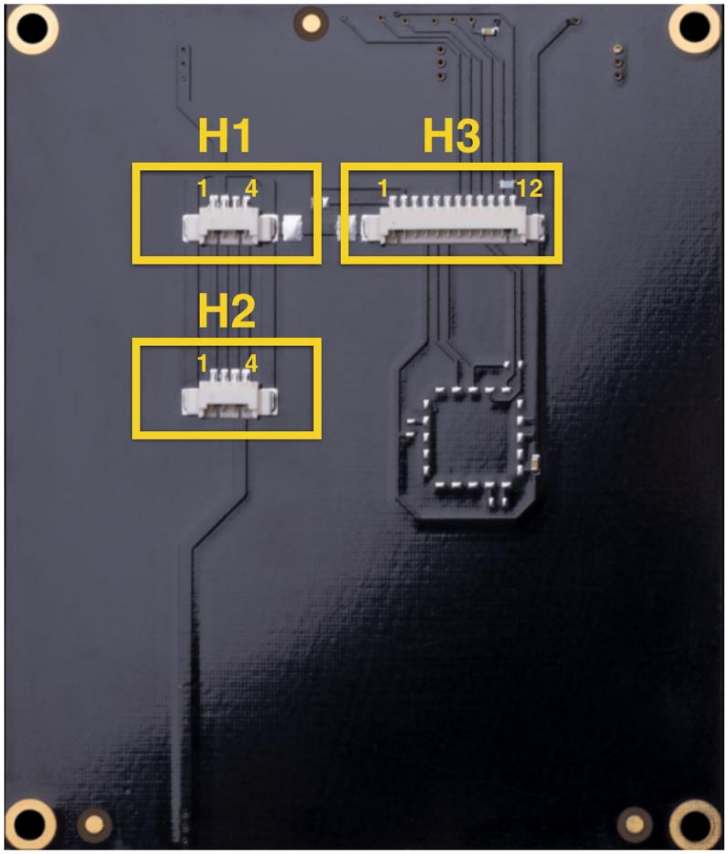


Figure 3: Solar Panel – Bottom Side

6.1.2 H1 Pinout (Power Output)

Pin	Mnemonic	Description
1	-	Negative
2	-	Negative
3	+	Positive
4	+	Positive

6.1.3 H2 Pinout (Power Output)

Pin	Mnemonic	Description
1	-	Negative
2	-	Negative
3	+	Positive
4	+	Positive

6.1.4 H3 Pinout (Sensors and Magnetorquer)

Pin	Mnemonic	Description
1	PWMB	Magnetorquer control B
2	PWMA	Magnetorquer control A
3	GND	Ground
4	Vgyro	Gyroscope power input
5	SPI CS1	Chip select gyroscope
6	SPI MOSI	SPI MOSI
7	AGND	Analog ground photodiode
8	PhotoDiode	Photodiode cathode
9	SPI SCK	SPI clock
10	SPI MISO	SPI MISO
11	Vcc	3.3Vdc
12	SPI CS2	Chip select temperature sensor

6.2 Remove Before Flight (RBF) Connector

The figure below shows the location and pinout of the RBF connector (MOLEX 53261-0271).

