Senior Thesis

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3.1 Solar Panels

3.1.1 Introduction

This is a client request. These solar panels let certain wavelengths of light through them, and absorb the rest of the spectrum. This allows plants to grow inside.

3.1.2 Data

Model: LUMO 20M100GH
Quantity: 24x
Company: Soliculture
Company Website: http://www.soliculture.com/
Product Page: http://www.soliculture.com/

3.1.3 Datasheet

todo

3.2 Charge Controller

3.2.1 Introduction

Solar panels cannot charge batteries directly for these reasons:

- They have unstable voltages, and thus should not be connected directly to the battery.
- Batteries with different chemical compositions charge differently.
- One solar panel cannot provide enough power to the battery alone, even if it reaches the nominal voltage of 12V.
- If we string 12 solar panels in series together and plug it into the batteries, the batteries will become permanently damaged.

Solar panels cannot charge batteries properly by themselves. We must have a charge controller to accompany the solar panels in order to charge the batteries properly. I like the TS-MPPT-60 because it is custom-programmable, and it can monitor a significant amount of values that could be useful someday. I included the values it can monitor below.

3.2.2 Data

Model: MORNINGSTAR TS-MPPT-60 TriStar MPPT 150V
Company: Morningstar
Company Website: https://www.morningstarcorp.com
Product link: https://www.morningstarcorp.com/products/tristar-mppt/
Quantity: 2x

Features

- Customizable Charge Settings
- Great networking capabilities
- RS-232 electrical interface for Microcontroller communication.
- Uses royalty-free MODBUS protocol for easy data harvesting
- Operating Range: -40°C to 40°C
- Up to 60A continuous battery current
- Compatible with 12V, 24V, and 48V battery systems
- Maximum 150V solar panels in series
- Keyholes for mounting

- Uses TrakStar MPPT technology to track the maximum power point of the solar panels.
- Temperature compensation
- Two Tristar Morningstar MPPT's can be attached to the same battery pack

Drawbacks

The internal PLC settings can only be changed with a PC that can run MSView, Morningstar's proprietary program that can program any Morningstar device, that can be downloaded from Morningstar's website, located here:

https://www.morningstarcorp.com/msview/

It can only handle 150V of solar panels. We have 24 solar panels, which in series total to a nominal voltage of 192V. Therefore, we must have at least 2.

3.2.3 Monitoring

A Tristar Morningstar MPPT can monitor these variables:

Internal ADC chips

- Battery Voltage
- Battery Terminal Voltage
- Battery Sense Voltage
- Array Voltage (of the solar panels)
- Battery Current
- Array Current (of the solar panels)
- 12V supply
- 3V supply
- meterbus voltage

- 1.8V supply
- Reference voltage

Temperature Data

- Heatsink Temperature
- RTS temperature
- Battery Regulation Temperature

Status Data

- Battery Voltage (slow)
- Charging Current (slow)
- Minimum Battery Voltage
- Maximum Battery Voltage
- Hourmeter
- Faults raised
- Alarms raised
- LED state
- DIP switch status

MPPT Data

- Output Power
- Input Power
- Max power of last sweep
- Vmp of last sweep
- Voc of last sweep

Charger Data

- Charge state
- Target Regulation Voltage
- Ah charge resettable:
- Ah charge total
- kWhr charge resettable
- kWhr charge total

Daily Data

- Battery Voltage Minimum
- Battery Voltage Maximum
- Input Voltage Maximum
- Amp Hours accumulated
- Watt hours accumulated
- Minimum Power output
- Minimum temperature
- Maximum temperature
- Time in equalize stage
- Time in float stage
- Alarms of the day
- Faults of the day
- Flags of the day

Current Charge Settings

- EV_absorp
- EV_float
- Et_absorp
- Et_absorp_ext
- EV_absorp_ext
- EV_float_cancel
- Et_float_exit_cum
- EV_eq
- Et_eqcalendar
- Et_eq_above
- Et_eq_reg
- Et_battery_service
- EV_tempcomp
- EV_hvd
- EV_hvr
- Evb_ref_lim
- ETb_max
- Etb_min
- Elb_lim
- EVa_ref_fixed_init
- EVa_ref_fixed_pct_init

LED settings

- EV_soc_g_gy
- EV_soc_gy_y
- EV_soc_y_yr
- EV_soc_yr_r

3.2.4 Recommended Accessories

Remote Temperature Sensor

Introduction The greenhouse will naturally change temperature more than 5 C during the year. The Morningstar Corporation recommends that you add the RTS sensor for the Charge Controller to operate more effectively under these circumstances. It is simple to install. Follow Morningstar's guide to installation.

Model: Remote Temperature Sensor
Quantity: 2x
Company: Morningstar
Company Website: https://www.morningstarcorp.com/
Product Page: https://www.morningstarcorp.com/products/remote-temperature-sensor/

RS-232 to USB cable

Introduction RS-232 must be converted to USB format for easy monitoring by the Raspberry Pi. Luckily, I don't have to reinvent the wheel. I can simply use this cable. It has an FTDI chip and board embedded inside the plug, so I don't have to worry about fabricating a chip.

I'm going with a USB terminal because my microcontroller is a Raspberry Pi, and it's simpler to use a USB and create a virtual COM port inside the Raspberry Pi's Linux operating system.

Model: C2G 26886 USB to DB9 Serial RS232 Adapter Cable, Blue (1.5 Feet, 0.45 Meters)
Quantity: 2x
Company: C2G
Company Website: https://www.cablestogo.com/
Product Page: https://www.amazon.com/C2G-Cables-26886-Serial-Adapter/dp/B000067RVJ

3.3 Batteries

3.3.1 Lithium-ion Battery Cell

Introduction

Solar panels do not produce power all the time. Even when they do produce power, they often don't produce enough power to satisfy the consumer. During the day, when the solar panels produce the most power, the consumer often isn't using the system. To resolve this, we need to have a battery pack. During the day, the battery pack will be charged by the solar panels, and during the evening, the battery pack will be discharged by the consumer.

Model: IFP71/180/278-CA180FI
Quantity: 8
Company: CALB Company website: http://www.calbusainc.com/ Product Page: https://www.ev-power.eu/LiFePO4-small-cells/Prismatic/CALB-CA180FI-Lithium-Cell-LiFePO4-3-2V-180Ah.html

Datasheet

TODO

3.4 Battery Management System

3.4.1 Introduction

Batteries don't discharge evenly. Every battery has its own individual chemistry due to imperfections in the manufacturing process. If we discharge batteries unevenly, one battery could be worn out while another battery remains untouched. To resolve this, we use a Battery Management System.

3.4.2 Main Controller

Model: G1 EMUS BMS control unit
Quantity: 1
Company: Emus
Company Website: https://emusbms.com/
Product Page: https://emusbms.com/product/g1-bms-control-unit

3.4.3 Features

Automatically controls the battery operation process utilizing various interfaces for measurement, control, data exchange, configuration and indication, and works with any charge controller.

Application

- Any lithium chemistry, series connected battery pack of up to 254 cells if using serial cell communication
- Any lithium chemistry, series connected battery pack, or pack of multiple parallel strings, up to 8128 cells total, if using EMUS CAN Cell Group Modules.
- Storage Temperature: -40°C to 95°C
- Operation Temperature: -40°C to 80°C
- USB interface for Microcontroller reading
- Proprietary serial interface for cell communication

3.4.4 Monitoring

BMS control unit can monitor:

System Status

- Battery Charge
- Charger Status
- Current and Voltage
- Distance and Energy (if applied to an electric vehicle)
- BMS status
- Time and Date
- Version Number

System status and Individual Cells

- Battery Balancing Rate
- Temperature
- Battery Voltage

Statistics

Has an internal events log (each event happening at a recorded time)

Has a statistics log at a recorded time. Possible statistics to log:

- Total Discharge
- Total Charge
- Total Discharge Energy
- Total Charge Energy
- Total Discharge Time
- Total Charge Time
- Total Distance
- Max Discharge Current
- Max Charge Current
- Min Cell Voltage
- Max Cell Voltage
- Max cell Voltage Difference
- Min pack voltage
- Max pack voltage
- Min Cell Module Temperature
- Max Cell Module Temperature
- Max Cell Module Temperature Difference

- Protection Counts (undervoltage, overvoltage, discharge overcurrent, charge overcurrent, cell module overheat, leakage protection, no cell communication, low voltage power reduction, high current power reduction, high cell module temperature power reduction, charger connect, charger disconnect, cell overheat, high cell module temperature power reduction)
- Miscellaneous counts (number of Preheat stages, Precharge stages, main charge stages, balancing stages, charging finished stages, charging errors, charging retries, trips, charge restarts)
- Min Cell Temperature
- Max Cell Temperature
- Max Cell Temperature Difference

3.4.5 Necessary Accessories

Cell Isolators

The BMS system requires that you have isolators to protect the main module. Only works if only 1 group of batteries is used.
Model: G1 Top/Bottom Isolator
Company Website: https://emusbms.com/
Product Page: https://emusbms.com/product/g1-top-bot-isolator
Quantity: 2x

Cell Modules

Every battery must have its own cell module. Different batteries require different cell modules.You can find all types of cell modules here:
https://emusbms.com/product-category/cell_modules
The standard solution is the A/B type, so that's what we're going with.We must order this package for each battery.

Ordering Schematic EMUS BMS Cell Module A – 1x EMUS BMS Cell Module B – 1x Ring Terminal M8 – 2x Communication Cable – 16cm – 2x

Ordering details Model: G1 Cell Module – A/B type
Company: Emus
Company Website: https://emusbms.com/
Product Page: https://emusbms.com/product/g1-cell-module-ab
Quantity: 8x

CAN Cell Group Module

We need to group batteries into groups. Since the batteries we picked are 3.2V, we group batteries into groups of 4.
Model: G1 CAN Cell Group Module
Company: Emus
Company Website: https://emusbms.com/
Product Page: https://emusbms.com/product/g1-can-cell-group-module
Quantity: 2x

3.4.6 Recommended Accessories

Current Sensor

In order to monitor current dispensing from the batteries to the load, you must have a current sensor. It's not necessary for operation, but it's recommended to have one. This one works using the hall effect, so it does not require contact with the wires; it only needs to have the wire running through its hole.

Model: G1 Loop Style Dual Range Current Sensor
Company: Emus
Company Website: https://emusbms.com/ Product Page: https://emusbms.com/product/g1-loop-style-dual-range-current-sensor
Quantity: 1x

3.5 Sensors – Faculty

3.5.1 Introduction

The client wants their own sensors exclusive for faculty. They want to measure temperature, humidity, and light. I propose that we use these classes of sensors for this:

- Temperature and Humidity Sensor
- Light Sensor

The product page for the parts and their respective datasheets will be hosted by different companies. This is because it is easier to order a breakout board than it is to order the individual parts, order a custom PCB for the sensor, and solder the parts onto the board. Companies that sell breakout boards and companies that manufacture parts are separate from one another.

3.5.2 Temperature and Humidity Sensor

Model: BME280
Company: Bosch
Company Website: https://bosch.us
Product Page: https://www.adafruit.com/product/2652
Datasheet: https://cdn-shop.adafruit.com/product-files/2652/2652.pdf

Details

- ±3% accuracy for humidity
- ±1% accuracy for temperature
- 1s response time maximum
- Operating range: -40C to 85C
- I2C interface
- Measures pressure if necessary

See datasheet for reading this sensor properly. Create a class in C++/python to read it.

3.5.3 Light Sensor

Model: VEML7700
Quantity: 2
Company: Vishay Semiconductors
Company Website:

Product Page: https://www.adafruit.com/product/4162?gclid=EAIaIQobChMIyOmfve7Q4wIV6
Datasheet: https://www.vishay.com/docs/84286/veml7700.pdf

Details

High resolution: 0.0036 lux/ct at night, 1.8 lux/ct in bright sunlight
Maximum 120,000 lux (bright sunlight)
I2C interface

See datasheet for reading this sensor properly (i.e. what addresses to read from, what slave address to use, etc.) Create a class in Python/C++ to read it.

3.6 Microcontroler Decision

3.6.1 Introduction

The slave microcontroller chosen needs to be able to:

- Collect 5 pieces of sensor data (minimum)
- Communicate with another microcontroller in some way (Bluetooth or RS-232), and send data to it.
- Collect power data from the Solar Panels themselves (current and Voltage for each panel)
- The master microcontroller chosen needs to be able to:
- Communicate with another microcontroller in some way (Bluetooth or RS-232), and request and receive data from it.
- Process data sent from the slave microcontroller.
- Collect Power data from both Tristar Controllers (String 1 and String 2)
- Collect Power data from the BMS (Current being driven, Current Battery voltage, How much power is currently in the battery bank, etc.)
- Communicate with the FONA device to send data to a web server.

3.6.2 Arduino

The Arduino has the capability of being a slave, but not a master. It can collect I2C data, UART data, and One-Wire data, but collecting more than 1 type of RS-232 data will be a challenge. Bluetooth communication requires purchase of an extra module, but it can be done. It requires the use of a UART port. However, the Bluetooth driver will likely require a lot of space.

If we go the Bluetooth route, and we want to add more slaves, we can buy another Arduino with a Bluetooth shield from their website, or we can buy a Raspberry Pi Zero W, which also comes with Bluetooth. Bluetooth requires no Wi-Fi, data plan, or wires. However, it uses a little more power this way. The Arduino uses 526mW of power on average with 10 pins. However, it is more than likely that these pins will either be insufficient, or not deliver enough power to power all our sensors due to hardware limitations. Most of the Arduino power data I found comes from forums, from people who tested the power consumption themselves, since reading microcontroller documentation is very difficult. But, the Raspberry Pi power data comes straight from their website.

3.6.3 Raspberry Pi

There are many raspberry pi models, but only 1 can truly be a master: the Raspberry Pi Model 3B+. The Raspberry Pi Model 3B+ has the capability of being a master or a slave. It can collect I2C data, UART data, One-wire data, and can multiplex a RS-232 bus. Bluetooth communication comes built-in with the Raspberry Pi 3B+. The Raspberry Pi uses 3.5W of power on average bare-boarded. This will be more than enough power to drive all the sensors. Since the amount of power is not limited by any hardware on the raspberry pi (i.e. it's only limited by the power supply and the connectors), we can plug in as many pins as we want. The recommended current limit is 2.5A, which translates to 12.5W. The 3.3V voltage regulator on the board is rumored to have a maximum of 1000mA before it breaks. A maximum of 100mA per pin should be more than enough. I don't know how much power the sensors have, so that's something I need to research.

The Raspberry Pi is capable of being programmed remotely by connecting it to Wi-Fi or Data, and SSH-ing into the controller from a remote computer, much like a server would be. I haven't yet figured out how to do it on my compute module, but I know it can be done. I have a Raspberry Pi compute module at home. I bought it because I thought I could design an I/O board for myself that includes an RS-232 header. Afterwards, I thought I could plug in an RS-232 hub into it, and plug in more microcontrollers. I ran out of time, and I found a website to do this: https://geppetto.gumstix.com/. But, the site costs $2000 for an initial setup fee! That's outrageous! I tried looking up resources to do this myself, but it's too complicated. I have no idea how to work with the Compute Module's SO-DIMM package! I need a teammate that knows how to work with SO-DIMM to design a custom I/O board with me in order to use the compute module.

3.6.4 Final Decision

I am going to go with the Raspberry Pi 3 Model B+.

3.7 Faculty Microcontroller

3.7.1 Introduction

In every computer system, there must be a main processor. In this greenhouse system, a master microcontroller is utilized to harvest data, process it, and send it to a main server somewhere on campus. See the website manual for details on how it's processed there. The main microcontroller must be able to communicate with the Faculty Sensors somehow, and communicate with the slave microcontrollers when we implement them. I have chosen to interface the main microcontroller with the slave microcontrollers via Bluetooth. Bluetooth is wireless, and easy to program. Does not require any wires running across the greenhouse floor, and reduces tripping hazard. So, our Microcontroller has these requirements:

- Must be capable of sending packets of data over a 2G internet connection to a server somewhere at UCSC.
- Must be capable of communicating over Bluetooth to a slave microcontroller somewhere in the greenhouse.
- Must be capable of reading I2C data.

The microcontroller I have chosen for this job is the Raspberry Pi Model 3B+. It is a capable microcontroller. It runs Linux on its systems, so it's easy to debug on site if necessary. The code can be stored on an SD card. If necessary, it will be possible to retrieve a log of the past 30 days of data from the Raspberry Pi. The Raspberry Pi Raspbian system uses a FAT32 file system, meaning the absolute maximum amount of data it is possible of addressing is 32GB. So, it should be enough for at least 30 days worth of data. But, the SD card also has to store the operating system it will use (Raspbian).

This microcontroller uses a +5V power source. Therefore, we will have to design a power source for it. The tolerance values for the microcontroller are tight: it only accepts +4.5V to +5.5V. It can draw up to 2A of current when running a stress-test. So, let's just say it draws a maximum of 10W of power.

3.7.2 Details

Model: Raspberry Pi 3 Model B+
Quantity: 1
Company: Raspberry Pi
Company page: https://www.raspberrypi.org/ Product Page: https://www.raspberrypi.org/prod
pi-3-model-b-plus/

Features

- 1.6GHz ARM processor
- C++ compiler
- Python interpreter
- 4 USB ports
- 20 GPIO pins
- I2C, UART, and SPI interface
- Runs Linux
- Bluetooth and Wi-Fi Capabilities
- Upgradeable

Drawbacks

Requires +4.5V to +5.5V of power.
Requires a Micro USB to power it. We can fabricate something that can deliver the necessary power to run it.

3.7.3 Recommended Accessories

Sixfab's GSM/GPRS shield

I don't like the FONA module. I would like to replace it. I would like to instead use this GSM/GPRS shield. It slides easily onto the master Raspberry Pi, and can also fit another shield onto it if so desired. I will be fabricating a faculty sensor shield utilizing the I2C protocol. This shield utilizes the UART protocol. The Raspberry Pi can only accommodate 1 use of the UART protocol using the GPIO pins. The others will be using the Virtual COM ports of the Raspberry Pi. The Tristars will be using a RS-232 to USB converters with an FTDI chip installed in them for communication, and the BMS system will be using a split-open USB wire that will connect directly to the BMS control unit.

Model: Raspberry Pi GSM/GPRS shield
Company: Sixfab
Company Page: http://sixfab.com/ Product Page: https://sixfab.com/product/gsmgprs-shield/

Features

- Uses Quectel M66 2G IoT modem.
- Fully compatible with Raspberry Pi models that have the 40-pin GPIO header (3, 2, B+, A+, Zero)
- High Data Speed: GPRS Multi-slot class 12, 85.6kbps downlink and 85.6kbps uplink data rates
- Quad-band: 850/900/1800/1900MHz
- Built-in PCB antenna, also there is an external antenna port available
- Supported Protocols: TCP/ UDP/ PPP/ FTP/ HTTP/ SMTP/ CMUX/ SSL
- Quectel's QuecLocator Feature, lets you get the location without GPS/GNSS
- Extremely low standby power consumption by M66, 1.3mA at DRX=5
- Efficient and low quiescent current regulator circuit can hold up to 3.6A

- Bluetooth Function, V3.0 specification, SPP and OPP profiles available.
- Micro SIM Card socket can easily reachable on the downside of the shield.
- Can be used standalone with PC/Laptop over micro USB, without stacking with Raspberry Pi thanks to FTDI chip on the shield.
- Sending/Receiving standard V.25ter AT commands over UART port to Raspberry Pi is available
- Working temperature range: -30°C to +80°C

Antenna

Any antenna that can physically connect to this shield will do. But, here's one from Sixfab:

Model: GSM 2G/3G Antenna – u.FL PCB Antenna – 0dBi
Company: Sixfab
Company page: https://sixfab.com/ Product Page: https://sixfab.com/product/gsm-2g-3g-antenna-u-fl-pcb-antenna-0dbi/

SIM Card

If we will be sending data with our GSM module, we must have a SIM card to tell the cell phone tower what carrier we are using, and if we have permission to use their cell phone tower. The SIM card only stores 1 piece of data: our ID number. That's all it does, but it's very important.

Model: Ting GSM SIM card
Quantity: 1
Carrier: Ting
Company Website: https://ting.com/
Product Page: https://ting.com/shop/gsmSIM

You must register with Ting and pay a monthly fee of $50 for an unlimited 2G service plan.

Custom-fabricated I2C shield for Raspberry Pi

Will be custom-designed at home here at UCSC. Will be rushed, though. If I find a design, will be using it. Will have these features:

- Capable of holding at least 8 I2C devices
- Capable of detaching I2C devices at will, like a plug.
- Has Pull-up resistors embedded inside

Touch screen for Raspberry Pi

This is not completely necessary, but it would be nice to be able to see what is happening inside the raspberry pi 3 at any given moment.
Model: Raspberry Pi Touch Display
Company: Raspberry Pi
Company Page: https://www.raspberrypi.org/
Product Page: https://www.raspberrypi.org/products/raspberry-pi-touch-display/

Case for Raspberry Pi Touch Display

If we have a Raspberry Pi touch display, we will need a case for it to add that extra touch. We will need to find a way to mount it, though.

Model: RS Raspberry Pi 7-Inch LCD Touch Screen Case, Black, Model number FBA_102035
Company: Raspberry Pi
Company Page: https://raspberrypi.org/
Product Page:Amazon.com

3.8 Sensors – Student

3.8.1 Introduction

As an optional feature, the client would like the system to be capable of having students be able to use their own sensors. Here are some potentially useful sensors for students:

3.8.2 Water Temperature sensors

DS18B20

The DS18B20 is sold in a different form factor from ADAFRUIT. This form factor is more usable, so we will be using that one. The sensor and its datasheet are provided by Maxim Integrated.

Model: DS18B20
Quantity: 1
Company: Maxim Integrated
Company Website: https://www.maximintegrated.com/en.html/
Product Page: https://www.adafruit.com/product/381?gclid=EAIaIQobChMIh5e–PmU4wIViJWzCh3vLA9XEAQYASABEgKZSfD_BwE/
Datasheet: https://datasheets.maximintegrated.com/en/ds/DS18B20.pdf

Details

- Interface: One-wire
- Reduce Component Count with Integrated Temperature Sensor and EEPROM
- Unique 1-Wire Interface Requires Only One Port Pin for Communication
- Measures Temperatures from -55°C to +125°C (-67°F to +257°F)
- +- 0.5°C Accuracy from -10°C to +85°C
- Programmable Resolution from 9 Bits to 12 Bits
- No External Components Required
- Parasitic Power Mode Requires Only 2 Pins for Operation (DQ and GND)
- Simplifies Distributed Temperature-Sensing Applications with Multidrop Capability
- Each Device Has a Unique 64-Bit Serial Code Stored in On-Board ROM
- Flexible User-Definable Nonvolatile (NV) Alarm Settings with Alarm Search Command
- Identifies Devices with Temperatures Outside Programmed Limits

- Available in 8-Pin SO (150 mils), 8-Pin uSOP, and 3-Pin TO-92 Packages

3.8.3 Soil Moisture Sensors

This one is a potential keeper for students.
Model: I2C Soil Moisture Sensor
Company: White Boxes
Company Page: https://www.whiteboxes.ch/
Product Page: https://www.whiteboxes.ch/shop/i2c-soil-moisture-sensor/?v=7516fd43adaa

Features

- Comes with its own Arduino and Raspberry Pi examples library, located here:
- https://github.com/Miceuz/i2c-moisture-sensor
- Version 2.7.5
- Supply voltage 3.3V – 5V
- Current consumption: 1.1mA @ 5V, 0.7mA @ 3.3V when idle, 14mA @ 5V, 7.8mA @ 3.3V when taking a measurement. When constantly polling sensor at full speed, current consumption averages to 4.5mA @ 5V, 2.8mA @ 3.3V
- Operating temperature 0°C – 85°C
- Moisture reading drift with temperature – < 10 % over full temp range

3.8.4 Pressure Sensors

Honeywell manufactures this pressure sensor, but ADAFRUIT distributes it.

Model: Adafruit MPRLS Ported Pressure Sensor Breakout - 0 to 25 PSI
Company: Honeywell
Company Page: https://sensing.honeywell.com/
Product Page: https://www.adafruit.com/product/3965?gclid=EAIaIQobChMIx4HYxr7-5AIVDtvACh3JSggcEAQYBSABEgJE7_D_BwE
Datasheet: https://sensing.honeywell.com/micropressure-mpr-series

Comes with its own example code library: https://github.com/adafruit/Adafruit_MPRLS

3.9 Student Microcontroller

3.9.1 Introduction

Instead of having every student plug into one microcontroller (which would require a lot of cables running around), I propose that for every experiment, we have a separate microcontroller that the student can take with them. The Raspberry Pi 3 Zero W is a great candidate for this. It's Bluetooth enabled, so they aren't burdened by a cable length. It's just as powerful as the normal Raspberry Pi, with the addition of writing their own code for their own sensors.

We will have to use our own sensor shields.

3.9.2 Raspberry Pi Zero W

Model: Raspberry Pi 3 Zero W
Quantity: 2
Company: Raspberry Pi Company Website: https://raspberrypi.org/
Product page: raspberrypi.org

Details

- 1GHz, single-core CPU
- 512MB RAM
- Mini HDMI and USB On-The-Go ports
- Micro USB power
- HAT-compatible 40-pin header
- Composite video and reset headers
- CSI camera connector

Networking

- 802.11 b/g/n wireless LAN
- Bluetooth 4.1
- Bluetooth Low Energy (BLE)

Drawbacks

- Requires a voltage range of +4.5V to +5.5V, and a power converter.
- Requires a Micro USB.

3.9.3 Recommended Accessories

Custom SPI, I2C, UART, and One-Wire shield

Will be designed in-house. Everything will be documented. Requirements:

- Take these data formatting protocols: SPI, I2C, UART, 1-wire.
- Be a wall bug. It will plug in to a 12V power supply with a 12V converter.

Custom Housing

Will be designed in-house. Everything will be documented. Requirements:

- Cover the Raspberry Pi Zero W from the elements.
- Have ports for:
- The 5V Power supply
- The SPI, I2C, UART, and 1-Wire
- Optional: Covers for the ports.
- Heater – Battery pack

3.10 Heater - Battery Pack

3.10.1 Introduction

All battery packs must have a heater. When batteries get too cold, there is a possibility of permanent damage to the batteries, and an unnatural reduction of life cycles might occur. There is no heater for the battery pack currently on-site, but here is my proposal: install a heater for wherever the batteries are stored. The heater will be controlled by a relay, which will be controlled by the BMS system. The BMS system has temperature sensors on-board to tell when the batteries are getting too cold.

Model: Asixx Air Heater, 100W 12V Energy Saving PTC Car Fan Air Heater Constant Temperature Heating Element Heaters for Heater, Humidifier, Air Conditioning and More
Company: Asixx
Company Website:
Product Page: amazon.com

3.10.2 Details

Rated Voltage: 12V Rated Power: 100W

Dimension Specs

- Mounting Hole Distance: Approx. 87mm / 3.4inch
- Mounting Hole Size: Approx. 4mm / 0.2inch
- Product Size: Approx. 6 * 6 * 4.2cm / 2.4 * 2.4 * 1.7inch
- Product Weight: Approx. 120g

We will mount this wherever the battery pack is.

3.11 Cooler – Battery pack

3.11.1 Introduction

We should be burying our batteries underground to protect against warmer temperatures (according to forum rumors). If the batteries have an excessive load, they become at risk for overheating. If the batteries are overheated for too long, they will become permanently damaged. We must have a cooler for our battery pack to cool the batteries. I propose we install a fan or a radiator. The air underground usually stays at least 25 – 30 C, so we can use that air to cool the batteries.

I don't have a solid choice of cooler yet, but this is my best choice so far:

3.11.2 Data

Model:
Company:
Company Page:
Product Page: amazon.com

3.11.3 Details

- Overall Diameter:11.73 INCH,
- Overall Thickness:2.56 INCH
- 1550 CFM Car Cooling Fans
- Amp Draw: 6.6 amp
- Watts:80W
- Blade Length: 11inch
- Number of Blades: 10
- Blade Type: straight
- High-quality, lightweight, and durable; great as replacement or upgrade from factory parts.
- Simple installation, no modifications required. Fan can be used as pusher or puller with the adaptable mounting kit.
- How to choose the correct fan?
- Step 1: Confirm the width and depth of your radiator
- Step 2: Compare the fan diameter and depth with radiator

- Step 3: Choose the right size fan
- ATTENTION: It can be installed only if the diameter of the fan is smaller than the width of radiator! Make sure the depth of the fan is smaller than the gap of radiator and other parts!

3.12 AC outlet

3.12.1 Introduction

Every once in a while, somebody will want to use an AC outlet to power a laptop or charge a phone. An AC outlet is absolutely necessary to do these things. To have an AC outlet on a DC power grid, we must have an inverter. Here's our inverter:

3.12.2 Data

Model: Morningstar Suresine Inverter 300W
Model number: SI-300-115V-UL (60Hz)
Company: Morningstar
Company Website: https://www.morningstarcorp.com/
Product Page: https://www.morningstarcorp.com/products/suresine/

3.12.3 Details

- Data Communications: RJ-11Connection with Morningstar Meterbus / MODBUS RTU (16-bit)
- Continuous Power Rating: 300W @ 25°C
- Peak Power Rating (10 minutes): 600W
- DC input voltage: 10.0V - 15.5 V
- Waveform: Pure Sine Waveform
- AC Output Voltage (RMS): 220V or 115V ± 10%
- AC Output Voltage Frequency: 50 or 60 Hz ± 0.1%
- Peak efficiency: 92%

- Total Harmonic Distortion (THD): < 4%
- Self Consumption:
  - Inverter On (no load): 450mA
  - Inverter Off: 25mA
  - Stand-by: 55mA
- Low voltage Disconnect (LVD): 11.5V or 10.5V
- Low Voltage Reconnect: 12.6V or 11.6V
- LVD Warning Threshold (buzzer): 11.8V or 10.8V
- LVD Delay Period: 4 minutes
- High voltage disconnect: 15.5V
- High Voltage Reconnect: 14.5V
- Standby On Threshold: 8W
- Standby Off Threshold: 8W
- High Temperature Disconnect: 95°C (heatsink)
- High temperature Reconnect: 80°C (heatisnk)

Electronic Protections

- Reverse Polarity (fused)
- AC Short Circuit
- AC overload
- DC Terminals: Max wire size: 2.5 to 35 mm^2 / 14 to 2 AWG
- Remote On/Off terminals: Max. Wire size: 0.25 to 1.0 mm^2 / 24 to 16 AWG
- Enclosure: IP20
- Cast anodized Aluminum

Physical Characteristics

- Dimensions: 213 x 152 x 105 mm (8.4 x 6.0 x 4.1 in)
- Weight: 4.5 Kg/10.0lbs
- AC terminals: Max wire size: 4 mm^2 / 12AWG

Environmental Protections

- Ambient Operating Temperature: -40°C to +45°C
- Storage Temperature: -55°C to +85°C
- Humidity: 100% (non-condensing)
- Tropicalization: Conformal coating on PCBs. Epoxy encapsulated transformer and inductors.

3.12.4 Accessories

3A fuse

100A fuse

GFCI outlet

Model: 15 Amp Self-Test smartlock pro slim duplex GFCI Outlet, white
Company: Home Depot
Company Website: https://www.homedepot.com/
Product Page: https://www.homedepot.com/p/Leviton-15-Amp-Self-Test-SmartlockPro-Slim-Duplex-GFCI-Outlet-White-R02-GFNT1-0KW/206001533

GFCI outlet box

Model: 1-Gang Weather Box While-In-Use cover
Company: Home Depot
Company Website: https://www.homedepot.com
Product Page: homedepot.com

3.12.5 Recommended Accessories

RJ-11 Meterbus to USB MODBUS adapter

Model: Morningstar USB MeterBus Adapter > UMC-1
Company: Morningstar
Company Website: https://www.morningstarcorp.com
Product Page: solarflexion.com

RJ-11 data communications cable

Model: USB Meterbus Adapter
Company: Morningstar
Company Website: https://www.morningstarcorp.com/ Product Page: https://www.morningstar
meterbus-adapter/

3.13 Web Server

3.13.1 Introduction

We must have a server to send the data to. I'm sending all my data in JSON format so it's easier for the website to read it.

Also, I would like to call upon the help of a professor for this one.

Host: ucsc.edu
Website link: arboretum-backend.soe.ucsc.edu/ (user requested)
Server Location: somewhere at UCSC. It's hard to tell. Who to call when things go bad: Heidi. This is an unsupported virtual machine, so we are on our own. Try referencing the Website Troubleshooting section of this document first.
Uptime Percentage: 99% (when power is on) Language Programmed in: Python

3.14 Power Conversion

3.14.1 Introduction

All our microcontrollers that we are using need +5V to operate properly. Our batteries distribute power in +12V packages. Therefore, we need a way to convert that power reliably.

3.14.2 Requirements

- Tolerance ranges: +4.5V to +5.5V
- Ends in a Micro-USB plug

We can either design a DC-DC voltage converter ourselves, or we could try to get one from a commercial retailer and hope it has good enough tolerances for our Raspberry Pi. Either way, we must have a DC-DC voltage converter. I propose that we get one from a commercial retailer. That way, if there are any malfunctions with it, we don't have to build another one ourselves, we can simply buy another one from the same retailer.

3.14.3 Details

Model: DC-DC 12V to 5V 3A Micro USB Converter Voltage Step Down Regulator Waterproof Power Converters for Car Smartphone
Company: Car Power Technlogies (CPT)
Company Website: N/A
Product Pages: amazon.com and https://www.aliexpress.com/item/32581610768.html

3.14.4 Sales pitch

- This voltage converter uses high quality industrial-grade chip, with high conversion rate and stability
- Widely used for car stereo, radio, monitoring, LED display, electric fan, motors and other electrical appliances, etc.
- It supports 3 intelligent security protection including over-current protection, over temperature protection and output short circuit protection
- Copper wire has great electrical conductivity, low thermal, low carbon and save more power
- Fire retardant plastic casing and organic silicone sealing technology has strong thermal conductivity, IP67 ingress rating, waterproof and shockproof
- Type: Non-isolated step-down voltage converter

3.14.5 Features

- Output Connector: Micro USB
- Input Voltage: DC12V
- Output Voltage: DC5V
- Output Current: 3A, 2.5A(no need to enhance heat dissipation for long time use)
- Output Power: 15W
- Max. Efficiency: >95%
- Operating Temperature: -40°C to 80°C
- Overall Length: 50cm/19.7in
- Block Size: 6.4*2.7*1.4cm/2.5*1.1*0.6in
- Weight: 41g(approx.)
- Working temperature: -40°C to 80°C

Chapter 4

Grand Plan

4.1 Goals

My goal is to create a solar-powered greenhouse. The requirements of the greenhouse are to store plants at a reasonable temperature, store a monitoring system inside, and power said monitoring system with rooftop solar panels providing power.

UCSC has 24 solar panels that provide 1.5kWhr of power per day. The power will be delivered to the system properly using a MPPT Solar Charge Controller, provided by Morningstar. Each charge controller can only take 150V, and the total amount of solar panels we have sums up to 196V. Therefore, we will have two charge controllers working in tandem to charge a battery pack. These charge controllers can charge the same battery pack without interference, according to Morningstar. Both charge controllers will have a remote temperature sensor connected to it in order to monitor the amount of charge being delivered to the batteries. The charge controllers will deliver power to a battery pack, but these charge controllers cannot regulate all the batteries by themselves.

The battery pack consists of 8 batteries, each with a maximum charge of 180Ah and nominal voltage of 3.2V, provided by CALB. The batteries will be connected in series in groups of four, summing up to 12.8V per group. The battery pack will be stabilized, its output current regulated, and its temperature regulated by a Battery Management System (BMS), provided by EMUS. The BMS consists of a central control module, two CAN Cell Group Modules, two top isolators, two bottom isolators, and 8 Cell Isolator boards. All components will be controlled by a CAN bus originating from the central control module, that EMUS has programmed for its end users.

The BMS will control the charging of the batteries using variables such as the voltage, current, temperature, and charge of each individual cell, and modify internal variables such as the battery balancing rate accordingly to prevent damage to the batteries. If an individual battery dies, the BMS system will alert you with its monitoring system. The monitoring system can monitor from each battery: current drawn, individual voltage, temperature, and more. The monitoring system will calculate how much charge the battery has based on its own internal logic system. If the charge of any battery gets too low, it will focus the incoming charge from the solar panels on that particular battery. If the maximum charge of any battery gets too low, it will let you know with an alert. The monitoring system will monitor the batteries' temperature. The BMS will cool the batteries if they get too hot, and warm the batteries if they get too cold. The monitoring system will let you know with an alert. There are other variables the monitoring system monitors. Check the components document for details.

The battery pack will power the internal computer system inside the greenhouse, an AC outlet somewhere in the greenhouse, and the 12V distribution nodes scattered throughout the greenhouse. Battery power will be converted from DC to AC using a power converter called the Suresine inverter, provided by Morningstar, that will be located near the Charge Controller. The AC power outlet will have a maximum power output of 300W. The 12V distribution nodes will distribute power to various devices that one might need for a greenhouse experiment, such as an air pump, hanging lights, a heater, a water pump, etcetera.

The internal monitoring system consists of a Raspberry Pi main microcontroller, which will be located next to the Charge Controllers for convenience, a 2G GSM shield attached to the main microcontroller, a 7" touch screen for convenience, the faculty sensors, the student sensors, and the Raspberry Pi slave microcontroller(s).

