Rogue Power Technologies

MPT-3024

30A - 12/24VDC MPPT
Photovoltaic Charge Controller

Installation Guide
and
Owner's Manual

Rogue Power Technologies, Ashland, OR 97520
www.roguepowertech.com

Warranty and Liability Information

Rogue Power Technologies (*hereafter RPT*) warrants the MPT-3024 to be free from defects in materials and workmanship for a period of five (5) years from date of purchase. Warranty applies only to the original purchaser. RPT will, at its option, either repair or replace a unit found to be defective under the terms of this warranty. RPT's sole liability shall be said repair or replacement of a defective unit. RPT shall not be held liable for incidental or consequential damages, or injury, arising from the installation or use of this unit, nor shall RPT provide reimbursement for labor, removal or installation, shipping charges, or other expenses not directly related to the terms of this warranty. RPT does not warrant the workmanship of any persons installing this unit.

Conditions that will invalidate this warranty:

- Operation or installation contrary to the instructions provided in this guide, including but not limited to: damage caused by reverse battery connection, installation in an unapproved location, improper wiring, etc.
- Damage caused by lightning or electrostatic discharge.
- Damage caused by abuse, neglect, or accident.
- Any unit which has been modified or repaired by anyone other than RPT.
- Damage cause by natural disaster, shipping, transportation, or any other circumstances outside of RPT's control.
- Damage caused by another component of the power system.
- Any unit that has had its serial number or identification tag removed or altered.
- Damage resulting from moisture or other environmental elements.
- Cosmetic damage, including scratches, scuffs, dents.

Before returning a unit for warranty service, please verify that the unit is in fact defective. Shipping must be prepaid and insurance must be purchased on any unit sent in for warranty service. RPT will pay return shipping and insurance on units after the validity of the warranty claim has been confirmed. Units sent in that are outside of their warranty period, or units that do not qualify for warranty service based on the above terms, will be returned at the expense of the sender. Units in need of warranty service should be sent to: Rogue Power Technologies, 15975 Baldy Creek Rd., Ashland, OR 97520. Include a copy of the original receipt and a detailed description of the problem.

Table of Contents

1. Introduction and Overview.. 5
2. Safety Information... 6
    2.1 General safety precautions... 6
3. Front Panel and LCD Display... 8
4. System design considerations... 9
    4.1 Distance of wire runs.. 9
    4.2 Wire size.. 9
    4.3 Optimal PV array voltage.. 11
    4.4 Optimal PV array power.. 12
    4.5 PV array location.. 13
    4.6 Matching array modules... 14
5. Lead-Acid Battery Charging... 14
    5.1 Charging basics... 14
    5.2 Charging modes... 15
6. Maximum Power Point Tracking.. 18
7. Remote Battery Temperature Sensor.. 24
8. Installation.. 25
    8.1 Mounting and thermal considerations............................... 25
    8.2 Wiring.. 26
    8.3 Grounding.. 28
    8.4 Disconnects and overcurrent protection........................... 30
    8.5 External surge protection.. 30
    8.6 External noise filtering... 30
    8.7 Remote temperature sensor installation........................... 31
9. Setup and Configuration.. 31
    9.1 Initialization... 32
    9.2 Setpoint adjustments... 32
    9.3 Compensating for voltage drop with setpoints.................. 35
10. Operation.. 35
    10.1 Backlight and autoexit features...................................... 36
11. Data Logging.. 36
12. Battery Equalization... 38
13. Use of Multiple/Other Charging Sources.. 40
14. Fault Messages.. 41
15. Specifications.. 43
16. Troubleshooting... 43

Tables, Graphs, and Diagrams

Tables

4.1.1. Copper wire resistance & power loss vs. gauge............................ 9
4.2.1. Wire distance vs. gauge & voltage drop for 12V........................... 10
4.2.2. Wire distance vs. gauge & voltage drop for 24V........................... 10
4.3.1. Typical voltage drop and power loss.. 11
4.4.1. Maximum PV array input... 13
9.2.1. Default values for setpoints... 34
14.1.1. Fault messages.. 42