6.2.1 RBF Location

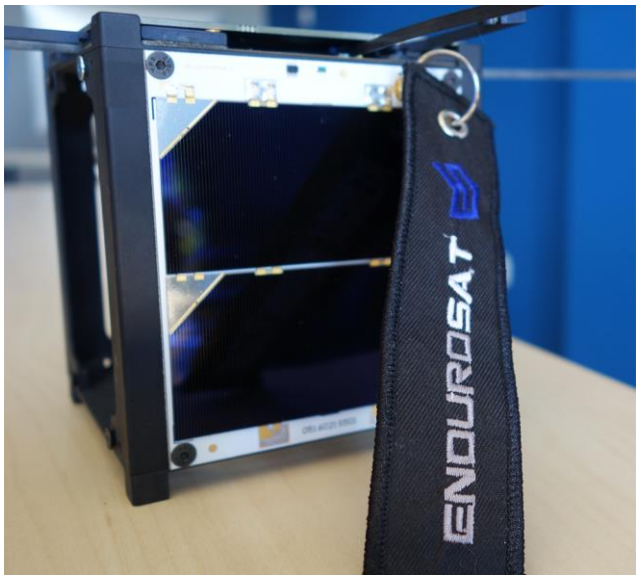


Figure 4: Remove Before Flight (RBF) Handle and Pin

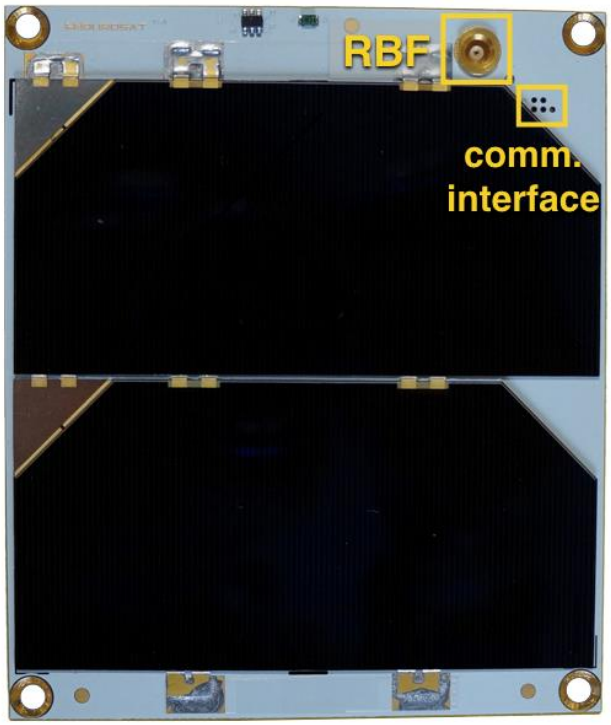


Figure 5: Remove Before Flight (RBF) Connector Socket – Top Side

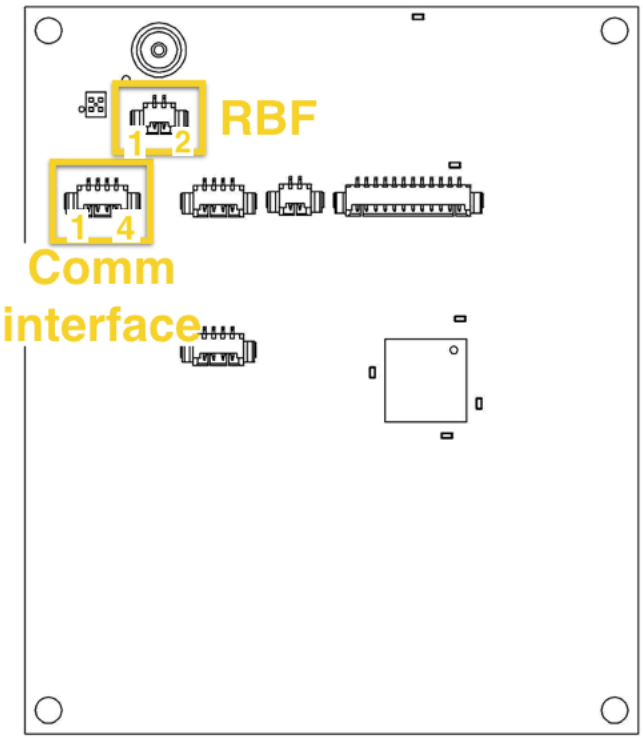


Figure 6: Remove Before Flight (RBF) Connector and Pinout – Bottom Side

6.2.2 RBF Pinout

Pin	Description
1	RBF
2	GND

6.3 Satellite Communication Interface Connector (SCIC)

The 5-pin Satellite Communication Interface Connector (SCIC) socket provides general purpose (e.g. testing) and user configurable communication or charging capabilities to the other modules within the satellite. Its purpose is to prevent disassembling of the satellite which can be very time consuming, or even forbidden after an official test campaign. The SCIC socket on the top side of the solar panel is an electrical bypass (of the solar panel) to its equivalent SCIC plug on the bottom side which can then be connected to the internal modules. In the EnduroSat platform for instance, these interfaces are used to access the USB port of the On-Board Computer (OBC), or for charging the batteries of the EnduroSat power module.

6.3.1 SCIC Location

The figures below show the location and pinout of the Satellite Communication Interface Connectors (SCIC). The top side SCIC has a pitch of 1.27mm (50mils), and the bottom side connector is a (MOLEX 53261-0471).