The faculty sensors will need to monitor light, humidity, and temperature, as per the client request. This can be achieved with light sensors and humidity & temperature combination sensors. Since I have the liberty to choose which sensors I will use, I will choose sensors that utilize the I2C serial protocol. This way, a daughterboard can be designed that will enable the main microcontroller to monitor up to 8 I2C devices. The daughterboard will have detachable inputs, so it is possible to change the sensors utilized in the greenhouse.

The main Raspberry Pi microcontroller is powerful enough to suit our needs. It will be running a Linux system called Raspbian. I will install a touch screen display to the main microcontroller, so if a faculty member needs to debug it, they can see what they're doing without needing to connect to the Raspberry Pi using an SSH connection. In case of an emergency, I will include a way to connect to the main Raspberry Pi using an SSH connection and the proper permissions. The main Raspberry Pi and the touch screen will have an enclosure to protect it from the elements. The main Raspberry Pi's tasks will consist of reading the sensor values from the faculty sensors using the I2C serial protocol, receiving a student sensor value package from the slave computers located around the greenhouse over the Bluetooth protocol, reading and storing the values generated from the Charge Controller's internal PLC, reading and storing the values generated from the Battery Management System's internal logic system, compiling all of that data, and then sending it over a 2G TCP connection directly to a server somewhere at UCSC with a GSM/GPRS daughterboard attachment. The 2G connection will be provided by Ting, as per client request.

The student sensors can consist of almost any type of sensor, and it seems random at this point in time. Here are some possibilities I can envision: water temperature sensors, soil moisture sensors, light sensors, humidity & temperature combination sensors, pressure sensors. Since it is impossible to know what serial protocol the student sensors will utilize, I will incorporate the most popular serial protocols into a daughterboard I will design, including I2C, SPI, UART, and 1-wire. I will incorporate a lot of UART ports into my daughterboard design, so that way if their sensor uses a strange protocol not listed here, a faculty member or another engineering student can make a bridge from that protocol to UART, write some code to read their sensor, and the slave microcontroller will be able to include their sensor in the data packet it sends to the master microcontroller.

The slave Raspberry Pi microcontrollers will be powerful enough to send data packets to other microcontrollers using the Bluetooth protocol, read sensor values over a variety of serial protocols, and process that data and compile it into a data packet. The slave Raspberry Pi will have an enclosure to protect it from the elements, but it will not have a sensor. It will be programmable from the main Raspberry Pi. The data packets will contain this type of data: name of owner, name of sensor, type of sensor, protocol utilized, value itself, what unit it's measured in, time and date of when the value was taken.

The main Raspberry Pi microcontroller will be sending a packet of data, utilizing the GSM daughterboard, to a UCSC server somewhere. Once the server receives the data, it will store it in a SQL-style database. That server will also be connected to the internet, so users can connect to it from their phones. When a user connects to this server, the server will serve a website back to the user. The user can then use that website to send a request to the server asking for student sensor data, faculty sensor data, Battery Management data, or Charge Controller data. The user can add a format to their request, such as a graph over time, instantaneous data, data from the last time the computer has polled, data from a specific point in time, etc.

If the user requests a graph over time, they will need to specify what type of data they are requesting, Y-Axis units (i.e. V, mA, etc.), X-axis data (i.e. units of time), and range and scale for both X and Y axis for each dataset they request. Optional: a caption, a title, names for the X and Y axis. The server will return a webpage containing their graph, and some graph metadata: how many data points are returned, what the scale and range are, and a legend if they requested multiple data sets.

Sources:

The Charge controller can work in tandem with another charge controller of the same brand:

https://www.morningstarcorp.com/parallel-charging-using-multiple-controllers-separate-pv-arrays/

Chapter 5

Morningstar Code Design Document

5.1 Introduction

The TSMPPT has a Programmable Logic Controller (PLC) inside. The PLC can be reprogrammed to respond to different battery voltages. Example: when the battery goes to 3.7V, the battery goes to the equalize stage. To reprogram the Tristar MPPT, you must use a PC and a RS-232 to USB cable, and the program MSView, provided by Morningstar. Link: https://www.morningstarcorp.com/msview/. I also have a document called Viewing Data on Morningstar Devices that explains how to use the software.

However, the Tristar MPPT can be monitored by any device capable of serial monitoring, such asa a Raspberry Pi. Morningstar.py will contain the code necessary to monitor data from a Tristar Morningstar MPPT solar charge controller.

Morningstar has a MODBUS specification document for the Tristar Morningstar MPPT. It should be in my App Notes section. If not, here's a link:

Link: https://www.stellavolta.com/content/MSCTSModbusCommunication.pdf

Morningstar.py contains a class that reads PLC data, denoted as Morningstar(). This class can monitor data by reading it and dumping the data to a JSON file. Details are in the upcoming sections.

5.2 Dependencies

5.2.1 modbus-tk

The Tristar MPPT uses a royalty-free serial protocol called MODBUS. There exist many libraries to read it. The Python language has pymodbus, and modbus-tk. Since pymodbus is not reliable (and I want reliable code), I will be using the modbus-tk library. It is distributed under the GNU-LGPL license (GNU Lesser General Public License) © 2009. Created by Luc Jean – luc.jean@gmail.com and Apidev – http://www.apidev.fr. No warranty of any kind.

5.2.2 json

Comes with every distribution of python. Necessary to convert dictionaries into JSON format and dump it directly to an outfile.

5.2.3 serial

This is a serial library for Python. It's easy to use, and free. Provided as-is. Install with pip install pyserial. Use by calling "import serial". ©2015 Chris Liechi clichi@gmx.net All Rights Reserved. Initialization

The Morningstar() class (like most other classes) has an __init__() function, that calls itself whenever a Morningstar() object is created. It requires port, baudrate, and the MODBUS slave number as arguments. When a Morningstar() object is created, it will initialize the serial connection to the PLC using this information. Then, it will create a MODBUS RtuMaster() class from the MODBUS-TK library.

After the MODBUS RtuMaster() class is initialized, it will call the internal function .scaling(). It will test what scaling factors are used.

Dictionaries in Python are everywhere in this code.

It will have methods to either dump data to the command line or dump data to an outfile. The outfile should be a .json file, since the contents will be written in JSON format.

5.3 Classes

5.3.1 Morningstar()

Description

Reads data from the Tristar MPPT PLC. Takes PORT, BAUDRATE, and SLAVE_NUMBER upon initialization.

Variables

PORT: what port number are you using?
BAUD: what baudrate are communicating at?
SLAVE_NUMBER: what is the MODBUS slave number you're reading from?
serial_connection: the serial connection from pyserial that actually communicates with the PLC.
master: the class from modbus_tk that converts serial data into data we can read.

Methods

.scaling(): Sets the classes internal scaling properties (V_PU and I_PU). Also prints the current running version to the console. Runs every time an object of this class is created.

.ADCdata(): Returns a dictionary containing 'battery voltage', 'battery terminal voltage', 'battery sense voltage', 'array voltage', 'battery current', 'array current', '12V supply', '3V supply', 'meterbus voltrage', '1.8V supply', and 'reference voltage'.

.TemperatureData(): Returns a dictionary containing 'heatsink temperature', 'RTS temperature', and 'battery regulation temperature'. All are in degrees Celsius.

.StatusData(): Returns a dictionary containing 'battery_voltage', 'charging_current', 'minimum battery voltage', 'maximum battery voltage', 'hour meter', a list of faults, a list of alarms, the current state of the DIP switch, and the current state of the LED.

.ChargerData(): Returns a dictionary containing 'Charge State', 'target regulation voltage', 'Ah Charge Resettable', 'Ah Charge Total', 'kWhr

Charge Resettable', and 'kWhr Charge Total'.

.MPPTData(): Returns a dictionary containing: 'output power', 'input power', 'max power of last sweep', 'Vmp of last sweep', and 'Voc of last sweep'.

.Logger_TodaysValues(): Returns a dictionary containing: 'Battery Voltage Minimum Daily', 'Battery Voltage Maximum Daily', 'Input Voltage Maximum Daily', 'Amp Hours Accumulated Daily', 'Watt hours accumulated daily', 'Maximum power output daily', 'Minimum temperature daily', 'Maximum Temperature Daily', a list of daily faults, a list of daily alarms, 'time_ab_daily', 'time_eq_daily', and 'time_fl_daily'.

.ChargeSettings(): Returns a dictionary containing: 'EV_absorp', 'EV_float', 'Et_absorp', 'Et_absorp_ext', 'EV_absorp_ext', 'EV_float_cancel', 'Et_float_exit_cum', 'EV_eq'], 'Et_eqcalendar', 'Et_eq_above', 'Et_eq_reg', 'Et_battery_service', 'EV_tempcomp', 'EV_hvd', 'EV_hvr', 'Evb_ref_lim', 'ETb_max', 'ETb_min', 'EV_soc_g_gy', 'EV_soc_gy_y', 'EV_soc_y_yr', 'EV_soc_yr_r', 'Elb_lim', 'EVa_ref_fixed_init', 'Eva_ref_fixed_pet_init'

.DumpInstantenousDataToJSONFile(outfile): Calls all instantaneous data internal class methods (ADCdata(), TemperatureData(), StatusData(), ChargerData(), MPPTData()), and dumps them into an outfile using json.dumps(). Preferably, the file's name will end in ".json" so the operating system can recognize that the file is in JSON format.

.DumpDailyDataToJSONFile(outfile): Calls all daily data internal class methods (Logger_TodaysValues() and ChargeSettings()) and dumps them into an outfile using json.dumps(). Preferably, the file's name will end in ".json" so the operating system can recognize that the file is in JSON format.

Chapter 6

BMS Code Design Document

6.1 Introduction

The Battery Management System (BMS) has a Programmable Logic Controller (PLC) in it. It can be used to monitor things such as charge dissipated, voltage levels of each individual cell, etc. The internal PLC can be monitored using a USB interface. This is what the Raspberry Pi will do using the interpreted Python Language. The Python language is dependent on classes to process data. So, I will be writing a Python class to extract data from the BMS PLC.

6.2 Dependencies

6.2.1 pyserial

This is a serial library for Python. It's easy to use, and free. Provided as-is. Install with pip install pyserial. Use by calling "import serial". ©2015 Chris Liechi clichi@gmx.net All Rights Reserved. Usage: https://pyserial.readthedocs.io/en/latest/pyse

6.2.2 crc8_dallas

This is a CRC-8 library that uses the exact polynomial we need for this application: $x^8 + x^2 + x + 1$. I had to modify the code to work with Python 3, since it was originally developed for Python 2.

6.2.3 sys

Comes with every distribution of python. Necessary to have a test bench.

Usage

https://docs.python.org/3/library/sys.html

6.2.4 json

Comes with every distribution of python. Necessary to convert dictionaries into JSON format and dump it directly to an outfile. Usage: https://docs.python.org/3/library/js
Initialization: Create a BMS() object, passing in PORT and BAUDRATE. This will initialize the serial connection to the BMS PLC. The BMS() object will destroy itself when python exits.

6.3 Classes

6.3.1 BMSStatistic()

Description

An internal class that contains a statistic from the sentence SS1(). Makes it easier to do mass data collection from a series of sentences if a request for every statistic available is made.

Variables

Every BMSStatistic object contains at least 4 variables:

- statisticIdentifier: what is the ID of this statistic (i.e. what protocol to use to process it)
- statisticValue: what is the value spat out (in decimal converted earlier from hexadecimal) from the BMS system?
- statisticValueAdditionalInfo: any additional information spat out from the BMS system (e.g. Cell ID)?
- timestamp: what time (in seconds since January 1, 1970 at 00:00 GMT) recorded. The BMS sys-tem records it in seconds since January 1, 2000 at 00:00 GMT).

Possible additional variables the class can have:

- Name: What is the real name of the statistic?
- Unit: what unit is the value recorded in (e.g. V, mA, W)? If N/A, the value is simply how many times an event occurred.

- Cell_ID: What is the ID of the cell the statistic came from?

Methods

- .dict(): converts this class into a dictionary with keys being the class variables it has, and their cor-responding values.
- .string(): converts this class into a string in JSON format.
- .__init__(): initializes the object. Takes statisticIdentifi-er,statisticValue,statisticValueAdditi Upon creation, runs a specific protocol to process the data based on its statisticIdentifier.

6.3.2 BMS()

Description

A class that can read the BMS system. Call the .DumpToJSONFile() method to dump all data to an outfile. Details below.

Variables

Every BMS() object contains at least 3 variables:

- PORT: what port number is the Raspberry Pi reading from?
- BAUDRATE: at what baudrate (in bits/second) is the Raspberry Pi reading at?
- ser: the serial object (from the pyserial library) that sends and receives data from the BMS.

Methods

- .VR1(): returns a dictionary containing hardware type, serial number, and firmware version.
- .BB1(): returns a dictionary containing number of cells, minimum balancing rate, and average cell balancing rate.
- .BB2(): returns a dictionary containing cell string number, first cell number, size of group, and in-dividual cell module balancing rate of each cell group.

- .BC1(): returns a dictionary containing battery charge, battery capacity, and state of charge.

- .BT1(): returns a dictionary containing the summary of cell module temperature values of the bat-tery pack.

- .BT2(): This sentence contains individual cell module temperatures of a group of cells. Each group consists of 1 to 8 cells. This sentence is sent only after Control Unit receives a request sentence from external device, where the only data field is '?' symbol. The normal response to BT2 request message, when battery pack is made up of two parallel cell strings:

- .BT3(): This sentence contains the summary of cell temperature values of the battery pack. It is sent periodically with configurable time intervals for active and sleep states (Data Transmission to Display Period).

- .BT4(): This sentence contains individual cell temperatures of a group of cells. Each group con-sists of 1 to 8 cells.

- .BV1(): Returns a dictionary containing a summary of cell voltages. contains number of cells, min-imum cell voltage, maximum cell voltage, average cell voltage, and total voltage.

- .BV2(): This sentence contains individual voltages of a group of cells. Each group consists of 1 to 8 cells.

- .CF2(parameterID): returns the parameter data of the parameter ID. Must be processed separately.

- .CG1(): This sentence contains the statuses of Emus internal CAN peripherals. Can include CAN current sensor, and CAN cell group, along with the cell group number.

- .CN1(): This sentence reports the CAN messages received on CAN bus by Emus BMS Control Unit, if "Send to RS232/USB" function is enabled.

- .CN2(): This sentence reports the CAN messages sent on CAN bus if "Send to RS232/USB func-tion is enabled.

- .CS1(): Returns a dictionary containing the parameters and status of the charger. Includes set volt-age, set current, actual voltage, actual current, number of connected charger, and CAN charger status.

- .CV1(): Returns a dictionary containing the values of total voltage of battery pack, and current flowing through the battery pack.
- .DT1(): This is a placeholder for an electric vehicle sentence. The code is being specifically pro-grammed for a greenhouse, so this sentence will not be programmed and return an error.
- .FD1(): This sentence resets the unit to factory defaults. Use at your own risk.
- .IN1(): This sentence returns a dictionary containing the status of the input pins (AC sense, IGN In, FAST_CHG).
- .LG1(clear): This sentence can either: retrieve events logged, or clear the event logger.
  - Retrieve Events Logged: pass in 'N' or a null value. Every event is recorded in a dictionary form like this: ["log event number 1"]: ["log event": "No event", "unix time stamp": 1567014467
    Possible events:
    * No Event
    * BMS started
    * Lost communication to cells
    * Established communication to cells
    * Cells voltage critically low
    * Critical low voltage recovered
    * Cells voltage critically high
    * Critical high voltage recovered
    * Discharge current critically high
    * Discharge critical high current recovered
    * Charge current critically high
    * Charge critical high current recovered
    * Cell module temperature critically high
    * Critical high cell module temperature recovered
    * Leakage detected
    * Leakage recovered
    * Warning: low voltage – reducing power
    * Power reduction due to low voltage recovered
    * Warning: high current – reducing power

        - Power reduction due to high current recovered
        - Warning: High Cell module temperature – reducing power
        - Power reduction due to high cell module temperature recovered.
        - Charger connected
        - Charger disconnected
        - Started pre-heating stage
        - Started pre-charging stage
        - Started main charging stage
        - Started balancing stage
        - Charging finished
        - Charging error occurred
        - Retrying charging
        - Restarting charging
        - Cell Temperature Critically high
        - Critically high cell temperature recovered
        - Warning: High cell temperature – reducing power
        - Unix Timestamp: Time recorded in seconds since January 1, 1970 at 00:00 GMT.
        - Log event number: what event number it
    - Clear Event Logger: pass in the ascii value 'C' or 'c'.

- .OT1(): Returns a dictionary containing the status of output pins (Charger pin, heater, bat. low, buzzer, chg. ind.)

- .PW1(request, password): Check the admin status with PW1('?'). Log into BMS system with PW1('P', password). Logout with PW1().

- .PW2(request, newPassword): Sets a new password, or clears a password. To set new password, call PW2('S',"mynewpassword"), and substitute "mynewpassword" with whatever password you want. To clear your password, call PW2('C'). Returns true if successful, false if not successful.

- .RC1(): Resets the current sensor reading to zero. Used after current sensor is initially installed.

- .RS1(): Resets the Emus BMS control unit entirely. Like a sudo reboot on a linux machine. Re-quires admin clearance.

- .RS2(): This sentence is used to retrieve the reset source history log.
- .SC1(percentage): This sentence sets the current state of the charge of the battery in
- .SS1(request, statisticIdentifier): This sentence can either: Request All Statistics, Request a Specific Statistic (pass in a number), or Clear all unprotected statistics.
  - Request All Statistics: call SS1('?'). This will return all statistics the BMS currently has in the form of dictionaries converted from BMSstatistic classes.
  - Request a Specific Statistic: call SS1('N', number), where number is a positive integer. Re-turns a dictionary containing a single statistic.
  - Clear all unprotected statistics: call SS1('c').
- .ST1(): This sentence returns the status of the BMS in dictionary form. It contains these statistics:
  - Charging flags: charging stage, last charging error, last charging error parameter (for de-bugging purposes), stage duration,
  - Status flags: Valid cell voltages, Valid balancing rates, valid number of live cells, battery charging finished, valid cell temperatures
  - Protection flags: undervoltage, overvoltage, discharge overcurrent, charge overcurrent, cell module overheat, leakage, no_cell_comm, cell_overheat
  - Power flags: warning: power reduction: low voltage, warning: power reduction: high cur-rent, warning: power reduction: high cell module temperature, warning: power reduction: high cell temperature
  - Pin flags: no_function, speed_sensor, fast_charge_switch, ign_key, charger_mains_AC_sense, heater_enable, sound_buzzer, battery_low, charging_indication, charger_enable_output, state_of_charge, battery_contactor, battery_fan, current_sensor, leakage_sensor, power_reduction, charging_interlock, analog_charger_control, ZVU_boost_charge, ZVU_slow_charge, ZVU_buffer_mode, BMS_failure, equaliza-tion_enable, DCDC_control, ESM_rectifier_current_limit, contactor_precharge
- .TD1(): Returns time and date according the BMS in dictionary form. Returns year, month, day, hour, minute, second, and the amount of uptime the unit has in seconds.

- .TC2(): Used to calibrate cell temperature by a PC, not a microcontroller.
- .DumpToJSONfile(outfile): Calls all data methods listed above, then dumps all data returned into an outfile in JSON format.

Note: Every data harvesting method returns “Cannot communicate to cells” if it fails. Private Methods: bitAt(bitfield, position): Description: Returns True if the bit is 1 at the position of the bitfield, False of 0. Used to analyze bitfields with fewer lines.

Chapter 7

Website Design Document

shit

Chapter 8

Troubleshooting

8.1 Viewing Charge Controller Data using MSView

Here's how to view live data using MSView from your PC:

8.1.1 Step 1: Downloading the Program

First, download MSView from Morningstar's Corporate Website, located here: https://www.morningstarcorp.com/msview/ Figure 8.2 shows what the website looks like.

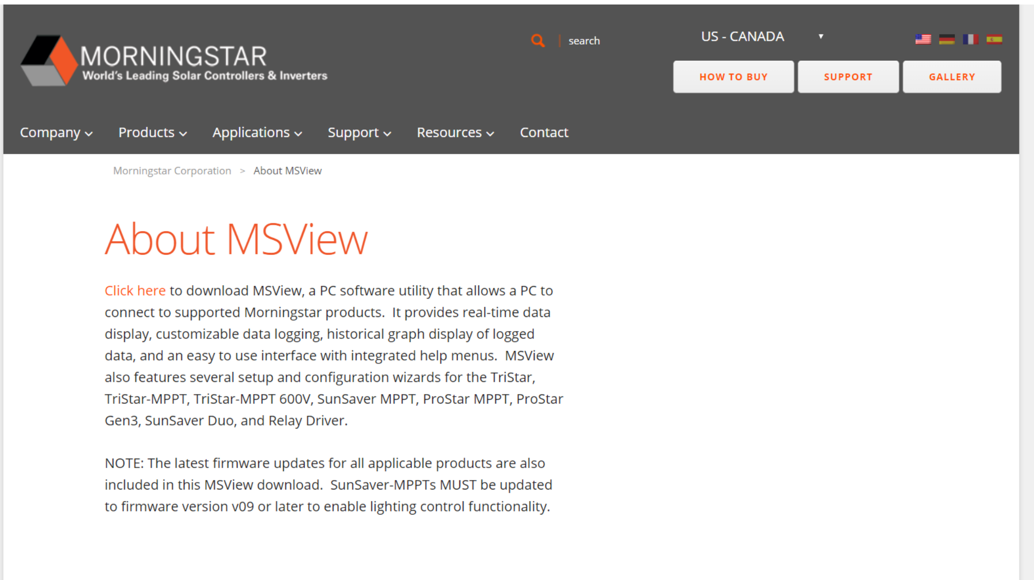


Figure 8.1: Menu 1

8.1.2 Step 2: Connecting the Morningstar

If you're using a RS-232 to USB serial connector to connect your PC, connect it now.

8.1.3 Step 3: Powering the Morningstar

Connect a 12V power supply to the battery terminal of the Tristar MPPT Charge Controller. It should draw approximately 189mA of current just for management.

8.1.4 Step 4: Using MSView

Open MSView. Under Devices, select Search for Connected Devices. Your Tristar MPPT should show up under whatever virtual COM port you connected your RS-232 to USB connector to. Double-click it. You should see something like this appear.

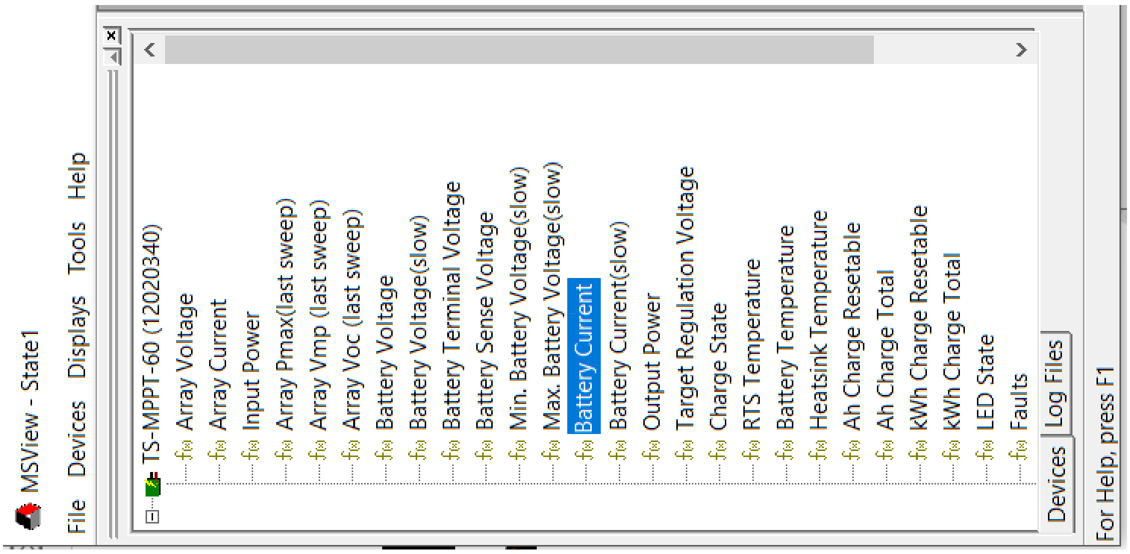


Figure 8.2: First Menu upon initialization

8.1.5 Step 5: Viewing Live Data

Under Displays, select New. Select 'State' when a dialog box saying New Display appears and press OK. Drag and drop whatever variables you want. Our Tristar MPPT can log:

- Array Voltage (Array is shorthand for our solar panel array),
- Array Current, Input Power (how much power our solar panels are producing),
- Array Pmax,
- Array Vmp,
- Array Voc,
- Battery Voltage (The Voltage of our Battery),
- Battery Voltage (slow),
- Battery Terminal Voltage,
- Battery Sense Voltage (there's a remote voltage sensor port on our Tristar MPPT that we can connect for safety),
- Min. Battery Voltage (slow),
- Max. Battery Voltage (slow),
- Battery Current,
- Battery Current(slow),
- Output Power (how much power we're consuming),
- target regulation voltage,
- charge state (Float, equalization, etc.),
- RTS temperature,
- Battery Temperature,
- Heatsink Temperature,
- Ah Charge Resetable,
- Ah Charge Total,
- kWh Charge Resetable,
- kWh Charge Total,

- LED State, Faults (did someone change the DIP switch?),
- Faults Daily,
- Alarms (did someone overcharge?),
- Alarms Daily,
- Hourmeter (how long have we been using this thing?),
- Settings Switches(the state of our DIP switch).

8.1.6 Step 6: Programming the Tristar MPPT using MSView

There are many different types of batteries: Lithium Ion, Lead-Acid, Lithium Polymer batteries, LiFePO4 batteries, etc. Each one of them requires its own different programming. The Tristar MPPT has 7 built-in programmable settings. To custom-program our Tristar MPPT to handle a battery, follow these steps:

Under Tools, click Tristar MPPT Setup Wizard. Read and click OK for both of the warnings against switching DIP switches while the power is applied.

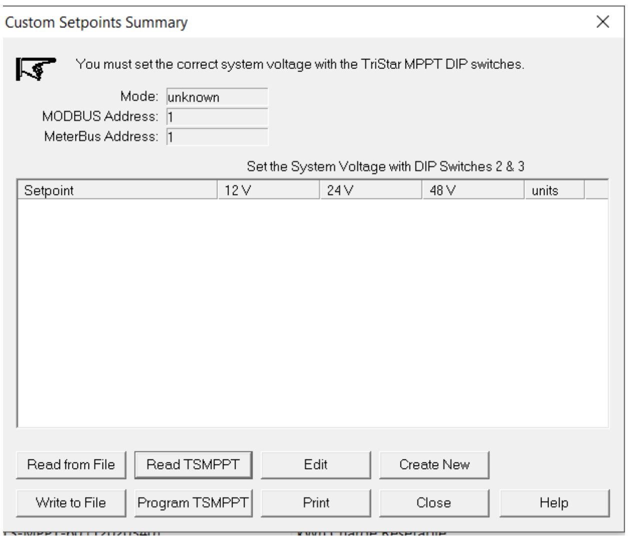


Figure 8.3: TSMPPT Setup Wizard

When on the screen that looks like Figure8.3, Click Read TSMPPT. Make sure it's set to Solar Charge Control. If you're using a serial connection, make sure you're using the right COM port. On our Tristar MPPT, the MODBUS address is 1.

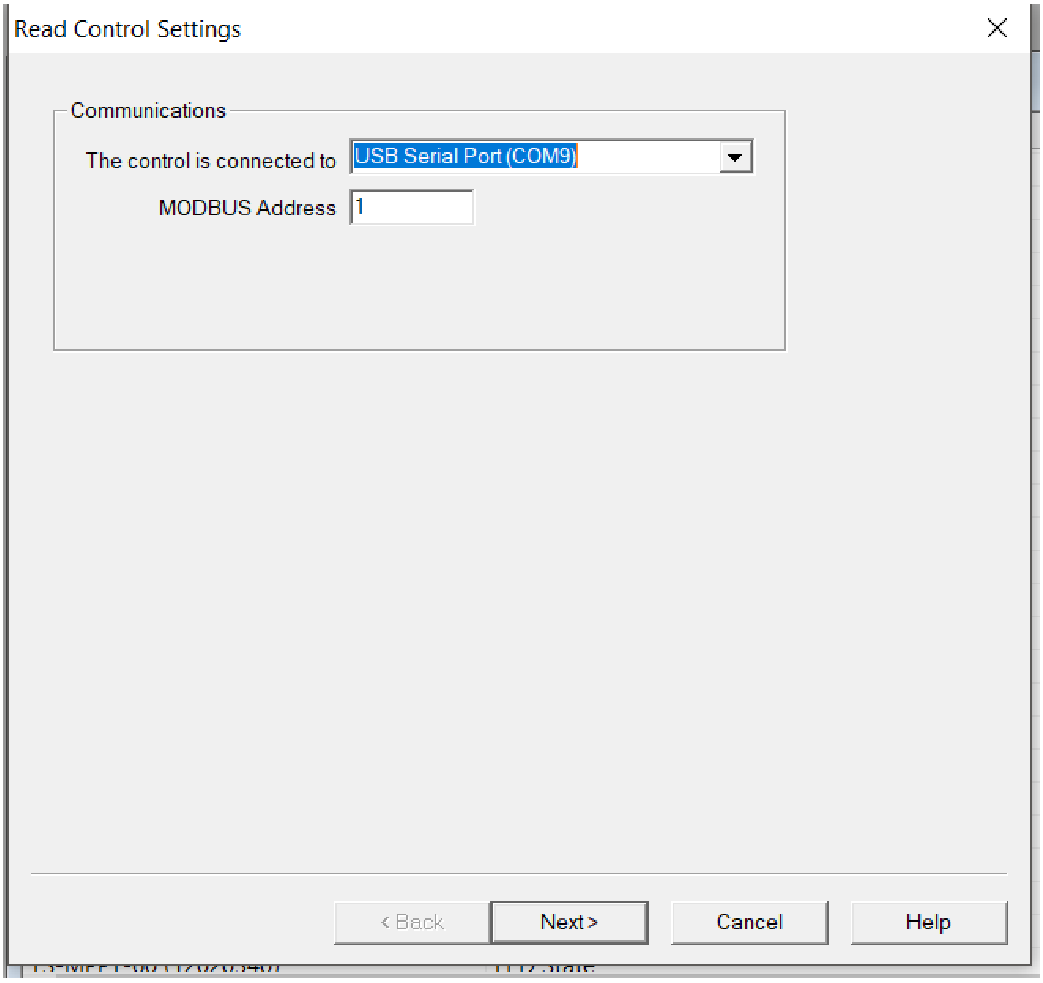


Figure 8.4: Communications settings

The Setup wizard should look something like this afterwards if reading the settings was successful.

Read the settings you extracted from the Tristar MPPT first before you reprogram it. If the settings are not to your liking (i.e. the batteries will not charge properly), you can reprogram the Tristar MPPT. If you have a file already saved, click Read from File, and all your previously made changes will be loaded. If you don't have a file made already, then click Edit. This will allow you to make your own custom settings. You can change all these

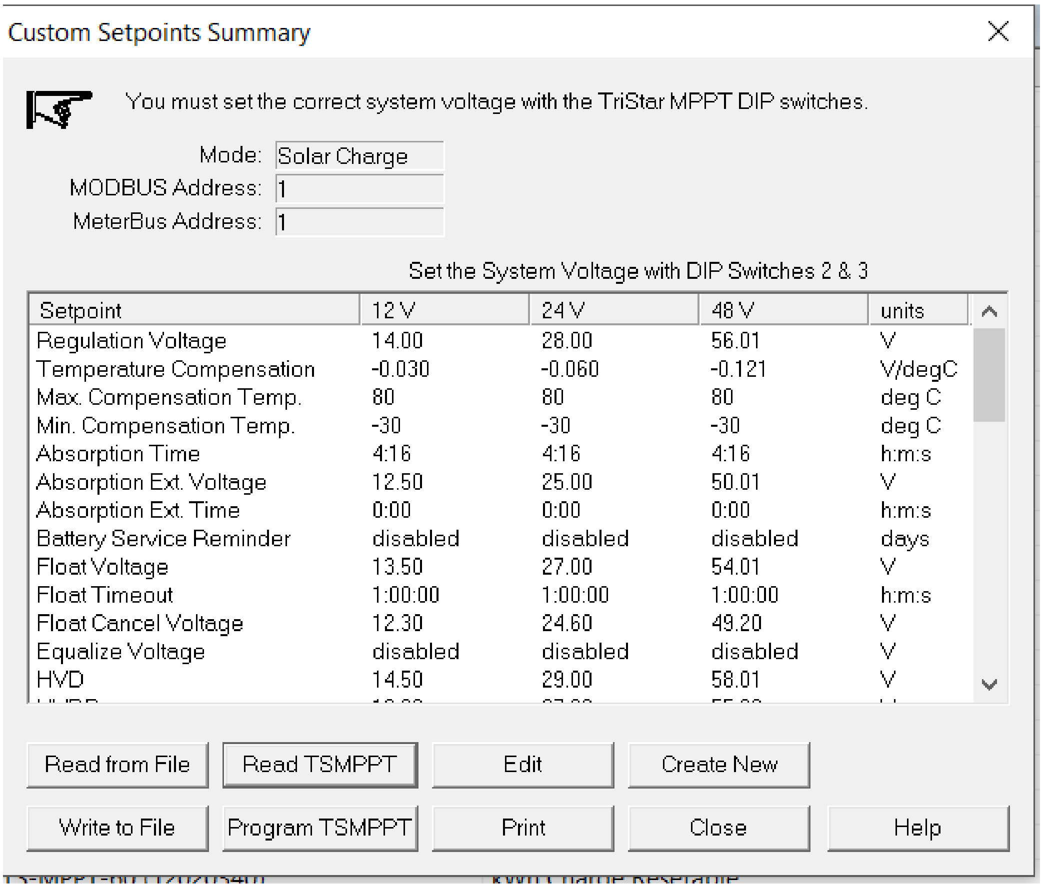


Figure 8.5: Tristar Morningstar Charge Settings Screen

settings shown below:

Once all of your changes are made, you can save it to a file, just in case you need to reprogram the Tristar MPPT. Save it by using Write to File.

Once you have your settings loaded, you need to program the Tristar MPPT. Click Program TSMPPT, and make sure the COM port is correct.

Now, your Tristar should be ready to be used with your batteries!

8.1.7 Final Step

Oh, one more thing! If you want to use custom charging settings, DIP switches 4,5, and 6 must be switched on! That's how the custom settings work! It even says so in MSView!
Also, this is a CHARGE CONTROLLER! It won't manage all your batteries for you! You must use a BMS system for that. Luckily, we have one. I've

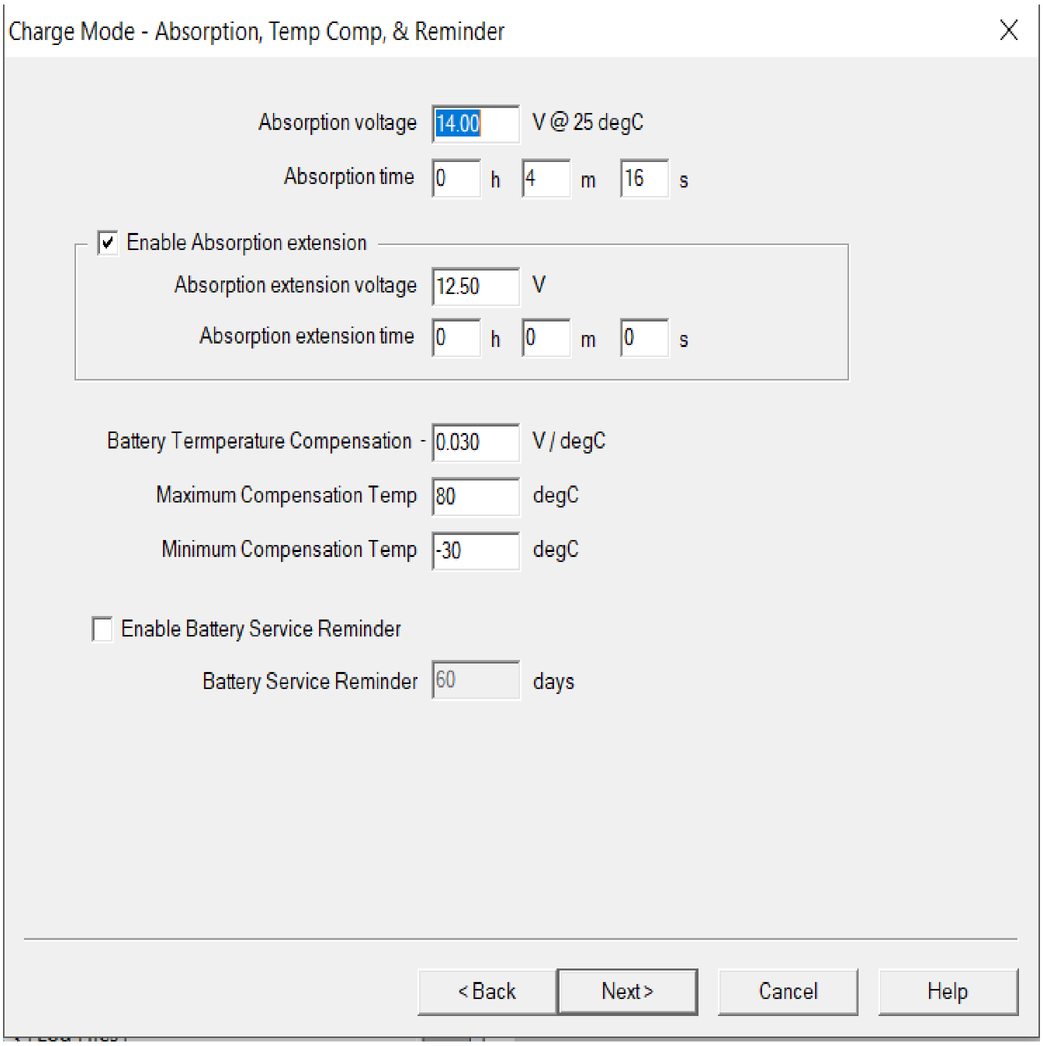


Figure 8.6: Absorption, Temperature Compensation, and Reminder Settings

got a separate document for that. It can help you balance out the charges on your batteries so that every battery has an even charge, and none of them use too many life cycles at the same time.

