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User Guide: First Solar Series 4 Module

North America

REV 3.1

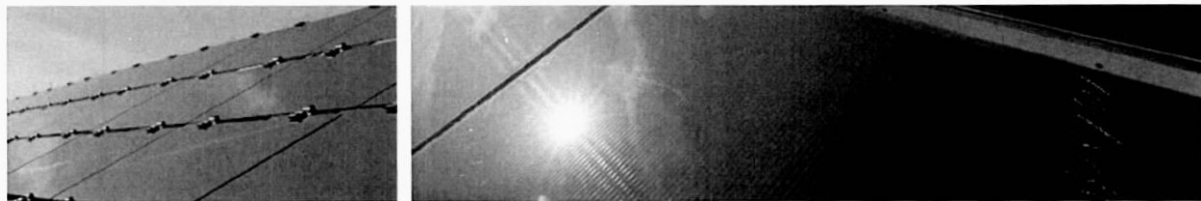


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1 Introduction

First Solar Series 4 and Series 4A Modules are manufactured in state-of-the-art facilities using a highly innovative process that rapidly deposits thin films of semiconductor on glass. Series 4A modules are constructed identically to Series 4 modules and add anti-reflective coated glass to Series 4 modules. The modules have been designed to have a long operating life and high energy yield when installed, operated, and serviced in accordance with the instructions in this User Guide. First Solar Series 4 and Series 4A Modules are electrically and mechanically compatible with one another, provided appropriate system design practices are employed. Series 4 and Series 4A Modules are not compatible with First Solar Series 3 Modules within the same interconnected string.

1.1 Before You Begin

This document provides guidelines and information on First Solar Series 4 and Series 4A Modules of model types FS-4xxx, FS-4xxxA, FS-4xxx-2, FS-4xxxA-2, FS-4xxx-3, and FS-4xxxA-3 for system designers, installers, and maintenance personnel. Read this User Guide thoroughly before beginning any work related to the installation, operation, or maintenance of the First Solar Series 4 or Series 4A Module. Only qualified personnel should install, operate, or maintain a PV module or system.

Failure to follow installation and handling instructions may result in injury.

Failure to maintain proper operating condition requirements for the modules will void the applicable warranties.

This user guide pertains to modules installed within North America only. If a module is being installed outside of North America, contact First Solar (technicalsupport@firstsolar.com) or visit www.firstsolar.com for the User Guide appropriate for other geographic areas.

Keep this User Guide for future reference.

Guidelines related to system construction are beyond the scope of this document and are not covered in this document.

1.2 Key Product Features

- High energy yields in real-world conditions.
- Size and weight that enables efficient handling and installation.
- Easy, quick-connect wiring for fast interconnection.
- Compatible with advanced 1500V plant architectures.
- Internationally recognized product certifications.
- Twenty-five year limited performance warranties.

1.3 Safety

WARNING

The Series 4 and Series 4A Modules may produce voltage up to 110 Volts DC (VDC) or current up to 3.0 Amps when exposed to sunlight. *A single module could create a lethal shock hazard during hours of daylight*, including periods of low light levels. The danger increases as modules are connected together in series and/or parallel.

To avoid fire and/or injury due to ground fault and associated electrical hazards:

- Do not unplug PV module connections while under load. Do not disconnect the module connectors during daylight hours unless the module is in an open circuit condition or all modules in series and parallel are covered with an opaque material, such as a tarp or blanket.
- Repair or replace damaged wires immediately. Keep all array wiring out of reach of non-qualified personnel.
- Do not concentrate light on the module in an attempt to increase power output.
- Never allow the PV array system voltage to exceed 1500VDC under any condition.
- Replace broken modules immediately.
- Repair any ground faults immediately.
- Do not work on modules or systems when the modules or wiring are wet.

Reverse currents higher than the rated values for a First Solar module (reverse current overload), may result in module failure, including module breakage. Extreme and continuous reverse current overload conditions may cause a fire or create electrical shock hazards. To avoid reverse current overload:

- Maintain equivalent voltage in parallel strings by installing an equal number of modules per string within the same source circuit. Failure to install modules with balanced voltage in parallel strings can result in voltage imbalance.
- Comply with all practices as stated in this document and repair ground faults.

It is the responsibility of the PV system installer to ensure compliance with all local building codes. As a minimum level of protection, all building mounted PV systems should utilize Ground Fault Circuit Interrupters and Arc Fault Circuit Interrupters to minimize risk of electrical shocks and fires.

Wear safety glasses (ANSI Z87.1-2003) and cut-resistant gloves when working on non-interconnected modules or systems. Wear electrically rated PPE when working on interconnected modules or system components.

Series 4 and Series 4A Modules are not compatible with Series 3 Modules within the same interconnected string.

- To avoid risk of fire, do not interconnect Series 4/4A Modules within the same interconnected string as Series 3 Modules.

2 Regulatory Compliance

It is the responsibility of the installer and/or system integrator to ensure compliance with all local electrical codes which may be applicable to the installation and use of First Solar Series 4 and Series 4A Modules.

- Before beginning the PV system design and installation, contact appropriate local authorities to determine local code, permit, and inspection requirements.
- For systems installed in Canada, installation shall be in accordance with CSA C22.1, Safety Standard for Electrical Installations, Canadian Electrical Code, Part 1.

First Solar Series 4 and Series 4A Modules are Listed by a Nationally Recognized Test Laboratory to UL 1703, the standard for Flat-Plate Photovoltaic Modules and Panels.

To maintain the modules' application as a UL Listed product:

- Use only components that have been Recognized or Listed by Underwriters Laboratories (UL) for their intended purpose.
- Ensure the PV array open-circuit voltage does not exceed 1500VDC (1000VDC for UL Canada).
- Install modules with mounting systems that have been evaluated for UL Listed application as specified in First Solar Application Note PD-5-320-04 NA.
- Protect modules from reverse currents in excess of the Maximum Series Fuse rating of 4.0A as specified in First Solar Application Note PD-5-308.

When using MC4 connectors, Series 4 and Series 4A Modules meet the requirements of Protection Class II for 1000VDC systems and Protection Class 0 for 1500VDC systems. When using MC4-EVO 2 connectors, Series 4 and Series 4A Modules meet the requirements of Protection Class II for 1000VDC and 1500VDC systems. Series 4 and Series 4A Modules are tested and certified per IEC 61730 with maximum overcurrent protection ratings of 4.0A. Series 4 and Series 4A Modules are tested and certified per IEC 61646 / IEC 61215 for a maximum system voltage of 1500V.

3 Electrical Specifications

MODEL NUMBERS AND RATINGS AT STC ¹								
Nominal Values		FS-490 FS-490A	FS-492 FS-492A	FS-495 FS-495A	FS-497 FS-497A	FS-4100 FS-4100A	FS-4102 FS-4102A	FS-4105A
Nominal Power ($\pm 5\%$)	$P_{MPP}(W)$	90.0	92.5	95.0	97.5	100.0	102.5	105.0
Voltage at P_{MAX}	$V_{MPP}(V)$	66.5	67.0	67.9	68.7	69.4	70.0	70.4
Current at P_{MAX}	$I_{MPP}(A)$	1.36	1.38	1.40	1.42	1.44	1.47	1.49
Open Circuit Voltage	$V_{OC}(V)$	85.5	86.0	86.5	87.0	87.6	88.0	88.2
Short Circuit Current	$I_{SC}(A)$	1.53	1.54	1.55	1.55	1.57	1.57	1.58
Maximum System Voltage	$V_{SYS}(V)$	1500 ²						
Maximum Series Fuse	$I_{CF}(A)$	4.0						

MODEL NUMBERS AND RATINGS AT STC ¹							
Nominal Values		FS-4100-2 FS-4100A-2	FS-4102-2 FS-4102A-2	FS-4105-2 FS-4105A-2	FS-4107-2 FS-4107A-2	FS-4110-2 FS-4110A-2	FS-4112-2 FS-4112A-2
Nominal Power ($\pm 5\%$)	$P_{MPP}(W)$	100.0	102.5	105.0	107.5	110.0	112.5
Voltage at P_{MAX}	$V_{MPP}(V)$	66.2	67.0	67.8	68.6	69.4	70.2
Current at P_{MAX}	$I_{MPP}(A)$	1.51	1.53	1.55	1.57	1.59	1.60
Open Circuit Voltage	$V_{OC}(V)$	84.7	85.3	86.0	86.6	87.2	87.7
Short Circuit Current	$I_{SC}(A)$	1.73	1.74	1.74	1.75	1.75	1.75
Maximum System Voltage	$V_{SYS}(V)$	1500 ²					
Maximum Series Fuse	$I_{CF}(A)$	4.0					

MODEL NUMBERS AND RATINGS AT STC ¹			
Nominal Values		FS-4115-2 FS-4115A-2	FS-4117-2 FS-4117A-2
Nominal Power ($\pm 5\%$)	$P_{MPP}(W)$	115.0	117.5
Voltage at P_{MAX}	$V_{MPP}(V)$	70.5	71.2
Current at P_{MAX}	$I_{MPP}(A)$	1.63	1.65
Open Circuit Voltage	$V_{OC}(V)$	87.8	88.2
Short Circuit Current	$I_{SC}(A)$	1.78	1.79
Maximum System Voltage	$V_{SYS}(V)$	1500 ²	
Maximum Series Fuse	$I_{CF}(A)$	4.0	