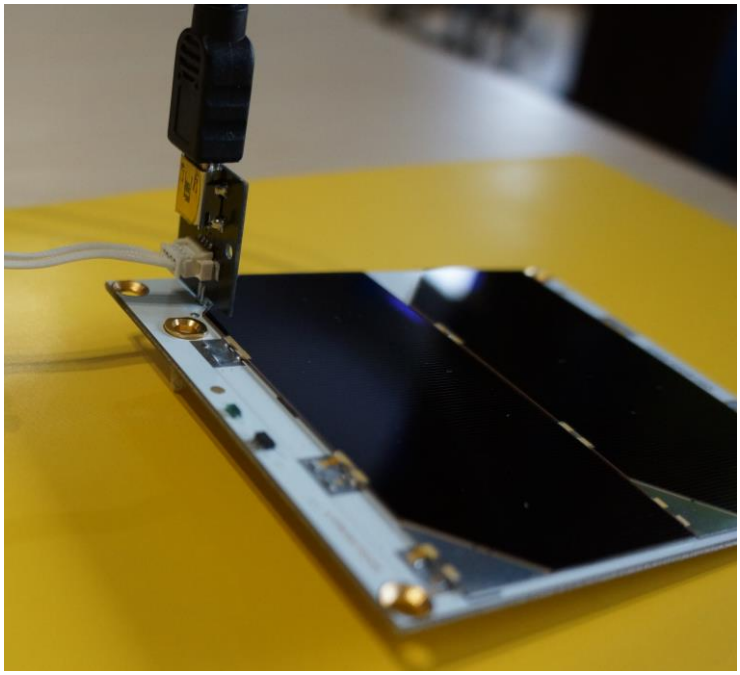


Figure 7: SCIC Adaptor - Top Side

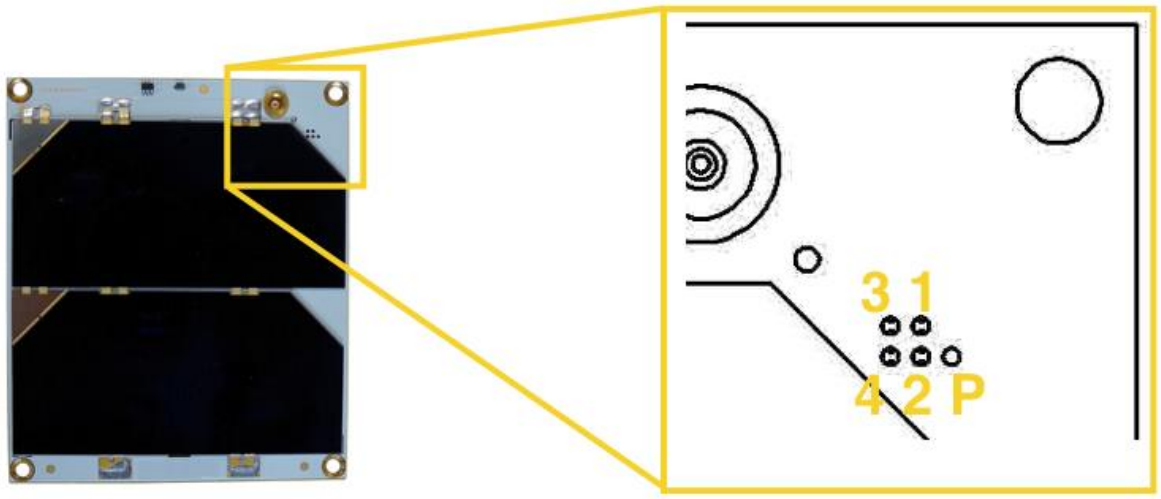


Figure 8: SCIC Connector - Top Side

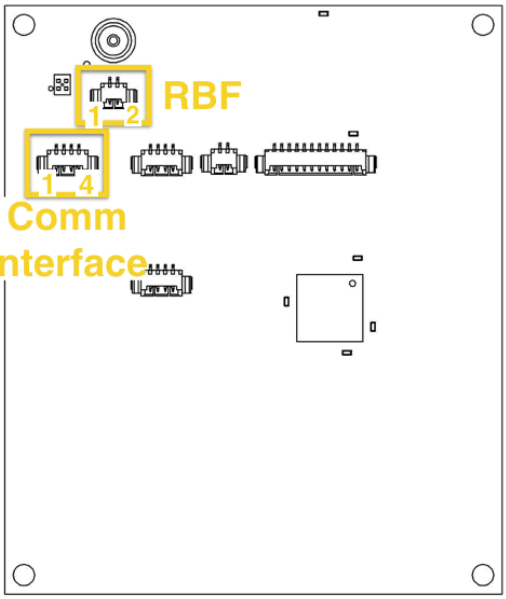


Figure 9: Satellite Communication Interface Connector (SCIC) and Pinout – Bottom Side

6.3.2 SCIC Pinouts

Pin	Description
1	User customizable
2	User customizable
3	User customizable
4	GND
P	Pin for polarization

7 SPECIFICATIONS

SOLAR CELL STRING					
Parameter	Unit	Condition	Min	Typ	Max
Voltage	V	25ºC			4.66
Current	mA	25ºC			517
Power	mW	25ºC			2400
Efficiency	%				29.5

TEMPERATURE SENSOR					
Parameter	Unit	Condition	Min	Typ	Max
Range	°C		-55		150
Accuracy	°C	-25°C to 85°C		±0.5	±1.5
	°C	-55°C to 125°C		±1	±2
	°C	-55°C to 150°C		±1.5	
Vcc	V		2.7		5.5
Quiescent Current	µA			50	75

GYROSCOPE					
Parameter	Unit	Condition	Min	Typ	Max
Sensitivity	°/sec/LSB	25°C, dynamic range = ±320°/sec		0.07326	
	°/sec/LSB	25°C, dynamic range = ±160°/sec		0.03663	
	°/sec/LSB	25°C, dynamic range = ±80°/sec		0.01832	
Vcc	V		4.75	5	5.25
Operating Temperature			-40°C		105°C
Calibration Temperature			-40°C		85°C

SUN SENSOR					
Parameter	Unit	Condition	Min	Typ	Max
Reverse light Current	µA	E_V =100lx CIE illuminant A	0.03	0.04	0.09
Range of Spectral bandwidth ($\lambda_{0.5}$)	nm			430 to 610	
Angle of half sensitivity	deg			±60°	

MAGNETORQUER					
Parameter	Unit	Condition	Min	Typ	Max
Resistance	Ω			42	
Current	mA	@3.3V		78	
Dipole Momentum[1]	Am^2	@3.3V		0.131	

[1] measured

8 MECHANICAL CHARACTERISTICS

EnduroSat solar panels should be mounted on the EnduroSat Structure using bolts of type:

Torx - DIN965/ISO 7046-1 - M3 – Length: 6mm

In the following paragraphs, the main dimensions of the solar panels are shown. All dimensions are in mm.