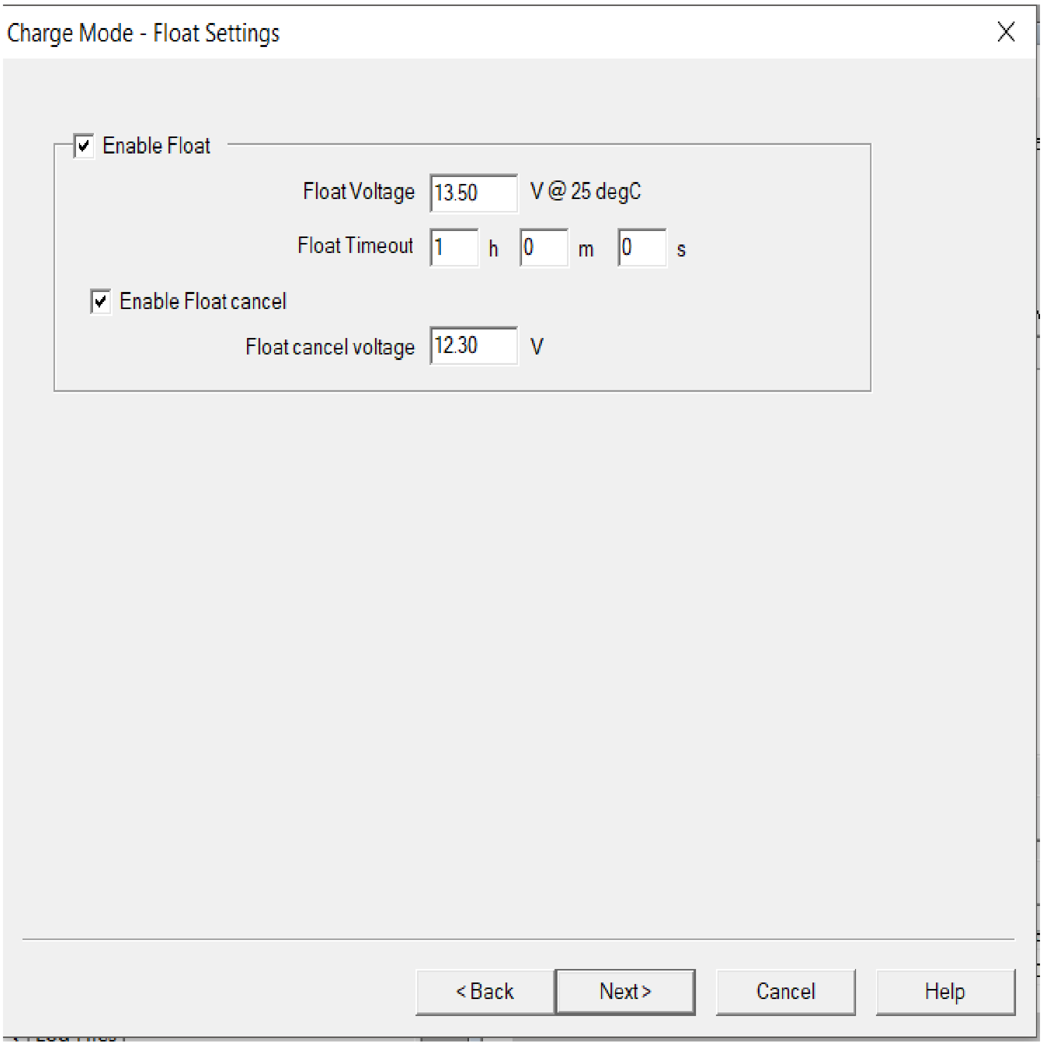


Figure 8.7: Float Settings

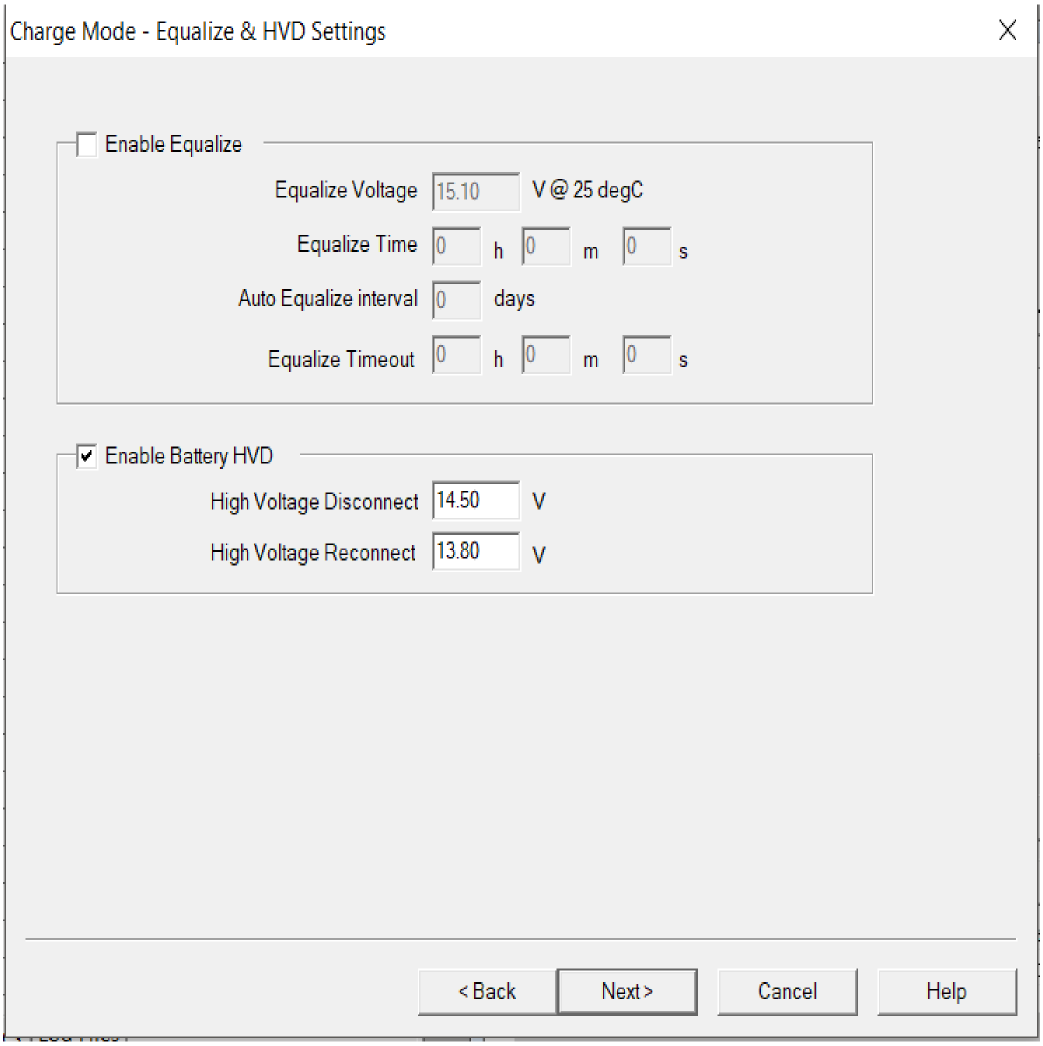


Figure 8.8: Equalize and HVD Settings

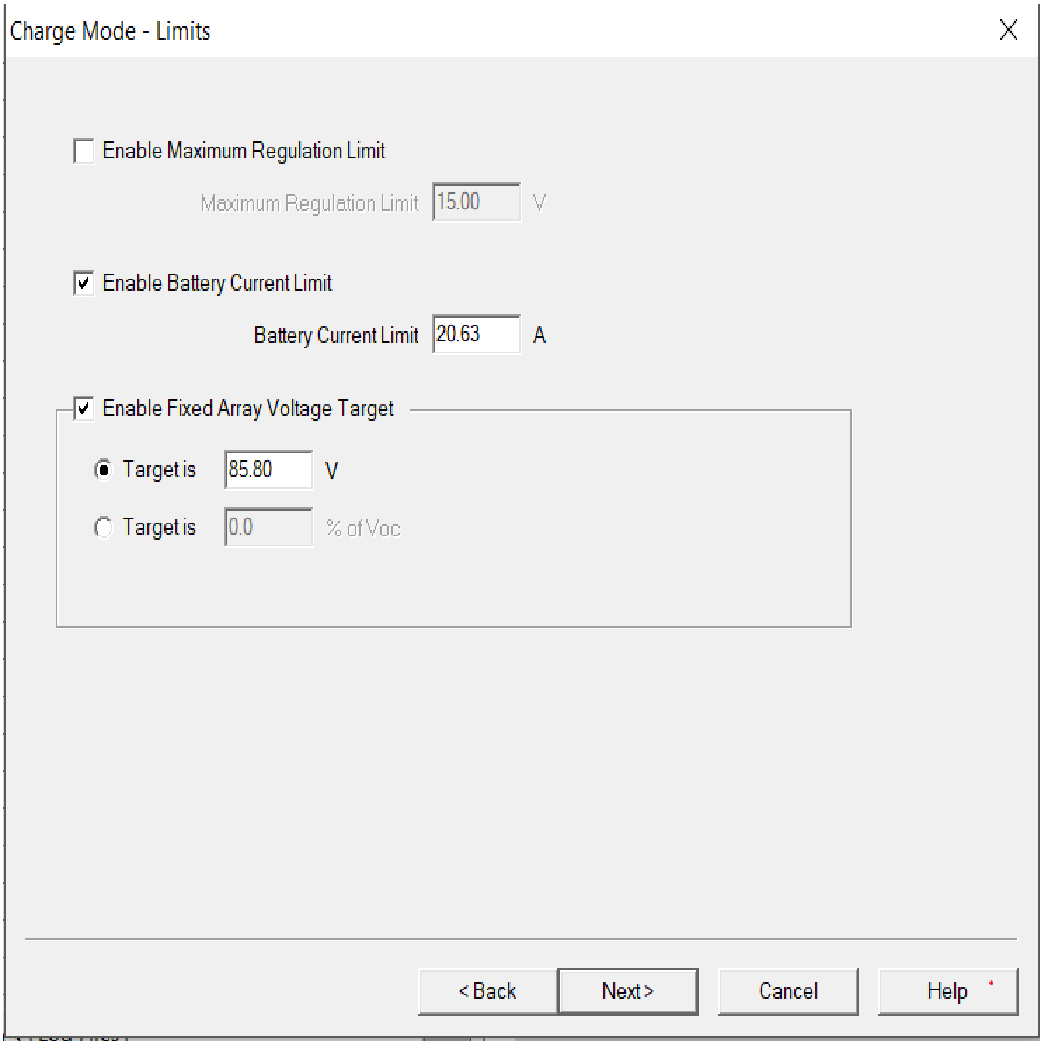


Figure 8.9: Limits Settings

Figure 8.10: LED Settings

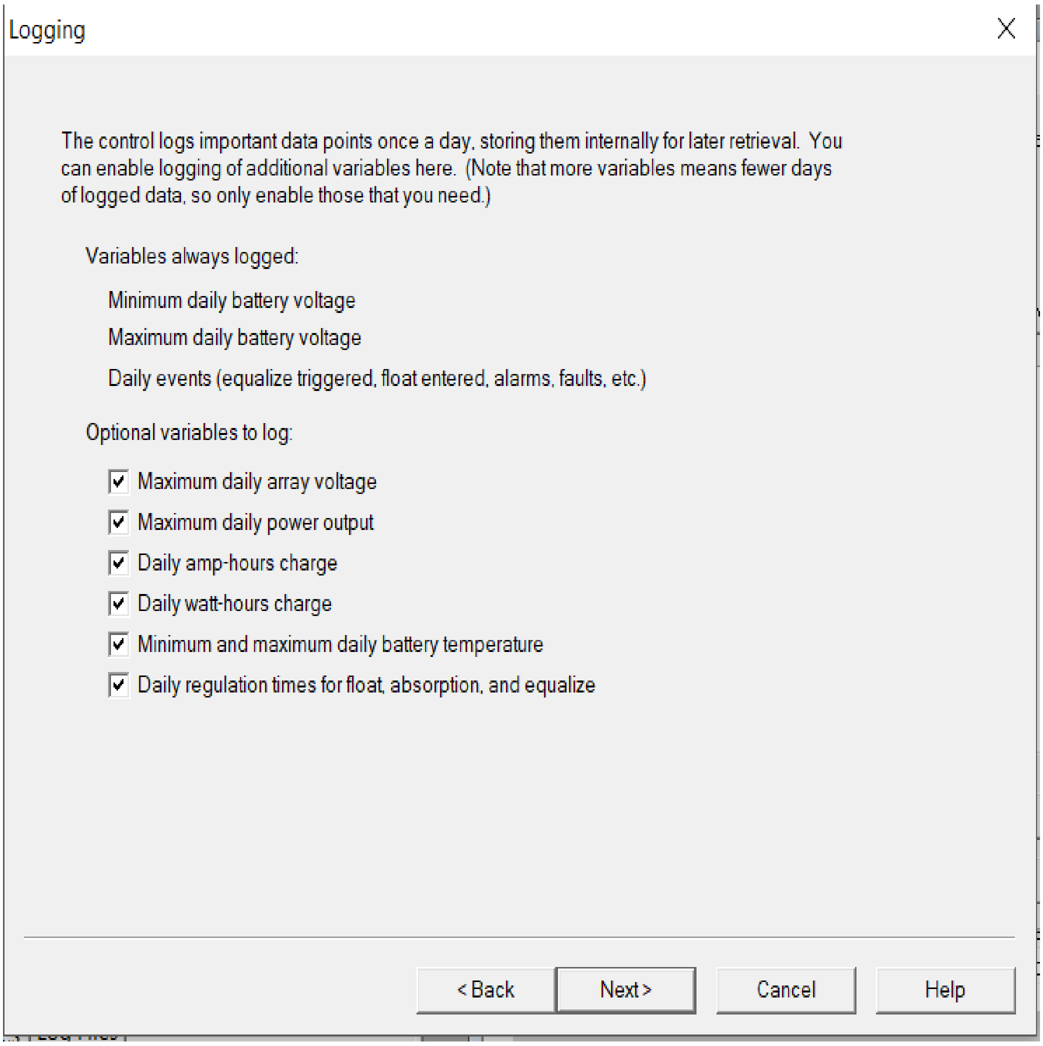


Figure 8.11: Logger Settings

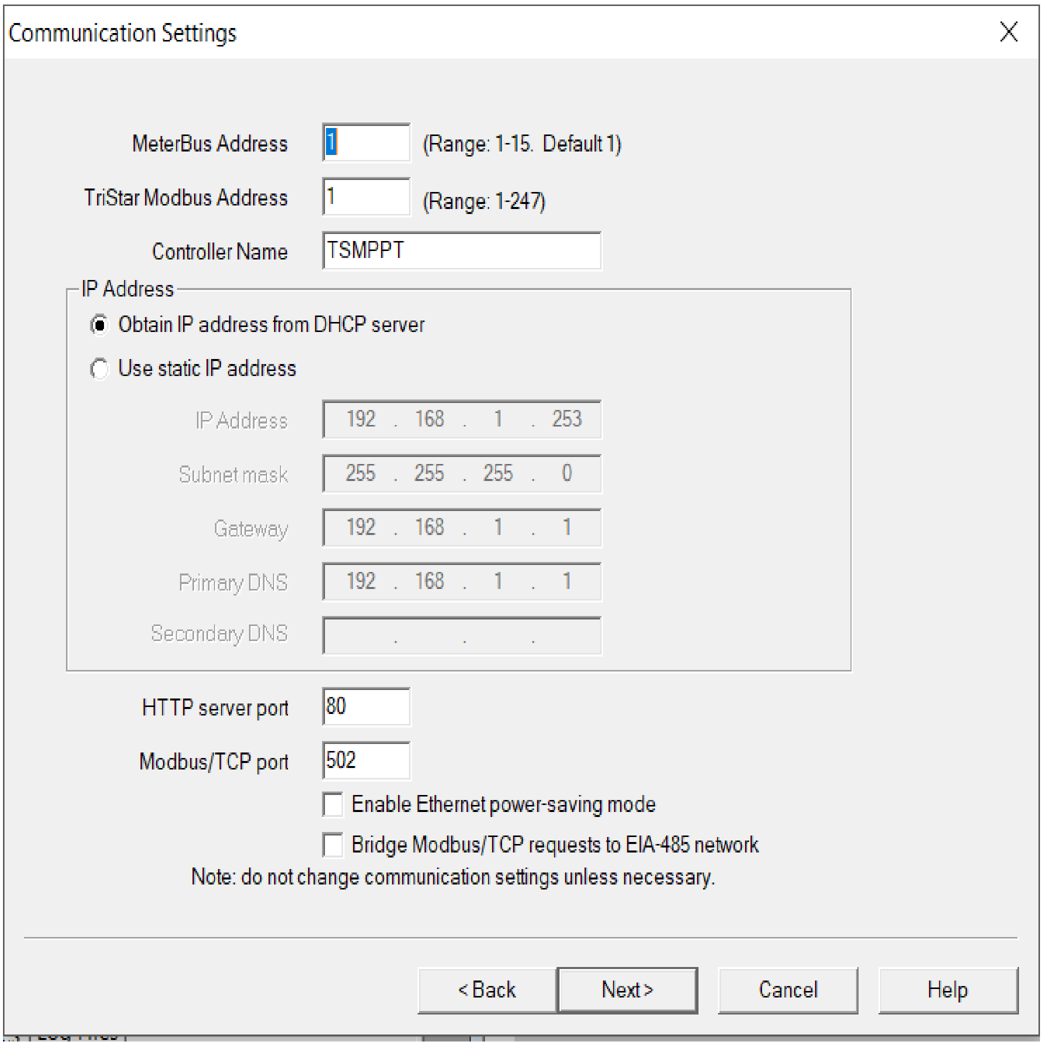


Figure 8.12: Commmunication Settings

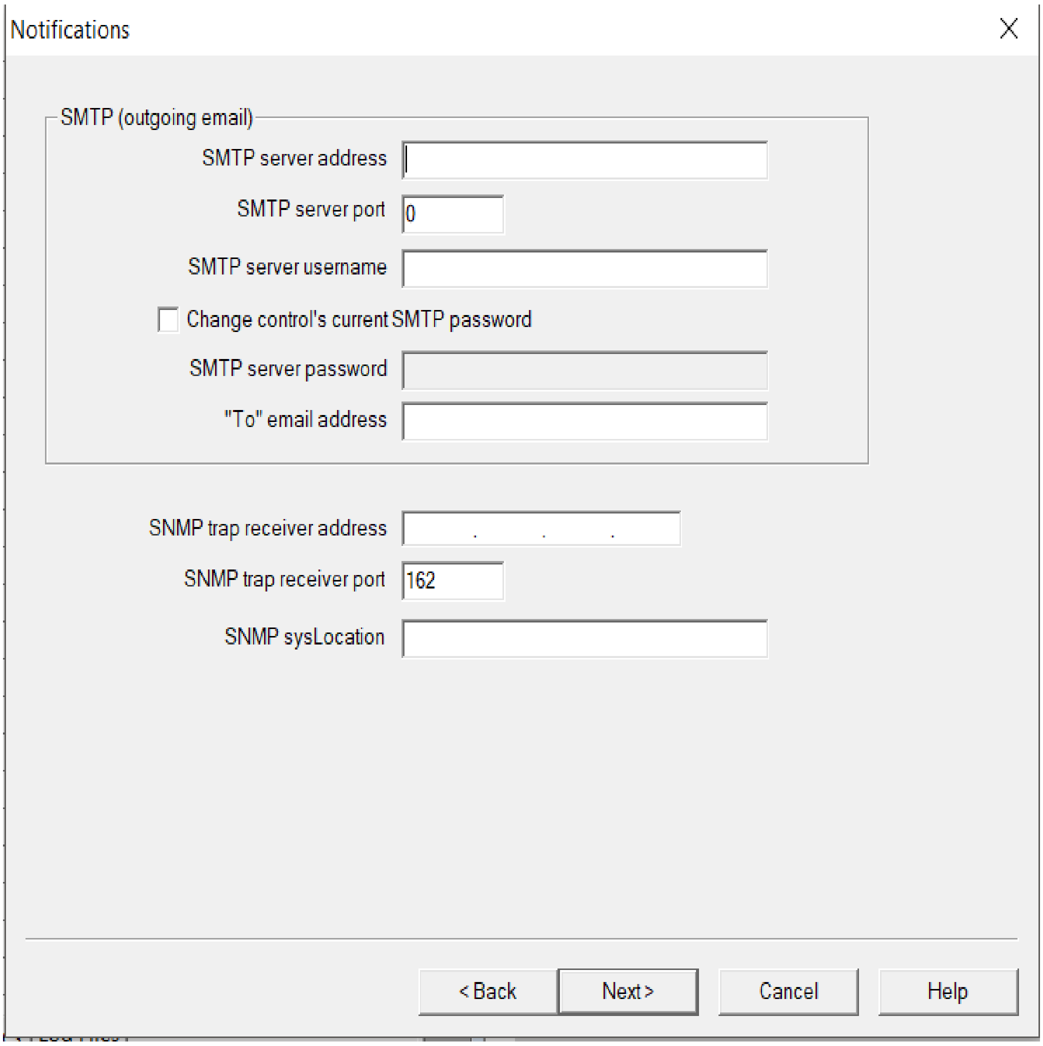


Figure 8.13: Mail Server Settings (TCP Exclusive)