MODEL NUMBERS AND RATINGS AT STC ¹							
Nominal Values		FS-4105-3 FS-4105A-3	FS-4107-3 FS-4107A-3	FS-4110-3 FS-4110A-3	FS-4112-3 FS-4112A-3	FS-4115-3 FS-4115A-3	FS-4117-3 FS-4117A-3
Nominal Power ³ (-0/+5W)	P _{MPP} (W)	105.0	107.5	110.0	112.5	115.0	117.5
Voltage at P _{MAX}	V _{MPP} (V)	66.2	67.0	67.8	68.5	69.3	70.1
Current at P _{MAX}	I _{MPP} (A)	1.59	1.61	1.62	1.64	1.66	1.68
Open Circuit Voltage	V _{OC} (V)	85.2	85.8	86.4	87.0	87.6	88.1
Short Circuit Current	I _{SC} (A)	1.81	1.82	1.82	1.83	1.83	1.83
Maximum System Voltage	V _{sys} (V)	1500 ²					
Maximum Series Fuse	I _{cr} (A)	4.0					

MODEL NUMBERS AND RATINGS AT STC ¹			
Nominal Values		FS-4120-3 FS-4120A-3	FS-4122-3 FS-4122A-3
Nominal Power ³ (-0/+5W)	P _{MPP} (W)	120.0	122.5
Voltage at P _{MAX}	V _{MPP} (V)	70.8	71.5
Current at P _{MAX}	I _{MPP} (A)	1.70	1.71
Open Circuit Voltage	V _{OC} (V)	88.7	88.7
Short Circuit Current	I _{SC} (A)	1.84	1.85
Maximum System Voltage	V _{sys} (V)	1500 ²	
Maximum Series Fuse	I _{cr} (A)	4.0	

¹ As received and stabilized ratings at Standard Test Condition (1000W/m², AM 1.5 25°C Cell Temperature) +/-10%

² 1000V Listed for UL Canada.

³ Measurement uncertainty applies.

The ratings listed above are UL Listed with a tolerance of +/- 10%.

Electrical specifications are subject to change. See the module label for additional electrical ratings.

3.1 System Derating Factors

Under normal operation, a photovoltaic module may experience conditions that produce more current and/or voltage than reported at Standard Test Conditions. Accordingly, the datasheet and label specification values listed for STC should be multiplied by a factor of 1.25 for voltage and current when determining component ratings. Adjustments of those factors might be needed to respect site specific climate conditions. As defined in the National Electric Code and IEC 62548, the maximum system voltage for a Photovoltaic System is determined using the open circuit voltage of the PV modules.

4 Installation

4.1 Mounting



Physically damaged modules may cause ground faults and associated electrical hazards. To avoid these conditions:



Do not install the modules during high wind or wet conditions to reduce the likelihood of injury.



Wear safety glasses (ANSI Z87.1-2003) and cut-resistant gloves when working on non-interconnected modules or systems.



Wear electrically rated PPE when working on interconnected modules or system components.

- Handle modules with care during installation, as heavy impact on the front, back, or edges could result in damage to the module. Do not walk or stand on modules or retaining clips.
- Do not stack or carry multiple modules on top of one another after removal from factory packaging to minimize the risk of breakage.
- Do not lift or pull on modules using lead wires or strain relief wire loops to minimize the risk of wire damage.

Mounting of the Series 4 and Series 4A Module to a suitable structure can be done by attaching the module directly to the structure using retaining clips (see Figure 5.1).

Any module without a frame (laminated) shall not be considered to comply with the requirements of UL 1703 unless the module is mounted with hardware that has been tested and evaluated with the module under this standard or by a field inspection certifying that the installed module complies with the requirements of UL 1703. The Series 4 and Series 4A Module is a frameless laminate and is considered to be in compliance with UL 1703 only when the module is mounted using approved hardware in the manner specified by the mounting instructions in First Solar Application Note PD-5-320-04 NA.

Additional mounting systems may be approved for use. The interface of the mounting structure to the module (including the retaining clip and rubber insulator) must meet the technical requirements specified in First Solar Application Note PD-5-320-04 and must be approved for use by First Solar prior to installation. The mounting system design must provide adequate support for the module to prevent damage from occurring when the module is subjected to pressures of 2400Pa (which equates to wind pressure of 130km/h (80.8 mph), with a safety factor of 3 for gusty conditions based on IEC 61646 / IEC 61215). The location of the clips shall be along the 1200mm (47.25 in) length of the module and the center point of the clip shall be located between 250mm (9.84 in) and 300mm (11.81 in) from the module edge. See Figure 5.1 for allowed location. Rubber insulator material, or equivalent must be used between the module and both the clip and mounting structure to provide adequate protection of the module and must meet all requirements described in PD-5-320-04 Module Mounting. No direct contact of rigid structures is permitted against the surface or edges of the module.

All mounting structures must provide a flat plane for the modules to be mounted on, and must not cause any twist or stress to be placed on the module.

Modules should not be installed in a way that restricts air circulation to the underside of the module. Modules generate heat and require adequate airflow for cooling.

Installation locations and module support structures should be selected to ensure modules and connectors (open or mated) are never submersed in standing water. First Solar modules are tested and certified for applications involving pressures from snow/ice/wind up to 2400 Pa (50.13 lb/ft²) when mounted properly. Snow drifts could result in a nonuniform loading of the modules which exceeds the tested pressure. If it is expected that loads will exceed 2400 Pa (50.13 lb/ft²), it is recommended to clear snow from modules, and ensure that ice/thaw/freeze cycles under snow drifts do not result in excessive stresses on the module.

Heavy construction and trenching should be completed prior to module installation to minimize debris and dust.

Ensure any site preparation or maintenance chemicals (soil binding agents or chemicals used for on-site dust control or weed control) do not spray, splash, or drift onto the surface of the modules or its associated components.

The UL approved design load of Series 4 and Series 4A Modules is 30 lb/ft² (1436 Pa).

Maximum allowable pressure on modules may not exceed 2400 Pa (50.13 lb/ft²) without additional module support that must be tested and approved by First Solar to receive a project specific approval.

For rooftop mounting, modules must be mounted over a fire resistant roof covering rated for the application. The recommended minimum standoff height is 3.25 in (82.55 mm). Modules used in UL Listed rooftop applications must be installed with approved mounting systems. If alternate mounting means are employed, this may affect the Listing fire class ratings and additional UL fire testing may be required. The fire rating of this module is valid only when mounted in the manner specified in the mechanical mounting instructions.

4.1.1 Series 4A Module Installation Considerations (with Anti-Reflective Coating)

Handle with gloves to preserve visual appearance of anti-reflective coated modules (Series 4A).

During handling and installation, avoid abrasive contact with top glass surface to prevent scratches of anti-reflective coating on Series 4A modules.

Do not remove cardboard separator paper before removing modules from box. Doing so may result in scratches of the ARC film when pulling modules out of the box.

When cleaning Anti-Reflective Coated modules, specific module cleaning guidelines documented in PD-5-804 Module Cleaning Guidelines must be followed. Failure to comply with the Module Cleaning Guidelines may void warranty.

Basic cleaning guidelines for Anti-Reflective Coated modules are as follows:

Allowable Cleaning Methods

- Low pressure **non-contact** water cleaning may be used with unlimited cycles (i.e. water spray is allowed, but scrubbing or brushing with water is prohibited).
- Dry cleaning with soft cloth mops up to six times annually

Prohibited Cleaning Methods

- Wet contact cleaning (i.e. combining water with mops, brushes, squeegees)
- Dry contact cleaning with anything other than soft cloths or mops (i.e. bristle brushes, sponges, or squeegees).

4.2 Module Orientation

PV performance modeling software should be used to determine the optimum orientation and tilt angle for each location.

For tilted free-field applications or single-axis tracker applications where there is row to row shading, modules shall be installed in landscape orientation.

4.3 Module Shading Considerations

To maximize performance, modules should be located in an area that receives direct sunlight from mid-morning to mid-afternoon (typically 9:00 a.m. to 3:00 p.m.). Installation must avoid locating the modules where shadows may be caused by buildings, trees, etc.

Specific shading patterns can cause damage to module cells due to the creation of localized areas of reverse bias. Reverse bias is generated by one or more series-connected cells being shaded while the rest of the cells are fully illuminated. When shading geometry is suitable for damage to occur, it can happen in very short durations (seconds to minutes) and under a wide range of irradiance (as low as 160 W/m²). An example of prohibited shading orientation is presented below.



There is no risk of module damage due to “row-to-row” shading in landscape orientation. There is also no risk if shading occurs while modules are in open circuit conditions or no risk from diffuse shading for objects greater than 2 meters or 7 feet.

There is a low risk of module damage due to shading from walking or standing in front of operating modules or from parking or driving vehicles in front of operating modules during illuminated times. Best practice is to stay close to the back side of the adjacent rack as one travels down a row of operating modules.

Instances of shading that will lead to a voided warranty include the High Risk items listed below.

High Risk (Prohibited) Shading

1. Resting or adhering slender objects (tools, brooms, clothing, wires, tape) on sunny side of operating modules, or when nearer than ~5-7 feet above operating modules, especially when shadow oriented parallel to cells.
2. Fixed objects within ~5-7 feet above operating modules that cast a shadow over the long dimension of the cells. Close objects like posts, ropes, signs, fences, or equipment can begin to increase risk of partial shading of full cells when nearer than ~5-7 feet from the sunny-side of operating module.
3. A support frame or mounting method on the short edge(s) of modules that fully shades the entire length of a cell (either partially or completely).
4. Working continuously with outstretched arms or tools over operating modules.
5. Cleaning apparatus, including cleaning robots and other mechanisms that traverse the module repeatedly while the system is operating (unless evaluated and approved by First Solar).