Graphs

5.2.1. Typical day of operation.. 19
6.1.1. Typical PV array power curve... 20
6.1.2. Efficiency.. 23

Diagrams

8.2.2. Wiring diagram.. 29
9.1.1. Operational flowchart... 33

1. Introduction and Overview

The Rogue MPT-3024 is a highly efficient 30 amp photovoltaic charge controller that features a proprietary maximum power point tracking algorithm for peak performance under a variety of atmospheric conditions. The MPT-3024 constantly monitors the PV array's output and automatically readjusts it as necessary to extract the most power available from it at any given moment. The array is never disconnected from the battery to make measurements, nor are periodic sweeps of the array conducted while the controller is operating in the power tracking stage. Either of these methods can result in more downtime and less power being delivered to the batteries. Boost of over 40% may be achieved with the MPT-3024 when the batteries are in a low state of charge, the PV array is cold, and the sun is bright.

The MPT-3024 is a pulse width modulated (PWM) controller based on a DC-DC buck converter topology. As such, it's capable of operating with a PV array input voltage that is higher than the voltage of the battery it's charging. The MPT-3024 will accommodate a 24-volt nominal PV array with either a 12-volt or 24-volt battery bank, or a 12-volt nominal PV array with a 12-volt battery bank. It will not operate with a PV array that generates less voltage than that of the battery it's charging. Output current is electronically limited to 30 amps.

The MPT-3024 has been designed and built using only the highest quality, most reliable components available, including ultra-low resistance MOSFETS; long life, high-temperature capacitors; a 40-MHz microprocessor; and a heavy-gauge, low resistance inductor. All electronic components meet Europe's RoHS (reduction of hazardous substances) protocol. Additionally, the MPT-3024 senses current without the use of resistive shunts. This results in an output gain of at least 3 watts over conventional current shunt technology.

The peak efficiency of the MPT-3024, when charging a 24-volt battery from a 24-volt nominal array, is 98.7%, making it one of the most efficient chargers available today. Once the controller enters sleep mode, it consumes only about 200mW (0.2W) of power. When idle (out of sleep mode, without the charger active), the controller consumes about 700mW (0.7W) with the backlight on.

The MPT-3024 utilizes an advanced six-stage charge routine to ensure that batteries are maintained properly for long life and minimal maintenance. All setpoints are fully adjustable from the front panel and are stored in a non-volatile memory that retains information even when the power is removed. Setpoints may be retrieved, viewed, and altered on the LCD display at any time during normal operation. Also included with the unit is a remote temperature sensor that will alter the programmed setpoints based on the temperature of the batteries being charged. This prevents overcharging when the batteries are warmer, and undercharging when the batteries are cooler.

Thirty days worth of data logging is also kept in non-volatile memory. The data log is retrievable during both normal operation and after the controller has entered sleep mode. It can be erased at any time.

2. Safety Information

Please take a moment to read this manual and become better acquainted with the features of the MPT-3024. As you read you will notice the following symbols. They are meant to alert you of potential hazards, cautions, or information that will require your attention as you install and use the MPT-3024. Read the notations accompanying them carefully and understand their content before continuing.

Potential hazard to health, life, or property.

Potential damage to charge controller or other ancillary equipment if instructions are not followed.

Information that is useful in obtaining maximum performance from the charge controller.

2.1 General safety precautions

1) This charger is intended for use only with lead-acid battery chemistries of 12- or 24-volt nominal system voltage. It may be suitable for other types of batteries; consult your battery manufacturer for more information.

2) Lead-acid batteries produce small amounts of flammable hydrogen gas during charging. Always work with batteries in a well-ventilated area and never allow flames, sparks, or other sources of ignition within the vicinity of batteries being charged.

3) Lead-acid batteries contain an electrolytic mixture of water and sulfuric acid. Wear suitable eye and skin protection while working with batteries. Make sure you have access to running water and a supply of baking soda nearby to neutralize any spilled or splashed acid. Should acid contact eyes, wash immediately with running water for at least ten minutes and get medical attention.

4) Batteries are capable of producing an extremely large current under short circuit conditions. This current can generate enough heat to weld metal and cause severe burns. Be careful when using metal tools around batteries and remove all metal jewelry before commencing work.