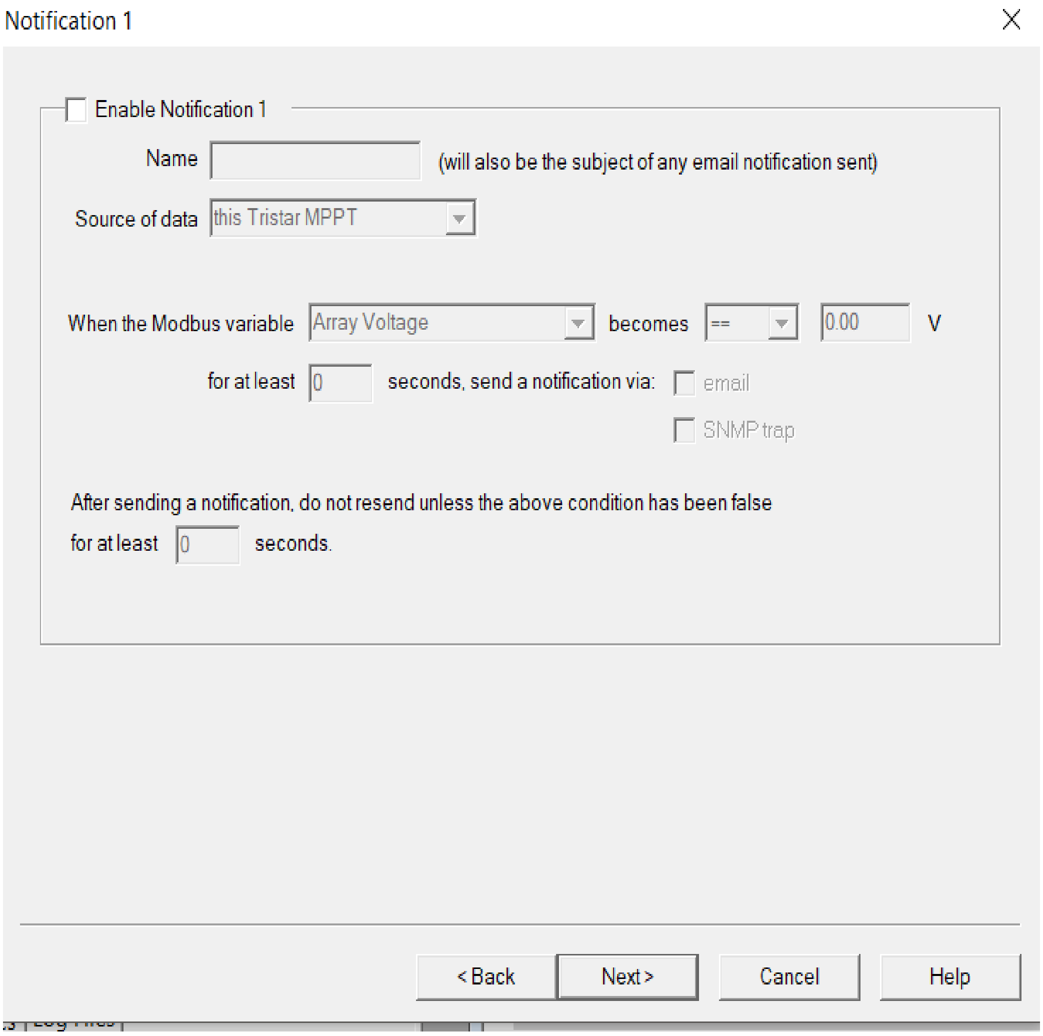


Figure 8.14: Notification 1

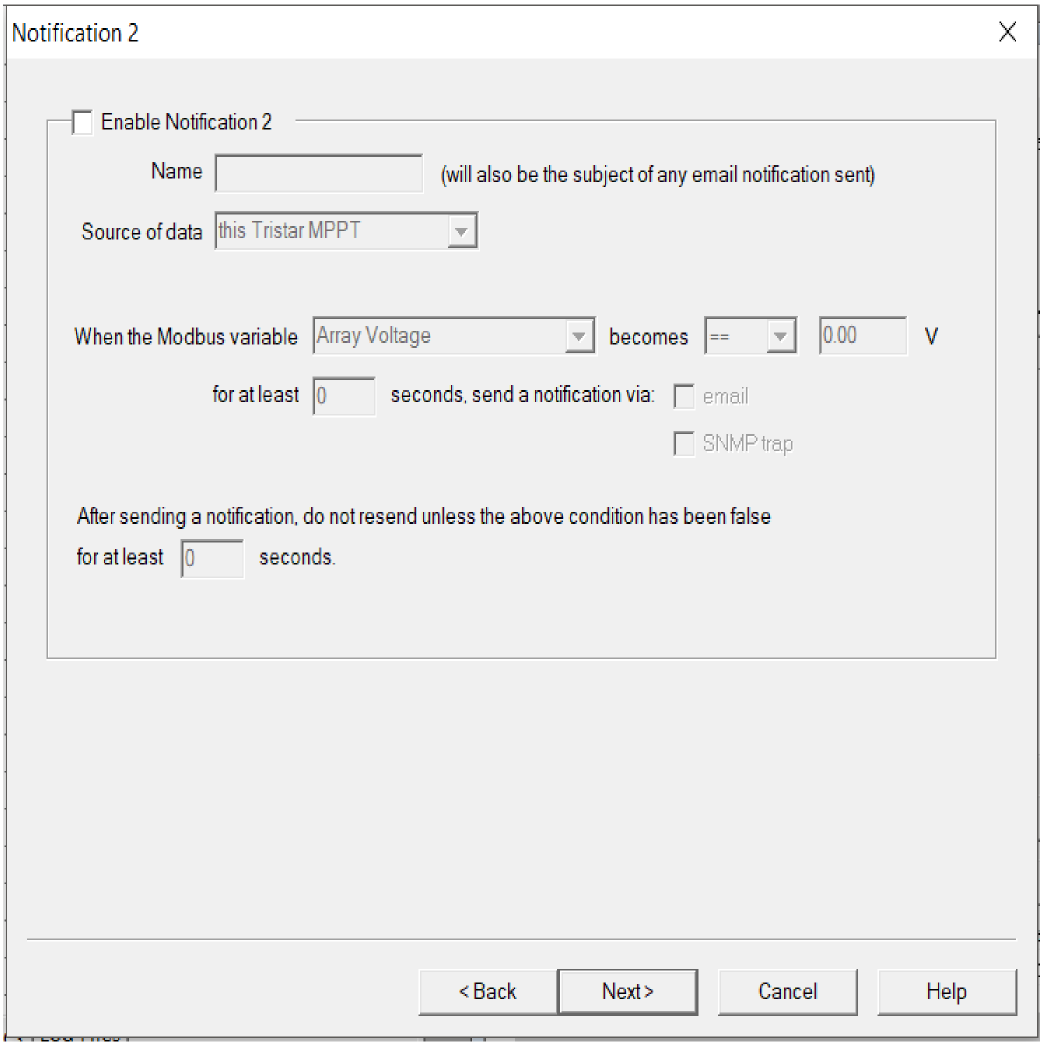


Figure 8.15: Notification 2

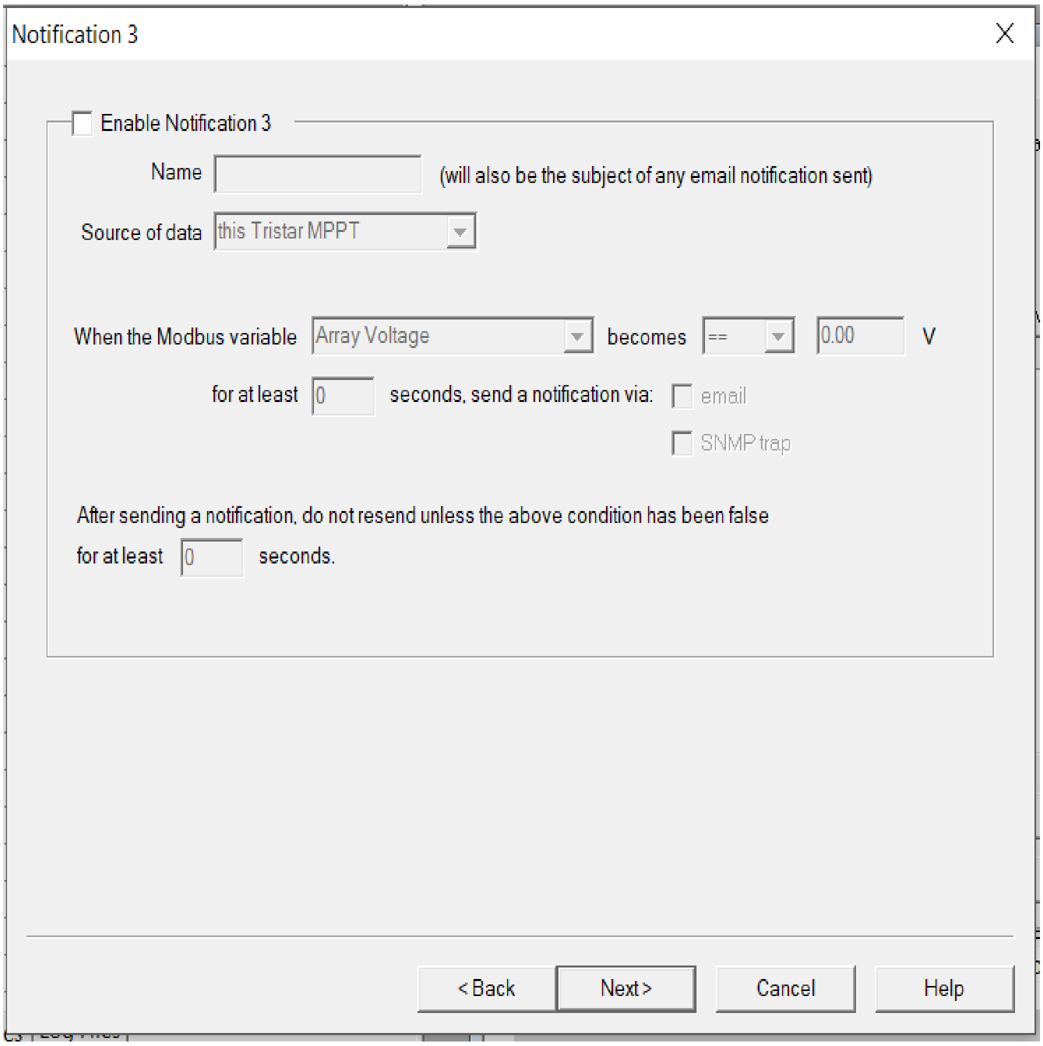


Figure 8.16: Notification 3

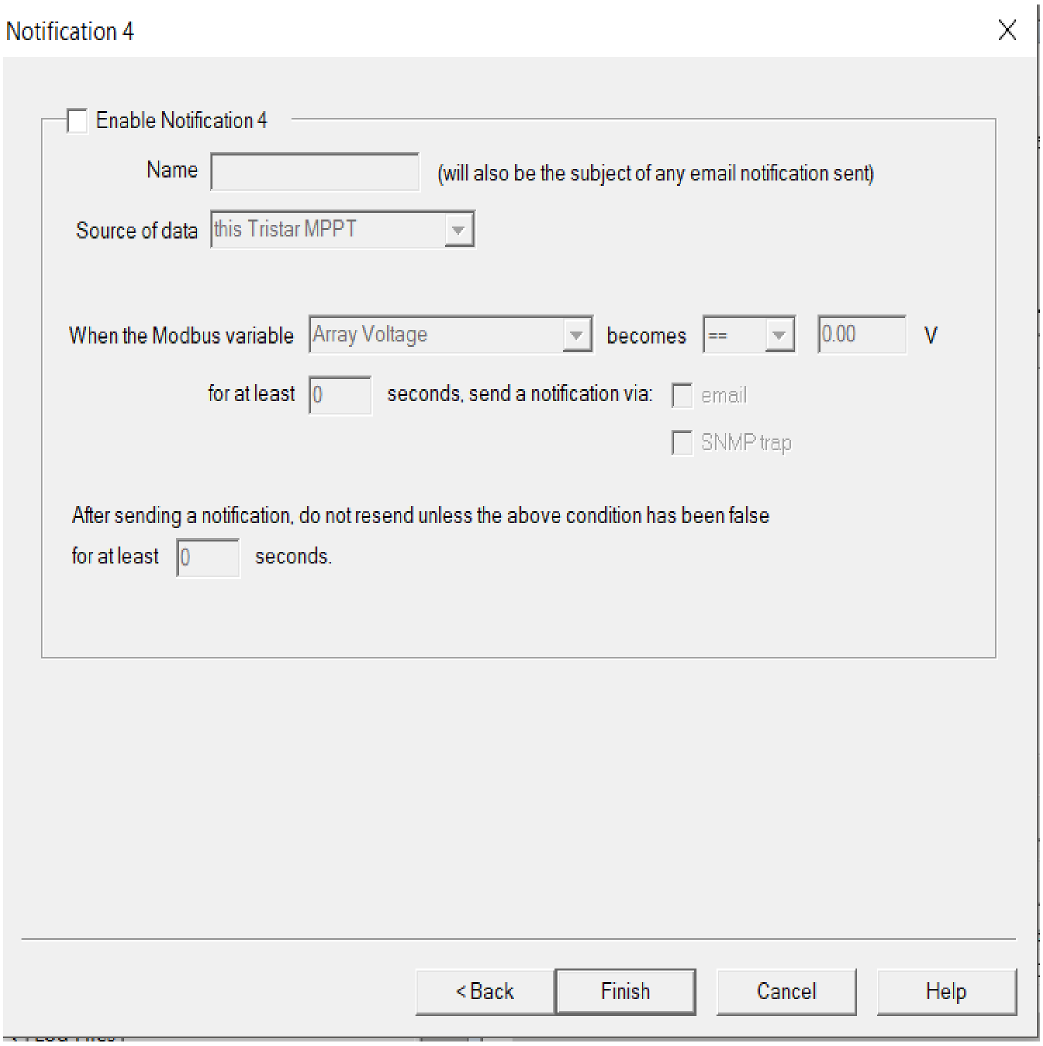


Figure 8.17: Notification 4

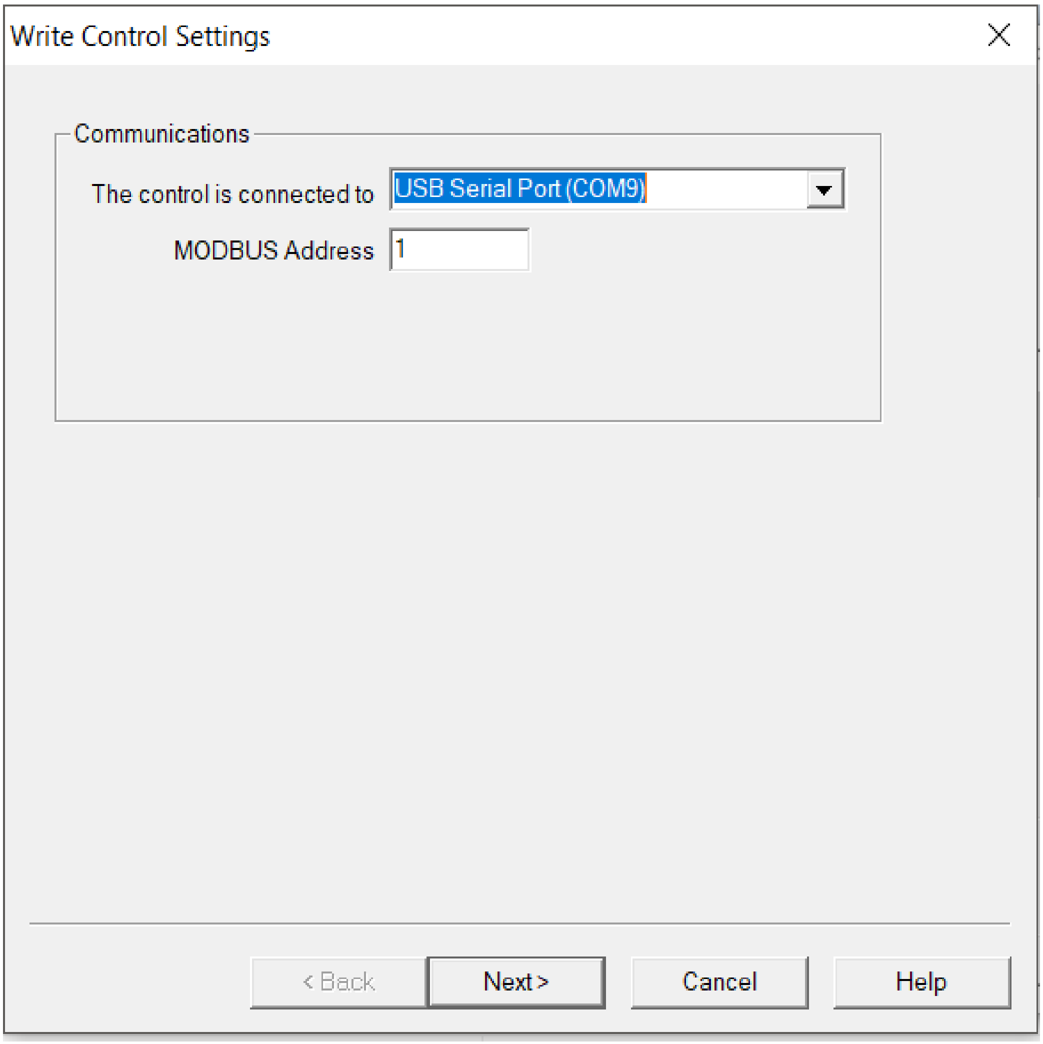


Figure 8.18: Write Control Communication Settings

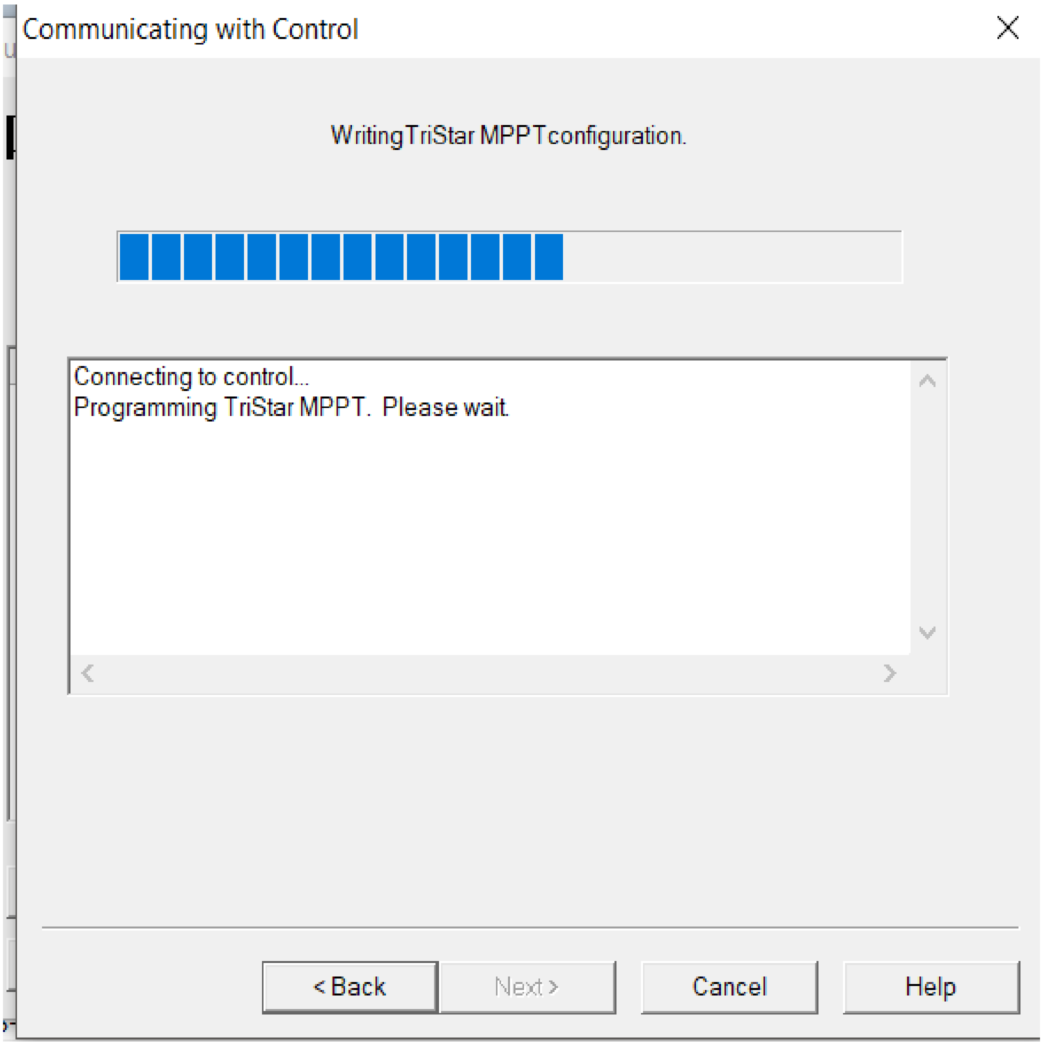


Figure 8.19: Writing Settings to the Tristar Screen

Chapter 9

Datasheets

9.1 TSMMPT datasheet

9.2 Sensor datasheet

9.2.1 TSL2591

TSL2591

Datasheet - Apr. 2013 - ams163.5

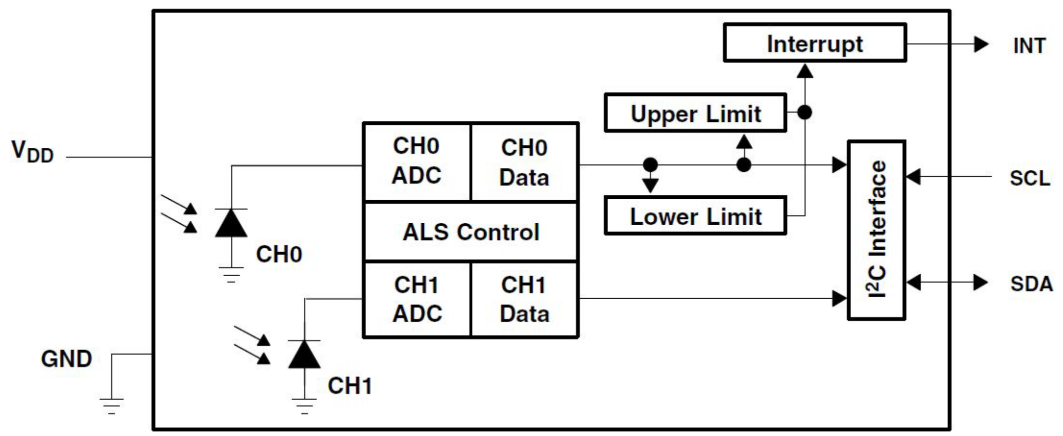
General Description

The TSL2591 is a very-high sensitivity light-to-digital converter that transforms light intensity into a digital signal output capable of direct I^2C interface. The device combines one broadband photodiode (visible plus infrared) and one infrared-responding photodiode on a single CMOS integrated circuit. Two integrating ADCs convert the photodiode currents into a digital output that represents the irradiance measured on each channel. This digital output can be input to a microprocessor where illuminance (ambient light level) in lux is derived using an empirical formula to approximate the human eye response. The TSL2591 supports a traditional level style interrupt that remains asserted until the firmware clears it.

Figure TSL2591 – 1:
Key Benefits and Features

Benefits	Features
Approximates Human Eye Response	Dual Diode
Flexible Operation	Programmable Analog Gain and Integration Time
Suited for Operation Behind Dark Glass	600M:1 Dynamic Range
Low Operating Overhead	• Two Internal Interrupt Sources • Programmable Upper and Lower Thresholds • One Interrupt Includes Programmable Persistence Filter
Low Power 3.0 µA Sleep State	User Selectable Sleep Mode
I^2C Fast Mode Compatible Interface	• Data Rates up to 400 kbit/s • Input Voltage Levels Compatible with 3.0V Bus

Figure TSL2591 – 2:
Block Diagram



Detailed Description

The TSL2591 contains two integrating analog-to-digital converters (ADC) that integrate currents from two photodiodes. Integration of both channels occurs simultaneously. Upon completion of the conversion cycle, the conversion result is transferred to the Channel 0 and Channel 1 data registers, respectively. The transfers are double-buffered to ensure that the integrity of the data is maintained. After the transfer, the device automatically begins the next integration cycle.

Communication with the device is accomplished through a standard, two-wire I^2C serial bus. Consequently, the TSL2591 can be easily connected to a microcontroller or embedded controller. No external circuitry is required for signal conditioning. Because the output of the device is digital, the output is effectively immune to noise when compared to an analog signal.

The TSL2591 also supports an interrupt feature that simplifies and improves system efficiency by eliminating the need to poll a sensor for a light intensity value. The primary purpose of the interrupt function is to detect a meaningful change in light intensity. The concept of a meaningful change can be defined by the user both in terms of light intensity and time, or persistence, of that change in intensity. The device has the ability to define two sets of thresholds, both above and below the current light level. An interrupt is generated when the value of a conversion exceeds either of these limits. One set of thresholds can be configured to trigger an interrupt only when the ambient light exceeds them for a configurable amount of time (persistence) while the other set can be configured to trigger an immediate interrupt.

Pin Assignment

The TSL2591 pin assignments are described below.

Figure TSL2591 – 3:
Pin Diagram

Package FN Dual Flat No-Lead (Top View): Package drawing is not to scale.

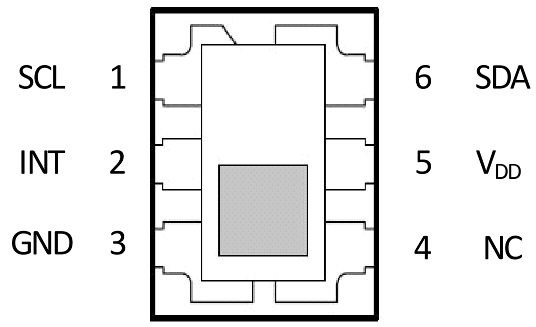


Figure TSL2591 – 4:
Pin Description

Pin Number	Pin Name	Description
1	SCL	I^2C serial clock input terminal
2	INT	Interrupt — open drain output (active low).
3	GND	Power supply ground. All voltages are referenced to GND.
4	NC	No connect — do not connect.
5	V_{DD}	Supply voltage
6	SDA	I^2C serial data I/O terminal

Ordering Information

Figure TSL2591 – 5:
Ordering Information

Ordering Code	Address	Interface	Delivery form
TSL25911FN	0x29	I^2C $V_{bus} = V_{DD}$ Interface	ODFN-6
TSL25913FN*	0x29	I^2C V_{bus} = 1.8V	ODFN-6

*Contact factory for availability.

Notes:
1. All products are RoHS compliant and ams green.
2. Buy our products or get free samples online at www.ams.com/ICdirect
3. Technical Support is available at www.ams.com/Technical-Support
4. For further information and requests, email us at sales@ams.com
5. (or) find your local distributor at www.ams.com/distributor
6. Please contact ams for alternate address device availability.

Absolute Maximum Ratings

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under "Operating Conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Figure TSL2591 – 6:
Absolute Maximum Ratings

Parameter	Min	Max	Units	Comments
Supply voltage, V_{DD}		3.8	V	All voltages are with respect to GND
Input terminal voltage	-0.5	3.8	V	
Output terminal voltage	-0.5	3.8	V	
Output terminal current	-1	20	mA	
Storage temperature range, T_{stg}	-40	85	ºC	
ESD tolerance, human body model		2000	V	

Electrical Characteristics

All limits are guaranteed. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

Figure TSL2591 – 7:
Recommended Operating Conditions

Symbol	Parameter	Min	Typ	Max	Units
V_{DD}	Supply voltage	2.7	3	3.6	V
T_A	Operating free-air temperature	-30		70	°C

Figure TSL2591 – 8:
Operating Characteristics, V_{DD}=3V, T_A=25°C (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
I_{DD}	Supply Current	Active Sleep state - no I^2C activity		275 2.3	325 4	µA
V_{OL}	INT, SDA output low voltage	3mA sink current 6mA sink current	0 0		0.4 0.6	V
I_{LEAK}	Leakage current, SDA, SCL, INT pins		-5		5	µA
V_{IH}	SCL, SDA input high voltage		0.7 V_{DD}			V
V_{IL}	SCL, SDA input low voltage				0.3 V_{DD}	V

Figure TSL2591 – 9:
ALS Characteristics, V_{DD}=3V, T_A=25°C, AGAIN = Max, AEN=1, (unless otherwise noted) (Notes 1, 2, 3),

Parameter	Conditions	Channel	Min	Typ	Max	Units
Dark ADC count value	$E_e = 0$, ATIME=000b (100ms)	CH0 CH1	0 0		25 25	counts
ADC integration time step size	ATIME = 000b (100ms)		95	101	108	ms
ADC number of integration steps (Note 4)			1		6	steps
ADC counts per step	ATIME = 000b (100ms)		0		37888	counts
ADC count value	ATIME = 101b (600ms)		0		65535	counts
ADC count value	White light (Note 2) $E_e = 4.98\ \mu W/cm^2$ ATIME = 000b (100 ms)	CH0 CH1	25500	30000 4996	34500	counts
	$\lambda_p = 850$ nm (Note 3) $E_e = 5.62\ \mu W/cm^2$, ATIME = 000b (100 ms)	CH0 CH1	25500	30000 19522	34500	counts
ADC count value ratio: CH1/CH0	White light (Note 2)		0.116	0.166	0.216	
	$\lambda_p = 850$ nm (Note 3)		0.456	0.652	0.848	
R_e Irradiance responsivity	White light (Note 2) ATIME = 000b (100 ms)	CH0 CH1		6024 1003		counts/ ($\mu W/cm^2$)
	$\lambda_p = 850$ nm (Note 3) ATIME = 000b (100 ms)	CH0 CH1		5338 3474		
Noise (Note 4)	White light (Note 2) $E_e = 4.98\ \mu W/cm^2$ ATIME = 000b (100 ms)	CH0		1	2	1 standard deviation
Gain scaling, relative to 1× gain setting	AGAIN = Low AGAIN = Med AGAIN = High AGAIN = Max			1 25 428 9876		×

Notes:

1. Optical measurements are made using small-angle incident radiation from light-emitting diode optical sources. Visible white LEDs and infrared 850 nm LEDs are used for final product testing for compatibility with high-volume production
2. The white LED irradiance is supplied by a white light-emitting diode with a nominal color temperature of 4000 K.
3. The 850 nm irradiance is supplied by a GaAs light-emitting diode with the following typical characteristics: peak wavelength λ_p = 850 nm and spectral halfwidth $\Delta\lambda½$ = 42 nm.
4. Parameter ensured by design and is not 100% tested.

Timing Characteristics

The timing characteristics of TSL2591 are given below.

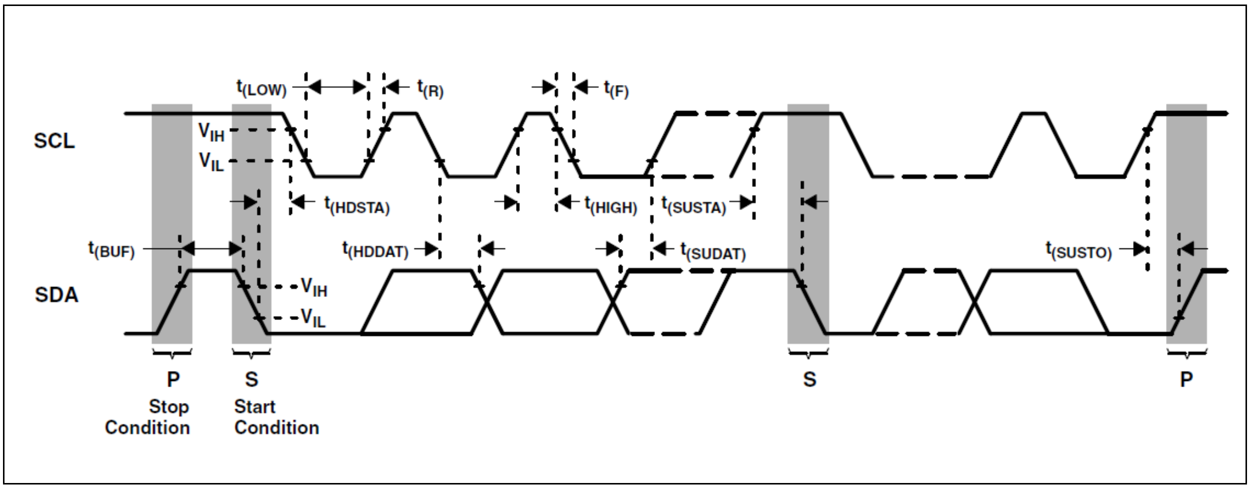
Figure TSL2591 – 10:
AC Electrical Characteristics, V_{DD} = 3 V, T_A = 25°C (unless otherwise noted)

Parameter†	Description	Min	Typ	Max	Units
$f_{(SCL)}$	Clock frequency (I²C only)	0		400	kHz
$t_{(BUF)}$	Bus free time between start and stop condition	1.3			µs
$t_{(HDSTA)}$	Hold time after (repeated) start condition. After this period, the first clock is generated.	0.6			µs
$t_{(SUSTA)}$	Repeated start condition setup time	0.6			µs
$t_{(SUSTO)}$	Stop condition setup time	0.6			µs
$t_{(HDDAT)}$	Data hold time	0			µs
$t_{(SUDAT)}$	Data setup time	100			ns
$t_{(LOW)}$	SCL clock low period	1.3			µs
$t_{(HIGH)}$	SCL clock high period	0.6			µs
t_F	Clock/data fall time			300	ns
t_R	Clock/data rise time			300	ns
C_i	Input pin capacitance			10	pF

† Specified by design and characterization; not production tested.

Timing Diagrams

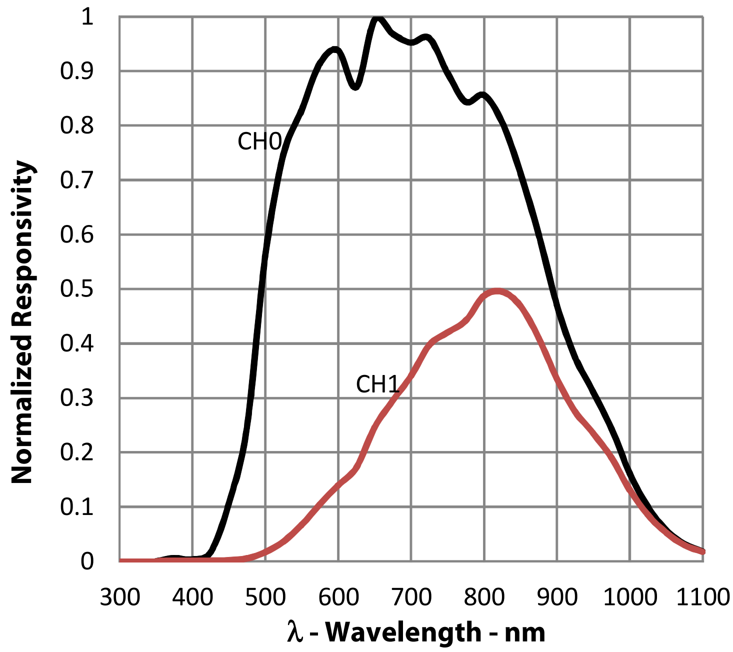
Figure TSL2591 – 11:
Parameter Measurement Information



Typical Operating Characteristics

Spectral Responsivity: Two channel response allows for tunable illuminance (lux) calculation regardless of transmissivity of glass.

Figure TSL2591 – 12:
Spectral Responsivity



White LED Angular Response: Near cosine angular response for broadband white light sources.

Figure TSL2591 – 13:
White Normalized Responsivity vs. Angular Displacement

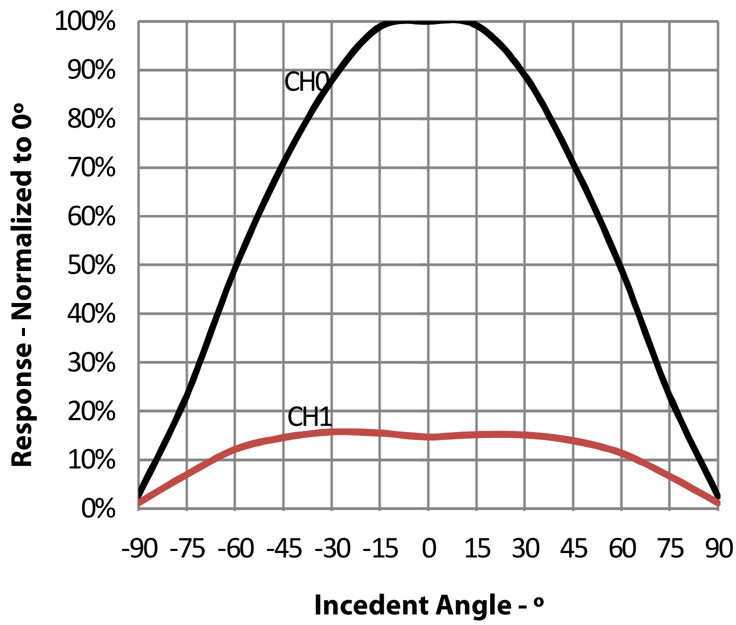


Figure TSL2591 – 14:
Normalized I_{DD} vs. V_{DD} and Temperature

I_{DD} vs. V_{DD} vs. Temp: Effect of supply voltage and temperature on active current.

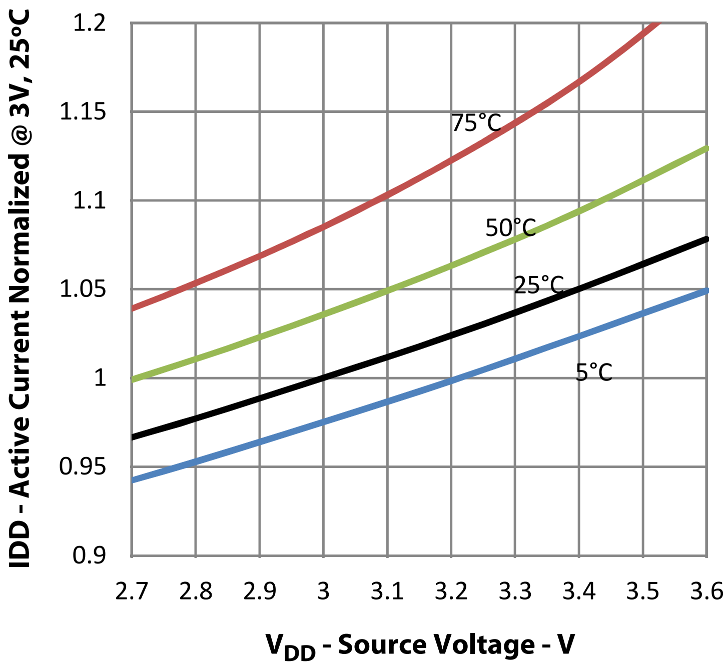
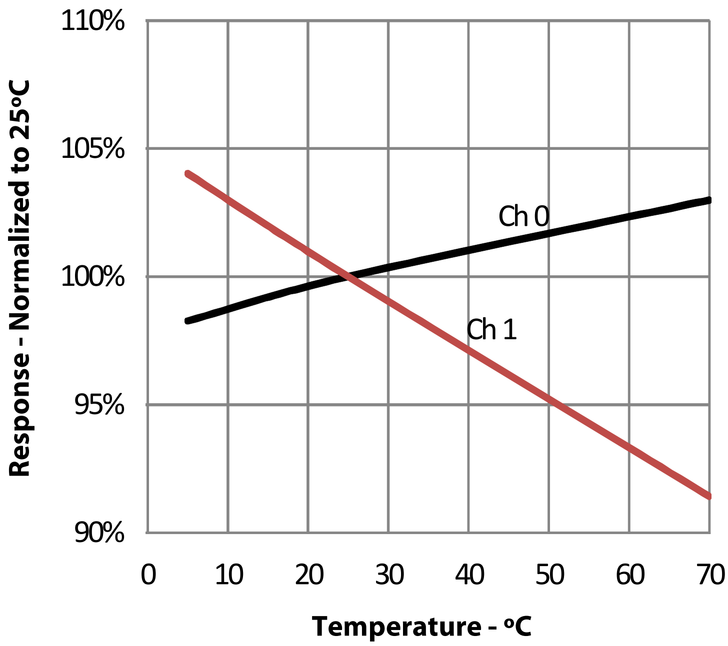


Figure TSL2591 – 15:
Response to White LED vs. Temperature

White LED Response v Temp: Effect of temperature on the device response for a broadband white light source.



Register Description

The device is controlled and monitored by registers accessed through the I^2C serial interface. These registers provide for a variety of control functions and can be read to determine results of the ADC conversions. The register set is summarized in Figure TSL2591 - 16.

Figure TSL2591 – 16: Register Description

Address	Register Name	R/W	Register Function	Reset Value
--	COMMAND	W	Specifies Register Address	0x00
0x00	ENABLE	R/W	Enables states and interrupts	0x00
0x01	CONFIG	R/W	ALS gain and integration time configuration	0x00
0x04	AILTL	R/W	ALS interrupt low threshold low byte	0x00
0x05	AILTH	R/W	ALS interrupt low threshold high byte	0x00
0x06	AIHTL	R/W	ALS interrupt high threshold low byte	0x00
0x07	AIHTH	R/W	ALS interrupt high threshold high byte	0x00
0x08	NPAILTL	R/W	No Persist ALS interrupt low threshold low byte	0x00
0x09	NPAILTH	R/W	No Persist ALS interrupt low threshold high byte	0x00
0x0A	NPAIHTL	R/W	No Persist ALS interrupt high threshold low byte	0x00
0x0B	NPAIHTH	R/W	No Persist ALS interrupt high threshold high byte	0x00
0x0C	PERSIST	R/W	Interrupt persistence filter	0x00
0x11	PID	R	Package ID	--
0x12	ID	R	Device ID	ID
0x13	STATUS	R	Device status	0x00
0x14	C0DATAL	R	CH0 ADC low data byte	0x00
0x15	C0DATAH	R	CH0 ADC high data byte	0x00
0x16	C1DATAL	R	CH1 ADC low data byte	0x00
0x17	C1DATAH	R	CH1 ADC high data byte	0x00

Note: JGS-Stopped here.

Command Register

The COMMAND register specifies the address of the target register for future read and write operations, as well as issues special function commands.

<table>
<tr><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td>CMD</td><td colspan="2">TRANSACTION</td><td colspan="5">ADDR/SF</td></tr>
</table>

<table>
<tr><th>Fields</th><th>Bits</th><th colspan="2">Description</th></tr>
<tr><td>CMD</td><td>7</td><td colspan="2">Select Command Register. Must write as 1 when addressing COMMAND register.</td></tr>
<tr><td rowspan="6">TRANSACTION</td><td rowspan="6">6:5</td><td colspan="2">Select type of transaction to follow in subsequent data transfers</td></tr>
<tr><td>FIELD VALUE</td><td>DESCRIPTION</td></tr>
<tr><td>00</td><td>Reserved - Do not use</td></tr>
<tr><td>01</td><td>Normal Operation</td></tr>
<tr><td>10</td><td>Reserved – Do not use</td></tr>
<tr><td>11</td><td>Special Function – See description below</td></tr>
<tr><td rowspan="8">ADDR/SF</td><td rowspan="8">4:0</td><td colspan="2">Address field/special function field. Depending on the transaction type, see above, this field either specifies a special function command or selects the specific control-status-data register for subsequent read and write transactions. The field values listed below apply only to special function commands.</td></tr>
<tr><td>FIELD VALUE</td><td>DESCRIPTION</td></tr>
<tr><td>00100</td><td>Interrupt set – forces an interrupt</td></tr>
<tr><td>00110</td><td>Clears ALS interrupt</td></tr>
<tr><td>00111</td><td>Clears ALS and no persist ALS interrupt</td></tr>
<tr><td>01010</td><td>Clears no persist ALS interrupt</td></tr>
<tr><td>other</td><td>Reserved – Do not write</td></tr>
<tr><td colspan="2">The interrupt set special function command sets the interrupt bits in the status register (0x13). For the interrupt to be visible on the INT pin, one of the interrupt enable bits in the enable register (0x00) must be asserted.
The interrupt set special function must be cleared with an interrupt clear special function. The ALS interrupt clear special functions clear any pending interrupt(s) and are self-clearing.</td></tr>
</table>

Enable Register (0x00)

The ENABLE register is used to power the device on/off, enable functions and interrupts.

7	6	5	4	3	2	1	0
NPIEN	SAI	Reserved	AIEN	Reserved		AEN	PON

Fields	Bits	Description
NPIEN	7	No Persist Interrupt Enable. When asserted NP Threshold conditions will generate an interrupt, bypassing the persist filter.
SAI	6	Sleep after interrupt. When asserted, the device will power down at the end of an ALS cycle if an interrupt has been generated.
Reserved	5	Reserved. Write as 0.
AIEN	4	ALS Interrupt Enable. When asserted permits ALS interrupts to be generated, subject to the persist filter.
Reserved	3:2	Reserved. Write as 0.
AEN	1	ALS Enable. This field activates ALS function. Writing a one activates the ALS. Writing a zero disables the ALS.
PON	0	Power ON. This field activates the internal oscillator to permit the timers and ADC channels to operate. Writing a one activates the oscillator. Writing a zero disables the oscillator.

Control Register (0x01)

The CONTROL register is used to configure the ALS gain and integration time. In addition, a system reset is provided. Upon power up, the CONTROL register resets to 0x00.

7	6	5	4	3	2	1	0
SRESET	Reserved	AGAIN		Reserved	ATIME		

<table>
<tr><th>Fields</th><th>Bits</th><th colspan="3">Description</th></tr>
<tr><td>SRESET</td><td>7</td><td colspan="3">System reset. When asserted, the device will reset equivalent to a power-on reset. SRESET is self-clearing.</td></tr>
<tr><td>Reserved</td><td>6</td><td colspan="3">Reserved. Write as 0.</td></tr>
<tr><td rowspan="6">AGAIN</td><td rowspan="6">5:4</td><td colspan="3">ALS gain sets the gain of the internal integration amplifiers for both photodiode channels.</td></tr>
<tr><td>FIELD VALUE</td><td colspan="2">DESCRIPTION</td></tr>
<tr><td>00</td><td colspan="2">Low gain mode</td></tr>
<tr><td>01</td><td colspan="2">Medium gain mode</td></tr>
<tr><td>10</td><td colspan="2">High gain mode</td></tr>
<tr><td>11</td><td colspan="2">Maximum gain mode</td></tr>
<tr><td>Reserved</td><td>3</td><td colspan="3">Reserved. Write as 0.</td></tr>
<tr><td rowspan="8">ATIME</td><td rowspan="8">2:0</td><td colspan="3">ALS time sets the internal ADC integration time for both photodiode channels.</td></tr>
<tr><td>FIELD VALUE</td><td>INTEGRATION TIME</td><td>MAX COUNT</td></tr>
<tr><td>000</td><td>100 ms</td><td>37888</td></tr>
<tr><td>001</td><td>200 ms</td><td>65535</td></tr>
<tr><td>010</td><td>300 ms</td><td>65535</td></tr>
<tr><td>011</td><td>400 ms</td><td>65535</td></tr>
<tr><td>100</td><td>500 ms</td><td>65535</td></tr>
<tr><td>101</td><td>600 ms</td><td>65535</td></tr>
</table>

ALS Interrupt Threshold Register (0x04 – 0x0B)

The ALS interrupt threshold registers provide the values to be used as the high and low trigger points for the comparison function for interrupt generation. If C0DATA crosses below the low threshold specified, or above the higher threshold, an interrupt is asserted on the interrupt pin.

If the C0DATA exceeds the persist thresholds (registers: 0x04 – 0x07) for the number of persist cycles configured in the PERSIST register an interrupt will be triggered. If the C0DATA exceeds the no-persist thresholds (registers: 0x08 – 0x0B) an interrupt will be triggered immediately following the end of the current integration.

Note that while the interrupt is observable in the STATUS register (0x13), it is visible only on the INT pin when AIEN or NPIEN are enabled in the ENABLE register (0x00).

Upon power up, the interrupt threshold registers default to 0x00.

Register	Address	Bits	Description
AILTL	0x04	7:0	ALS low threshold lower byte
AILTH	0x05	7:0	ALS low threshold upper byte
AIHTL	0x06	7:0	ALS high threshold lower byte
AIHTH	0x07	7:0	ALS high threshold upper byte
NPAILTL	0x08	7:0	No Persist ALS low threshold lower byte
NPAILTH	0x09	7:0	No Persist ALS low threshold upper byte
NPAIHTL	0x0A	7:0	No Persist ALS high threshold lower byte
NPAIHTH	0x0B	7:0	No Persist ALS high threshold upper byte

PERSIST Register (0x0C)

The Interrupt persistence filter sets the number of consecutive out-of-range ALS cycles necessary to generate an interrupt. Out-of-range is determined by comparing C0DATA (0x14 and 0x15) to the interrupt threshold registers (0x04 - 0x07). Note that the no-persist ALS interrupt is not affected by the interrupt persistence filter. Upon power up, the interrupt persistence filter register resets to 0x00.

7	6	5	4	3	2	1	0
Reserved				APERS			

Field	Bits	Description	
Reserved	7:4	Reserved. Write as 0.	
APERS	3:0	ALS interrupt persistence filter	
		FIELD VALUE	**PERSISTENCE**
		0000	Every ALS cycle generates an interrupt
		0001	Any value outside of threshold range
		0010	2 consecutive values out of range
		0011	3 consecutive values out of range
		0100	5 consecutive values out of range
		0101	10 consecutive values out of range
		0110	15 consecutive values out of range
		0111	20 consecutive values out of range
		1000	25 consecutive values out of range
		1001	30 consecutive values out of range
		1010	35 consecutive values out of range
		1011	40 consecutive values out of range
		1100	45 consecutive values out of range
		1101	50 consecutive values out of range
		1110	55 consecutive values out of range
		1111	60 consecutive values out of range

PID Register (0x11)

The PID register provides an identification of the devices package. This register is a read-only register whose value never changes.

7	6	5	4	3	2	1	0
Reserved		PACKAGEID		Reserved			

Field	Bits	Description
Reserved	7:6	Reserved.
PID	5:4	Package Identification = 00
Reserved	3:0	Reserved.

ID Register (I0x12)

The ID register provides the device identification. This register is a read-only register whose value never changes.

7	6	5	4	3	2	1	0
ID							

Field	Bits	Description
ID	7:0	Device Identification = 0x50

Status Register (0x13)

The Status Register provides the internal status of the device. This register is read only.

7	6	5	4	3	2	1	0
Reserved		NPINTR	AINT	Reserved			AVALID

Field	Bits	Description
Reserved	7:6	Reserved. Write at zero.
NPINTR	5	No-persist Interrupt. Indicates that the device has encountered a no-persist interrupt condition.
AINT	4	ALS Interrupt. Indicates that the device is asserting an ALS interrupt.
Reserved	3:1	Reserved.
AVALID	0	ALS Valid. Indicates that the ADC channels have completed an integration cycle since the AEN bit was asserted.

ALS Data Register (0x14 - 0x17)

ALS data is stored as two 16-bit values; one for each channel. When the lower byte of either channel is read, the upper byte of the same channel is latched into a shadow register. The shadow register ensures that both bytes are the result of the same ALS integration cycle, even if additional integration cycles occur between the lower byte and upper byte register readings.

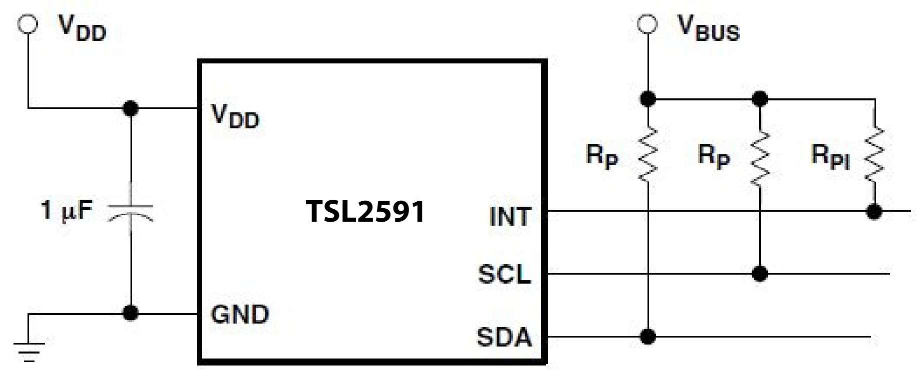
Each channel independently operates the upper byte shadow register. So to minimize the potential for skew between CH0 and CH1 data, it is recommended to read all four ADC bytes in sequence. The simplest way to accomplish this is to perform a four-byte I^2C read operation using the auto-increment protocol, which is set in the Command register TRANSACTION field.