A STEP file can be provided upon request.

8.1 1U Solar Panel X/Y

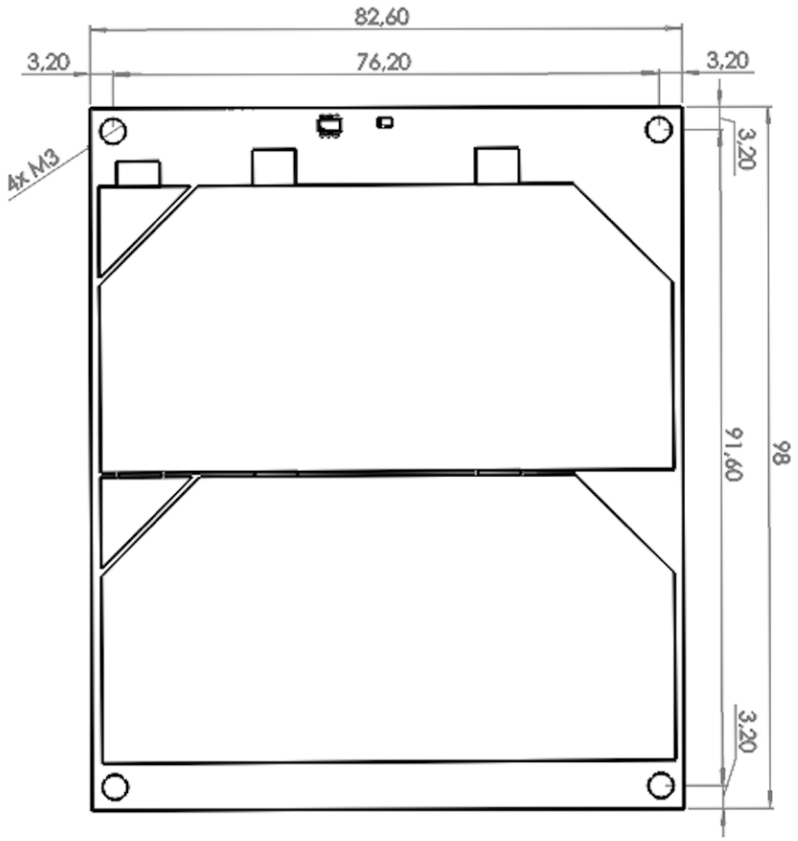


Figure 10: 1U Solar Panel X/Y - Top Side

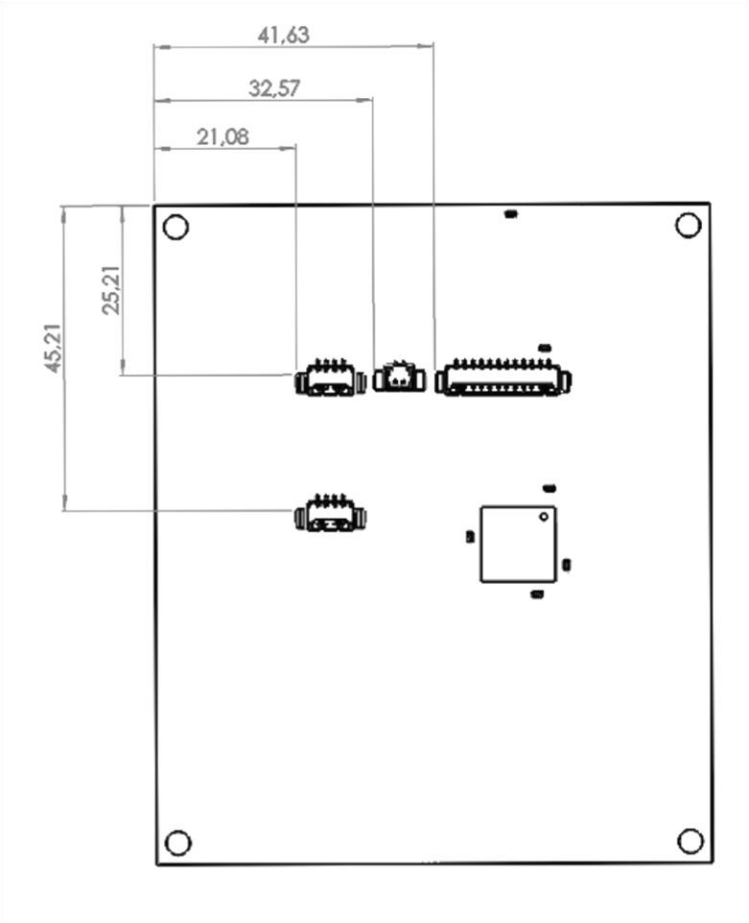


Figure 11: Solar Panel X/Y - Bottom Side (connector location)