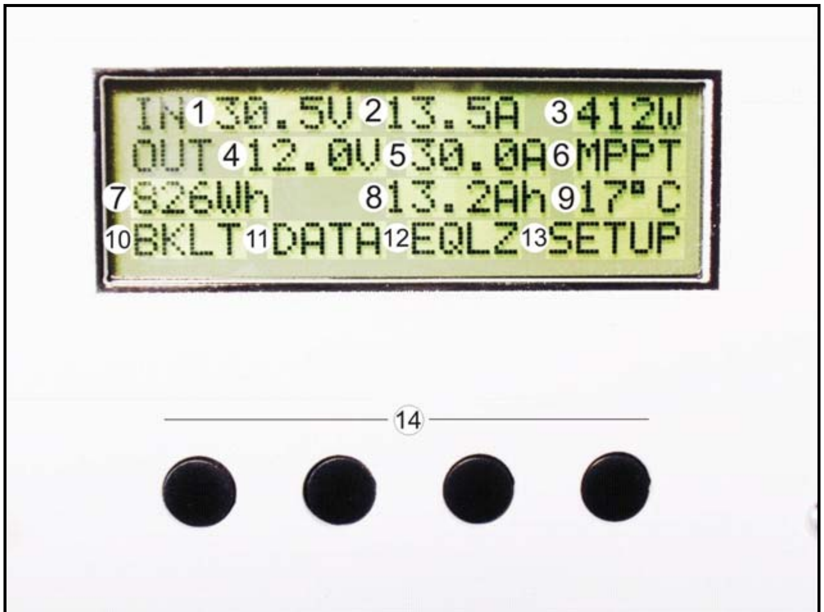
5) Never attempt to move or relocate a battery without first disconnecting it completely from its circuit.

6) Never charge a frozen battery.

7) Always ensure that the battery's electrolyte is filled to the level recommended by the manufacturer. Failure to do so may cause permanent damage to the battery.

8) The electricity generated by a PV array may be of sufficient voltage to cause electric shock or electrocution. Practice industry-standard safety techniques at all times when working around electricity and always disconnect electricity before you begin work on a circuit.

3. Front Panel and LCD Display



1 - Array voltage (volts)
2 - Array current (amps)
3 - Array power (watts)
4 - Battery voltage (volts)
5 - Battery current (amps)
6 - Charger operating mode

- MPPT - bulk power tracking mode
- ABSB - absorb mode
- FULL - battery full
- FLOT - float mode
- EQLZ - equalize mode

7 - Accumulated PV Watt-hours (kWh if greater than 999Wh)
8 - Accumulated Amp-hours (as delivered to BATTERY)
9 - Battery temperature (if sensor is connected)
10-13 - Keypad legend

- BKLT - press for backlight on/off
- DATA - press for data log
- EQLZ - press to invoke equalize routine
- SETUP - press to view and alter setpoints

14 - Keypad

4. System Design Considerations

Whether you are planning and installing your energy system for the first time or retrofitting an existing system, you'll obtain the best performance if you follow a few simple guidelines.

4.1 Minimize the distance of wire runs

Place the PV array and battery bank as close as practical to the MPT-3024. This will limit the power loss associated with long wire runs. Longer lengths of wire will cause an increase in power loss, especially at higher currents. See Table 4.1.1 to determine the resistance of selected wire gauges versus wire length.

Wire Gauge (copper)	Resistance (ohms/ft at 25°C)	Power Loss @ 30A (watts/ft)
#12	0.00162	1.46
#10	0.00102	0.92
#8	0.00064	0.58
#6	0.00040	0.36
#4	0.00025	0.23
#2	0.00016	0.14

Table 4.1.1. Copper wire resistance and power loss versus wire gauge.

4.2 Maximize wire size

The wire used to connect the PV array and battery bank to the MPT-3024 should be of a heavy enough gauge so as not to introduce excessive voltage drops and/or current limitations. At higher currents, light gauge wire may introduce a large voltage drop from the PV array, causing an extreme loss of power and erratic operation of the MPT-3024. Wire of insufficient size may also constrain charging current to the battery (which is charging at a relatively constant voltage at any given point in time). The effects of wire size may not be evident at lower charging currents; they may gradually appear and get worse as current increases.