Register	Address	Bits	Description
C0DATAL	0x14	7:0	ALS CH0 data low byte
C0DATAH	0x15	7:0	ALS CH0 data high byte
C1DATAL	0x16	7:0	ALS CH1 data low byte
C1DATAH	0x17	7:0	ALS CH1 data high byte

Application Information

Figure TSL2591 - 17 shows a typical hardware application circuit. A 1-µF low-ESR decoupling capacitor should be placed as close as possible to the V_{DD} pin. V_{BUS} in this figure refers to the I^2C bus voltage, which is equal to V_{DD}.

Figure TSL2591 – 17:
Typical Application Hardware Circuit

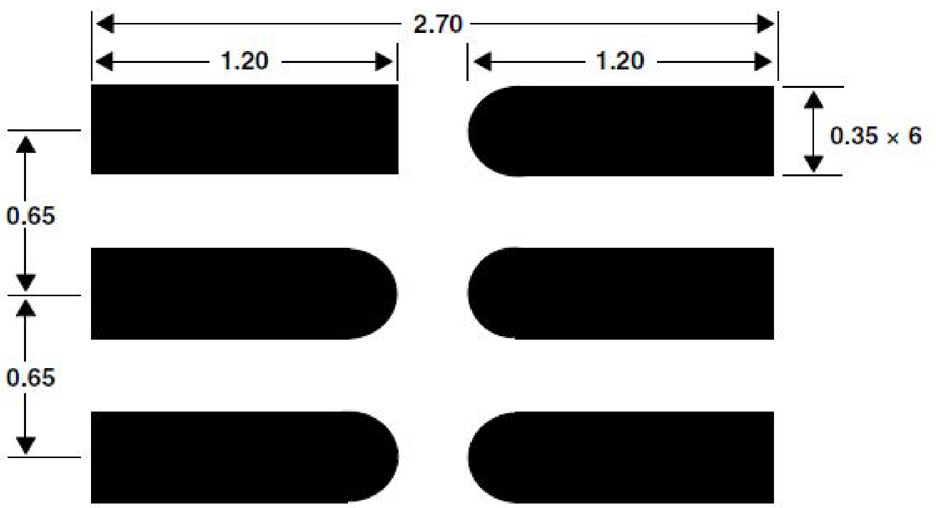


The I^2C signals and the Interrupt are open-drain outputs and require pull-up resistors. The pull-up resistor (RP) value is a function of the I^2C bus speed, the I^2C bus voltage, and the capacitive load. The ams EVM running at 400 kbps, uses 1.5-kΩ resistors. A 10-kΩ pull-up resistor (RPI) can be used for the interrupt line.

PCB Pad Layout

Suggested land pattern based on the IPC−7351B Generic Requirements for Surface Mount Design and Land Pattern Standard (2010) for the small outline no-lead (SON) package is shown in Figure TSL2591 - 18.

Figure TSL2591 – 18:
Suggested FN Package PCB Layout (Top View)

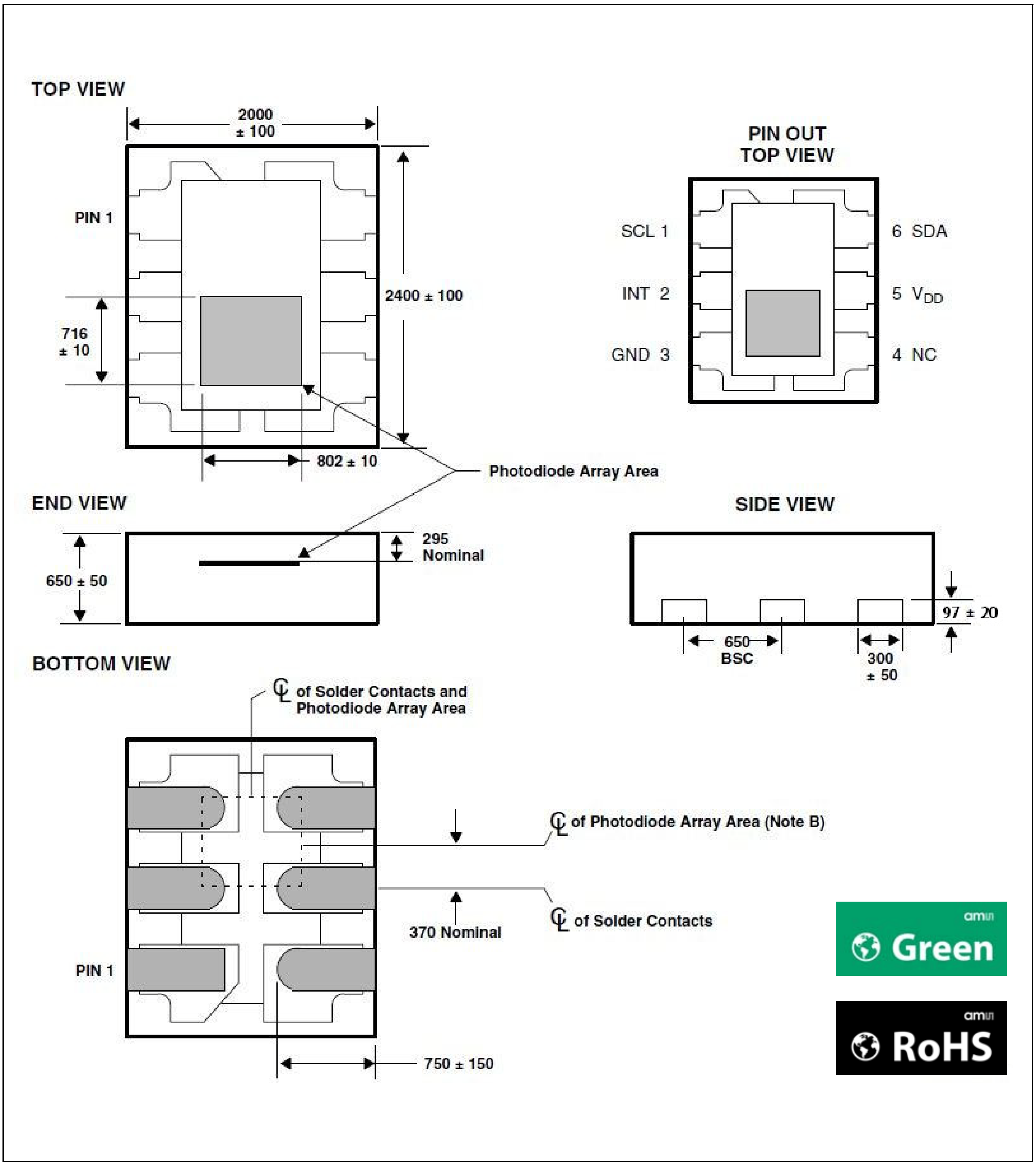


Notes:

1. All linear dimensions are in millimeters.
2. This drawing is subject to change without notice.

Package Drawings and Markings

Figure TSL2591 – 19:
FN Package – Dual Flat No-Lead Packaging Configuration

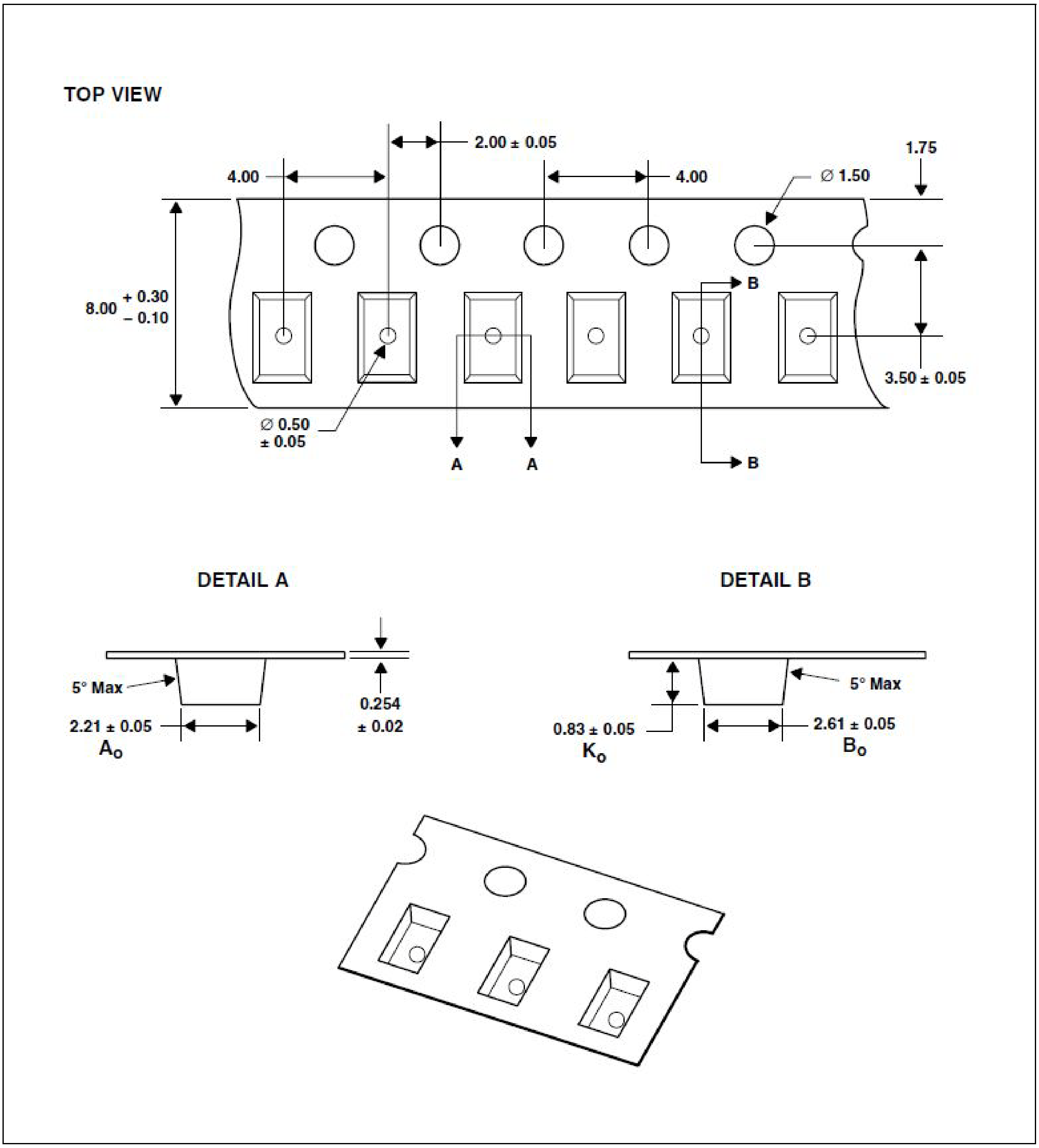


Notes:

1. All linear dimensions are in micrometers.
2. The die is centered within the package within a tolerence of ±75 µm.
3. Package top surface is molded with an electrically non-conductive clear plastic compound having an index of refraction of 1.55.
4. Contact finish is copper alloy A194 with pre-plated NIPdAu lead finish.
5. This package contains no lead (Pb).
6. This drawing is subject to change without notice.

Mechanical Data

Figure TSL2591 – 20:
FN Package Carrier Tape and Reel Information



Notes:

1. All linear dimensions are in millimeters. Dimension tolerance is ± 0.10 mm unless otherwise noted.
2. The dimensions on this drawing are for illustrative purposes only. Dimensions of an actual carrier may vary slightly.
3. Symbols on drawing A_O, B_O and K_O are defined in ANSI EIA Standard 481-B 2001.
4. Each reel is 178 millimeters in diameter and contains 3500 parts.
5. ams packaging tape and reel conform to the requirements of EIA Standard 481 - B.
6. In accordance with EIA Standard, device pin 1 is located next to the sprocket holes in the tape.
7. This drawing is subject to change without notice.

Soldering Information

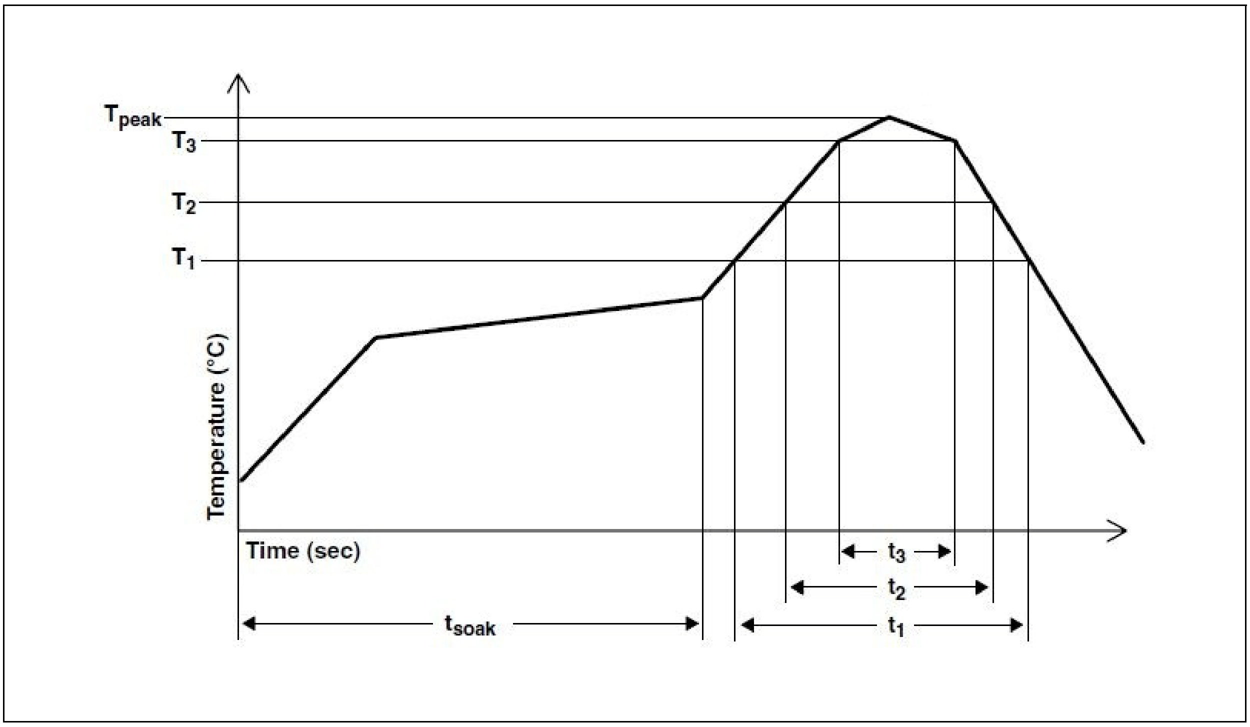
The package has been tested and has demonstrated an ability to be reflow soldered to a PCB substrate.

The solder reflow profile describes the expected maximum heat exposure of components during the solder reflow process of product on a PCB. Temperature is measured on top of component. The components should be limited to a maximum of three passes through this solder reflow profile.

Figure TSL2591 – 21:
Solder Reflow Profile

Parameter	Reference	Device
Average temperature gradient in preheating		2.5 °C/sec
Soak time	t_{soak}	2 to 3 minutes
Time above 217 °C (T1)	t_1	Max 60 sec
Time above 230 °C (T2)	t_2	Max 50 sec
Time above T_{peak} - 10 °C (T3)	t_3	Max 10 sec
Peak temperature in reflow	T_{peak}	260 °C
Temperature gradient in cooling		Max -5 °C/sec

Figure TSL2591 – 22:
Solder Reflow Profile Graph



Note: Not to scale – for reference only.

Storage Information

Moisture Sensitivity

Optical characteristics of the device can be adversely affected during the soldering process by the release and vaporization of moisture that has been previously absorbed into the package. To ensure the package contains the smallest amount of absorbed moisture possible, each device is baked prior to being dry packed for shipping.

Devices are dry packed in a sealed aluminized envelope called a moisture-barrier bag with silica gel to protect them from ambient moisture during shipping, handling, and storage before use.

Shelf Life

The calculated shelf life of the device in an unopened moisture barrier bag is 12 months from the date code on the bag when stored under the following conditions:

- Shelf Life: 12 months
- Ambient Temperature: < 40°C
- Relative Humidity: < 90%

Rebaking of the devices will be required if the devices exceed the 12 month shelf life or the Humidity Indicator Card shows that the devices were exposed to conditions beyond the allowable moisture region.

Floor Life

The FN package has been assigned a moisture sensitivity level of MSL 3. As a result, the floor life of devices removed from the moisture barrier bag is 168 hours from the time the bag was opened, provided that the devices are stored under the following conditions:

- Floor Life: 168 hours
- Ambient Temperature: < 30°C
- Relative Humidity: < 60%

If the floor life or the temperature/humidity conditions have been exceeded, the devices must be rebaked prior to solder reflow or dry packing.

Rebaking Instructions

When the shelf life or floor life limits have been exceeded, rebake at 50°C for 12 hours.

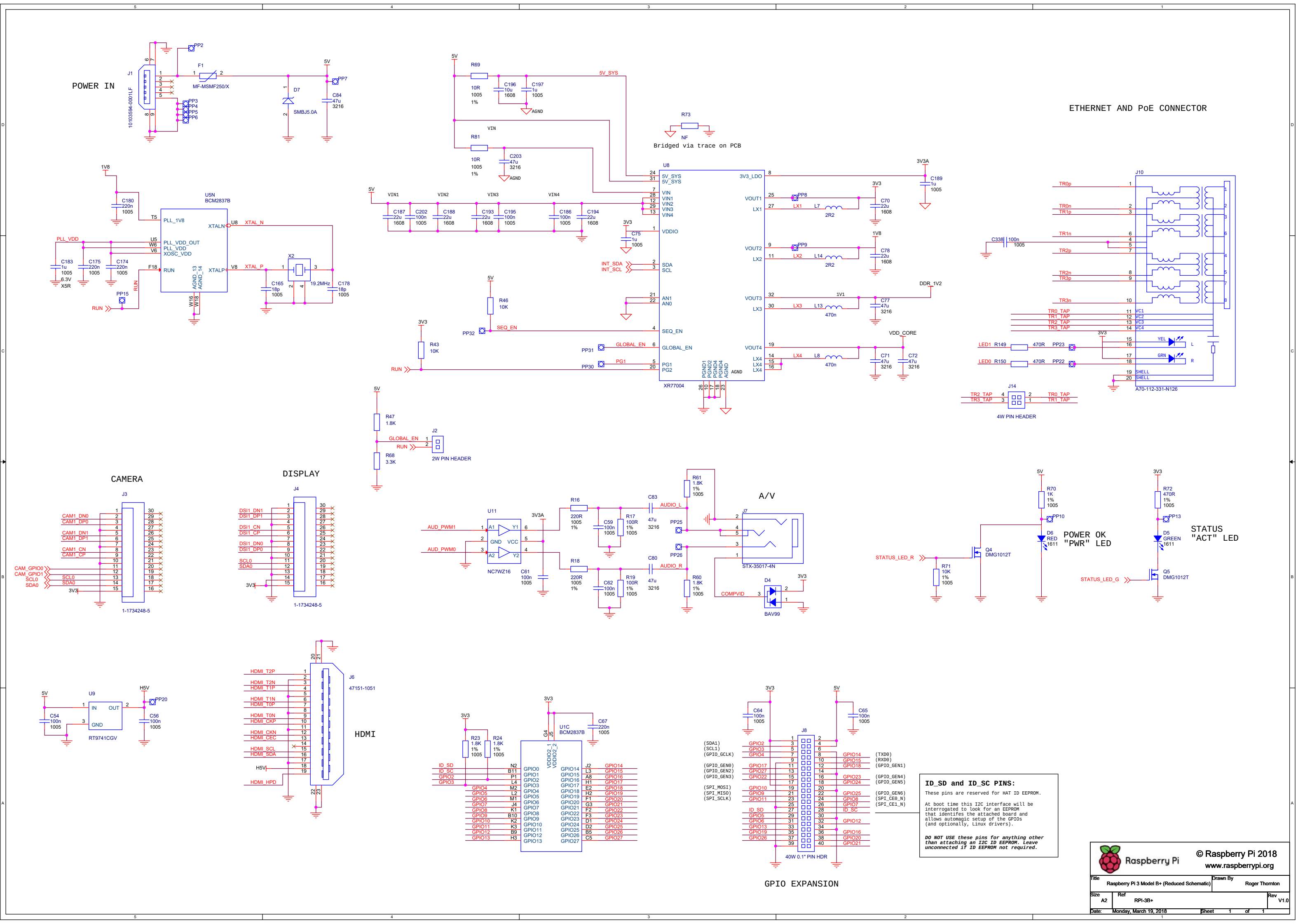
RoHS Compliant and ams Green Statement

The term RoHS complaint means that ams products fully comply with current RoHS directive. Our semiconductor products do not contain any chemicals for all 6 substance categories, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, RoHS compliant products are suitable for use in specified lead-free processes. ams Green means RoHS compliant and no Sb/Br). ams defines Green that additionally to RoHS compliance our products are free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material).

Important Information and Disclaimer The information provided in this statement represents ams knowledge and belief as of the date that it is provided. ams bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. ams has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. ams and ams suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

9.3 Microcontroller Datasheets

9.4 Raspberry Pi 3B+ Schematic


POWER IN
ETHERNET AND PoE CONNECTOR
Bridged via trace on PCB
CAMERA
DISPLAY
A/V
POWER OK
"PWR" LED
STATUS
"ACT" LED
HDMI
GPIO EXPANSION
ID_SD and ID_SC PINS:
These pins are reserved for HAT ID EEPROM.
At boot time this I2C interface will be interrogated to look for an EEPROM that identifes the attached board and allows automagic setup of the GPIOs (and optionally, Linux drivers).
DO NOT USE these pins for anything other than attaching an I2C ID EEPROM. Leave unconnected if ID EEPROM not required.
Raspberry Pi
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www.raspberrypi.org
Title
Raspberry Pi 3 Model B+ (Reduced Schematic)
Drawn By
Roger Thornton
Size
A2
Ref
RPI-3B+
Rev
V1.0
Date: Monday, March 19, 2018
Sheet 1 of 1

9.5 Tristar MPPT Operator's Manual

TRISTAR MPPT ™

Solar Charging System Controller

Installation, Operation and Maintenance Manual

For the most recent manual revisions, see the version at:
www.morningstarcorp.com

•••••

Solar Battery Charger

With

TrakStar™ Maximum Power Point Tracking Technology

•••••

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TS-MPPT-30
TS-MPPT-45
TS-MPPT-60
TS-MPPT-60M

TRAKSTAR™
MAXIMUM POWER POINT TRACKING

Dimensions in Inches [Millimeters]

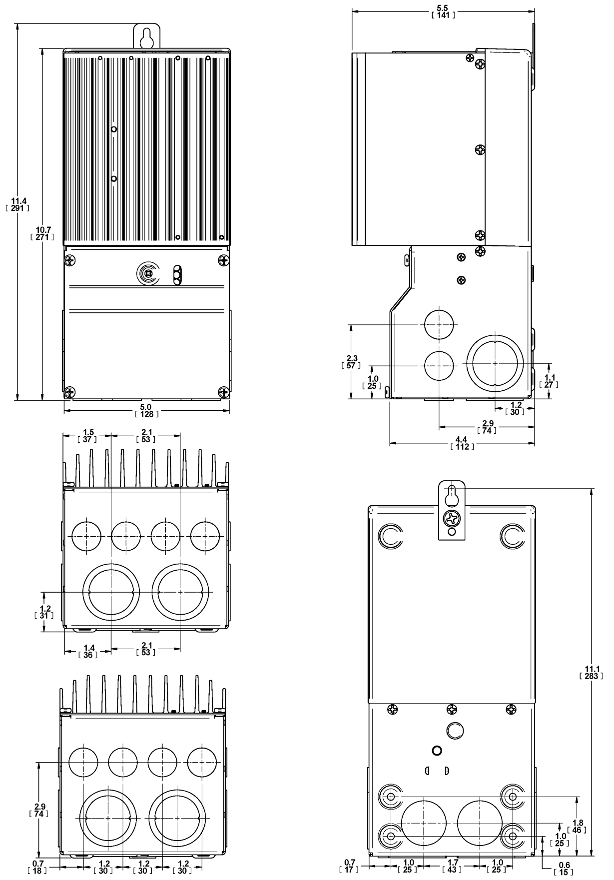


TABLE OF CONTENTS

1.0 Important Safety Instructions

SAVE THESE INSTRUCTIONS.
This manual contains important safety, installation and operating instructions for the TriStar MPPT 150V solar controller. The following symbols are used throughout this manual to indicate potentially dangerous conditions or mark important safety instructions:

WARNING:
Indicates a potentially dangerous condition. Use extreme caution when performing this task.

CAUTION:
Indicates a critical procedure for safe and proper operation of the controller.

NOTE:
Indicates a procedure or function that is important for the safe and proper operation of the controller.

AVERTISSEMENT :
Indique une condition potentiellement dangereuse. Faites preuve d'une prudence extrême lors de la réalisation de cette tâche.

PRUDENCE :
Indique une procédure critique pour l'utilisation sûre et correcte du contrôleur.

REMARQUE :
Indique une procédure ou fonction importante pour l'utilisation sûre et correcte du contrôleur.

Safety Information

- Read all of the instructions and cautions in the manual before beginning installation.
- There are no user serviceable parts inside the TriStar MPPT 150V. Do not disassemble or attempt to repair the controller.

WARNING: RISK OF ELECTRICAL SHOCK.
NO POWER OR ACCESSORY TERMINALS ARE ELECTRICALLY ISOLATED FROM DC INPUT, AND MAY BE ENERGIZED WITH HAZARDOUS SOLAR VOLTAGE. UNDER CERTAIN FAULT CONDITIONS, BATTERY COULD BECOME OVER-CHARGED. TEST BETWEEN ALL TERMINALS AND GROUND BEFORE TOUCHING.

- External solar and battery disconnects are required.
- Disconnect all sources of power to the controller before installing or adjusting the TriStar MPPT 150V.
- There are no fuses or disconnects inside the TriStar MPPT 150V Do not attempt to repair.

Informations de Sécurité

- Lisez toutes les instructions et les avertissements figurant dans le manuel avant de commencer l'installation.
- Le TriStar MPPT 150V ne contient aucune pièce réparable par l'utilisateur. Ne démontez pas ni ne tentez de réparer le contrôleur.

AVERTISSEMENT: RISQUE DE CHOC ÉLETRIQUE.
NON ALIMENTATION OU AUX BORNES D'ACCESSOIRES SONT ISOLÉS ÉLECTRIQUEMENT DE L'ENTRÉE DE C.C ET DOIT ÊTRE ALIMENTÉS À UNE TENSION DANGEREUSE SOLAIRE. SOUS CERTAINES CONDITIONS DE DÉFAILLANCE, LA BATTERIE POURRAIT DEVENIR TROP CHARGÉE. TEST ENTRE TOUTES LES BORNES ET LA MASSE AVANT DE TOUCHER.

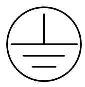
External solaire et la batterie se déconnecte sont nécessaires.

- Déconnectez toutes les sources d'alimentation du contrôleur avant d'installer ou de régler le TriStar MPPT 150V.
- Le TriStar MPPT ne contient aucun fusible ou interrupteur. Ne tentez pas de réparer.
- Installez des fusibles/coupe-circuits externes selon le besoin.

Installation Safety Precautions

WARNING:
This unit is not provided with a GFDI device. This charge controller must be used with an external GFDI device as required by the Article 690 of the National Electrical Code for the installation location.

- Mount the TriStar MPPT 150V indoors. Prevent exposure to the elements and do not allow water to enter the controller.
- Install the TriStar MPPT 150V in a location that prevents casual contact. The TriStar MPPT 150V heatsink can become very hot during operation.
- Use insulated tools when working with batteries.
- Avoid wearing jewelry during installation.
- The battery bank must be comprised of batteries of same type, make, and age.
- Do not smoke near the battery bank.
- Power connections must remain tight to avoid excessive heating from a loose connection.
- Use properly sized conductors and circuit interrupters.
- The grounding terminal is located in the wiring compartment and is identified by the symbol below.



Ground Symbol

- This charge controller is to be connected to DC circuits only. These DC connections are identified by the symbol below:

Direct Current Symbol

The TriStar MPPT 150V controller must be installed by a qualified technician in accordance with the electrical regulations of the country where the product is installed. A means of disconnecting all power supply poles must be provided. These disconnects must be incorporated in the fixed wiring.

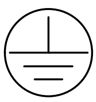
A permanent, reliable earth ground must be established with connection to the wiring compartment ground terminal.

The grounding conductor must be secured against any accidental detachment. The knock-outs in the wiring compartment must protect wires with conduit or rubber rings.

Précautions de Sécurité D'installation

AVERTISSEMENT: *L'appareil n'est pas fourni avec un dispositif GFDI. Ce contrôleur de charge doit être utilisé avec un dispositif GFDI externe tel que requis par l'Article 690 du Code électrique national de l'emplacement de l'installation.*

- Montez le TriStar MPPT 150V à l'intérieur. Empêchez l'exposition aux éléments et la pénétration d'eau dans le contrôleur.
- Installez le TriStar MPPT 150V dans un endroit qui empêche le contact occasionnel. Le dissipateur de chaleur peut devenir très chaud pendant le fonctionnement.
- Utilisez des outils isolés pour travailler avec les batteries.
- Évitez le port de bijoux pendant l'installation.
- Le groupe de batteries doit être constitué de batteries du même type, fabricant et âge.
- Ne fumez pas à proximité du groupe de batteries.
- Les connexions d'alimentation doivent rester serrées pour éviter une surchauffe excessive d'une connexion desserrée.
- Utilisez des conducteurs et des coupe-circuits de dimensions adaptées.
- La borne de mise à la terre se trouve dans le compartiment de câblage et est identifiée par le symbole ci-dessous estampillé dans le boit:



- Ce contrôleur de charge ne doit être connecté qu'à des circuits en courant continu. Ces connexions CC sont identifiées par le symbole ci-dessous:

Le contrôleur TriStar MPPT 150V doit être installé par un technicien qualifié conformément aux règlementations électriques du pays où est installé le produit.

Un moyen d'assurer la déconnexion de tous les pôles de l'alimentation doit être fourni. Cette déconnexion doit être incorporée dans le câblage fixe.

À l'aide de la borne de mise à la masse du TriStar MPPT 150V (dans le compartiment de câblage), un moyen permanent et fiable de mise à la terre doit être fourni. La fixation de la mise à la terre doit être fixée contre tout desserrage accidentel.

Les ouvertures d'entrée au compartiment de câblage du TriStar MPPT 150V doivent être protégées avec un conduit ou une bague.

Battery Safety

WARNING: *A battery can present a risk of electrical shock or burn from large amounts of short-circuit current, fire, or explosion from vented gases. Observe proper precautions.*

AVERTISSEMENT: *Une batterie peut présenter a ris que de choc électrique ou de brûlure de grandes quantités de court-circuit curlouer, incendie ou explosion de ventilé gaz. Observer précautions appropriées.*

WARNING: Risk of Explosion.
Proper disposal of batteries is required. Do not dispose of batteries in fire. Refer to local regulations or codes for requirements.

AVERTISSEMENT: Risque d'Explosion.
Au rebut des piles est nécessaire. Ne pas jeter les piles dans le feu. Se référer aux régle mentations locales ou des codes pour les exigences.

CAUTION: *When replacing batteries, proper specified number, sizes types and ratings based on application and system design*

PRUDENCE: *Lorsque le remplacement des piles, utilisez correctement nombre spécifié, tailles, types et les évaluations basées sur conception de système et d'application.*

CAUTION: *Do not open or mutilate batteries. Released electrolyte is harmful to skin, and may be toxic.*

PRUDENCE: *Ne pas ouvrir ou mutiler les piles. L'électrolyte est nocif pour la peau et peut être toxique.*

- Servicing of batteries should be performed, or supervised, by personnel knowledgeable about batteries, and the proper safety precautions.
- Be very careful when working with large lead-acid batteries. Wear eye protection and have fresh water available in case there is contact with the battery acid.
- Remove watches, rings, jewelry and other metal objects before working with batteries.
- Wear rubber gloves and boots
- Use tools with insulated handles and avoid placing tools or metal objects on top of batteries.
- Disconnect charging source prior to connecting or dis-connecting battery terminals.
- Determine if battery is inadvertently grounded. If so, remove the source of contact with ground. Contact with any part of a grounded battery can result in electrical shock. The likelihood of such a shock can be reduced if battery grounds are removed during installation and maintenance (applicable to equipment and remote battery supplies not having a grounded supply circuit).
- Carefully read the battery manufacturer's instructions before installing / connecting to, or removing batteries from, the TriStar MPPT.
- Be very careful not to short circuit the cables connected to the battery.
- Have someone nearby to assist in case of an accident.
- Explosive battery gases can be present during charging. Be certain there is enough ventilation to release the gases.
- Never smoke in the battery area.
- If battery acid comes into contact with the skin, wash with soap and water. If the acid contacts the eye, flood with fresh water and get medical attention.
- Be sure the battery electrolyte level is correct before starting charging. Do not attempt to charge a frozen battery.
- Recycle the battery when it is replaced.

- Entretien des batteries devrait être effectué ou supervisé, par un personnel bien informé sur les piles et les précautions de sécurité appropriées.
- Soyez très prudent quand vous travaillez avec des grandes batteries au plomb. Portez des lunettes de protection et ayez de l'eau fraîche à disposition en cas de contact avec l'électrolyte.
- Enlevez les montres, bagues, bijoux et autres objets mé talliques avant de travailler avec des piles.
- Porter des bottes et des gants de caoutchouc
- Utiliser des outils avec poignées isolantes et évitez de placer des outils ou des objets métalliques sur le dessus de batteries.
- Débrancher la source de charge avant de brancher ou dis-reliant les bornes de la batterie.
- Utilisez des outils isolés et évitez de placer des objets métalliques dans la zone de travail.
- Déterminer si batterie repose par inadvertance. Dans l'affirmative, supprimer la source du contact avec le sol. Contact avec n'importe quelle partie d'une batterie mise à la terre peut entraîner un choc électrique. La probabilité d'un tel choc peut être réduite si des motifs de batterie sont supprimés pendant l'installation et maintentretien (applicable à l'équipement et les fournitures de pile de la télécommande n'ayant ne pas un circuit d'alimentation mise à la terre *).
- Lisez attentivement les instructions du fabricant de la batterie avant d'installer / connexion à ou retrait des batteries du TriStar MPPT.
- Veillez à ne pas court-circuiter les câbles connectés à la batterie.
- Ayez une personne à proximité qui puisse aider en cas d'accident.

- Des gaz explosifs de batterie peuvent être présents pendant la charge. Assurez-vous qu'une ventilation suffisante évacue les gaz.
- Ne fumez jamais dans la zone des batteries
- En cas de contact de l'électrolyte avec la peau, lavez avec du savon et de l'eau. En cas de contact de l'électrolyte avec les yeux, rincez abondamment avec de l'eau fraîche et consultez un médecin.
- Assurez-vous que le niveau d'électrolyte de la batterie est correct avant de commencer la charge. Ne tentez pas de charger une batterie gelée.
- Recyclez la batterie quand elle est remplacée.

About this Manual

This manual provides detailed installation and usage instructions for the TriStar MPPT 150V controller. Only qualified electricians and technicians who are familiar with solar system design and wiring practices should install the TriStar MPPT 150V. The usage information in this manual is intended for the system owner/operator.

2.0 Getting Started

2.1 Overview

Thank you for selecting the TriStar MPPT 150V solar charge controller with TrakStar™ MPPT Technology. The TriStar MPPT 150V (TS-MPPT) is an advanced maximum power point tracking solar battery charger. The controller features a smart tracking algorithm that finds and maintains operation at the solar array peak power point, maximizing energy harvest.

The TriStar MPPT 150V battery charging process has been optimized for long battery life and improved system performance. Self-diagnostics and electronic error protections prevent damage when installation mistakes or system faults occur. The controller also features eight (8) adjustable settings switches, several communication ports, and terminals for remote battery temperature and voltage measurement.

Please take the time to read this operator's manual and become familiar with the controller. This will help you make full use of the many advantages the TriStar MPPT 150V can provide for your PV system.

2.2 Versions and Ratings

There are four versions of TriStar MPPT 150V controller:

TriStar-MPPT-30

- maximum 30 amps continuous battery current
- 12, 24 and 48 Volt dc systems
- maximum 150 Volt dc solar input voltage
- RS-232 and MeterBus™ communication ports

TriStar-MPPT-45

- maximum 45 amps continuous battery current
- 12, 24 and 48 Volt dc systems
- maximum 150 Volt dc solar input voltage
- RS-232 and MeterBus™ communication ports

TriStar-MPPT-60

- maximum 60 amps continuous battery current
- 12, 24 and 48 Volt dc systems
- maximum 150 Volt dc solar input voltage
- RS-232, EIA-485, MeterBus™, and Ethernet communication ports

TriStar-MPPT-60M

- maximum 60 amps continuous battery current
- 12, 24 and 48 Volt dc systems
- maximum 150 Volt dc solar input voltage
- RS-232, EIA-485, MeterBus™, and Ethernet communication ports
- Includes on-board meter display

2.3 Features

The features of the TriStar MPPT 150V are shown in Figure 2-1 below. An explanation of each feature is provided.