4.4 Electrical Interconnection

First Solar Series 4 and Series 4A Modules are pre-configured with industry standard connectors that are “touch proof” with all live parts protected against accidental contact and protected against polarity reversal. The cables and MC4 connectors are UV and weather resistant from -40°C to $+85^{\circ}\text{C}$, and rated for 1500VDC and 22.5A (minimum, before derating for ambient temperature). The cables and MC4-EVO 2 connectors are UV and weather resistant from -40°C to $+85^{\circ}\text{C}$, and rated for 1500VDC Protection Class II applications and 39A (ambient temperature).



Modules with different FS Series numbers (i.e. FS 3 vs. FS 4) have significantly different electrical operating characteristics and should not be interconnected within the same inverter or MPPT to prevent power output loss and voltage imbalance conditions that may create the risk of reverse current overload.



Damaged wires, connectors, or junction boxes may cause ground faults, and associated electrical hazards, including electrical shock. To avoid these conditions:

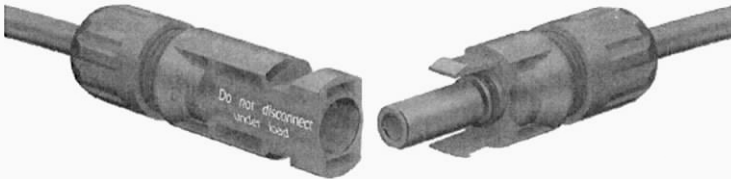
- Protect unmated connectors from dust and moisture by using sealing caps (not provided, available from connector manufacturer).
- Limit module connectors to 10 or fewer plug cycles.
- Do not pull lead wires tight at any time. After installation, the connected wire must not be under stress or tension.
- Do not use junction box assembly or lead wire strain relief loops to secure excess wire or to bear weight greater than that of a (properly wire managed) module's own wire and mated connector pair.
- Connector bodies and cables should not be tightly secured at both ends to any mounting structure to allow for thermal expansion and contraction.
- Secure wire or connected components so that no loose wires or components are hanging within 1.5 feet (0.46m) of the ground in free field applications, and so that wire/components are hanging clear of roof coverings or pooled water in rooftop applications.
- Ensure connectors are fully mated.
- Ensure wire securement methods, such as use of cable ties, do not damage wire insulation. The minimum module lead wire bend radius is 5 times wire diameter. Observe minimum bend radius specifications on all other PV system wiring.
- Ensure wires are not in contact with sharp edges of the mounting structure to avoid abrading the wire sheath.
- Inspect and maintain wire management requirements over the life of the plant.

Components used to interconnect the modules must be compatible with the connectors, and provide proper system operation and fault protection as required by any applicable codes. Field wiring must be rated for 90°C , and be of a type approved for use in accordance with the NEC.

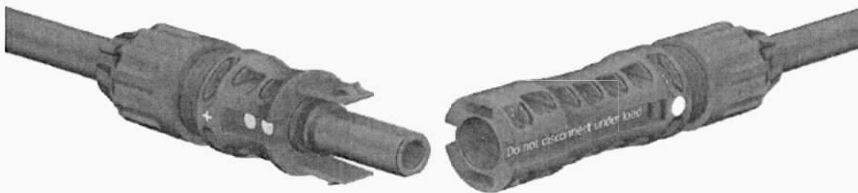
Module-to-module and module-to-harness interconnection is advised to be done between same manufacturer and type of connectors or using connectors certified as mateable. The First Solar module warranty is not affected by the interconnection of different supplier connectors, however, First Solar cannot guarantee that different connector types will be mateable in every connection instance.

Connector Identification

MC4 connectors of part numbers (PV-KST4/PV-KBT4)



MC4-EVO 2 connectors of part numbers (PV-KST-EVO2/PV-KBT-EVO2)



Connector manufacturer website: <http://ec.staubli.com/>

4.4.1 Inverter Compatibility

Series 4 and Series 4A Modules are designed for utility grid connected, commercial and industrial, off-grid energy access, and fuel displacement applications. First Solar FS Series PV Modules are compatible with a range of string, central, and transformer less inverters. When connecting modules or module strings in series ensure inverter ratings are appropriate.

When connecting First Solar Series 4 and/or Series 4A Modules in a series string, ensure that the system design voltage and inverter design specifications are not exceeded. For 1000VDC applications, this is typically ensured by limiting series strings to 10 modules or less. For 1500VDC applications, this is typically ensured by limiting series strings to 15 modules or less.

The Maximum Power Point (MPP) voltage of a module array must be considered for compatibility with the specified MPP window of the inverter. Similar to the maximum open-circuit voltage, the MPP voltage of the array is dependent on ambient conditions, and the system should be designed to ensure that the MPP voltage of the array remains within the MPP window for expected operating conditions.

When selecting an inverter, system bias conditions and grounding should also be considered. FS Series PV Modules can be used in negative-grounded or ungrounded installations. Use in bi-polar systems should be reviewed in detail by First Solar prior to approval. FS Series PV Modules should not be used in positive-grounded systems.

4.4.2 Grounding Method

Per the requirements of UL 1703, a module with exposed conductive parts is considered to be in compliance with UL 1703 only when it is electrically grounded in accordance with the instructions presented and the requirements of the National Electrical Code.

First Solar Series 4 and Series 4A Modules have no exposed conductive surfaces and do not require equipment grounding as long as a clip length of 100mm for a standard 4 clip mounting is not exceeded. In the U.S., the mounting structure must be grounded per the requirements of the NEC, sections 250 and 690.

First Solar Series 4 and Series 4A Modules can be used in negative-grounded, ungrounded, floating, and bi-polar system architectures, provided all appropriate design requirements are met and approved by First Solar. FS Series PV Modules should not be used in positive-grounded systems.

4.4.3 Overcurrent Protection

Series 4 and Series 4A Modules have a maximum series fuse rating of 4.0A as defined by UL 1703 test methods.

Series 4 and Series 4A Modules have a maximum overcurrent protection rating of 4.0A as defined by IEC 61730 test methods.

PV systems should be designed to comply with and provide module overcurrent protection consistent with local codes as appropriate for the intended application class of the system.

Connection of parallel strings must incorporate measures to protect modules against reverse currents exceeding their rating. Please refer to FS Application Note PD-5-308 for additional information on module overcurrent protection.

5 Mechanical Specifications & Drawings

Table 5.1: Mechanical Specifications

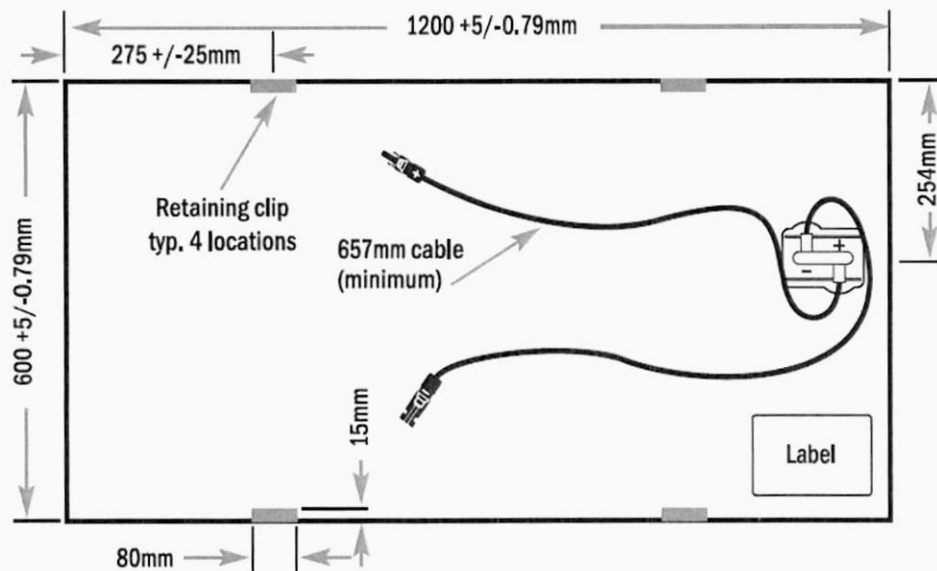
Specifications	Series 4 and Series 4A Modules	
Length	1200 mm	47.25 in
Width	600 mm	23.63 in
Thickness	6.8 mm	0.27 in
Total Area	0.72 m ²	7.75 ft ²
Individual Leadwire ¹	657 mm	25.86 in
Leadwire Connection Span ²	1314 mm	51.73 in
Weight	12 kg	26.5 lbs
Fire Performance Type ³	Type 10 Module Class A Spread of Flame Class B Burning Brand	
Operating Temperature	-40°C to +85°C	

¹Minimum from strain relief to connector mating surface

²Minimum from positive strain relief to negative strain relief of adjacent module

³Roof mounted fire rating is established by assessing rack and module as a unit

Figure 5.1 Mechanical Drawing for Series 4 and Series 4A Modules



6 Proper Operating Conditions

The proper operating condition requirements listed below must be maintained.

.....
Important: **Failure to maintain proper operating condition requirements for the modules will void the applicable warranties.**
.....