NEC 310-15 restricts the minimum wire size for a 30-amp circuit to 10-gauge. 12-gauge may be used for installations of 20 amps or less, provided that the length of the wire does not cause a significant voltage drop. Ideally the voltage drop in any of your wiring runs should be 2% or less of the system voltage: for example, this would be approximately 0.24 volts for a 12-volt system, or 0.48 volts for a 24-volt system. Refer to Tables 4.2.1 and 4.2.2 for help in determining the proper gauge of wire when factoring in voltage drop and distance.

	#12	#10	#8	#6	#4	#2
5A	30	47	75	119	190	302
10A	15	24	37	60	95	151
15A	10	16	25	40	63	101
20A	7	12	19	30	47	75
25A	—	9	15	24	38	60
30A	—	8	12	20	32	50

Table 4.2.1. Maximum distance (in feet) for wire at a specific gauge and current, which will result in no more than a 0.24v (2%) voltage drop when used with a **12-VOLT nominal** system. Divide these distances in half for a round-trip (both positive and negative) wire run.

	#12	#10	#8	#6	#4	#2
5A	59	94	150	238	379	604
10A	30	47	75	119	190	302
15A	20	31	50	79	126	201
20A	15	24	37	60	95	151
25A	—	19	30	48	76	121
30A	—	16	25	40	63	101

Table 4.2.2. Maximum distance (in feet) for wire at a specific gauge and current, which will result in no more than a 0.48v (2%) voltage drop when used with a **24-VOLT nominal** system. Divide these distances in half for a round-trip (both positive and negative) wire run.

➔ Each connection to the terminal block of the MPT-3024 will accept up to 4-gauge wire; however, for ease of installation and compliance with code, it's best to use wire no larger than 6-gauge within the enclosure. If it is determined that a size of wire larger than 6-gauge is required to meet the maximum voltage drop, a junction box may be used, in which a short run of 6-gauge wire from the MPT-3024 is terminated at the larger gauge wire.

4.3 Select the optimal PV array voltage

In most situations it's best to wire your PV array for 24-volt nominal output. A 24-volt array is preferable because it will provide the same amount of power as a 12-volt array of identical power output, but at half the current. Since power loss in a wire is directly dependent on current, less current flowing through a wire will result in less of a voltage drop across it. Using a 24-volt array instead of a 12-volt array of the same power output will result one-fourth of the power loss for any given wire gauge or distance. See Table 4.3.1 for an example of 24-volt versus 12-volt losses. The MPT-3024 will charge either a 12-volt or a 24-volt battery bank from a 24-volt array. Please note that some modules that are labeled for 24-volt use actually exhibit a V_{mp} that is less than the typical float voltage of a 24-volt battery. These types of modules must be used with a 12-volt battery bank to ensure satisfactory operation.

It can also be seen that as a PV array heats up, the voltage at which it produces its maximum power output (V_{mp}) drops. This results in little or no gain to be had by tracking the array's maximum power point when charging a battery bank of the same nominal voltage as the PV array.

PV Watts	PV Volts (nominal)	PV Amps	Vdrop for 30ft of 6ga	Ploss for 30ft of 6ga
300W	12.0V	25.0A	0.30V	7.500W
300W	24.0V	12.5A	0.15V	1.875W

Table 4.3.1. Example of voltage drop and power losses for a given length of wire when used with 300 watt, 12-volt and 24-volt systems. Notice that the voltage drop in the 24-volt system is half that of the 12-volt, and that the power loss drops by a factor of four.

⚠ The MPT-3024 will operate with an input voltage from the PV array of up to 60 volts. If the array produces more than this voltage at any time, the controller will suspend operation and a fault will appear on the LCD display (see Section 14). The user must power down the controller and correct the situation before the controller will resume normal operation. A 24-volt nominal array, which may produce more than 45 volts open-circuit on a cold sunny day, is the maximum recommended array configuration to be used with this controller. A 36-volt nominal array will normally have an open-circuit voltage of greater than 60 volts, which will exceed the operating voltage of the MPT-3024. Use of arrays greater than 24 volts nominal is therefore not recommended. The absolute maximum input voltage for the MPT-3024 is 75 volts. Above this voltage damage to the controller will result, which is not covered by warranty.