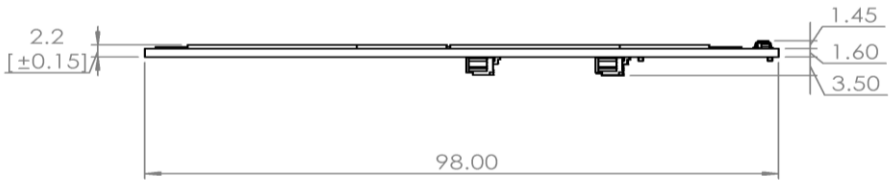


Figure 12: Solar Panel X/Y - Side View

8.2 1U Solar Panel X/Y MTQ

The dimensions of the 1U Solar Panel X/Y MTQ are identical to the 1U Solar Panel X/Y except for the thickness. The difference is due to the presence of the electromagnetic coils of the magnetorquer inside the PCB of the X/Y MTQ version.

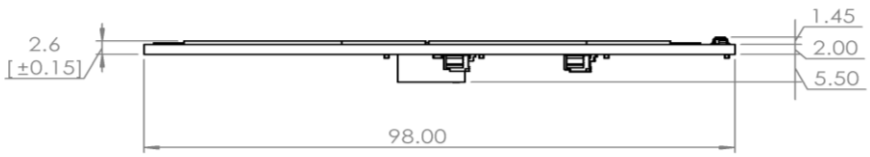


Figure 5: Solar Panel X/Y MTQ - Side View

8.3 1U Solar Panel Z

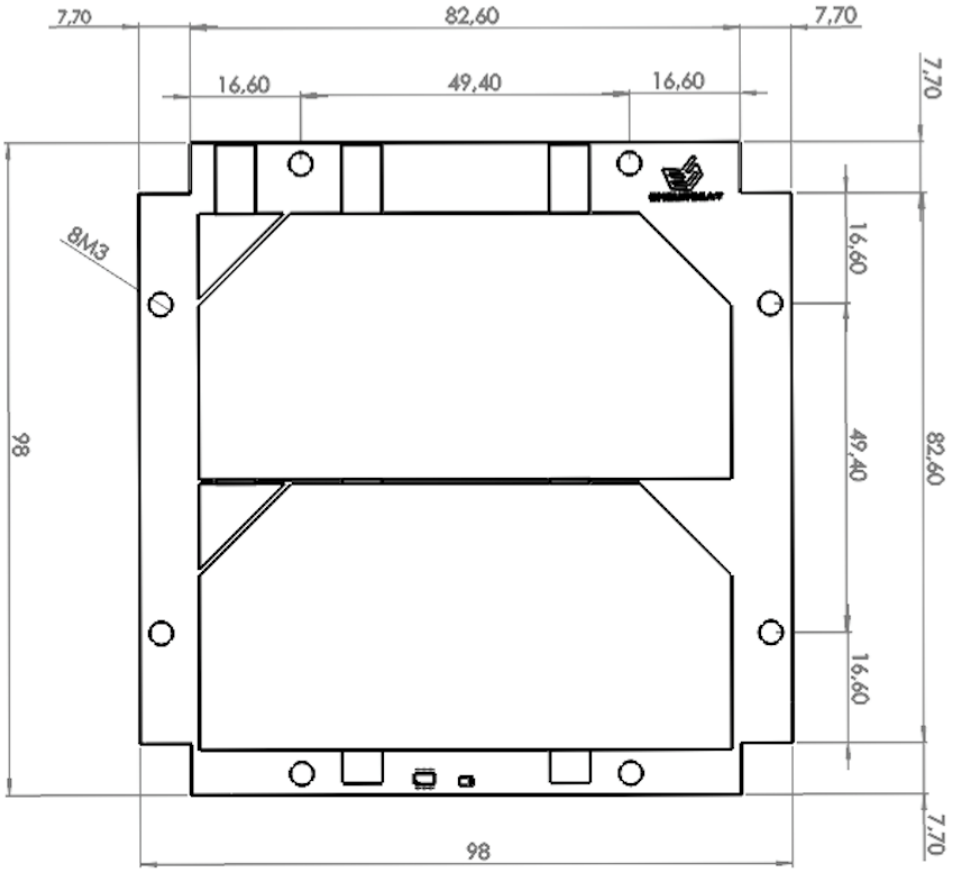