Requirements:

- Short circuit operation is permitted only during short duration system safety testing or in fail-safe system states.
- All electronic components that are interconnected to modules must be rated for the maximum operating voltage of the array, must have an operating voltage window that matches the maximum power point of the array, and must be capable of operating the array at the maximum power point.
- Modules must have adequate ventilation and airflow to prevent operating temperatures above 85°C.
- Module row-to-row shading in landscape orientation is acceptable; Module row-to-row shading in portrait orientation is prohibited.
- Strain relief cable ties must not be removed.
- If module cleaning is undertaken, modules must be cleaned only when in open circuit – either disconnected from load, or during times when inverter is turned off and otherwise in accordance with PD-5-804 “FS Series PV Module Cleaning Guidelines”.
- Series 4A Modules include anti-reflective coated glass. Use of prohibited cleaning methods can reduce the energy enhancing effects of the anti-reflective coated glass and void warranty. Please consult PD-5-804 “FS Series PV Module Cleaning Guidelines” for allowable cleaning methods compatible with Series 4A Modules.
- Module boxes must be handled per PD-5-801 Box Handling and Storage. Failure to follow the Box Handling and Storage guidelines may result in damage to modules that would not be covered under the Module Warranty Terms and Conditions.

7 Service



Cleaning activities create risk of damage to the modules and array components, as well as the potential for electric shock. Large amounts of dust and dirt on the surface of the module can reduce the power produced. Natural rainfall will typically remove most dust. Should auxiliary cleaning be required, please refer to the Module Cleaning Guidelines (PD-5-804) for additional information. Failure to comply with the Module Cleaning Guidelines may void warranty.



Broken modules should be replaced immediately. Periodically, annually at a minimum, inspect modules for any signs of damage or broken glass. If broken modules are found, place material into a closed container for return to First Solar recycling program, or dispose of module in accordance with local requirements. Please visit www.firstsolar.com/recycling for further details on the recycling program.

- It is normal for the modules to exhibit visual irregularities which do not impact power. Series 4A Modules with anti-reflective coated glass are more likely to exaggerate the visual appearance of normal scratches, fingerprints, and other blemishes due to the optical properties of the glass interface.
- Check that all electrical connections are tight and corrosion free.

The most common causes of lower than expected PV system power output are:

- Inverter failure
- Improper or faulty field wiring or connections
- Blown fuses or tripped circuit breakers
- Excessive amounts of dirt and dust on the modules
- Shading of modules by trees, poles, or buildings
- Improperly calibrated or malfunctioning monitoring equipment

8 Warranty Terms & Conditions

Please refer to "First Solar FS Series Module Warranty Terms & Conditions" for individual module warranty terms, limitations, and product return policies.

9 Notice

Changes to certain components of the module are common as First Solar continuously strives for product improvements. Changes may be a result of component improvements or changes by a supplier, or by minor design modifications initiated by First Solar. All products within the same model classification remain functionally equivalent and fully compatible with one another, even though there may be slight differences, provided appropriate system design practices are employed. Modifications that do not impact the functionality of the product will typically be made without customer notification. Internal testing, and review or retesting by a certifying agency, will be completed before component or design changes are introduced into the manufacturing process.

First Solar reserves the right to make changes in solar module design and/or specifications at any time without notice. Accordingly, the reader is cautioned to verify that data sheets are current before placing orders or finalizing system permitting and/or design. Information furnished by First Solar is believed to be accurate and reliable. However, no responsibility is assumed by First Solar or its subsidiaries for its use; nor for any infringements of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of First Solar or its subsidiaries.

In the event of a conflict between this module User Guide and the instructions of one of the system component manufacturers, the system component instructions should prevail.

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10 Document References

Document Number	Document Title
PD-5-320-04 NA	FS Series 4 PV Module Mounting for UL Applications
PD-5-308	FS Series PV Modules - Reverse Current Overload
PD-5-320-04	FS Series 4 PV Module Mounting
PD-5-804	FS Series PV Module Cleaning Guidelines
PD-5-801	FS Series PV Module - Box Handling and Storage

11 Revision History

Revision Number	Amendment Detail	Revision Date
1.0	Document Created	3/27/2014
1.1	Added Section 4.1.1	6/4/2014
1.2	Added 90W Electrical Specifications	7/11/2014
2.0	Added Section 4.1.1 and changed original 4.1.1 to 4.1.2 and 4.1.2 to 4.1.3. Added comment to Section 4.1 in regards to Series 4A ARC film scratch prevention. Added model types FS-4102 and FS-4105A to the ratings table under Section 3. Increased the fuse rating from 2.5A to 4.0A. Added FS-4XXX-2 and FS-4XXXA-2 model types.	10/13/2014
2.1	Modified 3.1 for calculating the maximum system voltage. Added 115 and 117.5W Model Types and Electrical Ratings. 4.4.3 added reverse current text.	5/1/2015
2.2	Updated for UL 1500V. Added PD-5-801 Reference. Added verbiage to Section 4.1.1. Added comment to Section 7 on cleaning risk of damage. Added Section 10 for Doc References. Revised order of Warnings in Sections.	12/17/2015
2.3	Added electrical ratings for FS-4xxx-3 and FS-4xxxA-3.	2/9/2016
2.4	Updated to reflect UL Canada 1000V Listing.	4/20/2016
2.5	Added local building code compliance to Section 1.3 Safety. Clarified inverter notification verbiage in Section 4.4.1. Clarified grounding method verbiage in Section 4.4.2. Added new reference document PD-5-334.	6/22/2016
2.6	Updated Table 5.1 to reflect Fire Performance Type.	10/6/2016
2.7	Added 122.5W bin class.	11/30/2016
3.0	Removed references for System Design and Application PD-2-303 and PD-5-435 NA. Added IEC 61215 Certification. Added MC4-EVO 2 Connectors.	4/14/2017
3.1	Added shading content. Added leadwire length and leadwire connection length. Updated module diagram. Removed references to shading documents.	7/11/2017

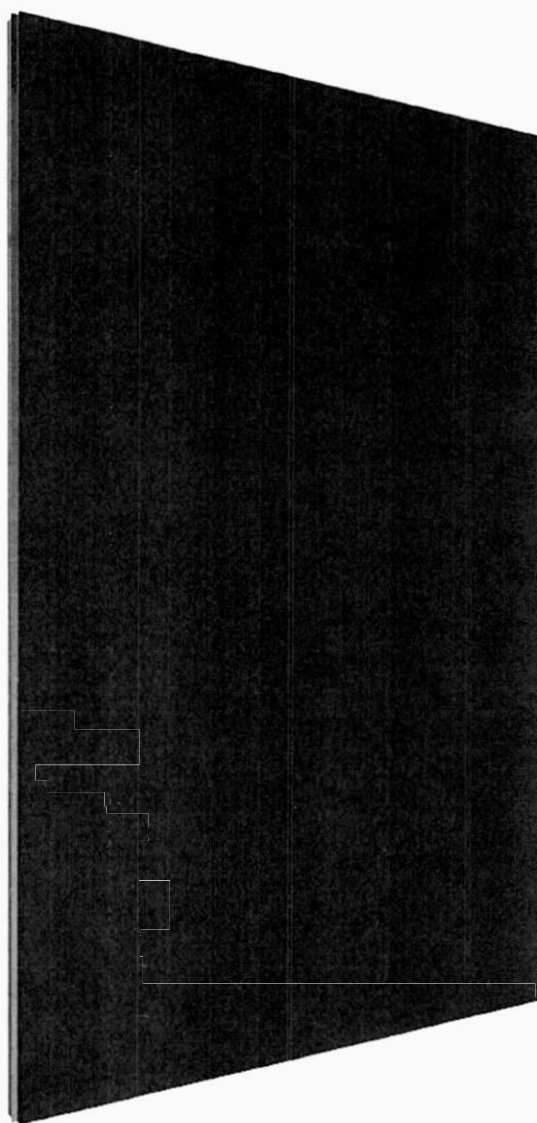


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1 INTRODUCTION

This document provides information on First Solar Series 6 Modules of model types FS-6XXX and FS-6XXXA ("XXX" references the module power rating) for system designers, installers, and maintenance personnel. Model types FS-6XXXA contain an anti-reflective coating (ARC) on the front side surface. Series 6 Modules are designed to have a long operating life and high energy yield when installed, operated, and serviced in accordance with the instructions in this User Guide. All products within the same model series classification remain fully compatible with one another, even though there may be slight differences, provided appropriate system design practices are employed. Read this User Guide thoroughly before beginning any work related to the installation, operation, or maintenance of the First Solar Series 6 Module.

Please refer to your First Solar Module Warranty Terms & Conditions for module warranty terms and product return policies. Failure to follow this User Guide may void your warranty.

Keep this User Guide for future reference and provide to all subsequent owners or users of the solar modules.

2 SAFETY

All instructions and safety information should be read and understood before attempting to handle, install, or electrically connect First Solar modules. Failure to follow safety, installation, and handling instructions may result in injury. Only qualified personnel should install, operate, or maintain PV modules or systems.

Series 6 Modules are designed for 1000V systems at altitudes up to 5000 m (16404 ft) and 1500V systems at altitudes up to 3000 m (9842 ft) per IEC 61730-1.

Select installation locations and module support structures to ensure modules and connectors (open or mated) are never submerged in standing water.