4.4 Optimize PV array power

A match between your PV array's output and your battery bank is important for proper maintenance of your batteries. Your PV array's output, and also the storage capacity of your battery bank, will be determined by several factors, including the average amount of sun available to your site and the demand that your loads present. Consult a system installer or an appropriate text for help in calculating your needs.

The MPT-3024 will charge battery banks given any amount of current provided (up to the maximum of 30 amps), but may not reach setpoints regularly, and may not equalize properly, if current is constantly insufficient. Conversely, an array that is oversized will consistently push the MPT-3024 to its maximum limit of 30A. At and beyond this limit the power from the array is constrained and the MPPT algorithm is overridden so that the controller does not exceed its maximum current output. To avoid wasting available power, follow the guidelines given in Table 4.4.1 when sizing your array.

NEC 690-8 requires that the maximum PV short-circuit current (I_{sc}.) used with the MPT-3024 be limited to 24 amps. This means that the maximum array power is limited to about 835 watts for a 24-volt array with a voltage of 34.8 volts at its maximum power point connected to a 24-volt battery, 418 watts for a 12-volt array with a V_{mp} of 17.4 volts connected to a 12-volt battery, and 418 watts for a 24-volt array with a V_{mp} of 34.8 volts connected to a 12-volt battery.

	PV Watts	PV Volts V_{mp}	PV Amps I_{sc}	Battery Amps	Battery Volts	Nominal PV/Bat
1	864	34.8	25	30**	28.8	24 / 24
2	835	34.8	24*	29	28.8	24 / 24
3	660	34.8	19	30**	22.0	24 / 24
4	432	34.8	12.4	30**	14.4	24 / 12
5	330	34.8	9.5	30**	11.0	24 / 12
6	432	17.4	25	30**	14.4	12 / 12
7	418	17.4	24*	29	14.4	12 / 12
8	330	17.4	19	30**	11.0	12 / 12

Table 4.4.1. Maximum PV array input versus battery arrangement and state of charge. * = PV input limited by NEC 690-8. ** = PV input limited by maximum 30A output of MPT-3024. Rows 1 and 6 suggest the maximum array sizes that are feasible without regard to NEC 690-8, using maximum 30A output limit for constraint. None of these values take into account losses from wiring and converter efficiency, so in reality you could use a slightly larger array than those shown to compensate for any system inefficiencies. Use of an array much larger than suggested will result in wasted power beyond the 30 amp limit of the MPT-3024.

4.5 Choose PV array location

Choose a location for your PV array, if possible, that will allow it full and unobstructed access to the sun. This will dramatically increase its output and will improve the tracking accuracy of its maximum power point.

A partially shaded array, especially an array that has panels wired in series, will result in substantially less output and less-than-optimal tracking of the maximum power point. If your PV array experiences partial shading for much of the day, and you are unable to relocate it to a better site, it is best to wire your modules in parallel so that those modules which may be receiving full illumination will not be hampered by shaded modules.

4.6 Match the modules of an array

Although the individual PV modules of an array need not necessarily be of the same make or model, you will achieve better tracking performance from an array in which all of the modules have the same maximum power point (V_{mp}). This is best accomplished by choosing modules of the same make and model. Even if modules are not identical, be sure that they each have the same number of cells. While it is possible to wire modules together with varying numbers of cells, this will degrade the output of the entire array.

5. Lead-Acid Battery Charging

5.1 Charging basics

It's possible to charge a lead-acid battery by any one of several different methods. Low-end chargers are typically on/off devices, where the charger cycles between full on and full off depending on the terminal voltage of the battery. These chargers may over- or undercharge a battery and provide no means of maintaining a battery's state once it has been completely charged.