Figure 13: 1U Solar Panel Z - Top View

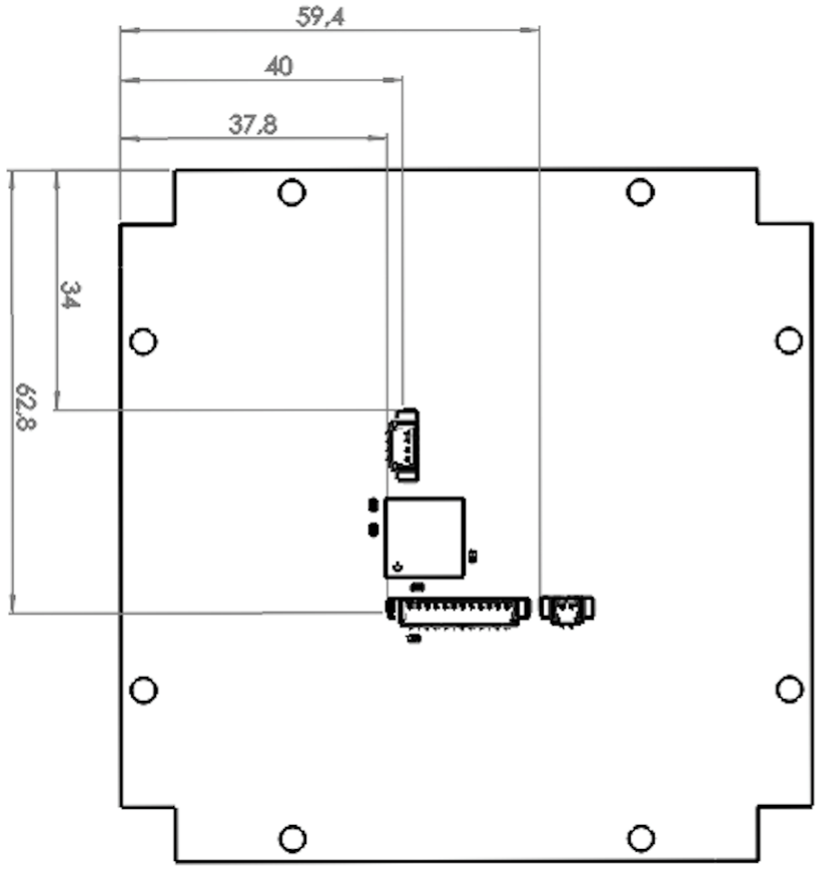


Figure 14: Solar panel Z - Bottom View (connector location)

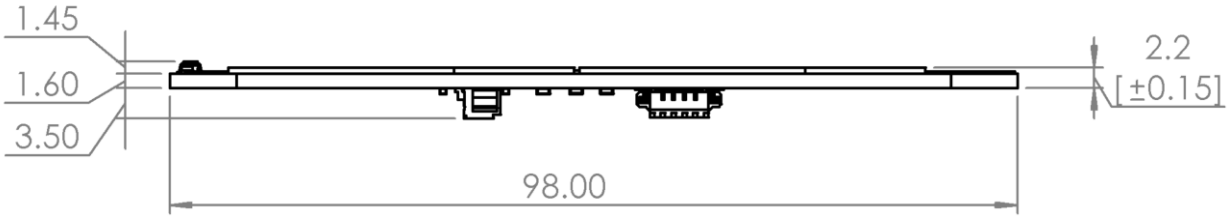


Figure 15: Solar Panel Z - Side View

8.4 1U Solar Panel Z MTQ

The dimensions of the 1U Solar Panel Z MTQ are identical to the 1U Solar Panel Z except for the thickness. The difference is due to the presence of the electromagnetic coils of the magnetorquer inside the PCB of the Z MTQ version.