DANGER



The Series 6 Modules may produce up to 275 Volts DC (VDC) and up to 4.0 Amps when exposed to sunlight. **A single module or multiple interconnected modules can create a lethal shock hazard during daylight hours, including periods of low light levels.** The danger increases as modules are connected together in series and/or parallel.

DANGER



To avoid fire and/or injury due to ground faults and associated electrical hazards:

- ▶ Do not unplug PV module connections while under load. Do not disconnect the module connectors during daylight hours unless the module is in an open circuit condition.
- ▶ Replace modules with damaged wires immediately. Keep all array wiring out of reach of non-qualified personnel.
- ▶ Do not concentrate light on the module in an attempt to increase power output.
- ▶ Never allow the PV array system voltage to exceed 1500VDC under any condition.
- ▶ Replace broken modules immediately.
- ▶ Repair ground faults immediately.
- ▶ Do not work on modules or systems when the modules or wiring is wet.
- ▶ All building mounted PV systems should utilize Ground Fault Detector Interrupters (GFDI) and ARC Fault Circuit Interrupters to minimize risk of electrical shocks and fires.

Series 6 Modules have a maximum series fuse rating of 6.0A as defined by UL 1703 and a maximum overcurrent protection rating of 6.0A as defined by IEC 61730-1/IEC 61730-2. PV systems should be designed to comply with and provide module overcurrent protection consistent with local codes.

The conditions necessary to trigger reverse current overload (RCOL) in Series 6 Modules do not occur in typical operating modes of a properly installed PV system. The system designer should ensure that modules are not subjected to RCOL. The use of GFDI devices or other advanced fault monitoring techniques can significantly reduce the likelihood of sustained ground faults. Properly selected and installed string fuses can increase protection against RCOL.

DANGER



Reverse currents higher than the rated values for a First Solar module, may result in module failure, including module breakage due to RCOL. Extreme and continuous RCOL conditions may cause a fire or create electrical shock hazards. To avoid RCOL:

- ▶ Maintain equivalent voltage in parallel strings by installing an equal number of modules per string within the same source circuit. Failure to install modules with balanced voltage in parallel strings can result in voltage imbalance.
- ▶ Incorporate measures to protect modules against RCOL for connections of parallel strings.

Modules damaged because of system-induced RCOL are not covered under the First Solar Module Warranty. Module warranty eligibility is not affected by the presence, absence, or type of reverse current protection used in a system design.

CAUTION



Wear safety glasses and **cut-resistant gloves** when working with non-interconnected modules or system components. **Wear electrically rated PPE** when working with interconnected modules or system components. Select PPE based on work consistent with local and/or national standards.

WARNING



To avoid risk of fire, do NOT interconnect Series 6 Modules with other FS Series Modules (e.g. – Series 4, Series 3, or Series 2) within the same interconnected string, inverter, or Maximum Power Point Tracker.

3 REGULATORY COMPLIANCE

It is the responsibility of the installer and/or system integrator to ensure compliance with all local structural and electrical codes, which may be applicable to the installation and use of First Solar Series 6 Modules.

- ▶ For systems installed in Canada, installation shall be in accordance with CSA C22.1, Safety Standard for Electrical Installations, Canadian Electrical Code, Part 1.

For systems installed in North America, First Solar Series 6 Modules are Listed by a Nationally Recognized Test Laboratory (NRTL) to UL 1703, the standard for Flat-Plate Photovoltaic Modules and Panels. To maintain the modules' application as a UL Listed product:

- ▶ Use only components that have been Recognized or Listed by Underwriters Laboratories (UL) for their intended purpose.
- ▶ Ensure the PV array open-circuit voltage does not exceed 1500 VDC (1000 VDC for UL Canada).
- ▶ Install modules with mounting systems that have been evaluated for UL Listed application.
- ▶ Protect modules from reverse currents in excess of the 6.0A maximum series fuse rating.

Series 6 Modules are tested and certified per IEC 61730-1/IEC 61730-2 and meet Class II requirements for 1500VDC systems.

Series 6 Modules are tested and certified per IEC 61215-1/IEC 61215-1-2/IEC 61215-2 for a maximum system voltage of 1500V.

4 PRODUCT IDENTIFICATION & RATINGS

4.1 PRODUCT IDENTIFICATION & RATINGS

Each module is equipped with a product label on the back and a laser-etched serial number on the front glass. The label identifies the model number, nameplate electrical ratings, and safety information.

The ratings in Table 1 are UL Listed with a tolerance of $\pm 10\%$ unless otherwise noted.

NOTICE: Electrical specifications are subject to change. See label for final electrical ratings.

Table 1: Model Numbers & Ratings at Standard Test Conditions (STC¹)

MODEL NUMBERS	RATED POWER ² (-0/+5%) $P_{MAX}(W)$	VOLTAGE AT P _{MAX} $V_{MAX}(V)$	CURRENT AT P _{MAX} $I_{MAX}(A)$	OPEN CIRCUIT VOLTAGE $V_{OC}(V)$	SHORT CIRCUIT CURRENT $I_{SC}(A)$	MAXIMUM SYSTEM VOLTAGE $V_{SYS}(V)$	MAXIMUM SERIES FUSE $I_{CF}(A)$
FS-6390 FS-6390A	390.0	173.9	2.24	214.8	2.49	1500 ³	6.0
FS-6395 FS-6395A	395.0	175.0	2.26	215.4	2.50		
FS-6400 FS-6400A	400.0	176.1	2.27	216.1	2.51		
FS-6405 FS-6405A	405.0	177.2	2.29	216.8	2.52		
FS-6410 FS-6410A	410.0	178.3	2.30	217.4	2.52		
FS-6415 FS-6415A	415.0	179.3	2.31	218.1	2.53		
FS-6420 FS-6420A	420.0	180.4	2.33	218.5	2.54		
FS-6425 FS-6425A	425.0	181.5	2.34	218.9	2.54		
FS-6430 FS-6430A	430.0	182.6	2.36	219.2	2.54		
FS-6435 FS-6435A	435.0	183.6	2.37	219.6	2.55		
FS-6440 FS-6440A	440.0	184.7	2.38	220.0	2.55		
FS-6445 FS-6445A	445.0	185.7	2.40	220.4	2.56		

¹ As received and stabilized ratings at STC (1000W/m², AM 1.5 25°C Cell Temperature) $\pm 10\%$

² Measurement uncertainty applies

³ 1000V Listed for UL Canada

4.2 SYSTEM DERATING FACTORS

Under normal operation, a PV module may experience conditions that produce higher current and/or voltage than reported at STC. Accordingly, the values of I_{sc} and V_{oc} listed for STC should be multiplied by a factor of 1.25 when determining component voltage ratings, conductor current ratings, and size of controls connected to the PV output. For UL installations, an additional 1.25 safety factor may be applicable, reference the National Electric Code (NEC) Article 690 for further details. Specific site conditions and local electric code requirements must be used for determining the maximum system voltage.

When calculating module V_{oc} at 125 mW/cm^2 , AM 1.5 spectrum, and cell temperature of -10°C , multiply the specific model type STC listed V_{oc} value by a factor of 1.098. When calculating module I_{sc} at 125 mW/cm^2 , AM 1.5 spectrum, and cell temperature of 75°C , multiply the specific model type STC listed I_{sc} value by a factor of 1.275.

5 HANDLING & STORAGE

When handling packs using forklifts or other mechanical aids, ensure uniform pack support, and the forks fully extend under the pallet. Series 6 packs can be lifted from either the short or long side of the pallet. Forklifts must engage the pallet a minimum of 1.3 m (51 in) for long side engagement and a minimum of 1.5 m (59 in) for short side engagement. Failure to meet engagement lengths may damage pallet and modules on bottom of pack.

Modules on a pack may lean or shift on a pallet during shipping. Module packs can be safely unloaded as long as the plastic banding straps are not broken.

Only originally banded, fully intact and loaded packs may be stacked for storage up to two high for extended periods. Series 6 packs should not be stacked if rebanded on site, are not fully loaded, any corner braces or top cap material has been removed, or if any banding is broken from the pack.

- Do not transport stacked packs around project site.
- Do not attempt to transport the pack once the straps have been removed.

Please evaluate site conditions for safe pack storage as uneven or recently disturbed ground and moisture may affect pack stability. Series 6 packs should not be exposed to standing water higher than the height of the pallet.

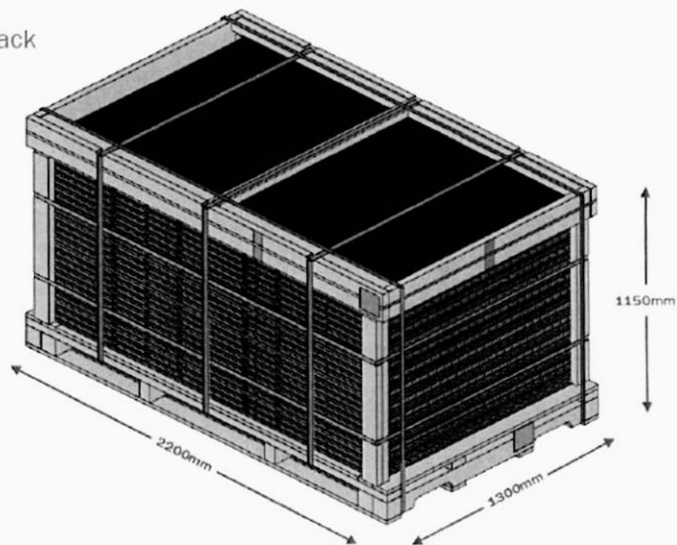
The pack's cap includes two green markings for module orientation purposes. The long edge orientation mark corresponds to the side of the module with the positive junction box cable.