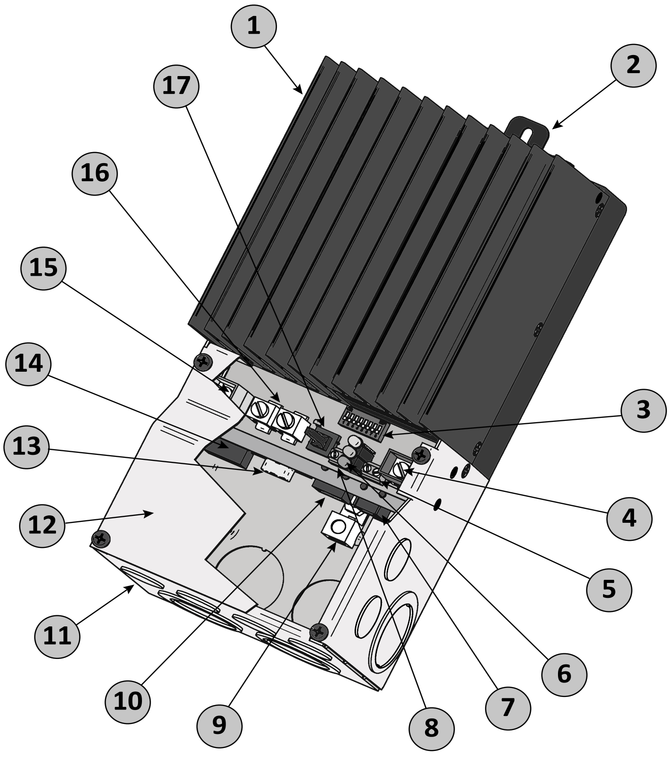


Figure 2-1. TriStar MPPT 150V features

1 - Heatsink
Aluminum heatsink to dissipate controller heat

2 - Mounting Hanger
Keyhole slot for mounting

3 - Settings Switches
Eight (8) settings switches to configure operation of the TriStar MPPT 150V

4 - Battery Positive Terminal (red)
Power connection for Battery (+)

5 - Remote Temperature Sensor Terminals
Connection point for a Morningstar RTS (optional) to remotely monitor battery temperature

6 - LED Indicators
Three *state of charge* (SOC) LED indicators show charging status and controller faults

7 - MeterBus™ Port
RJ-11 socket for Morningstar MeterBus™ network connections

8 - Battery Voltage Sense Terminals
Terminals for battery voltage input provide accurate battery voltage measurement

9 - Ground Terminal
A chassis ground terminal for system grounding

10 - Ethernet Port
RJ-45 socket for LAN/internet connections (TS-MPPT-60 model only)

11 - Wiring Box with Conduit Knockouts
Termination points for wiring conduit and wire glands

12 - Wiring Box Cover
Sheet metal wiring box cover protects power connections

13 - Serial RS-232 Port
9-pin serial connector (female)

14 - EIA-485 Port
Four (4) position screw terminal for EIA-485 bus connections (TS-MPPT-60 model only)

15 - Solar Positive Terminal (yellow)
Power connection for Solar (+)

16 - Common Negative Power Terminals
Two (2) negative terminals for negative system cable termination

17 - Push-button Switch
Manually reset from an error or fault, also used to start/stop a manual equalization.

2.4 Regulatory Information

NOTE:
This section contains important information for safety and regulatory requirements.

The TriStar MPPT 150V controller should be installed by a qualified technician according to the electrical rules of the country in which the product will be installed.

TriStar MPPT 150V controllers comply with the following EMC standards:
- Immunity: EN61000-6-2:1999
- Emissions: EN55022:1994 with A1 and A3 Class B1
- Safety: EN60335-1 and EN60335-2-29 (battery chargers)

A means shall be provided to ensure all pole disconnection from the power supply. This disconnection shall be incorporated in the fixed wiring.

Using the TriStar MPPT 150V grounding terminal (in the wiring compartment), a permanent and reliable means for grounding shall be provided. The clamping of the earthing shall be secured against accidental loosening.

The entry openings to the TriStar MPPT 150V wiring compartment shall be protected with conduit or with a bushing.

FCC requirements:

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.
Changes or modifications not expressly approved by Morningstar for compliance could void the user's authority to operate the equipment.

Note:
This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communication. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment on and off, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

This Class B digital apparatus complies with Canadian ICES-003.

Cet appareil numerique de la classe B est conforme a la norme NMB-003 du Canada.

2.5 Optional Accessories

The following accessories are available for purchase separately from your authorized Morningstar dealer:

TriStar Digital Meter 2 / TriStar Remote Meter 2 (Models: TS-M-2 / TS-RM-2)

The TriStar Digital Meter mounts directly on the TS-MPPT controller, replacing the wiring box cover. The TriStar Remote Meter can be flush mounted in a wall or into a standard duplex (2-gang) electrical box. A 2 x 16 character display shows system operating information, error indications, and self-diagnostic information. Four (4) buttons make navigating the meter menus easy.

For systems where multiple TS-MPPT controllers are networked together, one (1) meter can display full system information. The TriStar meters connect to the RJ- 11 MeterBus™ port on the TriStar-MPPT.

Meter Hub (HUB-1)

A Morningstar MeterBus™ network with multiple controllers requires a Meter Hub for electrical isolation. The HUB-1 allows communication between MeterBus™ compatible Morningstar products, including the TriStar MPPT 150V controller. DIN rail compatible. See section 5.2 for more details.

Relay Driver (RD-1)

The Relay Driver™ accessory enables the TriStar MPPT 150V to control external devices. Four (4) relay control ports can be configured (in various combinations) to perform the following tasks:

- generator control (2-, 3-, and 4-wire configurations)
- dry contacts for alarms and other signals
- advanced load control
- vent fan control
- DIN rail compatible or surface mount

For more information on the Relay Driver, visit our website at www.morningstarcorp.com or inquire with your local Morningstar dealer.

EIA-485 / RS-232 Communications Adapter (RSC-1)

Connect one or more TriStar MPPT 150V controllers to a PC or to other serial devices using the RSC-1 EIA-485 adapter. The adapter converts an RS-232 serial interface to EIA-485 compliant signals. An LED shows network activity and errors. DIN rail compatible.

Ethernet Meterbus Converter (EMC-1)

The EMC-1 acts as an Ethernet gateway that serves MODBUS IP, local Web pages, and Web Monitoring Services. Note that the Web Monitoring Service is not currently available. The EMC-1 supports any product with a MeterBus port by bridging MODBUS TCP/IP requests between an Ethernet connection and a connected Morningstar device.

3.0 Installation

3.1 General Information

The mounting location is important to the performance and operating life of the controller. The environment must be dry and protected from water ingress. If required, the controller may be installed in a ventilated enclosure with sufficient air flow. Never install the TriStar MPPT 150V in a sealed enclosure. The controller may be mounted in an enclosure with sealed batteries, but never with vented/flooded batteries. Battery fumes from vented batteries will corrode and destroy the TriStar MPPT 150V circuits.

Multiple TriStars can be installed in parallel on the same battery bank to achieve higher charging current. Additional parallel controllers can also be added in the future. Each TriStar MPPT 150V must have its own solar array.

WARNING: *Installation must conform to all requirements of the US National Electrical Code and the Canadian Electrical Code.*

AVERTISSEMENT: *Installation doit être conforme à toutes les requirments US National Electrical Code et Code Canadien d'Electricité.*

CAUTION: Equipment Damage or Risk of Explosion
Never install the TriStar MPPT 150V in an enclosure with vented/flooded batteries. Battery fumes are flammable and will corrode and destroy the TriStar MPPT 150V circuits.

CAUTION: Equipment Damage
When installing the TriStar MPPT 150V in an enclosure, ensure sufficient ventilation. Installation in a sealed enclosure will lead to over-heating and a decreased product lifetime.

PRUDENCE : Endommagement de l'équipement ou risque d'explosion
N'installez jamais le TriStar MPPT 150V dans une enceinte avec des batteries à évent/à électrolyte liquide. Les vapeurs des batteries sont inflammables et corroderont et détruiront les circuits du TriStar MPPT 150V.

PRUDENCE : Endommagement de l'équipement
Assurez une ventilation suffisante en cas d'installation du TriStar MPPT 150V dans une enceinte. L'installation dans une enceinte hermétique entraîne une surchauffe et une réduction de la durée de vie du produit.

The installation is straight-forward, but it is important each step is done correctly and safely. A mistake can lead to dangerous voltage and current levels. Be sure to carefully follow each instruction in this section. <u>Read all instructions first</u> before beginning installation.

The installation instructions are for installation of a negative grounded system. National Electrical Code (NEC) requirements are noted on occasion for convenience, however the installer should have a complete understanding of NEC and UL requirements for photovoltaic installations.

- Read through the entire installation section first before beginning installation.
- Be very careful when working with batteries. Wear eye protection. Have fresh water available to wash and clean any contact with battery acid.
- Use insulated tools and avoid placing metal objects near the batteries.
- Explosive battery gases may be present during charging. Be certain there is sufficient ventilation to release the gases.
- Do not install in locations where water can enter the controller.
- Loose power connections and/or corroded wires may result in resistive connections that melt wire insulation, burn surrounding materials, or even cause fire. Ensure tight connections and use cable clamps to secure cables and prevent them from swaying in mobile applications.
- Stranded wires to be connected to the terminals should be prepared first with e.g. clamped copper heads, tinned-wire ends, etc. to avoid the possibility of one conductor free out of the connection screw, and possible contact with the metal enclosure.
- Preset charging profiles are generally designed for lead acid batteries. Custom settings can be used for varied charging requirements (see sections 3.2 and 4.2 for details). Note that some battery types may not be compatible.
- The TriStar MPPT 150V battery connection may be wired to one battery, or a bank of batteries. The following instructions refer to a singular battery, but it is implied that the battery connection can be made to either one battery or a group of batteries in a battery bank.
- The TriStar MPPT 150V uses stainless steel fasteners, an anodized aluminum heat sink, and conformal coating to protect it from harsh conditions. However, for acceptable service life, extreme temperatures and marine environments should be avoided.
- The TriStar MPPT 150V prevents reverse current leakage at night, so a blocking diode is not required in the system.
- Solar and battery fuses or DC breakers are required in the system. These protection devices are external to the TriStar MPPT 150V controller, and must be a maximum of 45 amps for the TS-MPPT-30. 70 amps for the TS-MPPT 45 and 90 amps for the TS-MPPT-60.
- Maximum battery short-circuit current rating must be less than the interrupt current rating of the battery over-current protection device referenced above.

Recommended Tools:

- Wire strippers
- Wire cutters
- #2 & #0 Phillips screwdriver
- slotted screwdrivers
- Pliers
- Drill
- 3/32" (2.5 mm) drill bit
- Level
- hack saw (cutting conduit)

3.2 Controller Installation

Step 1 - Remove the wiring box cover

CAUTION: Shock Hazard
Disconnect all power sources to the controller before removing the wiring box cover. Never remove the cover when voltage exists on any of the TriStar MPPT 150V power connections.

PRUDENCE : Risque de décharge électrique
Déconnectez toutes les sources d'alimentation du contrôleur avant d'enlever le couvercle du boîtier de câblage. Ne retirez jamais le couvercle en présence de tension sur une des connexions d'alimentation du TriStar MPPT.

Use a #2 Phillips screw driver to remove the four (4) screws that secure the wiring box cover as shown in figure 3-1 below.

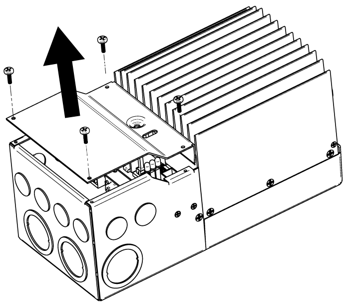


Figure 3-1. Remove the wiring box cover.

If a TriStar Digital Meter 2 display is installed, be sure to disconnect the RJ-11 cable.

Step 2 - Remove the Knock-Outs

Knockouts are provided for routing cables through conduit or wire glands. Table 3-1 below provides the knockout sizes and quantity on the TriStar MPPT 150V wiring box. Knockout locations and dimensions are on the inside front cover.

Quantity	Trade Size	Hole Dimension
8	1/2" or M20	7/8" (22.2 mm)
6	1 "	1 - 23/64 " (34.5 mm)
4	1 - 1/4 "	1 - 23/32 " (43.7 mm)

Table 3-1. Knockout sizes

CAUTION: Shock Hazard
Always use bushings, connectors, clamp connectors, or wire glands in the knockout openings to protect wiring from sharp edges.

PRUDENCE : Risque de décharge électrique
Utilisez toujours des bagues, des connecteurs, des raccordements à collets ou des fouloirs dans les ouvertures afin de protéger le câblage des bords coupants.

CAUTION: Shock Hazard
Never route network cables in the same conduit as the power conductors.

PRUDENCE : Risque de décharge électrique
N'acheminez jamais les câbles réseau dans le même conduit que les conducteurs d'alimentation.

Plan the routing of each conductor that will connect to the TriStar MPPT 150V before removing any knockouts. The 1/2" (M20) knockouts are ideal for routing network cables, which must be placed in separate conduit.

Step 3 - Mount to a Vertical Surface

CAUTION: Risk of Burns
Install the TriStar MPPT 150V in a location that prevents casual contact. The TriStar MPPT 150V heatsink can become very hot during operation.

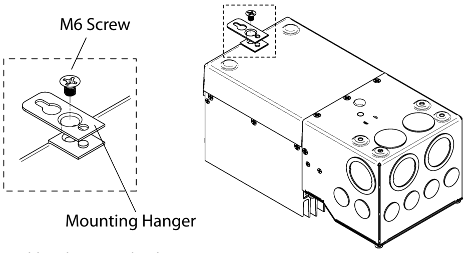


Figure 3-2. Attaching the mounting hanger

1. Attach the mounting hanger to the bottom of the TriStar MPPT 150V with the M6 screw provided as shown in figure 3-2.
2. Place the TriStar MPPT 150V on a vertical surface protected from direct sun, high temperatures, and water. The TriStar MPPT 150V requires at least 6" (150 mm) of clearance above and below and at least 1" (25 mm) on each side for proper air flow as shown in figure 3-3 below.

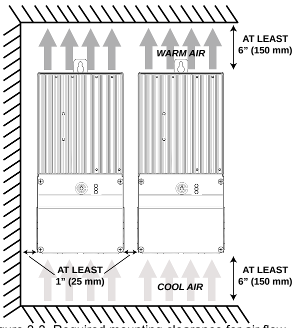


Figure 3-3. Required mounting clearance for air flow.

3. Place a mark on the mounting surface at the top of the keyhole.
4. Remove the controller and drill a 3/32" (2.5 mm) hole at the drill mark.
5. Insert a #10 screw (included) into the top pilot hole. Do not tighten the screw completely. Leave a 1/4" (6 mm) gap between the mounting surface and screw head.
6. Carefully align the keyhole on the TriStar MPPT 150V with the screw head. Slide the TriStar MPPT 150V down over the keyhole.
7. Check for vertical plumb with a level.
8. Mark two (2) mounting hole locations in the wiring box.
9. Remove the controller and drill 3/32" (2.5 mm) holes at the drill marks.
10. Carefully align the keyhole on the TriStar MPPT 150V with the screw head. Slide the TriStar MPPT 150V down over the keyhole.
11. The pre-drilled pilot holes should align with the mounting holes in the wiring box. Secure the controller with two (2) #10 mounting screws.
12. Tighten the keyhole screw.

Step 4 - Adjust Settings Switches

Switch 1: Reserved for Future Use
Settings switch 1 should remain in the "OFF" position.

Mode	Switch 1
Solar Charging	OFF
future use	ON

Switches 2 & 3: System Voltage
Four (4) system voltage configurations are available as shown in the table below:

System Voltage	Switch 2	Switch 3
Auto	OFF	OFF
12	OFF	ON
24	ON	OFF
48	ON	ON

The "auto" setting allows the TriStar MPPT 150V to detect the system voltage automatically on start up. The test is *only* performed at start up and the detected system voltage will never change during operation.

Generally, it is best to choose a specific system voltage. The auto detect feature should only be used in situations where the system voltage is unknown ahead of time or in systems where the system voltage may change periodically.

Switches 4, 5, & 6: Battery Charging Settings

It is important to select the battery type that matches the system battery to ensure proper charging and long battery life. Refer to the specifications provided by the battery manufacturer and choose a setting that best fits the recommended charging profile.

Settings Switches 4 - 5 - 6	Battery Type	Absorp. Stage (Volts)	Float Stage (Volts)	Equalize Stage (Volts)	Equalize Interval (Days)
off-off-off	1 - Gel	14.00	13.70		
off-off-on	2 - Sealed*	14.15	13.70	14.40	28
off-on-off	3 - Sealed*	14.30	13.70	14.60	28
off-on-on	4 - AGM/Flooded	14.40	13.70	15.10	28
on-off-off	5 - Flooded	14.60	13.50	15.30	28
on-off-on	6 - Flooded	14.70	13.50	15.40	28
on-on-off	7 - L-16	15.40	13.40	16.00	14
on-on-on	8 - Custom	Custom	Custom	Custom	Custom

** "Sealed" battery type includes gel and AGM batteries*

All settings are for 12 Volt nominal systems. Multiply the charge voltage settings by 2 for 24 Volt systems or by 4 for 48 Volt systems. A description of each setting is provided below. See section 4.3 for full details on battery charging and a description of each of the settings in the battery charging table.

<u>Battery Type</u> - The most common battery type associated with the specified charging settings.

<u>Absorption Stage</u> - This stage limits input current so that the Absorption voltage is maintained. As the battery becomes more charged, the charging current continues to taper down until the battery is fully charged.

<u>Float Stage</u> - When the battery is fully charged, the charging voltage will be reduced to the Float voltage setting.

<u>Equalize Stage</u> - During an equalization cycle, the charging voltage will be held constant at the specified voltage setting.

<u>Equalize Interval</u> - The number of days between equalization charges when the controller is configured for automatic equalizations (settings switch 7).

Switch 7: Battery Equalization

Choose between manual and automatic battery equalization charging. In the manual equalization setting, an equalization will only occur when manually started with the push-button or when requested from the equalize menu on the TriStar meter. Automatic equalization will occur according to the battery program specified by settings switches 4, 5, & 6 in the previous step.

In both settings (auto and manual), the push-button can be used to start and stop battery equalization. If the selected battery charging setting does not have an equalization stage an equalization will never occur, even if requested manually.

Equalize	Switch 7
manual	OFF
automatic	ON

Switch 8: Ethernet Security

The Ethernet Security switch enables or disables configuration of the TriStar MPPT 150V settings through the Ethernet connection. When switch eight is set to *disabled*, write commands to the TriStar MPPT 150V custom memory are not allowed. This a safety feature to prevent unintended changes to custom settings, but it is not a replacement for proper network security.

Configuration via TCP/IP	Switch 8
disabled	OFF
enabled	ON

NOTE:
Adjustment of network settings and custom set-points is always enabled via the RS-232 and EIA-485 connections. The Ethernet Security switch only enables/disables remote configuration via TCP/IP.

CAUTION: Risk of Tampering
The Ethernet Security settings switch does not block write commands to devices bridged via EIA-485.

REMARQUE :
Le réglage des paramètres de réseau et des points de consignes personnalisés est toujours activé par les connexions RS-232 et EIA-485. Le contacteur de sécurité Ethernet n'active/désactive que la configuration à distance par TCP/IP.

PRUDENCE : Risque de tentative d'altération
Le contacteur des paramètres de sécurité Ethernet ne bloque pas les commandes d'écriture sur les dispositifs reliés par EIA-485.

Step 5 - Remote Temperature Sensor

The included Remote Temperature Sensor (RTS) is recommended for effective temperature compensated charging. Connect the RTS to the 2-position terminal located between the battery (+) terminal lug and the LED stack (see figure 2-1). The RTS is supplied with 33 ft (10 m) of 22 AWG (0.34 mm^2) cable. There is no polarity, so either wire (+ or -) can be connected to either screw terminal. The RTS cable may be pulled through conduit along with the power wires. Tighten the connector screws to 5 in-lb (0.56 Nm) of torque. Separate installation instructions are provided inside the RTS bag.

WARNING: Risk of Fire.
If no Remote Temperature Sensor (RTS) is connected, use the TriStar MPPT 150V within 3m (10 ft) of the batteries. Internal Temperature Compensation will be used if the RTS is not connected. Use of the RTS is strongly recommended.

AVERTISSEMENT: Risque d'incendie.
Si non Capteur de température distant (RTS) est connecté, utilisez le MPPT ProStar moins de 3m (10 pi) de les batteries. Compensation de la température interne sera utilisée si la RTS n'est pas connecté. Utilisation de la RTS est fortement recommandé.

CAUTION:
The TriStar MPPT 150V will not temperature compensate charging parameters if the RTS is not used.

CAUTION: Equipment Damage
Never place the temperature sensor inside a battery cell. Both the RTS and the battery will be damaged.

NOTE:
The RTS cable may be shortened if the full length is not needed. Be sure to reinstall the ferrite choke on the end of the RTS if a length of cable is removed. This choke ensures compliance with electromagnetic emissions standards.

PRUDENCE:
Le TriStar MPPT 150V ne compense pas la température des paramètres de charges si le RTS n'est pas utilisé.

PRUDENCE : Endommagement de l'équipement
Ne placez jamais la sonde de température dans un élément de batterie. Le RTS et la batterie seraient endommagés.

REMARQUE :
Le câble de RTS peut être raccourci si la totalité de la longueur n'est pas nécessaire. Assurez-vous de réinstaller la bobine en ferrite sur l'extrémité du RTS si une longueur de câble est enlevée. Cette bobine assure la conformité avec les normes d'émissions électromagnétiques.

Step 6 - Grounding and Ground Fault Interruption

WARNING:
This unit is not provided with a GFDI device. This charge controller must be used with an external GFDI device as required by the Article 690 of the National Electrical Code for the installation location.

NOTE:
Conductors identified by the colors green or green/yellow should only be used for earthing conductors.

AVERTISSEMENT :
L'appareil n'est pas fourni avec un dispositif GFDI. Ce contrôleur de charge doit être utilisé avec un dispositif GFDI externe tel que requis par l'Article 690 du Code électrique national de la région de l'installation.

Use a copper wire to connect the grounding terminal in the wiring box to earth ground. The grounding terminal is identified by the ground symbol shown below that is stamped into the wiring box just below the terminal:

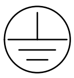


Figure 3-4. Ground Symbol

Do not connect the system negative conductor to this terminal. NEC requires the use of an external ground fault protection device (GFPD). The TriStar MPPT 150V does not have internal ground fault protection. The system electrical negative should be bonded through a GFPD to earth ground at one (and only one) location. The grounding point may be located in the solar circuit or the battery circuit.

Per NEC 690.45 (A) and NEC Table 250.122, minimum sizes for copper grounding wire are:

- TS-MPPT-30 10 AWG (5 mm^2)
- TS-MPPT-45 10 AWG (5 mm^2)
- TS-MPPT-60/M 8 AWG (8 mm^2)

OR, of the same, or greater, cross-sectional area as the PV wires.

WARNING: Risk of Fire
DO NOT bond system electrical negative to earth ground at the controller. Per NEC requirements, system negative must be bonded to earth ground through a GFPD at only one point.

AVERTISSEMENT : Risque d'incendie
NE LIEZ PAS le côté négatif du système à la mise à la terre au niveau du contrôleur. Selon les exigences du CNE, le côté négatif du système doit être mis à la terre par un GFPD à un seul point.

Step 7 - Battery Voltage Sense

The voltage at the battery connection on the TriStar MPPT 150V may differ slightly from the voltage directly at the battery bank terminals due to connection and cable resistance. The *Battery Voltage Sense* connection enables the TriStar MPPT 150V to measure the battery terminal voltage precisely with small gauge wires that carry very little current, and thus have no voltage drop. Both battery voltage sense wires are connected to the TriStar at the 2-position terminal located between the push-button and the positive (+) terminal lug (see figure 2-1).

A battery voltage sense connection is not required to operate your TriStar MPPT 150V controller, but it is recommended for best performance. If a TriStar meter will be added to the controller, the battery voltage sense will ensure that the voltage and diagnostic displays are very accurate.

The voltage sense wires should be cut to length as required to connect the battery to the voltage sense terminal. The wire size can range from 16 to 24 AWG (1.0 to 0.25 mm^2). A twisted pair cable is recommended but not required. Use UL rated 300 Volt conductors. The voltage sense wires may be pulled through conduit with the power conductors.

Fuse the positive (+) voltage sense wire as close to the battery as possible. Size the fuse based on wire ampacity - a 1A fuse can be used for #24 wire.

Tighten the connector screws to 5 in-lb (0.56 Nm) of torque.

The maximum length allowed for each battery voltage sense wire is 98 ft (30 m).

Be careful to connect the battery positive (+) terminal to the voltage sense positive (+) terminal. No damage will occur if the polarity is reversed, but the controller cannot read a reversed sense voltage. Connecting the voltage sense wires to the RTS terminal will cause an alarm.

If a TriStar meter is installed, check the “TriStar Settings” to confirm the Voltage Sense and the RTS (if installed) are both present and detected by the controller. MSView™ PC software can also be used to confirm the voltage sense is working correctly.

Step 8 - Network Connections

Network connections allow the TriStar MPPT 150V to communicate with other controller or computers. A network can be as simple as one controller and one PC, or as complex as dozens of controllers monitored via the internet. Review section 5.0 for more information about networking and the connection(s) required for your system.

WARNING: Shock Hazard
Never route network cables in the same conduit as the power conductors.

WARNING: Shock Hazard
Only use 300 Volt UL rated communication cable.

AVERTISSEMENT : Risque de décharge électrique
N’acheminez jamais les câbles réseau dans le même conduit que les conducteurs d’alimentation.

AVERTISSEMENT : Risque de décharge électrique
N’utilisez qu’un câble de communication 300 V homologué UL.

Connect the appropriate network cables to the TriStar MPPT 150V at this time. Access to the network ports is easier before the power cables are attached. The ports are located inside the conduit wiring box on the lower circuit board as shown in figure 3-5.

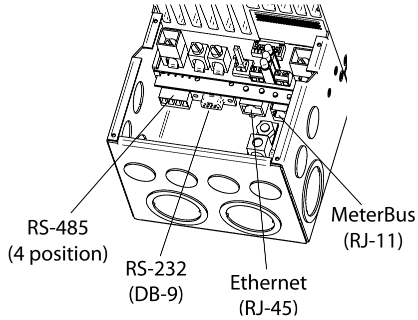


Figure 3-5. TriStar MPPT 150V network port locations

EIA-485 Connection

The four (4) position EIA-485 connector on the TriStar MPPT 150V must be removed to access the terminal screws. Remove the socket connector by firmly grasping the connector body and pulling away from the circuit board as shown in Figure 3-6.

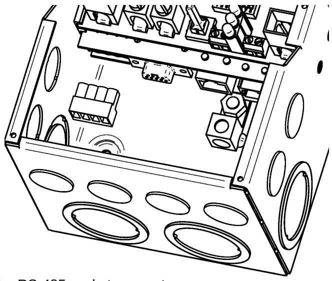


Figure 3-6. Removing the RS-485 socket connector

RS-232 Connection
The serial RS-232 port is a standard 9-pin (DB9) female connector. A low-profile serial connector is recommended to save room in the wiring box.

NOTE:
The RS-232 and EIA-485 ports share hardware. Both ports cannot be used simultaneously.

REMARQUE :
Les ports RS-232 et EIA-485 partagent le matériel. Ils ne peuvent pas être utilisés simultanément.

Ethernet Connection
The RJ-45 Ethernet jack features two (2) indicator LEDs for connection status and network traffic. Use CAT-5 or CAT-5e twisted pair cable and RJ-45 plugs. If possible, pull the network cable through conduit before crimping on the RJ-45 connectors. If using pre-assembled cables, take care not to damage the plugs when the cables are pulled through conduit.

MeterBus™ Connection
MeterBus™ networks use standard 4-wire or 6-wire RJ-11 telephone cables. If possible, pull the telephone cable through conduit before crimping on the RJ-11 connectors. If using pre-assembled cables, take care not to damage the plugs when the cables are pulled through conduit.

Y-cable Connections for EMC-1 Use
TS-MPPT-30 and TS-MPPT-45 units can be Ethernet connected using the EMC-1 accessory and an EMC-1 provided Y-cable. These models need to be connected to the EMC-1 with the Y-cable (DB-9 serial and RJ-11 plugs at the TS-MPPT) and an RJ-11 plug at the EMC-1.

Step 9 - Power Connections

NOTE:
To comply with the NEC, the TriStar MPPT 150V must be installed using wiring methods in accordance with the latest edition of the National Electric Code, NFPA 70.

CAUTION: Risk of Fire and Shock
Connect battery terminals prior to the connection of array terminals. The battery positive (+) terminal has a red cover, the solar positive (+) terminal has a yellow cover.

REMARQUE :
Pour la conformité CNE, le TriStar MPPT 150V doit être installé selon des méthodes de câblage conformes à la dernière édition du Code électrique national, NFPA 70.

PRUDENCE : Risque d'incendie et de décharge électrique
Branchez les bornes de la batterie avant la connexion des bornes de réseau. La borne positive (+) de la batterie a un capuchon rouge, la borne positive (+) solaire a un capuchon jaune.

Wire Size
The four large power terminals are sized for 14 - 2 AWG (2.5 - 35 mm²) wire. The terminals are rated for copper and aluminum conductors. <u>Use UL-listed Class B 300 Volt stranded wire only.</u> Good system design generally requires large conductor wires for the solar and battery connections that limit voltage drop losses to 2% or less. The wire tables in the appendix on pages 51-54 provide wire sizing information for connecting the solar array and battery bank to the TriStar MPPT 150V with a maximum of 2% voltage drop.

Minimum Wire Size
The NEC requires that the wires carrying the system current never exceed 80% of the conductor's current rating. The table below provides the minimum size of copper and aluminum wire allowed by NEC for all TriStar MPPT 150V models when the current equals the full nameplate rating (30, 45 or 60 amps). Wire types rated for 75°C and 90°C are included.

Minimum wire sizes for ambient temperatures to 45°C are provided in table 3-2 below:

Model	Wire Type	75°C Wire	90°C Wire
TS-MPPT-30	Copper	8 AWG (8.36 mm²)	8 AWG (8.36 mm²)
TS-MPPT-30	Aluminum	6 AWG (13.3 mm²)	8 AWG (8.36 mm²)
TS-MPPT-45	Copper	4 AWG (21.1 mm²)	6 AWG (13.3 mm²)
TS-MPPT-45	Aluminum	3 AWG (26.7 mm²)	4 AWG (21.1 mm²)
TS-MPPT-60	Copper	3 AWG (26.7 mm²)	4 AWG (21.1 mm²)
TS-MPPT-60	Aluminum	1 AWG (42.4 mm²)	2 AWG (33.6 mm²)

Table 3-2 Minimum wire sizes

Disconnects

WARNING: Shock Hazard
Fuses, circuit breakers, and disconnect switches should never open grounded system conductors. Only GFDI devices are permitted to disconnect grounded conductors.

AVERTISSEMENT : Risque de décharge électrique
Les fusibles, coupe-circuits et interrupteurs ne doivent jamais ouvrir les conducteurs du système mis à la terre. Seuls les dispositifs GFDI sont autorisés à déconnecter les conducteurs reliés mis à la terre.

The NEC requires solar and battery fuses or DC breakers to be installed in the system. These protection devices are external to the TriStar MPPT 150V controller, and must be a maximum of 45 amps for the TS-MPPT-30, 70 amps for the TS-MPPT 45, and 90 amps for the TS-MPPT-60/M.

Maximum battery short-circuit current rating must be less than the interrupt current rating of the battery over-current protection device referenced above.

WARNING: *Breakers and fuses may require lower ratings than referenced above, so as not to exceed any specific wire ampacity.*

AVERTISSEMENT: *Disjoncteurs et fusibles peuvent exiger des cotes inférieures que mentionnés ci-dessus de manière à ne pas pour dépasser n'importe quel fils particulier admissible.*

Connect the Power Wires

WARNING: Shock Hazard
The solar PV array can produce open-circuit voltages in excess of 150 Vdc when in sunlight. Verify that the solar input breaker or disconnect has been opened (disconnected) before installing the system wires.

AVERTISSEMENT : Risque de décharge électrique
Le réseau PV solaire peut produire des tensions de circuit ouvert supérieures à 150 Vdc à la lumière du soleil. Vérifiez que le coupe-circuit ou l'interrupteur d'entrée solaire a été ouvert (déconnexion) avant d'installer les câbles du système.

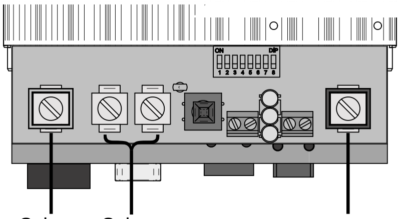


Figure 3-7. Power terminal locations

Connect the four (4) power conductors shown in figure 3-7 above in the following steps:

1. Confirm that the system input and output disconnect switches are both turned off before connecting the power wires to the controller. There are no disconnect switches inside the TriStar MPPT 150V.
2. Provide for strain relief if the bottom knockouts are used and conduit is not used.
3. Pull the wires into the wiring box. The Remote Temperature Sensor and Battery Sense wires can be inside the conduit with the power conductors. It is easier to pull the RTS and Sense wires before the power cables.

WARNING: Risk of Damage
Be very certain that the battery connection is made with correct polarity. Turn on the battery breaker/disconnect and measure the voltage on the open battery wires BEFORE connecting to the TriStar MPPT 150V. Disconnect the battery breaker/disconnect before wiring to the controller.

AVERTISSEMENT : Risque d'endommagement
Assurez-vous que la connexion a la batterie est effectuée avec la polarité correcte. Activez le coupe-circuit/interrupteur de la batterie et mesure la tension sur les câbles ouverts AVANT la connexion au TriStar MPPT 150V. Déconnectez le coupe-circuit/interrupteur de la batterie avant le câblage sur le contrôleur.

4. Connect the Battery + (positive) wire to the Battery + terminal on the TriStar MPPT 150V. The Battery + terminal has a red cover.
5. Connect the Battery - (negative) wire to one of the Common Negative terminals on the TriStar MPPT 150V.

WARNING: Risk of Damage
Be very certain that the solar connection is made with correct polarity. Turn on the solar array breaker/disconnect and measure the voltage on the open wires BEFORE connecting to the TriStar MPPT 150V. Disconnect the solar breaker/ disconnect before wiring to the controller.

AVERTISSEMENT : Risque d'endommagement
Assurez-vous que la connexion solaire est effectuée avec la polarité correcte. Activez le coupe-circuit/interrupteur de réseau solaire et mesure la tension sur les câbles ouverts AVANT la connexion au TriStar MPPT 150V. Déconnectez le coupe-circuit/interrupteur solaire avant le câblage sur le contrôleur.

6. Connect the Solar + (positive) wire to the Solar + terminal on the TriStar MPPT 150V. The Solar + terminal has a yellow cover.
7. Connect the Solar - (negative) wire to one of the Common Negative terminals on the TriStar MPPT 150V.

Torque all four (4) power terminals to 50 in-lbs (5.65 Nm)

Power-up

WARNING: Risk of Damage
Connecting the solar array to the battery terminal will <u>permanently damage</u> the TriStar MPPT 150V.

WARNING: Risk of Damage
Connecting the solar array or battery connection with reverse polarity will <u>permanently damage</u> the TriStar MPPT 150V.

AVERTISSEMENT : Risque d'endommagement
La connexion du réseau solaire sur la borne de la batterie endommagera le TriStar MPPT 150V de façon permanente.

AVERTISSEMENT : Risque d'endommagement
La connexion du réseau solaire ou la connexion de la batterie avec une polarité inversée endommagera le TriStar MPPT 150V de façon permanente.

- Confirm that the Solar and Battery polarities are correct.
- Turn the battery disconnect switch on first. Observe that the LEDs indicate a successful start-up. (LEDs blink Green - Yellow - Red in one cycle)
- Note that a battery must be connected to the TriStar MPPT 150V to start and operate the controller. The controller will not operate only from solar input.
- Turn the solar disconnect on. If the solar array is in full sunlight, the TriStar MPPT 150V will begin charging. If an optional TriStar Meter is installed, charging current will be reported along with charging state.

To Power-down

WARNING: Risk of Damage
ONLY disconnect the battery from the TriStar MPPT 150V AFTER the solar input has been disconnected. Damage to the controller may result if the battery is removed while the TriStar MPPT 150V is charging.

AVERTISSEMENT : Risque d'endommagement
Le TriStar MPPT 150V SEULEMENT déconnecter la batterie APRÈS l'entrée solaire a été déconnectée. Le contrôleur pourrait endommager si la batterie est retirée quand le TriStar MPPT 150V est en charge.

- To prevent damage, power-down must be done in the reverse order as power-up.

4.0 Operation

The TriStar MPPT 150V operation is fully automatic. After installation is completed, there are few operator tasks to perform. However, the operator should be familiar with the operation and care of the TriStar MPPT 150V as described in this section.

4.1 TrakStar™ MPPT Technology

The TriStar MPPT 150V utilizes Morningstar's TrakStar™ Maximum Power Point Tracking (MPPT) technology to extract maximum power from the solar array. The tracking algorithm is fully automatic and does not require user adjustment. TrakStar™ technology tracks the array *maximum power point* as it varies with weather conditions, ensuring that maximum power is harvested from the array throughout the course of the day.

Current Boost

Under most conditions, TrakStar™ MPPT technology will "boost" the solar charge current. For example, a system may have 36 Amps of solar current flowing into the TS-MPPT and 44 Amps of charge current flowing out to the battery. The TriStar MPPT 150V does not create current! Rest assured that the power into the TriStar MPPT 150V is the same as the power out of the TriStar MPPT 150V. Since power is the product of voltage and current (Volts x Amps), the following is true*:

(1) Power Into the TriStar MPPT 150V = Power Out of the TriStar MPPT 150V
(2) Volts In x Amps In = Volts Out x Amps Out

* assuming 100% efficiency. Losses in wiring and conversion exist.