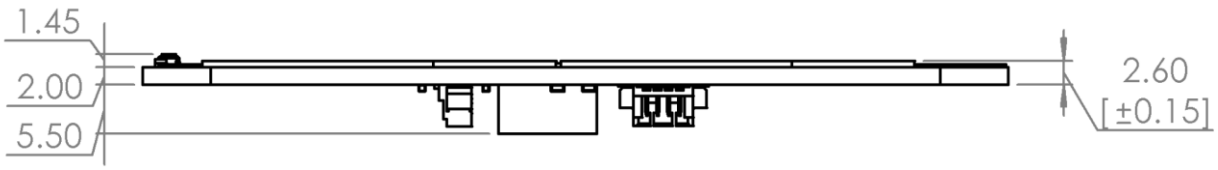


Figure 16: Solar Panel Z with Magnetorquer - Side View

8.5 1U Solar Panel X/Y RBF

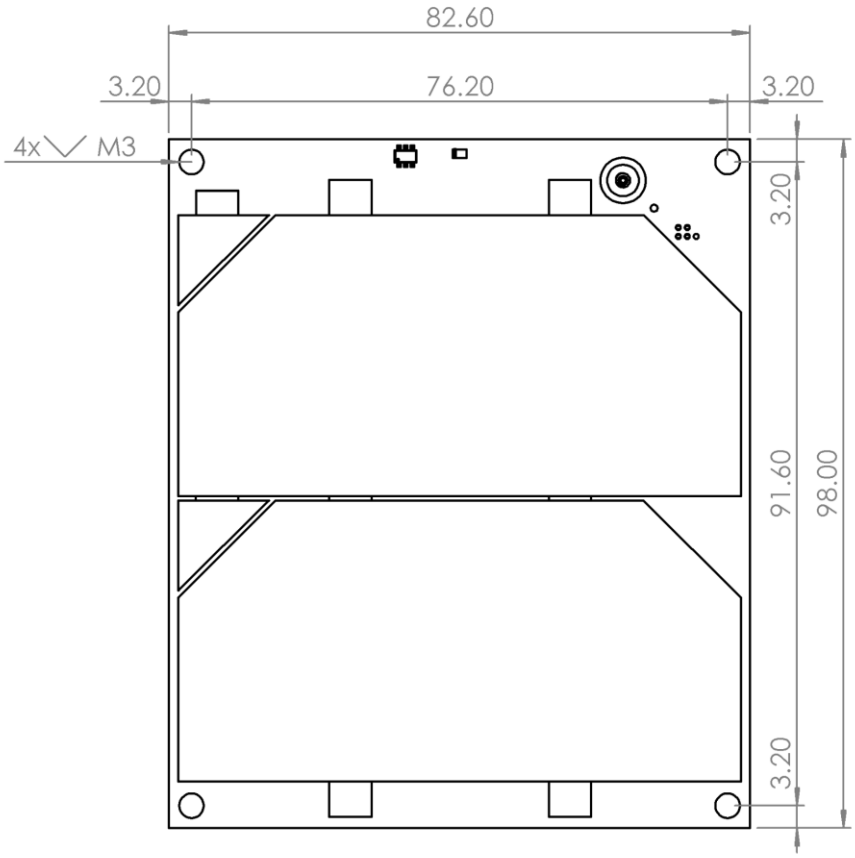


Figure 17: 1U Solar Panel X/Y RBF - Top View

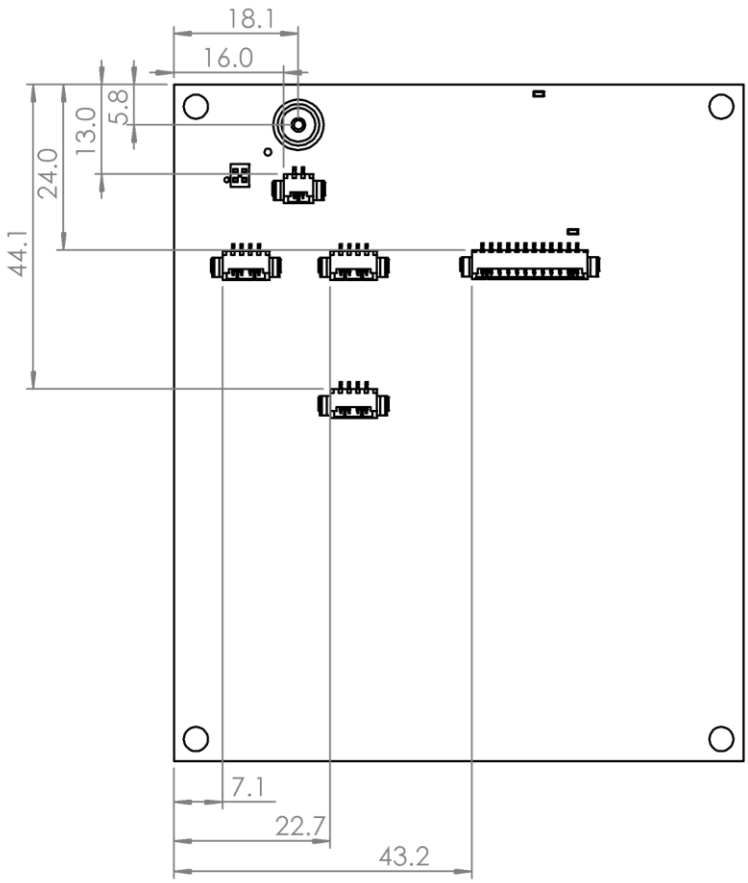


Figure 18: Solar panel X/Y RBF - Bottom View (connector location)

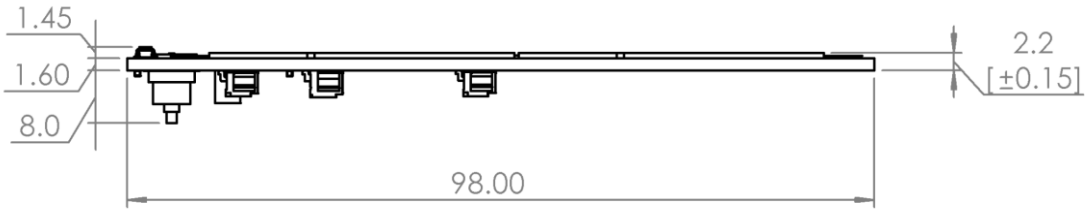


Figure 19: Solar Panel X/Y RBF - Side View

Note: When it is inserted, the maximum height of the RBF pin from the top surface of the PCB is 5mm

8.6 Tolerances

The outer edge dimensions of the 1U solar panels have a tolerance of ±0.1mm (±4mil).

The thickness of the 1U solar panels have a tolerance of ±0.15mm (±6mil).

9 CUSTOMIZATION

EnduroSat's 1U Solar Panels can be customized with an additional connector for an external magnetorquer. Figure 3 shows the location of the pads for mounting the MOLEX 53261-0271 connector.