WARNING



Open the packaging with care. A single person should not attempt to lift a Series 6 Module. **Lift the modules from the pallet with two or more persons or with lift assist.** Do not attempt to lift multiple modules off the stack at the same time.

Figure 1: Example Series 6 Module Pack



6 MECHANICAL SPECIFICATIONS

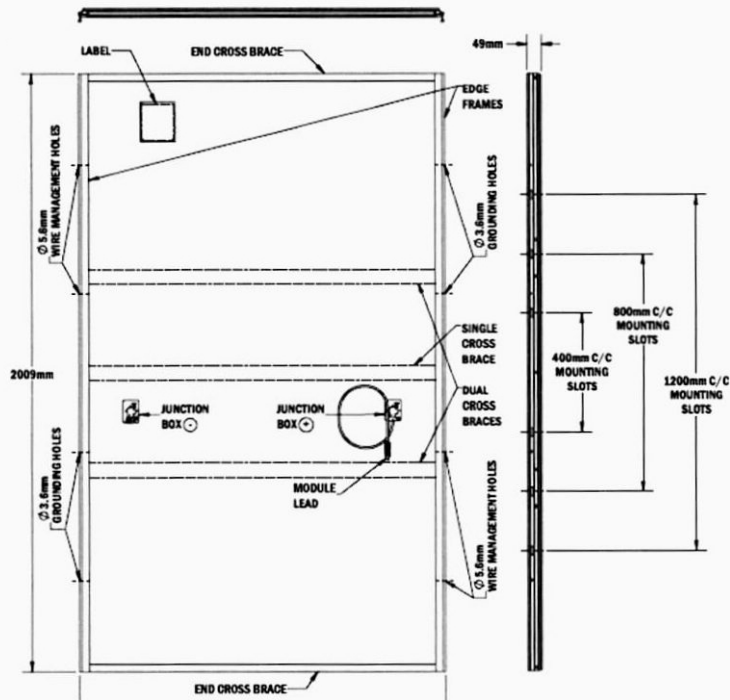
Table 2: Mechanical Specifications

SPECIFICATIONS	SERIES 6 MODULES
Length	2009 mm $\pm 3/-1$ mm (79.1 ± 0.11 / -0.04 in)
Width	1232 mm ± 5 mm (48.5 ± 0.2 in)
Thickness	49 mm ± 1 mm (1.9 ± 0.04 in)
Total Area	2.47 m ² (26.5 ft ²)
Module Weight	36 ± 1 kg (79 ± 2.2 lbs)
Junction Box Lead Wire ⁴	2.5 mm ² (14 AWG), 720 mm (28.35 in) (+) & Bulkhead (-)
Fire Performance ⁵	Class A Spread of Flame / Class C Burning Brand
Operating Temperature	- 40°C to + 85°C

⁴ Length from junction box exit to connector mating surface

⁵ Module UL 1730 fire rating is valid only when mounted in the manner specified in this User Guide. Roof mounted fire rating is established by assessing rack and module as a unit.

Figure 2: Series 6 Module Mechanical Drawing



Module frames may be configured with either a single or dual cross brace design as shown in Figure 2.

Figure 3: Grounding Hole & Wire Management Hole Locations Symmetric from Frame Center

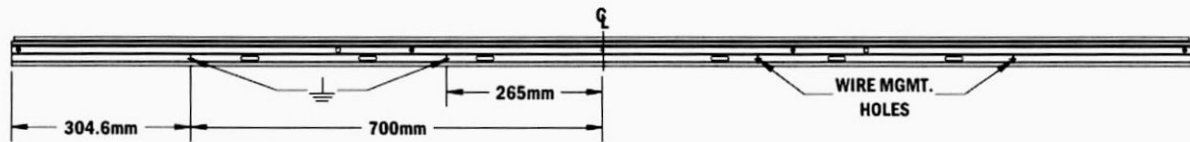
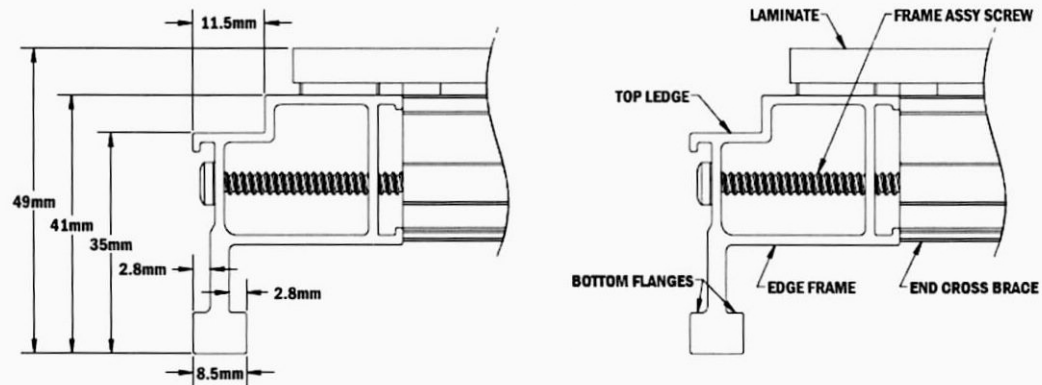


Figure 4: Frame End View



7

INSTALLATION & MOUNTING

7.1 MOUNTING

It is best practice to complete heavy construction and trenching prior to module installation to minimize module exposure to dust. Ensure any site preparation or maintenance chemicals (soil binding agents or chemicals used for on-site dust control or weed control) do not spray, splash, or drift onto the surface of the modules or its associated components.

It is the responsibility of the qualified engineer and/or qualified installer to ensure the system and its components meet applicable structural and electrical code requirements for the product application's jurisdiction. First Solar is not responsible for bonding failure, breakage, damage, wear, corrosion, or module performance issues that are deemed to be caused by design or installation practices that do not comply with this User Guide.

CAUTION



Safety hazards or potentially unsafe practices:

- ▶ Do not install the modules during high wind or wet conditions.
- ▶ Handle modules with care during installation, as heavy impact to the front, back, or edges could result in damage to the module. Do not walk, stand, or sit on modules.
- ▶ Do not carry multiple modules on top of one another after removal from pack.
- ▶ Do not lift or pull on modules using lead wire or junction boxes.
- ▶ Do not rest objects (such as tools, etc.) on module glass.

Modules must have adequate ventilation and airflow to prevent operating temperatures above 85°C.

For rooftop mounting, mount modules over a fire resistant roof covering rated for the application. The recommended minimum standoff height is 8 cm (3.15 in). The Series 6 Modules may be installed at an installation angle up to 60°.

7.2 MOUNTING LOCATIONS & LOAD RATINGS

The interface of the mounting structure to the module frame must meet the technical requirements specified in this User Guide. The mounting system design must provide adequate support for the module to prevent load damage from occurring based on the loading requirements for the given application and the chosen mounting locations. Structures must not come into direct contact with the surface or edges of the module glass.

Modules can be secured to the support structure with top (front side) mounting clamps or by frame slots (known as SpeedSlots).

The module meets the following load ratings when mounted as specified in this User Guide and evaluated according to the listed standard in Table 3.

Table 3: Load Ratings

Standard	Design Load	Test Load
IEC 61215	$\pm 1600 \text{ Pa}$ ($\pm 33.4 \text{ lb/ft}^2$)	$\pm 2400 \text{ Pa}$ ($\pm 50.1 \text{ lb/ft}^2$)
UL 1703	$\pm 1436 \text{ Pa}$ ($\pm 30 \text{ lb/ft}^2$)	$\pm 2154 \text{ Pa}$ ($\pm 45 \text{ lb/ft}^2$)

- ▶ Top clamp mounting range: 400 mm to 1200 mm
- ▶ SpeedSlot clamp mounting locations: 400 mm, 800 mm, and 1200 mm

Symmetrically secure the module using a minimum of four frame contact points regardless if mounted from the top or through SpeedSlot. Other mounting methods not discussed in this User Guide are not permitted unless evaluated and approved by First Solar (technicalsupport@firstsolar.com).

- ▶ The modules shall have a minimum spacing gap of 6 mm (0.24 in) between each other. Usable junction box lead wire lengths accommodate spacing up to 245 mm (9.65 in) (assuming no substructure interference).
- ▶ Do not use module frame ends (1232 mm length) or center cross braces for mounting.
- ▶ Do not modify the module frame in any way. This includes drilling additional holes, altering mounting features (slots), or otherwise cutting, trimming, or shaping any part of the module frame.
- ▶ Module mounting structure support under clamps must maintain a minimum length of 35 mm (1.38 in) and maintain full frame bottom flange engagement under load.
- ▶ Module attachment hardware (i.e. clamps, bolts, etc.) must not contact the module glass.
- ▶ Tighten clamps to the torque stated by the mounting hardware manufacturer.
- ▶ Mounting clamps certified/designed to electrically bond and/or ground the module frame are allowed when used in accordance with the clamp manufacturer's instructions.
- ▶ The maximum clamp force shall not exceed 5500N for either top or SpeedSlot clamps.
- ▶ Minor clamp deformation under load may be acceptable as long as clamping force requirements are maintained and the deformation does not contribute to a weakening of the clamp or dislodgement of the module.