More advanced chargers utilize a multi-stage approach that closely monitors the battery's voltage and the current being drawn by the battery during the charging process. These chargers select a charging mode which best suits the condition of the battery at any given time, resulting in optimal charging, less maintenance, and extended battery life.

A lead-acid battery which is discharged generally begins charging at a rate equal to its capacity in amp-hours divided by a value of five to twenty (C/5 to C/20). C/10 is a good rate, which allows for fairly rapid, well-controlled charging. A charger operating at this rate is in the BULK mode. A charge controller operating from a PV array that is properly matched to its battery bank seldom produces more than the C/10 rate, so it will usually charge a battery in the bulk mode with all available power from the PV array.

A multi-stage charge controller will constantly monitor the terminal voltage at the batteries during the BULK mode. The battery will be considered nearly full once it reaches its absorption voltage (which is around 14.3 - 14.7 volts for most lead-acid batteries). At this voltage, the BULK mode will terminate and the charger will begin charging the battery at a constant voltage equal to its absorption voltage. This is the ABSORB mode. As the battery reaches full charge the charging current will gradually diminish because the battery voltage is being held steady. Ideally, the ABSORB mode will terminate once the charging current to the battery falls below a predetermined value (typically equal to the battery capacity in Ah divided by 100). In some situations (external loading), battery charging current cannot be accurately determined and so a timer may be used instead to limit the amount of time that the charger spends in this mode.

The battery is considered to be fully charged once the ABSORB mode is terminated. Upon completion of this mode, the controller will initiate the FLOAT mode, which charges the battery at a constant, predetermined voltage (usually around 13.4 - 13.6 volts). The charging current will slowly rise as this voltage is held steady and will eventually taper off to a steady value. The FLOAT mode will persist indefinitely unless external factors (such as attached loads or a change in the available input power) force the controller to revert to a previous mode because the battery voltage begins to fall below the float setpoint.

Loads that are being powered during the charging procedure will cause power that would otherwise be used for charging to be diverted. This will greatly influence both the duration and sequence of the various charging modes. Moderate to heavy loading will often prevent the battery from becoming fully charged, and so the controller will remain in the BULK mode.

See the following section (5.2) for a more detailed explanation of each mode as it pertains to the MPT-3024.

5.2 Charging modes

The MPT-3024 employs six distinct modes of charger operation.

1) MPPT: This is the default charging mode, also called the BULK mode, which commences when the controller first has power applied and when it first wakes up after sleeping. In this mode, the controller determines the voltage (V_{mp}) at which the PV array produces the most power (see the discussion of maximum power point tracking in Section 5 to understand how this works). While operating in the MPPT mode, the controller will find this point and constantly track it as it changes with array temperature and insolation. The result of this operation is maximum power delivered to the batteries when they are less than fully charged. As the charger operates in this mode, battery voltage will gradually rise until it equals the absorb setpoint, at which point the batteries are typically within 25% or less of being fully charged. PV voltage will be maintained at its V_{mp} during this mode.

2) ABSORB: The controller will transition to this mode from the MPPT mode when the battery voltage equals the absorb setpoint. The batteries will then be charged at this constant voltage and a timer will begin counting down based on the value of the FLOTM setpoint. The charger will remain in this mode until one of these two conditions are met: A) The battery charging current eventually decreases to the value defined by the FLOTR setpoint, or B) The time defined by the FLOTM setpoint has elapsed. In general, if the charger is supplying current to loads as well as charging batteries in this mode, the FLOTR setpoint will never be met because the loads will almost always be demanding a current greater than that of the FLOTR setpoint. The timer will instead elapse and force a transition to the full state. If the controller cannot maintain the battery voltage within 0.2 volts of the absorb setpoint (because of insufficient current from the PV array and/or excessive loads), it will revert back to the MPPT mode and will once more begin charging up to the absorb setpoint. The absorb timer will be reset and will begin counting down again when the controller next enters the absorb mode. This transition between MPPT and ABSORB modes may occur back and forth a number of times when the battery voltage is near the absorb setpoint on partly cloudy days. The absorb mode may be disabled by setting the FLOTM setpoint to its minimum value of zero minutes. If absorb is disabled, the controller will transition immediately to full upon reaching the absorb setpoint voltage, and will remain in this mode indefinitely unless triggered back into the MPPT mode, as described above. Note that if both the absorb mode and the float mode have been disabled, the charger will remain in the absorb mode indefinitely. The absorb mode will be re-enabled (FLOTM will be reset to its default of 180 minutes or 3 hours) if power is disconnected from the MPT-3024 while absorb is disabled.