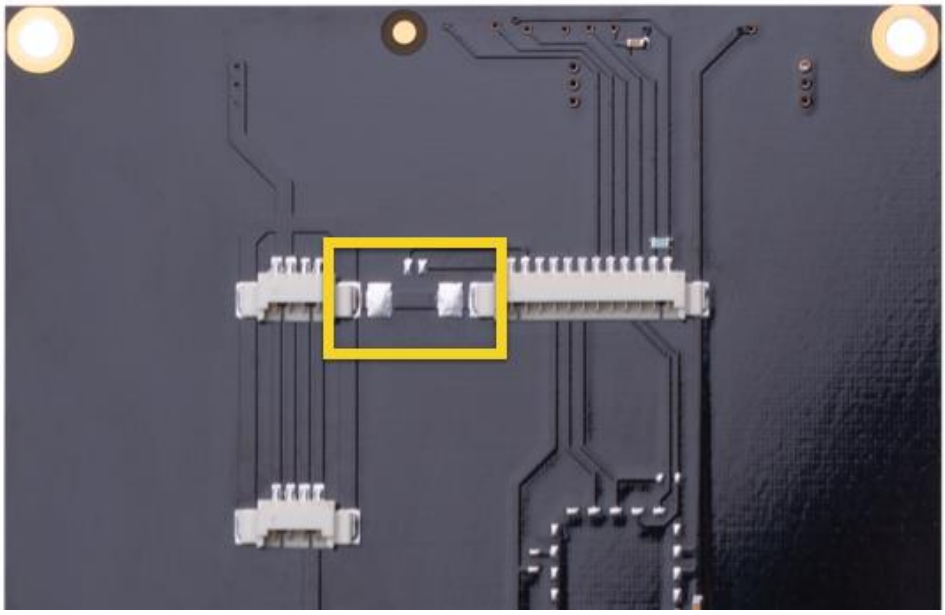


Figure 6: Solar Panel - Bottom Side (location of pads for the external magnetorquer connector)

Upon request, solar panels can be customized with additional connectors and external interfaces.

10 MATERIAL AND ASSEMBLING

The solar panel's PCB material is FR4-Tg170. Production process follows quality standard:

- IPC-A-600H Ⅱ (Surface),
- IPC-A-6012 (Function),
- IPC-TM-650 (Test Method).

Component mounting quality standards:

- IPC-A-600 Acceptability of printed boards,
- IPC-A-610E Acceptability of Electronic Assemblies,
- J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies,
- ISO 14644 Cleanrooms and associated controlled environments,
  IEC 61340 Electrostatics ESD: Protection of electronic devices from electrostatic phenomena.

11 ENVIRONMENTAL AND MECHANICAL TESTS

A full campaign of tests at qualification level was performed on the solar panel's qualification engineering model. Qualification test levels and duration follow the ESA standard ECSS-E-ST-10-03C and GEVS: GSFC-STD-7000A. Tests performed were:

- Thermal Cycling
- Thermal Vacuum
- Random Vibration
- Sine Vibration
- Shock Test

12 INCLUDED IN THE SHIPMENT

EnduroSat provides along with the Solar Panel:

- Power cable (PTFE Material Jacket, 26AWG), connector MOLEX 51021-0400[1]
- Sensors and magnetorquer cable (PTFE Material Jacket, 26AWG), connector MOLEX 51021-1200[2]
- Bolts Torx - DIN965/ISO 7046-1 - M3 – Length: 6mm
- RBF external pin (solar panel X/Y with RBF)
- USB stick with user manual

[1]Available lengths: 21cm, 15cm, 8cm.

[2]Available lengths: 20cm, 18cm, 10cm, 5cm

Customized cables and connectors can be provided upon request

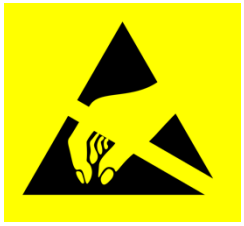
13 HANDLING AND STORAGE

Particular attention shall be paid to the avoidance of damage to the solar cells of the solar panels during handling, storage and preservation. The handling of the solar panel should be performed in compliance with the following instructions:

- Handle using PVC, latex, cotton (lint free) or nylon gloves.
- The environment where the solar panels will be handled shall meet the requirements for a class environment 100,000, free of contaminants such as dust, oil, grease, fumes and smoke from any source.
- Do not touch the solar cells.
- Solar panels must be handled by touching the PCB edges only.
- Solar Panels shall be stored in such a manner as to preclude stress and prevent damage.
- To prevent the deterioration of the solar cells, then the solar panel must be stored in a controlled environment (i.e. the temperature and humidity levels shall be maintained in the proper ranges:
    - Ideal storage temperature range: 15ºC to 27ºC.
    - Ideal storage humidity range: 30% to 60% relative humidity (RH).

14 WARNINGS

This product uses very fragile components. Observe precautions for handling.



This product uses semiconductors that can be damaged by electrostatic discharge (ESD). Observe precautions for handling

Sensitive electronic device. Do not ship or store near strong electrostatic, electromagnetic, magnetic or radioactive fields.