7.3 TOP MOUNTING

Top mounting clamps should be mounted within the frame SpeedSlot ranges depicted in Figure 2. Top mounting clamps must have a uniform frame engagement area of 9 mm (0.35 in) minimum width on the top ledge and 30 mm (1.18 in) minimum length as depicted below in Figure 5. Clamps that do not meet the minimum requirements may not preserve module certifications or warranty and must be evaluated by First Solar (technicalsupport@firstsolar.com).

Figure 5: Example Top Clamp

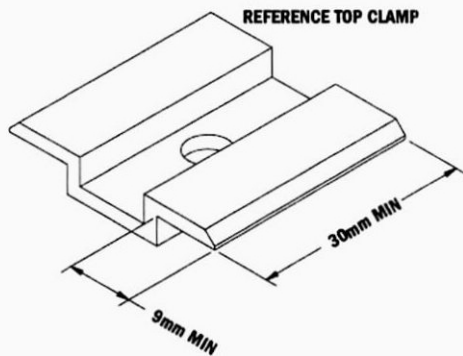
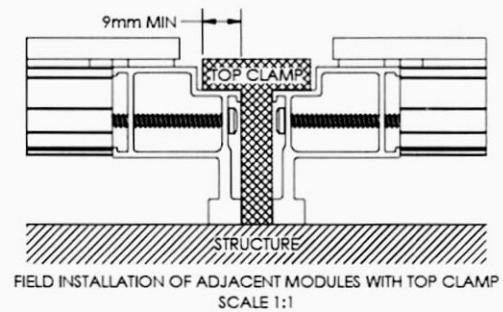


Figure 6: Example Shared Top Clamp



7.4 SPEEDSLOT MOUNTING

The Series 6 Module frames include six SpeedSlots (See Figure 9 and 10 for details). SpeedSlot clamps must either extend 10 mm (0.39 in) beyond the inner edge of the frame or have a retention feature to prevent module frame dislodgement under load. SpeedSlot clamps must be at least 12 mm (0.47 in) wide from attachment point through the 10 mm (0.39 in) extension or until point of retention feature. Clamps should rest on flat surface of SpeedSlot.

Figure 7: Example of SpeedSlot clamp

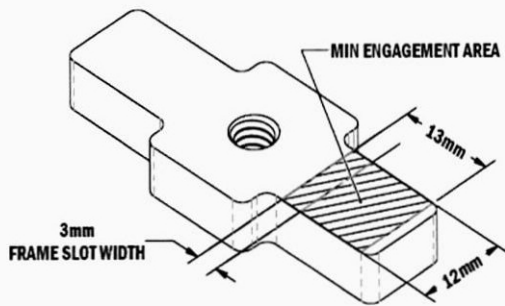


Figure 8: Shared SpeedSlot clamp

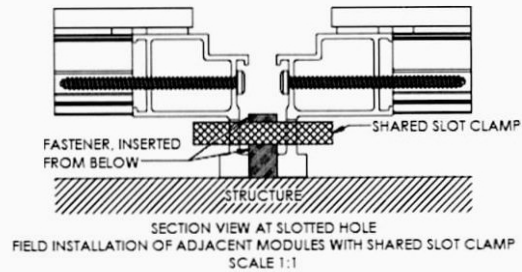


Figure 9: SpeedSlot dimensions

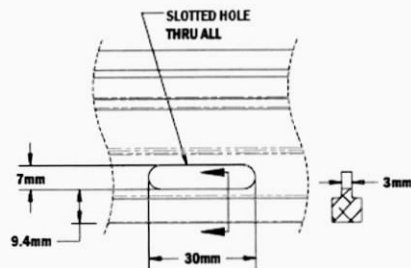
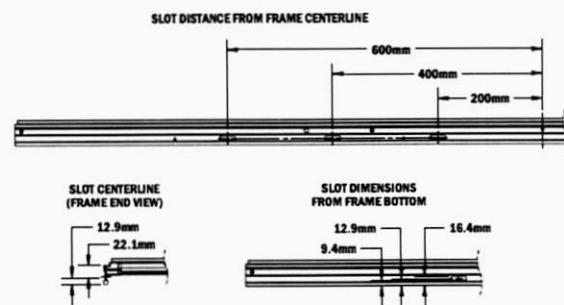


Figure 10: SpeedSlot detail on frame



7.5 MODULE ORIENTATION

PV performance modeling software, such as PlantPredict (www.PlantPredict.com) should be used to determine the optimum orientation and tilt angle for each location.

Mount modules in portrait orientation for applications where row-to-row shading could occur. Landscape orientation is permitted only in flat mount applications where the module long edge is not completely shaded and when compliant with Section 7.6 Module Shading Considerations.

7.6 MODULE SHADING CONSIDERATIONS

Specific shading patterns can cause damage to module cells due to the creation of localized areas of reverse bias. Reverse bias is generated by one or more series-connected cells being shaded while the rest of the cells are fully illuminated. When at-risk shading patterns occur, damage can occur in short durations (seconds to minutes) and a wide range of irradiance (as low as 160 W/m^2).

There is no risk of module damage due to shading that occurs while modules are in open circuit. Shading that occurs at a distance greater than 2 m (6.6 ft), also known as diffuse shading, carries minimal risk and should be avoided where possible. Row-to-row shading of modules installed in portrait orientation is acceptable.

There is a low risk of module damage due to shading from repeatedly walking or standing in front of operating modules or from repeatedly parking or driving vehicles in front of operating modules during illuminated times. It is best practice to stay close to the backside of the adjacent rack as one travels down a row of operating modules.

Do not subject modules to high risk shading instances listed below:

- Resting or adhering slender objects (tools, brooms, clothing, wires, tape) on front-side of operating modules, or when within ~1.5 to 2 m (~4.9 to 6.6 ft) above operating modules, especially when the shadow is oriented parallel to cells
- Fixed objects within ~1.5 to 2 m (~4.9 to 6.6 ft) above operating modules that cast a shadow over the long dimension of the cells. Close objects (posts, ropes, fences, etc.) can begin to increase risk of partial shading of full cells when within ~1.5 to 2 m (~4.9 to 6.6 ft) from the front-side of operating module
- A support frame or mounting method on the long edge(s) of modules that fully shades the entire length of a cell (either partially or completely)
- Cleaning robots or other mechanisms that traverse the module while the system is operating
- Row-to-row shading when the modules are installed in landscape orientation

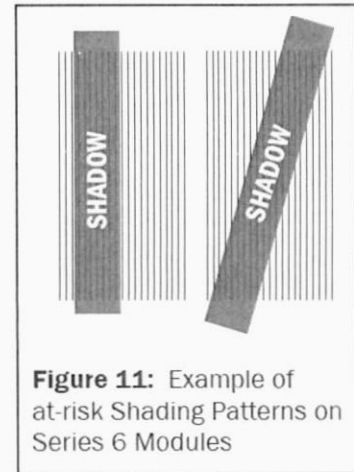


Figure 11: Example of at-risk Shading Patterns on Series 6 Modules

7.7 INSTALLATION CONSIDERATIONS FOR ARC MODULES

Model types containing the letter 'A' (FS-6XXXA) include ARC on the front side surface.

- ▶ Handle with gloves to preserve visual appearance of ARC modules.
- ▶ During handling and installation, do not make abrasive contact with top glass surface to prevent scratches of ARC film.

7.8 WIRE MANAGEMENT

All wire management must comply with the applicable local requirements (i.e. - NEC/IEC codes and standards) for maintaining and managing wires.

Typically, the Series 6 Module lead wire connection does not require wire retention or securement due to the proximity of the junction boxes on adjacent modules.

Above-ground DC cabling (typically a bundle of harness and homerun PV cables) may be supported by utilizing the wire management holes located on the Series 6 frame. The module frame includes four 5.6 mm (0.22 in) wire management holes in locations depicted in Figures 2 and 3. The maximum cable weight carried by each module in totality may not exceed 3.5 kg (7.6 lbs).

7.9 ELECTRICAL INTERCONNECTION

All electric components that are interconnected to modules must have an operating voltage range that matches the maximum power point of the array, and be capable of operating the array at the maximum power point at all times.

Short circuit operation is permitted only during short duration system safety testing or in fail-safe system states.

Series 6 Modules are pre-configured with industry standard connectors that are "touch proof" with all live parts protected against accidental contact and protected against polarity reversal. The cables and connectors are UV and weather resistant from -40°C to +85°C, and rated for 1500VDC and 35A (ambient temperature).

Series 6 Modules use Staubli produced (<http://ec.staubli.com>) MC4-EVO 2 connectors (PV-KST-EVO2/ PV-KBT-EVO2). Module-to-module and module-to-harness interconnection is advised to be done between same manufacturer and type of connectors. First Solar cannot guarantee that different connector types will be compatible in every connection instance.