3) FULL: In this mode, the charger has been turned off so that no power is being supplied to the batteries. The controller will transition to this mode upon completion of the ABSORB mode, or any time the battery charging current drops to zero while the controller is in float mode (as may happen if the float setpoint is lowered while the controller is in float mode). It will remain in this mode until the battery voltage drops to about 0.05 volt below the value defined by the float setpoint and the batteries begin drawing current.

4) FLOAT: This mode commences after the batteries have become fully charged, when they once again begin to draw current. A battery in good condition will typically draw less than 0.5A of current per 100Ah of battery capacity once float has stabilized. The charger will remain in this constant voltage mode indefinitely and will maintain the batteries in the full state, compensating for self-discharge. The PV voltage will often be very near the array's V_{oc} during float mode. If the controller cannot maintain the battery voltage within 0.2 volts of the float setpoint (because of insufficient current from the PV array and/or excessive loads), it will revert back to the MPPT mode and the charge routine starts over. As the sun sets at the end of the day and/or the PV array becomes shaded, the controller will exit float mode and will return to MPPT mode, where it will remain until the PV array is unable to provide at least 100mA of current to the charger. At less than 100mA, the controller will enter sleep mode. The float mode may be disabled by increasing the float setpoint beyond its maximum value, until the display reads "DSABL." If float mode is disabled, the charger will remain in absorb mode indefinitely upon reaching the absorb setpoint voltage, unless triggered back into MPPT mode as described above. Float cannot be disabled while the charger is presently operating in float mode.

5) SLEEP: The controller will enter sleep mode when the PV array is unable to provide at least 100mA of current. Upon entering this mode, the batteries are no longer receiving a charge, the PV array is disconnected, the microprocessor operates at a reduced speed, and only essential circuit elements continue to receive power. These measures ensure that the MPT-3024 consumes minimal power while sleeping. In this mode the controller will check the open-circuit voltage (V_{oc}) of the PV array every five minutes. If the array's V_{oc} is at least 2.0 volts above the battery voltage, the controller will wake up, enter MPPT mode, and attempt to charge the batteries. The PV array must be able to provide at least 100mA of current at this point, or the controller will resume sleeping, and will try again in another five minutes. The controller may wake up and go back to sleep several times in the morning and evening before finally settling in a steady state. Sleep mode may also occasionally be invoked due to adverse weather conditions, such as snow or heavy clouds. The sleep mode consumes about 200mW of power (approximately 8mA of current with a 24-volt battery bank).

6) EQUALIZE: This mode is not one of the routine modes of normal charger operation and must be initiated manually by pressing the **EQLZ** key during normal charger operation (see Section 12 for instructions). Upon selecting this mode the controller will resume operation in the MPPT mode (if it's presently in any other mode, it will exit that mode and enter MPPT mode), and will begin an attempt to charge the batteries until their voltage reaches the value determined by the EQLZ setpoint. Once the equalize setpoint has been met, the controller will transition to the equalize mode and will try to maintain the battery voltage at the equalize setpoint for the amount of time specified by the user. The controller will remain in this mode until either the timer has elapsed, the user aborts the operation, or the controller enters the sleep mode. If the controller enters the sleep mode before the equalize setpoint has been met, or before the timer has fully elapsed, it will display an error when it reawakens and will not attempt to resume operation in the equalize mode. For safety reasons, equalize must always be initiated (or re-initiated) manually.

See Figure 5.2.1 for mode transitions during a typical day of operation.

6. Maximum Power Point Tracking

A PV array, for the most part, delivers a constant current over a wide range of voltages. For this reason, it's usually thought of as a *constant current* source. By contrast, a battery will provide a relatively constant voltage over a wide range of currents; it's called a *constant voltage* source.