If the solar module's *maximum power voltage* (V_{mp}) is greater than the battery voltage, it follows that the battery current must be proportionally greater than the solar input current so that input and output power are balanced. The greater the difference between the V_{mp} and battery voltage, the greater the current boost. Current boost can be substantial in systems where the solar array is of a higher nominal voltage than the battery as described in the next section.

High Voltage Strings and Grid-Tie Modules

Another benefit of TrakStar™ MPPT technology is the ability to charge batteries with solar arrays of higher nominal voltages. For example, a 12 volt battery bank may be charged with a 12, 24, 36, or 48 volt nominal off-grid solar array. Grid-tie solar modules may also be used as long as the solar array *open circuit voltage* (V_{oc}) rating will not exceed the TriStar MPPT 150V 150 Volt maximum input voltage rating <u>at worst-case (coldest) module temperature</u>. The solar module documentation should provide V_{oc} vs. temperature data.

Higher solar input voltage results in lower solar input current for a given input power. High voltage solar input strings allow for smaller gauge solar wiring. This is especially helpful and economical for systems with long wiring runs between the controller and the solar array.

An Advantage Over Traditional Controllers

Traditional controllers connect the solar module directly to the battery when recharging. This requires that the solar module operate in a voltage range that is usually below the module's V_{mp}. In a 12 Volt system for example, the battery voltage may range from 10 - 15 Vdc, but the module's V_{mp} is typically around 16 or 17 Volts. Figure 4-1 shows typical current vs. voltage and power output curves for a nominal 12 Volt off-grid module.

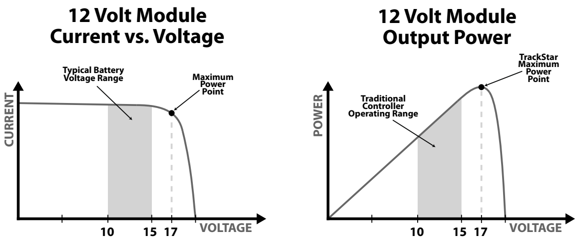


Figure 4-1. Nominal 12 Volt Solar Module I-V curve and output power graph.

The array V_{mp} is the voltage where the product of output current and voltage (Amps x Volts) is greatest, which falls on the "knee" of the solar module I-V curve as shown on the left in Figure 4-1.

Because traditional controllers do not always operate at the V_{mp} of the solar array, energy is wasted that could otherwise be used to charge the battery and power system loads. The greater the difference between battery voltage and the V_{mp} of the module, the more energy is wasted. TrakStar™ MPPT technology will always operate at the maximum power point resulting in less wasted energy compared to traditional controllers.

Conditions That Limit the Effectiveness of MPPT

The V_{mp} of a solar module decreases as the temperature of the module increases. In very hot weather, the V_{mp} may be close or even less than battery voltage. In this situation, there will be very little or no MPPT gain compared to traditional controllers. However, systems with modules of higher nominal voltage than the battery bank will always have an array V_{mp} greater than battery voltage. Additionally, the savings in wiring due to reduced solar current make MPPT worthwhile even in hot climates.

4.2 Battery Charging Information

4-Stage Charging

The TriStar MPPT 150V has a 4-stage battery charging algorithm for rapid, efficient, and safe battery charging. Figure 4-2 shows the sequence of the stages.

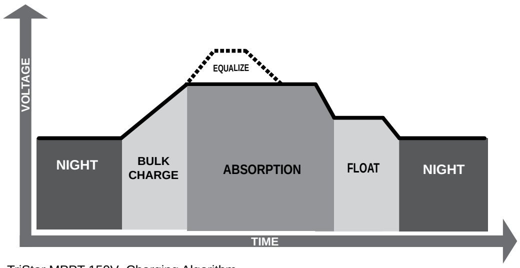


Figure 4-2. TriStar MPPT 150V Charging Algorithm

Bulk Charge Stage

In Bulk charging stage, the battery is not at 100% state of charge and battery voltage has not yet charged to the Absorption voltage set-point. The controller will deliver 100% of available solar power to recharge the battery.

Absorption Stage

When the battery has recharged to the Absorption voltage set-point, constant-voltage regulation is used to maintain battery voltage at the Absorption set-point. This prevents heating and excessive battery gasing. The battery is allowed to come to full state of charge at the Absorption voltage set-point. The green SOC LED will blink once per second during Absorption charging.

The battery must remain in the Absorption charging stage for a cumulative 150 - 180 minutes, depending on battery type, before transition to the Float stage will occur. However, Absorption time will be extended by 30 minutes if the battery discharges below 12.5 Volts (25 Volts @24 V, 50 Volts @48 V) the previous night.

The Absorption set-point is temperature compensated if the RTS is connected; otherwise, voltages set-points are based on the reference of 25°C.

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Float Stage

After the battery is fully charged in the Absorption stage, the TriStar MPPT 150V reduces the battery voltage to the Float voltage set-point. When the battery is fully recharged, there can be no more chemical reactions and all the charging current is turned into heat and gasing. The float stage provides a very low rate of maintenance charging while reducing the heating and gasing of a fully charged battery. The purpose of float is to protect the battery from long-term overcharge. The green SOC LED will blink once every two (2) seconds during Float charging.

Once in Float stage, loads can continue to draw power from the battery. In the event that the system load(s) exceed the solar charge current, the controller will no longer be able to maintain the battery at the Float set-point. Should the battery voltage remain below the Float set-point for a cumulative 60 minute period, the controller will exit Float stage and return to Bulk charging.

The Float set-point is temperature compensated if the RTS is connected; otherwise, voltages set-points are based on the reference of 25°C.

Equalize Stage

WARNING: Risk of Explosion
Equalizing vented batteries produces explosive gases. The battery bank must be properly ventilated.

CAUTION: Equipment Damage
Equalization increases the battery voltage to levels that may damage sensitive DC loads. Verify all system loads are rated for the temperature compensated Equalize voltage before beginning an Equalization charge.

CAUTION: Equipment Damage
Excessive overcharging and gasing too vigorously can damage the battery plates and cause shedding of active material from the plates. An equalization that is too high or long can be damaging. Review the requirements for the particular battery being used in your system.

AVERTISSEMENT : Risque d'explosion
Les batteries à évent et compensation produisent des gaz explosifs. Le groupe de batteries doit être correctement ventilé.

PRUDENCE : Endommagement de l'équipement
La compensation augmente la tension des batteries à des niveaux pouvant endommager les charges sensibles en CC. Vérifiez que toutes les charges du système sont conçues pour la tension de compensation par température avant de commencer une charge de compensation.

PRUDENCE : Endommagement de l'équipement
Une surcharge excessive et un dégagement gazeux trop vigoureux peuvent endommager les plaques de batteries et provoquer l'élimination du matériau actif des plaques. Une compensation trop élevée ou trop longue peut provoquer des dégâts. Examinez les exigences pour la batterie particulière utilisée dans votre système.

Certain battery types benefit from a periodic boost charge to stir the electrolyte, level the cell voltages, and complete the chemical reactions. Equalize charging raises the battery voltage above the standard absorption voltage so that the electrolyte gases. The green SOC LED will blink rapidly two (2) times per second during equalization charging.

The duration of the equalize charge is determined by the selected battery type. See table 4-1 in this section for more details. The *Equalization Time* is defined as time spent at the equalize set-point. If there is insufficient charge current to reach the equalization voltage, the equalization will terminate after an additional 60 minutes to avoid over gasing or heating the battery. If the battery requires more time in equalization, an equalize can be requested using the TriStar Meter or push-button to continue for one or more additional equalization cycles.

The Equalize set-point is temperature compensated if the RTS is connected; otherwise, voltages set-points are based on the reference of 25℃.

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When to Equalize

The ideal frequency of equalizations depends on the battery type (lead-calcium, lead-antimony, etc.), the depth of discharging, battery age, temperature, and other factors. One very broad guide is to equalize flooded batteries every 1 to 3 months or every 5 to 10 deep discharges. Some batteries, such as the L-16 group, will need more frequent equalizations.

The difference between the highest cell and lowest cell in a battery can also indicate the need for an equalization. Either the specific gravity or the cell voltage can be measured. The battery manufacturer can recommend the specific gravity or voltage values for your particular battery.

Why Equalize?

Routine equalization cycles are often vital to the performance and life of a battery - particularly in a solar system. During battery discharge, sulfuric acid is consumed and soft lead sulfate crystals form on the plates. If the battery remains in a partially discharged condition, the soft crystals will turn into hard crystals over time. This process, called "lead sulfation," causes the crystals to become harder over time and more difficult to convert back to soft active materials.

Sulfation from chronic undercharging of the battery is the leading cause of battery failures in solar charging systems. In addition to reducing the battery capacity, sulfate build-up is the most common cause of buckling plates and cracked grids. Deep cycle batteries are particularly susceptible to lead sulfation.

Normal charging of the battery can convert the sulfate back to the soft active material if the battery is fully recharged. However, a solar charged battery is seldom completely recharged, so the soft lead sulfate crystals harden over a period of time. Only a long controlled overcharge, or equalization, at a higher voltage can reverse the hardening of sulfate crystals.

Preparation for Equalization

First, confirm that all of the system loads are rated for the equalization voltage. Consider that at 0°C (32°F) the equalization voltage will reach 16.75 Volts for 12 Volt L-16 batteries (67.0 Volts for 48 Volt systems) with a temperature sensor installed. Disconnect any loads at risk of damage due to the high input voltage.

If Hydrocaps are used, be sure to remove them before starting an equalization. Replace the Hydrocaps with standard battery cell caps. The Hydrocaps can get very hot during an equalization. Also, if Hydrocaps are used, the equalization should be set for manual only (DIP switch #7 is Off).

After the equalization is finished, add distilled water to each cell to replace gasing losses. Check that the battery plates are covered.

Equalize a Sealed Battery?

The *Battery Charging Settings* table (see table 4-1 in this section) shows two sealed battery settings with an Equalization cycles. These are minimal "boost" cycles to level individual cells. This is not an equalization, and will not vent gas from sealed batteries that require up to 14.4V charging (12V battery). Many VRLA batteries, including AGM and gel, have charging requirements up to 14.4V (12V battery). Depending on the battery manufacturer's recommendation, the "boost" cycle for sealed cells can be disabled by setting the equalize setting switch to manual, if required.

Battery Charging Settings

Preset TriStar MPPT 150V battery charging options are shown in tables 4-1 and 4-2 below. All voltage settings listed are for nominal 12 Volt batteries. Multiply the voltage settings by two (2) for 24 Volt batteries or by four (4) for 48 Volt systems.

NOTE: *These settings are general guidelines for use at the operator's discretion. The TriStar MPPT 150V can be set or programmed to charge to virtually any specific requirements, but only the battery manufacturer can recommend optimal settings for* <u>*their*</u> *products.*

Settings Switches 4 - 5 - 6	Battery Type	Absorp. Stage (Volts)	Float Stage (Volts)	Equalize Stage (Volts)	Absorp. Time (Minutes)	Equalize Time (Minutes)	Equalize Interval (Days)
off-off-off	1 - Gel	14.00	13.70		150		
off-off-on	2 - Sealed*	14.15	13.70	14.40	150	60	28
off-on-off	3 - Sealed*	14.30	13.70	14.60	150	60	28
off-on-on	4 - AGM/Flooded	14.40	13.70	15.10	180	120	28
on-off-off	5 - Flooded	14.60	13.50	15.30	180	120	28
on-off-on	6 - Flooded	14.70	13.50	15.40	180	180	28
on-on-off	7 - L-16	15.40	13.40	16.00	180	180	14
on-on-on	8 - Custom	Custom	Custom	Custom	Custom	Custom	Custom

** "Sealed" battery type includes gel and AGM batteries*

Table 4-1. Battery charging settings for each selectable battery type

The TriStar MPPT 150V provides seven (7) standard battery charging settings that are selectable with the settings DIP switches (see Figure 4.1 above). These standard charging settings are suitable for lead-acid batteries ranging from sealed (gel, AGM, maintenance-free) to Flooded and L-16 cells. In addition, an 8th charging setting provides for custom set-points using MSView™ PC software.

Shared Settings	Value	Units
Absorption Extension Voltage	12.50	Volts
Absorption Extension Time	Absorption Time + 30	minutes
Float Exit Timeout	60	minutes
Float Cancel Voltage	12.30	Volts
Equalize Timeout	Equalize Time + 60	minutes
Temperature Compensation Coefficient*	- 5	millivolts / °C / cell

** 25°C reference*

Table 4-2. Battery settings that are shared between all battery types

The shared settings in Table 4-2 above are common to all battery types. The following illustrations graphically explain the shared settings.

Absorption Extension

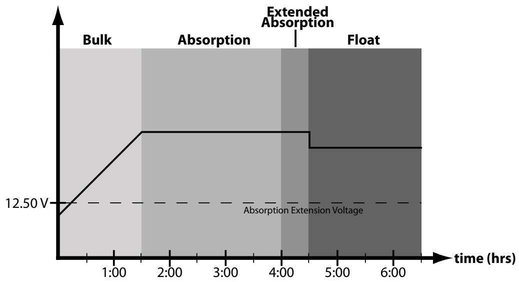


Figure 4-3. Absorption extension charging profile.

If battery voltage discharges below 12.50 Volts (25.00 Volts @ 24 V, 50 Volts @ 48 V) the previous night, Absorption charging will be extended on the next charge cycle as shown in figure 4-3 above. 30 minutes will be added to the normal Absorption duration.

Float Time-out

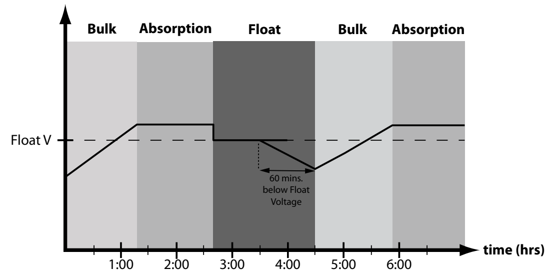


Figure 4-4. Float exit time-out charging profile

After entering Float stage, the controller will only exit Float if the battery voltage remains below Float voltage for 60 cumulative minutes. In figure 4-4, a system load turns on at 3:30 hrs when the controller is in Float stage, runs for one hour, and turns off at 4:30 hrs. The load current draw is larger than the charge current, causing battery voltage to drop below Float voltage for 60 minutes. After the load runs for 60 minutes, the time-out causes the controller to return to Bulk charging, and then Absorption stage once again. In this example, a load runs continuously for 60 minutes. However, because the Float exit timer is cumulative, multiple momentary load events that pull the battery voltage below Float voltage for a combined 60 minutes duration will also force an exit from Float stage.

Float Cancel Voltage

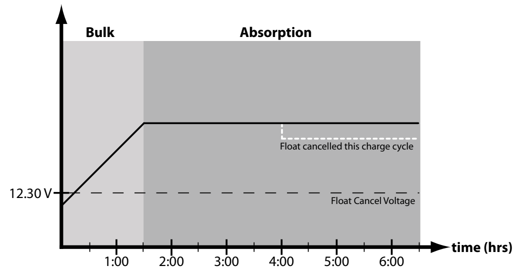


Figure 4-5. Float cancelled charging profile

If the battery bank discharges below 12.30 Volts (24.60 Volts @ 24 V, 49.20 Volts @ 48 V) the previous night, Float charging stage will be cancelled for the next charge cycle. Figure 4-5 above illustrates this concept. At 0:00 hrs (dawn), battery voltage is below the Float Cancel threshold voltage. The diagram shows where Float stage would have occurred if Float was not cancelled.

Equalize Time-out

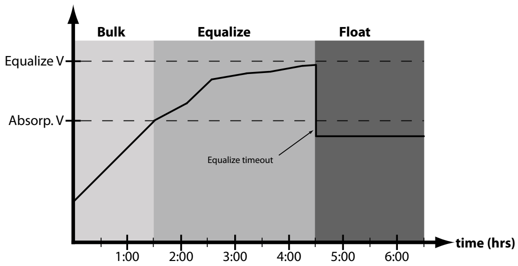


Figure 4-6. Equalize timeout charging profile

The charging profile in figure 4-6 shows an *Equalize Timeout* event. The timeout timer begins as soon as battery voltage exceeds the Absorption voltage setpoint. If there is insufficient charging current or system loads are too large, the battery voltage may not reach the Equalize setpoint. Equalize Timeout is a safety feature that prevents high battery voltage for extended periods of time which may damage the battery.

Temperature Compensation

All charging settings are based on 25°C (77°F). If the battery temperature varies by 5°C, the charging setting will change by 0.15 Volts for a 12 Volt battery. This is a substantial change in the charging of the battery, and the use of the Remote Temperature Sensor (RTS) is recommended to adjust charging to the actual battery temperature.

The need for temperature compensation depends on the temperature variations, battery type, how the system is used, and other factors. If the battery appears to be gasing too much or not charging enough, the RTS can be added at any time after the system has been installed. See Section 2.3 - Step 4 for installation instructions.

Battery Sense

Voltage drops are unavoidable in power cables that carry current, including the TriStar MPPT 150V battery cables. If Battery Sense wires are not used, the controller must use the voltage reading at the battery power terminals for regulation. Due to voltage drops in the battery cables, the battery power connection voltage will be higher than the actual battery bank voltage while charging the battery.

Two sense wires, sized from 1.0 to 0.25 mm^2 (16 to 24 AWG), can be used for battery voltage sense. Because these wires carry no current, the voltage at the TriStar will be identical to the battery voltage. A 2-position terminal is used for the battery sense connection.
Generally accepted wiring practice is to limit voltage drops between the charger and the battery to 2%. Even properly sized wiring with 2% drop can result in a 0.29 Volt drop for 14.4V charging (or 1.15 Volt for a 48 Volt nominal system). Voltage drops will cause some undercharging of

the battery. The controller will begin Absorption or limit equalization at a lower battery voltage because the controller measures a higher voltage at the controller's terminals than is the actual battery voltage. For example, if the controller is programmed to start Absorption at 14.4V, when the controller "sees" 14.4V at its battery terminals, the true battery voltage would only be 14.1V if there is a 0.3V drop between the controller and battery.

Note that the battery sense wires will not power the controller, and the sense wires will not compensate for losses in the power wires between the controller and the battery. The battery sense wires are used to improve the accuracy of the battery charging.

See Section 3.2 - Step 7 for instructions on how to connect the battery sense wires.

4.3 Push-button

The following functions can be enabled with the push-button (located on the front cover):

PUSH

- Reset from an error or fault.
- Reset the battery service indication if this has been activated in custom settings. A new service period will be started, and the flashing LEDs will stop blinking. If the battery service is performed before the LEDs begin blinking, the push-button must be pushed at the time when the LEDs are blinking to reset the service interval and stop the blinking.

PUSH AND HOLD 5 SECONDS

- Request battery equalization manually. The TriStar MPPT 150V will begin equalization in either the manual or automatic equalization mode. Equalization will begin when there is sufficient solar power to charge the battery up to the equalization voltage. The LEDs will blink the sequence defined in table 4-3 below to confirm that an equalize has been requested. The equalization request will automatically stop per the battery type selected (see Section 4.4). Equalization will only occur if the selected battery type has an equalization stage.
- Stop an equalization that is in progress. This will be effective in either the manual or automatic mode. The equalization will be terminated. The LEDs will blink to confirm the equalize has been cancelled as shown in table 4-3 below.

Push-button Action	SOC LED Indication*
Manual Equalization Started	Green / Yellow / Red - Green / Yellow / Red - Green - Green
Stop Equalization	Green / Yellow / Red - Green / Yellow / Red - Red - Red

Table 4-3. Manual equalization LED indications

* See key on p. 44

NOTE:
For multiple TriStar MPPT 150V controllers on a MeterBus^{TM} network, initialize a battery equalization using the TriStar meter so that all controllers are synchronized.

> ***REMARQUE :***
> *Avec plusieurs contrôleurs TriStar MPPT 150V sur un réseau MeterBusTM, initialisez une compensation de batteries à l'aide de l'outil de mesure TriStar afin de synchroniser tous les contrôleurs.*

Note that if two or more TriStar MPPT 150V controllers are charging in parallel, each controller may attempt to equalize on a different day. Systems with multiple controllers should only equalize manually to ensure synchronization between controllers.

4.4 LED Indications

Valuable information can be provided by the three LEDs visible through the front cover. Although there are many different LED indications, they have similar patterns to make it easier to interpret each LED display. Consider as three groups of indications: General Transitions // Battery Status // Faults & Alarms.

LED Display Explanation
G = green LED is lit
Y - R = yellow LED is lit, then red LED is lit alone
G / Y = green and yellow are both lit at the same time
G / Y - R = green & yellow both lit, then red is lit alone

Sequencing LED patterns (faults) repeat until the fault is cleared

General Transitions

• Controller start-up	G - Y - R (one cycle)
• Equalize start request	G / Y/ R - G / Y / R - G - G
• Equalize cancelled	G / Y / R - G / Y / R - R - R
• Battery service is required*	all three LEDs blinking until service is reset

**battery service notification is only enabled in custom settings, or when any custom edit is programmed*

Battery Status

• General state-of-charge	See battery SOC LED indications below
• Absorption state	G blinking (½ second on / ½ second off)
• Equalization state	G fast blink (2.5 times per second)
• Float state	G slow blink (1 second on / 1 second off)

Faults & Alarms

• Over-temperature	Y - R sequencing
• High voltage disconnect	G - R sequencing
• DIP switch fault	R -Y - G sequencing
• Self-test faults	R - Y - G sequencing
• Remote Temperature Sensor (RTS)	G - R sequencing, with constant yellow
• Battery voltage sense	G - R sequencing, with constant yellow
• Battery over-current	R / Y - G sequencing

Battery State-of-Charge LED Indications

G	80% to 95% SOC
G / Y	60% to 80% SOC
Y	35% to 60% SOC
Y / R	0% to 35% SOC
R	battery is discharging

Refer to the Specifications (Section 8.0) for the State-of-Charge voltages.
Note that because these State-of-Charge LED displays are for all battery types and system designs, they are only approximate indications of the battery charge state.

Ethernet Jack Indications

In addition to the SOC LEDs, two (2) small LEDs can be found on the Ethernet RJ-45 jack inside the wiring box. These LEDs indicate the LAN/WAN network link and activity status as follows:

Condition	Green LED	Yellow LED
Network Connection OK	ON	OFF
Network Activity	ON	Blinking
Error	OFF	ON

4.5 Protections, Faults & Alarms

The TriStar MPPT 150V protections and automatic recovery are important features that ensure the safe operation of the system. Additionally, the TriStar MPPT 150V features real-time self diagnostics that report Fault and Alarm conditions as they occur.

Faults are events or conditions that require the TriStar MPPT 150V to cease operation. A Fault usually occurs when a limit such as voltage, current, or temperature has been surpassed. Fault conditions are indicated with unique LED sequences and are also displayed on the TriStar Meter.

Alarms are events or conditions that may require the TriStar MPPT 150V to modify operation. Alarms are commonly used to alert the user that the controller is nearing a specific voltage, current, or temperature limit. Alarm conditions are only displayed on the TriStar Meter.

Protections

Solar Overload
The TriStar MPPT 150V will limit battery current to the *Maximum Battery Current* rating. An over-sized solar array will not operate at peak power. The solar array should be less than the TriStar MPPT 150V *Nominal Maximum Input Power* rating for optimal performance. For more information see the Nominal Maximum Input Power asterisk on p. 63.

Solar Short Circuit
The TriStar MPPT 150V will disconnect the solar input if a short circuit is detected in the solar wiring. Charging automatically resumes when the short is cleared. No LED indication.

High Input Voltage Current Limit
The TriStar MPPT 150V will limit the solar input current as the solar array Voc approaches the maximum input voltge rating. The array Voc should never exceed the 150 volt maximum input voltage - see the array voltage de-rating graph in Appendix.

Very Low Battery Voltage
If battery discharges below ~7 Volts the controller will go into brownout and shut down. When the battery voltage rises above the 8 Volt minimum operating voltage, the controller will restart.

Faults

Remote Temperature Sensor Failure (G - R sequencing, with constant yellow**)**
If a fault in the RTS (such as a short circuit, open circuit, loose terminal) occurs after the RTS has been working, the LED's will indicate a failure. However, if the controller is restarted with a failed RTS, the controller may not detect that the RTS is connected, and the LEDs will not indicate a problem. A TriStar meter or the PC software can be used to determine if an RTS is detected and working properly.

Battery Voltage Sense Failure (G - R sequencing, with constant yellow**)**
If a fault in the battery sense connection (such as a short circuit, open circuit or loose terminal) occurs after the battery sense has been working, the LEDs will indicate a failure. If the controller is restarted with the failure still present, the controller may not detect that the battery sense is connected and the LEDs will not indicate a fault. A TriStar meter or the PC software can be used to determine if the battery sense is working properly.

Battery Over-Current (R / Y - G)

While rare, if battery charging current exceeds approximately 130% of the controller's output current rating, this fault can occur. The fault is generally related to fast, large battery voltage transients (connecting a very heavy or capacitive load like an inverter) that are faster than the controller can regulate and it shuts off to protect the circuitry. The controller will automatically re-start in 10 seconds.

Settings (DIP) Switch Changed (R-Y-G sequencing)
If a settings switch is changed while there is power to the controller, the LEDs will begin sequencing and the solar input will disconnect. The controller must be re-started to clear the fault and begin operation with the new settings.

Battery High Voltage Disconnect (G-R sequencing)
This fault is set when battery voltage is above normal operating limits. The controller will disconnect the solar input and set a High Voltage Disconnect fault. This fault is commonly caused by other charging sources in the system charging the battery above the TriStar MPPT 150V regulation voltage. When the battery voltage returns to normal levels, the fault will automatically clear.

Custom Settings Edit (R -Y- G sequencing)
A value has been modified in custom settings memory. The controller will stop charging and indicate a fault condition. After all settings have been modified, the controller must be reset by removing and then restoring power to the controller. The new programmed settings will be used after the power reset.

Firmware Update Failure
The firmware update was not successfully programmed. The controller will not indicate the full power-up LED sequence of G - Y - R when power to the controller is reset. Instead, the controller will display green and then stop on yellow. The yellow LED will continue to be lit and the controller will not complete start up or begin charging. Retry the firmware update. The firmware must be successfully loaded before the controller will start up.

Alarms

High Temperature Current Limit
The TriStar MPPT 150V will limit the solar input current if the heatsink temperature exceeds safe limits. Solar charge current will be tapered back (to 0 amps if needed) to reduce the heatsink temperature. The TriStar MPPT 150V is designed to operate at full rated current at the maximum ambient temperature. This alarm indicates that there is insufficient airflow and that the heatsink temperature is approaching unsafe limits. If the controller frequently reports this alarm condition, corrective action must be taken to provide better air flow or to relocate the controller to a cooler spot.

High Input Voltage Current Limit
The TriStar MPPT 150V will limit the solar input current as the solar array Voc approaches the maximum input voltage rating. The array Voc should never exceed the 150 Volt maximum input voltage. See the array voltage derating graph in Section 8.0.

Current Limit
The array power exceeds the rating of the controller. This alarm indicates that the TriStar MPPT 150V is limiting battery current to the maximum current rating.

RTS Open
The Remote Temperature Sensor is not connected to the controller. Use of the RTS is recommended for proper battery charging.

Heatsink Temperature Sensor Open / Shorted
The heatsink temperature sensor is damaged. Return the controller to an authorized Morningstar dealer for service.

Battery Sense Out of Range / Disconnected
A battery sense wire is disconnected. Inspect the battery sense connections. This alarm is set when the voltage at the battery sense voltage differs by more than 5 volts from the voltage at the battery terminals.

Uncalibrated
The controller was not factory calibrated. Return the controller to an authorized Morningstar dealer for service.

4.6 Inspection and Maintenance

WARNING: RISK OF ELECTRICAL SHOCK.
NO POWER OR ACCESSORY TERMINALS ARE ELECTRICALLY ISOLATED FROM DC INPUT, AND MAY BE ENERGIZED WITH HAZARDOUS SOLAR VOLTAGE. UNDER CERTAIN FAULT CONDITIONS, BATTERY COULD BECOME OVER-CHARGED. TEST BETWEEN ALL TERMINALS AND GROUND BEFORE TOUCHING.

AVERTISSEMENT: RISQUE DE CHOC ÉLETRIQUE.
NON ALIMENTATION OU AUX BORNES D'ACCESSOIRES SONT ISOLÉS ÉLECTRIQUEMENT DE L'ENTRÉE DE C.C ET DOIT ÊTRE ALIMENTÉS À UNE TENSION DANGEREUSE SOLAIRE. SOUS CERTAINES CONDITIONS DE DÉFAILLANCE, LA BATTERIE POURRAIT DEVENIR TROP CHARGÉE. TEST ENTRE TOUTES LES BORNES ET LA MASSE AVANT DE TOUCHER.

WARNING: Shock Hazard
Disconnect all power sources to the controller before removing the wiring box cover. Never remove the cover when voltage exists on the TriStar MPPT 150V power connections.

AVERTISSEMENT: Risque de décharge électrique
Un moyen de déconnexion de tous les poteaux d'alimentation doit être fourni. Ceux-ci se déconnecte doit être intégrée dans le câblage fixe. Ouvrir que toutes les source d'énergie se déconnecte avant de retirer le couvercle de la contrôleur, ou accès au câblage.

Table 4-6 below lists the recommended maintenance schedule to keep your TriStar MPPT 150V performing optimally.

Schedule	Maintenance Items
2 weeks after installation	Re-tighten power terminal connections to specified torque values.
3 months after installation	Re-tighten power terminal connections to specified torque values.
Monthly or After Each Equalization	Inspect the battery bank. Look for cracked or bulging cases, and corroded terminals. For wet cell (flooded type) batteries, make sure the water level is correct. Wet cell water levels should be checked monthly or according to the manufacturer's recommendations.
Annually	Clean the heatsink fins with a clean, dry rag. Inspect all wiring for damage or fraying. Inspect for nesting insects. Re-tighten all wiring terminal connections to specified torque values. Inspect the system earth grounding for all components. Verify all grounding conductors are appropriately secured to earth ground.

Table 4-6. Maintenance Schedule

5.0 Networking and Communication

5.1 Introduction

The TriStar MPPT 150V provides several communication options. The TriStar MPPT 150V uses a proprietary protocol for the MeterBus™ network and the non-proprietary open standard MODBUS™ and MODBUS TCP/IP™ protocols for RS-232, EIA-485, and ethernet networks. Additionally, HTTP, SMTP, and SNMP are supported for web page, email, and network message support. Morningstar's MSView™ PC software provides system monitoring and logging capabilities via RS-232, EIA-485, and ethernet. MSView™ PC software is available for free on our website at:

http://www.morningstarcorp.com.

Further, hardware and third party software that supports the MODBUS™ protocol can also be used to communicate with a TriStar MPPT 150V.

Multiple communication ports can be used simultaneously. For example, a TriStar MPPT 150V may be connected to a MeterBus™ network for on-site system metering, connected to the internet for remote monitoring, and connected to an EIA-485 network to bridge data from other controllers in the system to an internet connection. Note that the RS-232 and EIA-485 connections share hardware and therefore cannot be used simultaneously.

Table 5-1 below provides a summary of supported features for each communication interface.

	MeterBus	RS-232	EIA-485	Ethernet
Display system/network data on a TriStar meter	●			
Connect a TSMPPT to a Relay Driver or other MS Accessory	●			
Connect multiple TSMPPT together in a network	●		●	●
View and log data with MSView™ PC Software		●	●	●
View logged data stored in the TriStar MPPT 150V internal memory	●	●	●	●
Update TriStar MPPT 150V firmware		●		
Program custom settings		●	●	●
View data in a web browser				●
Email notification				●
Text Message Alerts				●
SNMP Alerts				●

Table 5-1. Communication summary

5.2 Morningstar MeterBus™

Morningstar's proprietary MeterBus™ protocol allows communication between compatible Morningstar products. Use a MeterBus™ network to:

- display net system data for multiple TriStar / TriStar MPPT 150V systems**
- communicate with a TriStar Digital Meter 2 or TriStar Remote Meter 2
- communicate with a Relay Driver or other compatible Morningstar accessories (see section 2.5 for more details)

***A Morningstar MeterBus Hub (HUB-1) and either a TriStar Digital Meter 2 (TS-M-2) or TriStar Remote Meter 2 (TS-RM-2) are required, not included.*

A MeterBus Hub (model: HUB-1) is required for MeterBus networks containing multiple TriStar MPPT 150V controllers. The ports on the hub are electrically isolated to prevent damage in the event of broken grounds or voltage differences between controllers. Figure 5-1 below shows an example MeterBus™ network with two (2) TriStar MPPT 150V controllers and a TriStar Remote Meter 2 (TS-RM2).

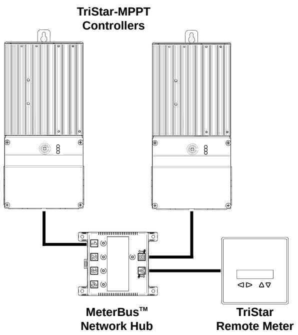


Figure 5-1. An example MeterBus network.

Up to five (5) controllers can be networked together with a single hub. Multiple hubs can be daisy-chained together to allow networks of up to 14 controllers and a meter.
Refer to the HUB-1 and TriStar Meter manuals for more information about Morningstar MeterBus™ networking.

5.3 Serial RS-232

The serial port connection on the TriStar MPPT 150V is a standard 9-pin isolated RS-232 port. See figure 3-5 for the port location.The TriStar MPPT 150V communicates through the serial port via the open standard MODBUS™ protocol.

Connect the TriStar MPPT 150V to the serial port on a PC to:

- program custom charge settings with MSView™ PC software
- view real-time data with MSView™ PC software
- log real-time data with MSView™ PC software
- configure ethernet settings
- update controller firmware with MSLoad™ firmware utility

NOTE:
The RS-232 and EIA-485 ports share hardware. Both ports cannot be used simultaneously.

NOTE:
If your PC does not have a serial port, a USB to Serial cable can be purchased at your local electronics retailer.

The serial connection is ideal for configuring custom settings or monitoring a single TriStar MPPT 150V controller. Figure 5-2 shows a serial connection between the controller and a PC with MSView™ PC software.

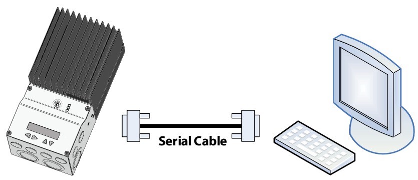


Figure 5-2. A serial connection between a PC and the TriStar MPPT 150V

Serial Port Settings

Adjust the serial port settings as follows:

- 9600 BAUD
- 8 data bits
- 1 or 2 stop bits
- no parity

The serial RS-232 connection provides a direct connection between a TriStar MPPT 150V and a PC (or other serial device). **Firmware updates can only be programmed through the RS-232 connection.** The serial connection is not typically used for multi-controller networking. However, networking is possible using a USB hub and USB-Serial cables. For more information, refer to the “Morningstar Communications Document” on our website at:

www.morningstarcorp.com

5.4 EIA-485 (formerly RS-485)

NOTE:
The EIA-485 connection is only available on the TS-MPPT-60/M model.

NOTE:
The RS-232 and EIA-485 ports share hardware. Both ports cannot be used simultaneously.

EIA-485 is a networking standard for serial communication between multiple devices on a bus. The TriStar MPPT 150V communicates over an EIA-485 network via the open standard MODBUS™ protocol. Use EIA-485 networking to:

- connect multiple TriStar MPPT 150V controllers on a network to log and view real-time data using MSView™ PC software
- program each controller on the network with custom charge settings using MSView™ PC software
- connect the TriStar MPPT 150V to other Morningstar controllers with the RSC-1 Serial to EIA-485 Adapter (sold separately)
- bridge an Ethernet connection through a TriStar MPPT 150V to an EIA-485 network

The EIA-485 port has four (4) connections: Power, Data A, Data B, and Ground. Data A & B are differentially driven data lines that carry the network data. Power and Ground connections provide power to the network. The TriStar MPPT 150V does not supply power to the EIA-485 network, therefore an external power source is required. The source voltage must be between 8-16 Vdc. For 12 Volt systems, the network can be powered directly from the system battery. Use a DC-DC converter for 24, 36, and 48 Volt systems.

CAUTION: Equipment Damage
Tapping power off of individual batteries in a series string of batteries can cause a voltage imbalance. Damage to the batteries may result. Always use a DC-DC converter to power the EIA-485 network if the nominal system voltage is greater than 12 volts.

PRUDENCE : Endommagement de l’équipement
L’arrêt progressif de batteries individuelles dans une série de batteries peut provoquer un déséquilibre de tension. Les batteries peuvent être endommagées. Utilisez toujours un convertisseur CC-CC pour convertir l’alimentation au réseau EIA-485 si la tension nominale du système est supérieure à 12 V.

For more information on EIA-485 networking, refer to the “Morningstar Communications Document” on our website at:

HTTP://www.morningstarcorp.com/

5.5 Ethernet

NOTE:
Ethernet is only available on the TS-MPPT-60/M model.

CAUTION: Risk of Tampering
The TS-MPPT does not feature built-in network security. It is the responsibility of the user or network administrator to place the TS-MPPT behind a network firewall to prevent unauthorized access.

PRUDENCE : Risque de tentative d'altération
Le TS-MPPT ne comporte pas de sécurité réseau intégrée. Il incombe à l'utilisateur ou à l'administrateur du réseau de placer le TS-MPPT derrière un pare-feu réseau afin d'empêcher l'accès non autorisé.