CAUTION



Damaged wires, connectors, or junction boxes may cause ground faults, and associated electrical hazards, including electrical shock. To avoid these conditions:

- ▶ Protect unmated connectors from dust and moisture by using sealing caps (not provided, available from connector manufacturer).
- ▶ Limit module connectors to 10 or fewer plug cycles.
- ▶ Do not pull junction box lead wires tight. After installation, connected wire must not be under stress or tension.
- ▶ The minimum module junction box lead wire bend radius is five times the wire diameter. Observe minimum bend radius specifications on all other PV system wiring.
- ▶ Do not use junction box assembly to bear weight greater than that of a (properly wire managed) module's own wire and mated connection
- ▶ Secure wire or connected components so they are hanging greater than 0.46 m (1.5 ft) above the ground in free field applications, and so they are hanging clear of roof coverings or pooled water in rooftop applications.
- ▶ Ensure connectors are fully mated and locking clip on connector engages.
- ▶ Do not loosen, alter, or modify the factory-installed connectors on the module junction box. Do not attempt to unscrew or tighten connector back nut.
- ▶ Ensure wire securement methods, such as use of cable ties, do not damage wire insulation.
- ▶ Ensure wires are not in contact with sharp edges of the mounting structure to avoid abrading the wire sheath.
- ▶ Inspect and maintain wire management requirements over the life of the plant.

Wiring harnesses are recommended in system designs with Series 6 Modules. The shorter string size and low string current of Series 6 Modules make it possible to connect multiple strings together in parallel and return a single pair of DC cables to the combiner box or string inverter. Design wiring harnesses that are optimal for the structural layout. For example, a structure with 84 modules per row typically uses two, 7-string harnesses in the DC design in a 1500V system.

Components used to interconnect the modules must be compatible with the connectors, and provide proper system operation and fault protection as required by applicable codes. Field wiring must be rated for 90°C, and be of a type approved for use in accordance with the NEC (US only).

7.10 INVERTER COMPATIBILITY

Series 6 Modules are compatible with a range of string, central, transformer, and transformerless inverters. When connecting modules or module strings in series ensure inverter ratings are appropriate.

Do not exceed system design voltage and inverter design specifications when connecting Series 6 Modules in a series string. This is typically ensured by limiting series strings to four modules for 1000 VDC applications or six modules for 1500 VDC applications.

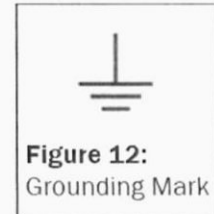
The Maximum Power Point (MPP) voltage of a module array must be considered for compatibility with the specified inverter MPP window. Similar to the maximum open-circuit voltage, the MPP voltage of the array is dependent on ambient conditions, and the system should be designed to ensure the array MPP voltage remains within the MPP window for expected operating conditions.

7.11 GROUNDING METHOD

For North America, a module with exposed conductive parts is considered to comply with UL 1703 only when it is electrically grounded in accordance with the instructions presented and the requirements of NFPA 70: National Electrical Code, article 250.

First Solar recommends Series 6 Modules be used in negative-grounded systems. Series 6 Modules must not be subjected to negative voltage bias conditions that can occur in floating or bi-polar systems (subjecting modules to conditions that could drive potential induced degradation). If traditional negative grounding is not used, alternative methods of preventing negative voltage bias on modules, such as the use of system level voltage controllers (i.e. float controllers) or integrated inverter array voltage control, must be implemented and must include hourly (at minimum) logged PV (-ve) to ground voltage to demonstrate compliance in event of a future warranty evaluation. Series 6 Modules must not be used in positive-grounded systems.

Utilize marked grounding holes (see Figure 12) in frame or UL/IEC Listed grounding/bonding hardware. Where using common grounding hardware (lugs, nuts, bolts, star washers, split-ring lock washers, flat washers and the like) to attach a listed grounding/bonding device, the attachment must be in conformance with the grounding device manufacturer's instructions.



Grounding kits containing #8-32 (M4x0.7) self-threading stainless steel components (Example: Self-threading Screw, flat washer, cup washer, and toothed washer) or other compatible UL/IEC listed hardware can be used to attach copper grounding wire to one of the frame's marked grounding holes per manufacturer instructions. Example: Slide the flat washer on the screw, followed by the cupped toothed washer with the smaller end of the cup washer closest to the cap bolt head. Affix the copper grounding wire between the flat washer and the cupped toothed washer and tighten the screw securely into the frame grounding hole.

Common hardware items (such as nuts, bolts, star washers, lock washers and the like) that have not been evaluated or certified for electrical conductivity or for use as grounding devices, should be used only for maintaining mechanical connections and holding electrical grounding devices in proper position for electrical conductivity. Such devices, where supplied with the module and evaluated through the requirements in UL 1703, may be used for grounding connections in accordance with the instructions provided with the module.

In order to provide a reliable grounding connection to the Series 6 Module frame for model types FS-6XXX or FS-6XXXA, the following hardware or equivalent is required per UL 1703:

- ▶ A UL Listed Grounding Lug with paint cutting star washer and #8-32 by 3/8 inch thread forming screw.
- ▶ A UL Listed grounding strap type EM2050 as manufactured by Electric Motion CO. Inc.
- ▶ Grounding means must be secured to grounding hole opening on frame and torqued to 25 in-lbs.

Mounting clamps that are UL listed for grounding/bonding may be used in instances where the structure and module have been tested to meet UL 2703.

8 MAINTENANCE

8.1 MAINTENANCE

Only qualified personnel should perform maintenance on PV systems. Maintenance (cleaning, electrical inspection, etc.) may pose a risk of electrical shock, injury, or module damage.

A regular inspection and maintenance schedule should include, but is not limited to:

- Annually at a minimum, inspect modules for any signs of damage or broken glass. Replace broken modules immediately.
- Keep modules free from debris, particulates, or large volumes of snow to maximize system performance.
- Ensure the module surface pressure is at or below the design load by removing snow.
- Inspect wiring and wire management periodically.
- Inspect and confirm electrical connections are tight and corrosion free.

The most common causes of lower than expected PV system power output are:

- Improperly calibrated or malfunctioning monitoring equipment
- Inverter failure
- Improper or faulty field wiring or connections
- Blown fuses or tripped circuit breakers
- Excessive amounts of dirt and dust on the modules
- Shading of modules by trees, poles, or buildings

It is normal for the modules to exhibit visual irregularities, which do not impact power. ARC modules are more likely to exaggerate the visual appearance of scratches, fingerprints, and other blemishes due to the optical properties of the glass interface.

Snowdrifts may result in a non-uniform loading of modules. If it is expected that snow loads will exceed design, clear snow from modules to ensure that ice/thaw/freeze cycles under snow drifts do not result in excessive stresses on the module. Snow may be cleared from the modules by using the Dry Cleaning Guidelines (Table 5).

8.2 MODULE CLEANING GUIDANCE

In most climates, First Solar modules do not require cleaning. Installed modules may collect a light layer of dust and/or dirt (soiling) over time and periodic rainfall should be sufficient to remove light soiling in most cases. If cleaning is performed to maximize system performance, please follow the below guidelines.

CAUTION

Cleaning activities create risk of damage to the modules and array components, as well as the potential for electric shock. Failure to comply with the Module Cleaning Guidance may reduce energy enhancing effects of anti-reflective coating.

CAUTION

Cracked or broken modules represent a shock hazard due to leakage currents. The risk of shock increases when modules are wet. Before cleaning, thoroughly inspect modules for cracks, damage, and loose connections.

Clean modules only when in open circuit – either disconnected from load, or during times when the inverter is off.

First Solar (technicalsupport@firstsolar.com) must review and approve of:

- Automated, manual or motorized cleaning tools and methods
- Cleaning fixtures or tools which are supported by or rest on modules

Acceptable cleaning methods vary depending on whether or not the modules include ARC.

- ▶ Only clean the front side of modules. Do not spray water at sealed interfaces of module.
- ▶ Do not use abrasive cleaners or degreasers, cleaning solutions containing hydrochloric acid, D-Limonene, ammonia, or sodium hydroxide on any module type.
- ▶ Do not use Wet-Contact Cleaning, including any combination of water and scrubbing/wiping with agitating tool, on ARC modules.
- ▶ Excessively soiled spots on modules (i.e. bird droppings) may be spot-cleaned with soft cloth or mop and water if necessary for localized cleaning only (<10% of module area).

Table 4: Wet Cleaning

WET CLEANING GUIDELINES (WATER REQUIREMENTS)	NON-ARC MODULES (FS-6XXX)	ARC MODULES (FS-6XXXXA)
RO water, Fresh water: TDS < 1500 mg/L (2.91*10 ⁻³ slug/ft ³), low mineral tap water, or deionized water; Conductivity <250 mS/cm, Chlorides ≤ 250 mg/mL (0.49 slug/ft ³)	✓	✓
Hard water (must be squeegeed off to prevent scale buildup)	✓	
Water temperature must be ± 20°C from module temperature applied with water pressure <35 bar (500 psi) at nozzle	✓	✓

Table 5: Dry Cleaning

DRY CLEANING GUIDELINES	NON-ARC MODULES (FS-6XXX)	ARC MODULES (FS-6XXXXA)
Agitating brushes or sponges: Non-conductive nylon, or similar material; non-abrasive to glass, aluminum, or steel	✓	
Dry cleaning with soft cloths or mops (limited to <12 times annually for ARC modules)	✓	✓

8.3 MODULE DISPOSAL

Modules may be recycled or disposed of in accordance with applicable local requirements.

Please visit www.firstsolar.com/modules/recycling for further details on the recycling program.

9 REVISION HISTORY

REVISION NUMBER	AMENDMENT DETAILS	REVISION DATE
1.0	Document created	12/19/2017
2.0	Updated from single to dual crossbar frame design; Handling and Storage update.	7/31/2018
2.1	Added single and dual crossbar frame designs; Updated UL grounding information, added system derating information, updated Handling and Storage section. Added SpeedSlot nomenclature.	2/15/2019