The Ethernet port supports HTTP, MODBUS TCP/IP™, SMTP, and SNMP protocols to provide a fully web-enabled interface between the TriStar MPPT 150V and a LAN/WAN network or the internet. Some of the many features the Ethernet connection provides include:

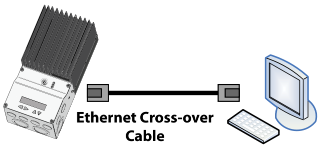
- program custom settings with MSView™ PC software
- monitor the controller from a web browser
- modify controller settings from a web browser
- log and monitor the system with MSView™ PC software anywhere on the internet
- create custom web pages to show system data
- send an email or text message if a fault, alarm, or user-defined event occurs
- monitor and receive messages on an SNMP network

This section provides a summary of each of the features. For detailed information about Ethernet connectivity and networking, refer to the "Morningstar Communications Document" on our website at:

HTTP://www.morningstarcorp.com/

Network Information

Connect to the TriStar MPPT 150V via an Ethernet network (LAN/WAN) or connect the controller directly to a PC using an ethernet cross-over cable. Use CAT-5 or CAT-5e twisted pair Ethernet cables with RJ-45 connectors. A network diagram for both scenarios is shown in figure 5-3 below.



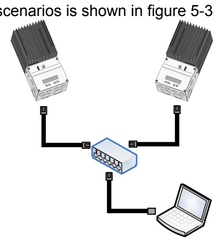


Figure 5-3. Ethernet network diagrams.

Factory Default Network Settings

DHCP	enabled
Live View Web Address	http://tsmppt + serial number **
IP	192.168.1.253 (if DHCP is not enabled)
Subnet Mask	255.255.255.0
Gateway	192.168.1.1
Primary DNS Server	169.254.1.1
MODBUS TCP/IP™ Port	502

*** The Live View web address is unique to each controller. If the TriStar MPPT 150V serial number is 09501234, then the Live View address is: http://tsmppt09501234. The Live View address is printed on the serial label on the side of the unit for reference.*

The controller's MAC Address is located on the serial label on the side of the controller.
Two (2) LEDs on the Ethernet jack indicate link and activity status.

Condition	Green LED	Yellow LED
Network Connection OK	ON	OFF
Network Activity	ON	Blinking
Error	OFF	ON

Web Pages

Connect the TriStar MPPT 150V controller to the network using an Ethernet cable. Wait 5 to 10 minutes for the controller to connect to the network. Open a web browser on any PC on the network. Enter the Live View web address in the address bar of the web browser. The TriStar MPPT 150V main Live View webpage will load. Links are provided to real-time data, history, and network settings adjustment pages.

Pages served by the TriStar MPPT 150V are ideal for retrieving quick information about the charge controller and making adjustments to network settings. However, there is no ability to customize the layout or data displayed. Also, information from multiple controllers cannot be displayed on the same webpage.

Custom Settings

The *TriStar MPPT 150V Setup Wizard* in MSView™ provides an interface to adjust all operating parameters. Morningstar's MSView™ PC software can connect to any TriStar MPPT 150V on the Ethernet network or through a RS-232 serial connection. Refer to the help documentation included with MSView™ for more information.

Email & SMS Alerts

The email and SMS alerts feature sends notification to an email address or mobile phone if one of the following occurs:

- TriStar MPPT 150V self diagnostics fault condition
- TriStar MPPT 150V self diagnostics alarm condition
- User-defined event (e.g. battery voltage is less than 46 Volts)

Up to four email and SMS alerts can be configured from the network settings web page in the MSView TriStar MPPT 150V wizard.

View Logged Data

The TriStar MPPT 150V logs up to 200 days* of daily data. The controller always logs the standard values listed below. Using MSView, the controller can be configured to log additional optional values each day. The maximum number of days that can be stored decreases as the number of logged values increases.

Standard Values

- Minimum Battery Voltage
- Maximum Battery Voltage
- Daily Events (Equalize triggered, Entered Float, Alarm/Fault occurred, Controller Reset)
- Faults / Alarms - recorded only if a fault or alarm occurs that day

Optional Values

- Maximum Array Voltage
- Maximum Power Output
- Charge Amp-hours
- Charge Watt-hours
- Minimum/Maximum Battery Temperature
- Charge stage regulation timers for Absorption, Float, Equalize

** logging only standard values*

SNMP

For telecom and industrial applications that require SNMP monitoring of deployed systems, the TriStar MPPT 150V will behave as an SNMP agent and supports the following commands:

TRAP
GET
GETNEXT

A link to the agent *Management Information Base* file (*.MIB) is available on the TriStar MPPT 150V Live View *Network Settings* page.

6.0 Troubleshooting

WARNING: RISK OF ELECTRICAL SHOCK.
NO POWER OR ACCESSORY TERMINALS ARE ELECTRICALLY ISOLATED FROM DC INPUT, AND MAY BE ENERGIZED WITH HAZARDOUS SOLAR VOLTAGE. UNDER CERTAIN FAULT CONDITIONS, BATTERY COULD BECOME OVER-CHARGED. TEST BETWEEN ALL TERMINALS AND GROUND BEFORE TOUCHING.

AVERTISSEMENT: RISQUE DE CHOC ÉLETRIQUE.
NON ALIMENTATION OU AUX BORNES D'ACCESSOIRES SONT ISOLÉS ÉLECTRIQUEMENT DE L'ENTRÉE DE C.C ET DOIT ÊTRE ALIMENTÉS À UNE TENSION DANGEREUSE SOLAIRE. SOUS CERTAINES CONDITIONS DE DÉFAILLANCE, LA BATTERIE POURRAIT DEVENIR TROP CHARGÉE. TEST ENTRE TOUTES LES BORNES ET LA MASSE AVANT DE TOUCHER.

WARNING: Shock Hazard
A means of disconnecting all power supply poles must be provided. These disconnects must be incorporated in the fixed wiring. Open all power source disconnects before removing controller wiring cover, or accessing wiring.

AVERTISSEMENT: Risque de décharge électrique
Un moyen de déconnexion de tous les poteaux d'alimentation doit être fourni. Ceux-ci se déconnecte doit être intégrée dans le câblage fixe. Ouvrir que toutes les source d'énergie se déconnecte avant de retirer le couvercle de la contrôleur, ou accès au câblage.

Battery Charging and Performance Issues

Problem:
No LED indications, controller does not appear to be powered

Solution:
With a multi-meter, check the voltage at the battery terminals on the TriStar MPPT 150V. Battery voltage must be 8 Vdc or greater. If the voltage on the battery terminals of the controller is between 8 and 72 Vdc and no LEDs are lit, contact your authorized Morningstar dealer for service. If no voltage is measured, check wiring connections, fuses, and breakers.

Problem:
The TriStar MPPT 150V is not charging the battery.

Solution:
Check the three (3) battery SOC LEDs. If they are flashing a sequence, see *Section 4.4 Faults & Alarms* of this manual to determine the issue. If a TriStar Meter 2 is connected, the diagnostics menu will display reported faults and alarms.
If the LED indications are normal, check the fuses, breakers, and wiring connections in the solar array wiring. With a multi-meter, check the array voltage directly at the TriStar MPPT 150V solar input terminals. Input voltage must be greater than battery voltage before charging will begin.

NOTE:
For more in-depth testing and diagnosis, download the TriStar MPPT 150V Testing Document from the Support section on our website: www.morningstarcorp.com/

Network and Communication Issues

Problem:
Cannot connect to the controller via RS-232

Solution:
Check the following:

- The RS-232 cable is straight-through, not a Null Modem (cross-over)
- If using a serial-USB adapter, verify that the adapter software is installed and a serial COM port has been mapped. Check the activity light on the USB adapter if it has one. If there is no activity, the wrong COM port has been chosen or there is a configuration issue with the adapter.
- The default MODBUS ID of the TriStar MPPT 150V is 1. Verify that the PC software is configured to communicate using the correct MODBUS ID.

Problem:
Cannot connect to the controller via EIA-485

Solution:
Check the following:

- The RS-232 port is not in use. The EIA-485 and RS-232 ports cannot be used simultaneously. Only one port can be used at a time.
- The RSC-1 adapter used to connect the PC to the EIA-485 network shows a green LED and pulses red when a connection is attempted. See the RSC-1 documentation for more information.
- Each controller or device on the EIA-485 network has been programmed with a unique MODBUS ID.
- A serial cross-over (Null Modem) cable is used for the connection between the PC and the Morningstar RSC-1 485 Adapter. A straight-through serial cable will not work.
- Power is supplied to the 4-wire bus on the Power/Ground lines. The bus requires voltage in the range: 8 - 16 Vdc.
- All bus connections are secure and each terminal is wired in parallel: line A to line A, line B to line B, etc.

Problem:
Cannot connect to the controller via Ethernet

Solution:
See the *TriStar MPPT 150V Networking Companion Document*, available on our website.

7.0 Warranty and Claim Procedure

LIMITED WARRANTY Morningstar Solar Controllers and Inverters

The TriStar MPPT 150V is warrantied to be free from defects in material and workmanship for a period of FIVE (5) years from the date of shipment to the original end user. Morningstar will, at its option, repair or replace any such defective units.

WARRANTY EXCLUSIONS AND LIMITATIONS:

This warranty does not apply under the following conditions:

♦ Damage by accident, negligence, abuse or improper use
♦ PV or load currents exceeding the ratings of the product
♦ Unauthorized product modification or attempted repair
♦ Damage occurring during shipment
♦ Damage results from acts of nature such as lightning and weather extremes

THE WARRANTY AND REMEDIES SET FORTH ABOVE ARE EXCLUSIVE AND IN LIEU OF ALL OTHERS, EXPRESS OR IMPLIED. MORNINGSTAR SPECIFICALLY DISCLAIMS ANY AND ALL IMPLIED WARRANTIES, INCLUDING, WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NO MORNINGSTAR DISTRIBUTOR, AGENT OR EMPLOYEE IS AUTHORIZED TO MAKE ANY MODIFICATION OR EXTENSION TO THIS WARRANTY.

MORNINGSTAR IS NOT RESPONSIBLE FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DOWN-TIME, GOODWILL OR DAMAGE TO EQUIPMENT OR PROPERTY.

R15-8/15

WARRANTY CLAIM PROCEDURE

1. Before proceeding, please refer to product manual, including troubleshooting section.

2. Contacting your authorized Morningstar distributor or dealer from whom you purchased the unit is the first step in the warranty process. Local dealers can often address warranty issues quickly.

3. If supplier is unable to address the issue, please contact Morningstar by e-mail (support@morningstarcorp.com) with:

(A) purchase location -- business or company name

(B) full model and serial numbers (SN is 8-digits on unit bar label)

(C) failure behavior, including LED indications

(D) array configuration, panel Pmax, Voc, Vmp, Isc, and battery voltage; these specifications are needed to receive assistance.

(E) multi-meter available (for field troubleshooting)

4. After warranty replacement has been approved and new unit(s) received, please return failed unit(s) using pre-paid shipping label, and follow any product specific instructions if requested by Morningstar Warranty Dept.

5. If instructed by Morningstar, after warranty replacement shipment has been received, return of failed unit(s) is required before further warranty replacements can be considered for the original or future cases.

NOTE: Please do not return units without an RMA or case number. Doing so will increase the time required to resolve your claim.

8.0 Specifications

Electrical

	TS-MPPT-30	TS-MPPT-45	TS-MPPT-60/M
Nominal System Voltage		All: 12, 24 or 48 Volts dc	
Maximum Battery Current	30 Amps	45 Amps	60 Amps
Maximum Solar Input Voltage		All: 150 Volts dc	
Battery Operating Voltage Range		All: 8 - 72 Volts dc	
Nominal Maximum Input Power*			
12 Volt	400 Watts	600 Watts	800 Watts
24 Volt	800 Watts	1200 Watts	1600 Watts
48 Volt	1600 Watts	2400 Watts	3200 Watts
Voltage Accuracy		12 / 24 V: ≤ 0.1% ± 50 mV	
		48 V: ≤ 0.1% ± 100 mV	
Self consumption (tare loss)		All: 1.3 - 2.7 Watts	
Transient Surge Protection		All: 4500 Watts / port	

* These power levels refer to the maximum wattage each of the TS-MPPTs can process at a certain system voltage. Higher power arrays can be used without damaging a controller, but array cost-benefits will be reduced at power levels much beyond the nominal ratings.

Battery Charging

Charging algorithm	4 - stage
Charging stages	Bulk, Absorption, Float, Equalize
Temperature compensation coefficient	-5 mV / °C / cell (25 °C ref.)
Temperature compensation range	-30 °C to +80 °C
Temperature compensated set-points	Absorption, Float, Equalize, HVD

Charging Set-points:

Settings Switches	Battery Type	Absorp. Stage	Float Stage	Equalize Stage	Absorp. Time	Equalize Time	Equalize Timeout	Equalize Interval
sw: 4-5-6		**Volts**	**Volts**	**Volts**	**Minutes**	**Minutes**	**Minutes**	**Days**
off-off-off	1 - Sealed*	14.00	13.70		150			
off-off-on	2 - Sealed*	14.15	13.70	14.40	150	60	120	28
off-on-off	3 - Sealed*	14.30	13.70	14.60	150	60	120	28
off-on-on	4 - AGM/Flooded	14.40	13.70	15.10	180	120	180	28
on-off-off	5 - Flooded	14.60	13.50	15.30	180	120	180	28
on-off-on	6 - Flooded	14.70	13.50	15.40	180	180	240	28
on-on-off	7 - L-16	15.40	13.40	16.00	180	180	240	14
on-on-on	8 - Custom	Custom	Custom	Custom	Custom	Custom	Custom	Custom

** "Sealed" battery type includes gel and AGM batteries*

See section 4.2 for more information

NOTE:
All charging voltage set-points listed are for 12 Volt systems.
Multiply 2X for 24 Volt systems, 4X for 48 Volt systems.

Battery Charging Status LEDs

LED Indication	Battery Charging Status
Green Flashing (fast) - 2.5 times per second	Equalize charging stage
Green Flashing - 1/2 sec on, 1/2 sec off	Absorption charging stage
Green Flashing (slow) - 1 sec on, 1 sec off	Float charging stage
Green	13.3 Volts ≤ Vbattery
Green & Yellow	13.0 Volts ≤ Vbattery < 13.3 Volts
Yellow	12.7 Volts ≤ Vbattery < 13.0 Volts
Yellow & Red	12.0 Volts ≤ Vbattery < 12.7 Volts
Red	Vbattery < 12.0 Volts

Mechanical

Dimensions:	(H) 291 mm / 11.44” (W) 130 mm / 5.12” (D) 142 mm / 5.58”
Product Weight:	4.14 kg / 9 lbs 2 oz
Shipping Weight (2 pcs/carton)	11.6 kg / 25 lbs 9oz
Power terminals:	
Minimum wire size:	2.5 mm^2 / 14 AWG
Maximum wire size:	35 mm^2 / 2 AWG
Recommended torque:	5.65 Nm / 50 in-lb
RTS / Sense terminals:	
Minimum wire size	0.25 mm^2 / 24 AWG
Maximum wire size	1.0 mm^2 / 16 AWG
Recommended torque	0.40 Nm / 3.5 in-lb
Knockouts (trade sizes):	M20 & 1/2”, 1”, 1 - 1/4”
Mounting:	Vertical surface

Environmental

Operating Altitude	Below 2000 meters
Ambient Temperature Range	-40 °C to +45 °C
Storage Temperature	-55 °C to +85 °C
Humidity	100% N.C.
Enclosure	IP20 Type 1 (indoor & vented)

Protections

Solar high voltage disconnect
Solar high voltage reconnect
Battery high voltage disconnect
Battery high voltage reconnect
High temperature disconnect
High temperature reconnect

De-ratings

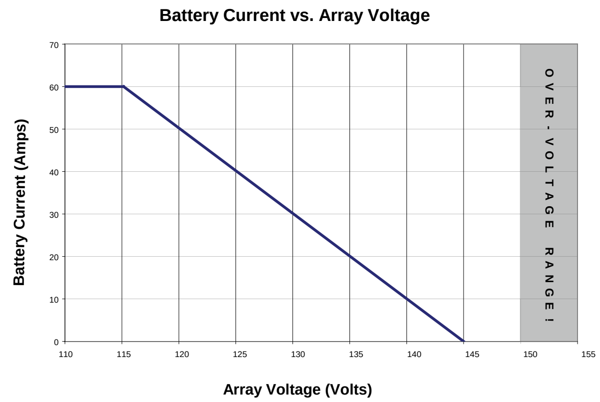


Figure 8-7. Battery Current vs. Array Voltage

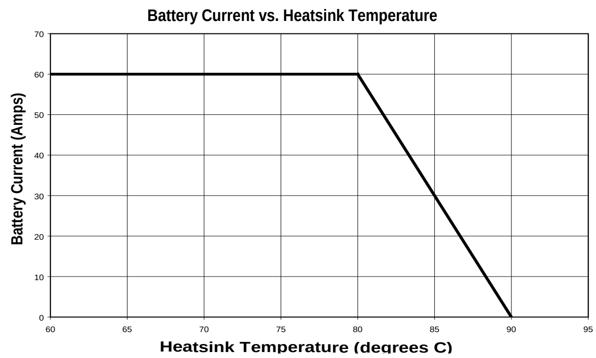
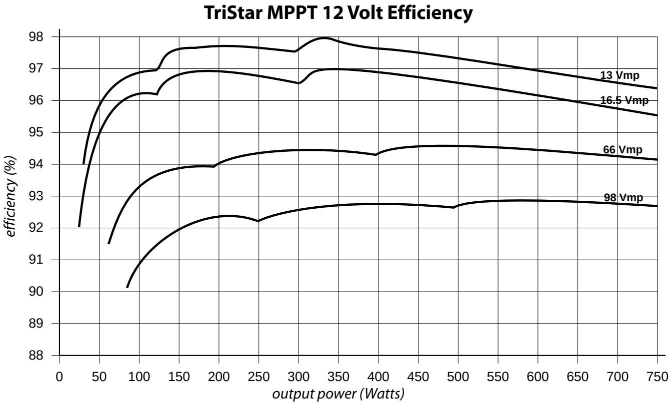


Figure 8-8. Battery Current vs. Heatsink Temperature

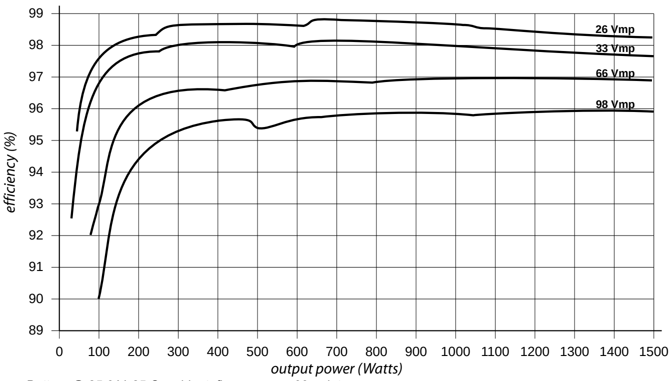
Efficiency

TriStar MPPT 12 Volt Efficiency



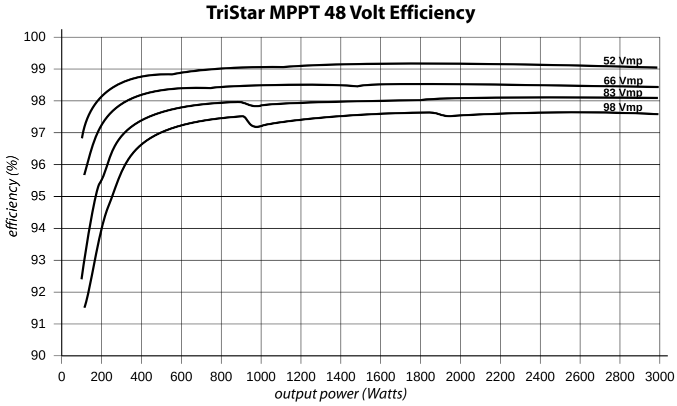
Battery @ 12.8 V, 25 C ambient, firmware ver. 08 or later

TriStar MPPT 24 Volt Efficiency



Battery @ 25.6 V, 25 C ambient, firmware ver. 08 or later

TriStar MPPT 48 Volt Efficiency



Battery @ 51.2 V, 25 C ambient, firmware ver. 08 or later

2% Voltage Drop Charts for 75°C Stranded Copper Wire

1-Way Wire Distance (feet), 12 Volt System

Wire Size (AWG)	60 Amps	55 Amps	50 Amps	45 Amps	40 Amps	35 Amps	30 Amps	25 Amps	20 Amps	15 Amps
2/0 **	22.4	24.4	26.9	29.9	33.6	38.4	44.8	53.8	67.2	89.6
1/0 **	17.8	19.4	21.3	23.7	26.6	30.4	35.5	42.6	53.3	71.0
2	11.2	12.2	13.4	14.9	16.8	19.1	22.3	26.8	33.5	44.7
4	7.0	7.7	8.4	9.4	10.6	12.1	14.1	16.9	21.1	28.1
6	4.4	4.8	5.3	5.9	6.6	7.6	8.8	10.6	13.2	17.7
8	2.8	3.0	3.3	3.7	4.2	4.8	5.6	6.7	8.4	11.1
10	1.7	1.9	2.1	2.3	2.6	3.0	3.5	4.2	5.2	7.0
12	1.1	1.2	1.3	1.5	1.6	1.9	2.2	2.6	3.3	4.4
14	0.7	0.8	0.8	0.9	1.0	1.2	1.4	1.7	2.1	2.8

Table 8-1. Maximum 1-way wire distance for 12 Volt systems, stranded copper, 2% voltage drop

1-Way Wire Distance (meters), 12 Volt System

Wire Size (mm^2)	60 Amps	55 Amps	50 Amps	45 Amps	40 Amps	35 Amps	30 Amps	25 Amps	20 Amps	15 Amps
70 **	6.83	7.45	8.20	9.11	10.24	11.71	13.66	16.39	20.49	27.32
50 **	5.41	5.91	6.50	7.22	8.12	9.28	10.83	12.99	16.24	21.65
35	3.40	3.71	4.08	4.54	5.11	5.84	6.81	8.17	10.21	13.62
25	2.14	2.34	2.57	2.86	3.22	3.68	4.29	5.15	6.43	8.58
16	1.35	1.47	1.61	1.79	2.02	2.31	2.69	3.23	4.04	5.38
10	0.85	0.93	1.02	1.13	1.27	1.46	1.70	2.04	2.55	3.40
6	0.53	0.58	0.64	0.71	0.80	0.91	1.07	1.28	1.60	2.13
4	0.33	0.36	0.40	0.44	0.50	0.57	0.67	0.80	1.00	1.33
2.5	0.21	0.23	0.25	0.28	0.32	0.36	0.42	0.50	0.63	0.84

Table 8-2. Maximum 1-way wire distance for 12 Volt systems, solid copper, 2% voltage drop

*** Wires sizes larger than 2 AWG (35 mm²) must be terminated at a splicer block located outside of the TriStar MPPT 150V wiring box. Use 2 AWG (35 mm²) or smaller wire to connect to the TriStar MPPT 150V to the splicer block.*

Notes:

- The specified wire length is for a pair of conductors from the solar or battery source to the controller (1-way distance)
- For 24 volt systems, multiply the 1-way length in the table by 2.
- For 48 volt systems, multiply the 1-way length in the table by 4.
- Shaded cells in the table indicate that the current exceeds the ampacity of the wire for a given ambient temperature as defined in the following table:

Wire Ampacity* Key	
	Exceeds wire ampacity at 60°C ambient temperature
	Exceeds wire ampacity at 50°C ambient temperature
	Exceeds wire ampacity at 40°C ambient temperature
	Exceeds wire ampacity at 30°C ambient temperature

**Ampacity for not more than three current-carrying conductors in a raceway, cable, or earth (buried).*

2% Voltage Drop Charts for 75°C Solid Copper Wire

1-Way Wire Distance (feet), 12 Volt System

Wire Size (AWG)	60 Amps	55 Amps	50 Amps	45 Amps	40 Amps	35 Amps	30 Amps	25 Amps	20 Amps	15 Amps
2/0 **	27.8	30.3	33.4	37.1	41.7	47.7	55.6	66.7	83.4	111.2
1/0 **	22.0	24.1	26.5	29.4	33.1	37.8	44.1	52.9	66.1	88.2
2	13.9	15.1	16.6	18.5	20.8	23.8	27.7	33.3	41.6	55.4
4	8.7	9.5	10.5	11.6	13.1	14.9	17.4	20.9	26.2	34.9
6	5.5	6.0	6.6	7.3	8.2	9.4	11.0	13.2	16.5	21.9
8	3.4	3.8	4.1	4.6	5.2	5.9	6.9	8.3	10.3	13.8
10	2.2	2.4	2.6	2.9	3.3	3.7	4.3	5.2	6.5	8.7
12	1.4	1.5	1.6	1.8	2.0	2.3	2.7	3.3	4.1	5.5
14	0.9	0.9	1.0	1.1	1.3	1.5	1.7	2.1	2.6	3.4

Table 8-3. Maximum 1-way wire distance for 12 Volt systems, solid copper, 2% voltage drop

1-Way Wire Distance (meters), 12 Volt System

Wire Size (mm^2)	60 Amps	55 Amps	50 Amps	45 Amps	40 Amps	35 Amps	30 Amps	25 Amps	20 Amps	15 Amps
70 **	8.47	9.24	10.17	11.30	12.71	14.53	16.95	20.34	25.42	33.90
50 **	6.72	7.33	8.06	8.96	10.08	11.52	13.44	16.13	20.16	26.88
35	4.23	4.61	5.07	5.63	6.34	7.24	8.45	10.14	12.68	16.90
25	2.66	2.90	3.19	3.54	3.99	4.56	5.32	6.38	7.97	10.63
16	1.67	1.82	2.01	2.23	2.51	2.87	3.34	4.01	5.01	6.69
10	1.05	1.15	1.26	1.40	1.58	1.80	2.10	2.52	3.15	4.21
6	0.66	0.72	0.79	0.88	0.99	1.13	1.32	1.59	1.98	2.64
4	0.42	0.45	0.50	0.55	0.62	0.71	0.83	1.00	1.25	1.66
2.5	0.26	0.29	0.31	0.35	0.39	0.45	0.52	0.63	0.78	1.05

Table 8-4. Maximum 1-way wire distance for 12 Volt systems, solid copper, 2% voltage drop

*** Wires sizes larger than 2 AWG (35 mm²) must be terminated at a splicer block located outside of the TriStar MPPT 150V wiring box. Use 2 AWG (35 mm²) or smaller wire to connect to the TriStar MPPT 150V to the splicer block.*

Notes:

- The specified wire length is for a pair of conductors from the solar or battery source to the controller (1-way distance)
- For 24 volt systems, multiply the 1-way length in the table by 2.
- For 48 volt systems, multiply the 1-way length in the table by 4.
- Shaded cells in the table indicate that the current exceeds the ampacity of the wire for a given ambient temperature as defined in the following table:

Wire Ampacity* Key	
	Exceeds wire ampacity at 60°C ambient temperature
	Exceeds wire ampacity at 50°C ambient temperature
	Exceeds wire ampacity at 40°C ambient temperature
	Exceeds wire ampacity at 30°C ambient temperature

**Ampacity for not more than three current-carrying conductors in a raceway, cable, or earth (buried).*

2% Voltage Drop Charts for 90°C Stranded Copper Wire

1-Way Wire Distance (feet), 12 Volt System

Wire Size (AWG)	60 Amps	55 Amps	50 Amps	45 Amps	40 Amps	35 Amps	30 Amps	25 Amps	20 Amps	15 Amps
2/0 **	22.4	24.4	26.9	29.9	33.6	38.4	44.8	53.8	67.2	89.6
1/0 **	17.8	19.4	21.3	23.7	26.6	30.4	35.5	42.6	53.3	71.0
2	11.2	12.2	13.4	14.9	16.8	19.1	22.3	26.8	33.5	44.7
4	7.0	7.7	8.4	9.4	10.6	12.1	14.1	16.9	21.1	28.1
6	4.4	4.8	5.3	5.9	6.6	7.6	8.8	10.6	13.2	17.7
8	2.8	3.0	3.3	3.7	4.2	4.8	5.6	6.7	8.4	11.1
10	1.7	1.9	2.1	2.3	2.6	3.0	3.5	4.2	5.2	7.0
12	1.1	1.2	1.3	1.5	1.6	1.9	2.2	2.6	3.3	4.4
14	0.7	0.8	0.8	0.9	1.0	1.2	1.4	1.7	2.1	2.8

Table 8-5. Maximum 1-way wire distance for 12 Volt systems, stranded copper, 2% voltage drop

1-Way Wire Distance (meters), 12 Volt System

Wire Size (mm^2)	60 Amps	55 Amps	50 Amps	45 Amps	40 Amps	35 Amps	30 Amps	25 Amps	20 Amps	15 Amps
70 **	6.83	7.45	8.20	9.11	10.24	11.71	13.66	16.39	20.49	27.32
50 **	5.41	5.91	6.50	7.22	8.12	9.28	10.83	12.99	16.24	21.65
35	3.40	3.71	4.08	4.54	5.11	5.84	6.81	8.17	10.21	13.62
25	2.14	2.34	2.57	2.86	3.22	3.68	4.29	5.15	6.43	8.58
16	1.35	1.47	1.61	1.79	2.02	2.31	2.69	3.23	4.04	5.38
10	0.85	0.93	1.02	1.13	1.27	1.46	1.70	2.04	2.55	3.40
6	0.53	0.58	0.64	0.71	0.80	0.91	1.07	1.28	1.60	2.13
4	0.33	0.36	0.40	0.44	0.50	0.57	0.67	0.80	1.00	1.33
2.5	0.21	0.23	0.25	0.28	0.32	0.36	0.42	0.50	0.63	0.84

Table 8-6. Maximum 1-way wire distance for 12 Volt systems, stranded copper, 2% voltage drop

*** Wires sizes larger than 2 AWG (35 mm²) must be terminated at a splicer block located outside of the TriStar MPPT 150V wiring box. Use 2 AWG (35 mm²) or smaller wire to connect to the TriStar MPPT 150V to the splicer block.*

Notes:

- The specified wire length is for a pair of conductors from the solar or battery source to the controller (1-way distance)
- For 24 volt systems, multiply the 1-way length in the table by 2.
- For 48 volt systems, multiply the 1-way length in the table by 4.
- Shaded cells in the table indicate that the current exceeds the ampacity of the wire for a given ambient temperature as defined in the following table:

Wire Ampacity* Key	
	Exceeds wire ampacity at 60°C ambient temperature
	Exceeds wire ampacity at 50°C ambient temperature
	Exceeds wire ampacity at 40°C ambient temperature
	Exceeds wire ampacity at 30°C ambient temperature

**Ampacity for not more than three current-carrying conductors in a raceway, cable, or earth (buried).*

2% Voltage Drop Charts for 90°C Solid Copper Wire

1-Way Wire Distance (feet), 12 Volt System

Wire Size (AWG)	60 Amps	55 Amps	50 Amps	45 Amps	40 Amps	35 Amps	30 Amps	25 Amps	20 Amps	15 Amps
2/0 **	27.8	30.3	33.4	37.1	41.7	47.7	55.6	66.7	83.4	111.2
1/0 **	22.0	24.1	26.5	29.4	33.1	37.8	44.1	52.9	66.1	88.2
2	13.9	15.1	16.6	18.5	20.8	23.8	27.7	33.3	41.6	55.4
4	8.7	9.5	10.5	11.6	13.1	14.9	17.4	20.9	26.2	34.9
6	5.5	6.0	6.6	7.3	8.2	9.4	11.0	13.2	16.5	21.9
8	3.4	3.8	4.1	4.6	5.2	5.9	6.9	8.3	10.3	13.8
10	2.2	2.4	2.6	2.9	3.3	3.7	4.3	5.2	6.5	8.7
12	1.4	1.5	1.6	1.8	2.0	2.3	2.7	3.3	4.1	5.5
14	0.9	0.9	1.0	1.1	1.3	1.5	1.7	2.1	2.6	3.4

Table 8-7. Maximum 1-way wire distance for 12 Volt systems, solid copper, 2% voltage drop

1-Way Wire Distance (meters), 12 Volt System

Wire Size (mm^2)	60 Amps	55 Amps	50 Amps	45 Amps	40 Amps	35 Amps	30 Amps	25 Amps	20 Amps	15 Amps
70 **	8.47	9.24	10.17	11.30	12.71	14.53	16.95	20.34	25.42	33.90
50 **	6.72	7.33	8.06	8.96	10.08	11.52	13.44	16.13	20.16	26.88
35	4.23	4.61	5.07	5.63	6.34	7.24	8.45	10.14	12.68	16.90
25	2.66	2.90	3.19	3.54	3.99	4.56	5.32	6.38	7.97	10.63
16	1.67	1.82	2.01	2.23	2.51	2.87	3.34	4.01	5.01	6.69
10	1.05	1.15	1.26	1.40	1.58	1.80	2.10	2.52	3.15	4.21
6	0.66	0.72	0.79	0.88	0.99	1.13	1.32	1.59	1.98	2.64
4	0.42	0.45	0.50	0.55	0.62	0.71	0.83	1.00	1.25	1.66
2.5	0.26	0.29	0.31	0.35	0.39	0.45	0.52	0.63	0.78	1.05

Table 8-8. Maximum 1-way wire distance for 12 Volt systems, solid copper, 2% voltage drop

*** Wires sizes larger than 2 AWG (35 mm²) must be terminated at a splicer block located outside of the TriStar MPPT 150V wiring box. Use 2 AWG (35 mm²) or smaller wire to connect to the TriStar MPPT 150V to the splicer block.*

Notes:

- The specified wire length is for a pair of conductors from the solar or battery source to the controller (1-way distance)
- For 24 volt systems, multiply the 1-way length in the table by 2.
- For 48 volt systems, multiply the 1-way length in the table by 4.
- Shaded cells in the table indicate that the current exceeds the ampacity of the wire for a given ambient temperature as defined in the following table:

Wire Ampacity* Key	
	Exceeds wire ampacity at 60°C ambient temperature
	Exceeds wire ampacity at 50°C ambient temperature
	Exceeds wire ampacity at 40°C ambient temperature
	Exceeds wire ampacity at 30°C ambient temperature

**Ampacity for not more than three current-carrying conductors in a raceway, cable, or earth (buried).*

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9.0 Certifications

- Complies with UL 1741, 62109 and CSA-C22.2 No. 107.1-01
- Complies with IEC 62109-1: 2010
- Complies with the US National Electrical Code
- FCC Class B compliant

ENs Directives:

- Complies with ENs and LVD standards for CE marking
  EN 61000-6-2:2005 EMC Immunity, Industrial Environments
  EN 55022:2007 (Class B) EMC Emissions
  EN 60335-1:2002 Safety
  EN 60335-2-29:2005 Safety
  IEC 62109-1:2010 Safety of Power Converters in PV Systems

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MS-000946 v6.1

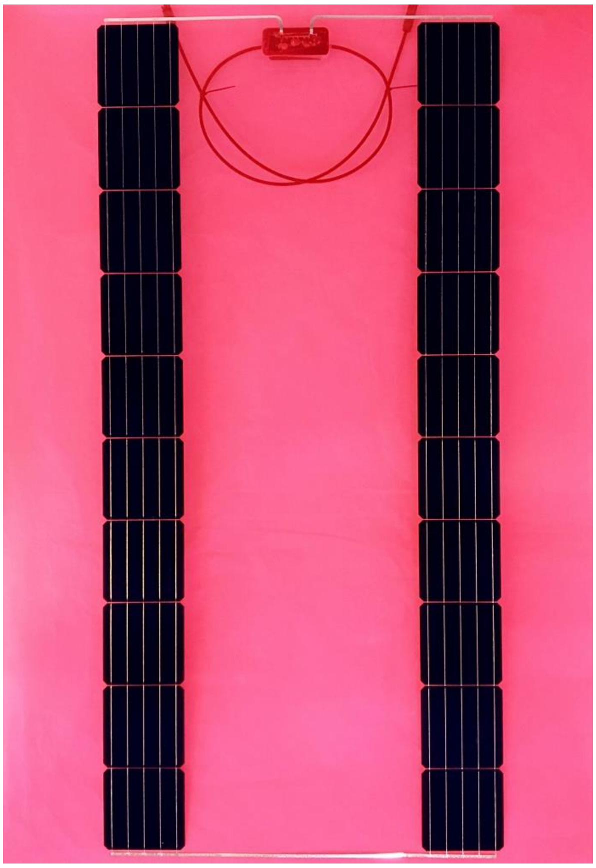
9.6 Solar Panel Datasheet

LUMO 20M100GH Greenhouse Integrated Panel

The only panel designed specifically for crop production and power generation

Luminescent quantum conversion of light for enhanced crop growth

Tested in commercial greenhouses for 7 years, crop data available upon request



Electrical Data (STC)	
Peak Rated Power	100 Watts
Maximum Power Voltage	10.6 Volts
Maximum Power Current	9.50 Amps
Open Circuit Voltage	13.3 Volts
Short Circuit Current	9.96 Amps
Mechanical Data	
Dimensions (mm)	1648 x 990 x 4.2
Dimensions (inch)	64.9 x 38.0 x 0.165
Weight	17 kg (37.5 lbs)
Frame	None
Junction Box	Tyco PV Bar 4
Cables / Connectors	Tyco PV4-S
Solar Cells	Bifacial PERC 5BB
Temperature Ratings	
Temperature Coefficient of Pma	-0.39%/C
Temperature Coefficcient Voc	-0.31%/C
Temperatre Coefficient of Isc	-0.045%/C
Maximum Ratings	
Maximum System Voltage	1000 V
Maximum Series Fuse Rating	15A
Maximum Hail Resistance	38mm (1.5 in.)