An array that is sold for 12-volt use, for example, actually generates anywhere from zero to about 21 volts, depending on the load it's connected to and the number of individual cells comprising the array. A PV array will develop its highest voltage without a load; this is the open-circuit condition, and the voltage measured at this point is called V_{oc}. Since there is no load in the open-circuit condition, the resistance of the load is essentially infinite, and therefore the array will produce no current at V_{oc}. With no current flowing, and because power equals voltage multiplied by current (P=VxI) the power being produce by the array will be zero watts.

At the other extreme, the load connected to the array can be a short circuit, the resistance of which is zero ohms. Under this condition the array will produce the maximum amount of current of which it's capable, called I_{sc}. Since the load under this condition (ideally) offers no resistance, there can be no voltage across it. The array under a short circuit therefore generates no voltage, and like the open-circuited array, produces no power.

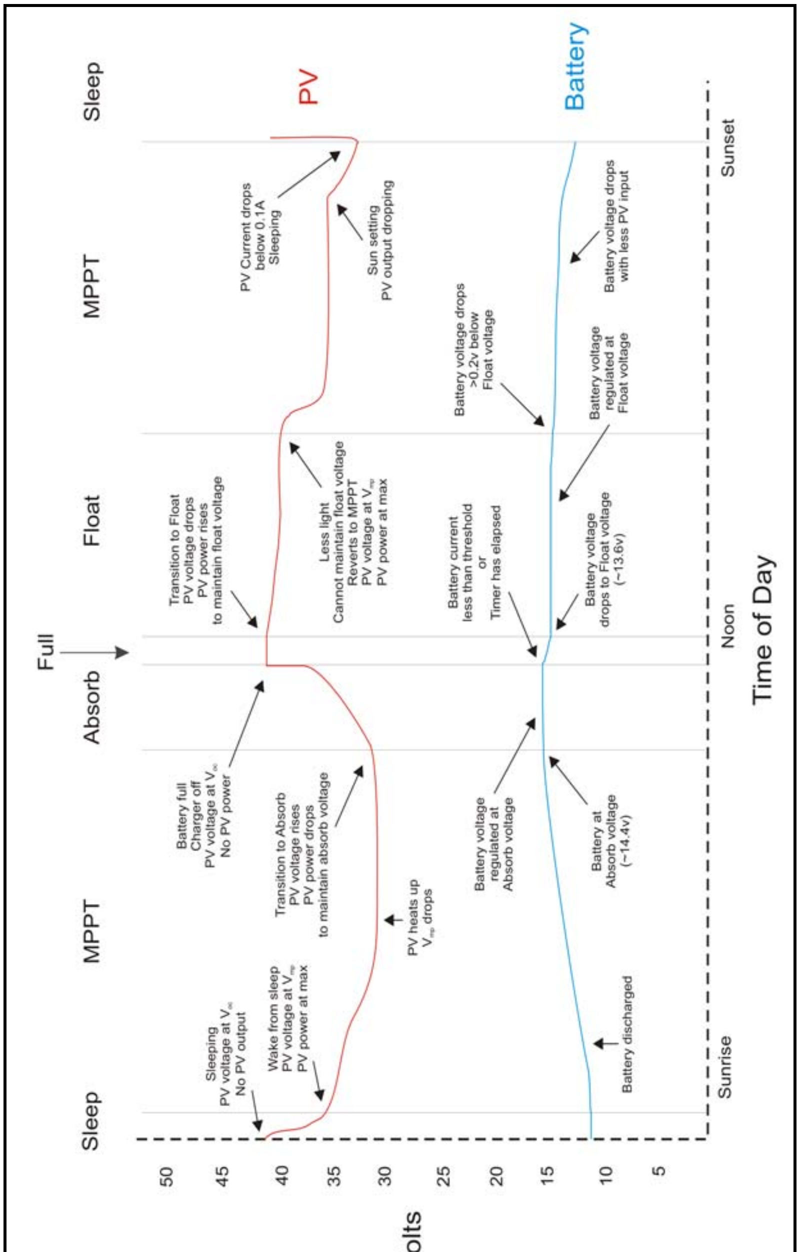


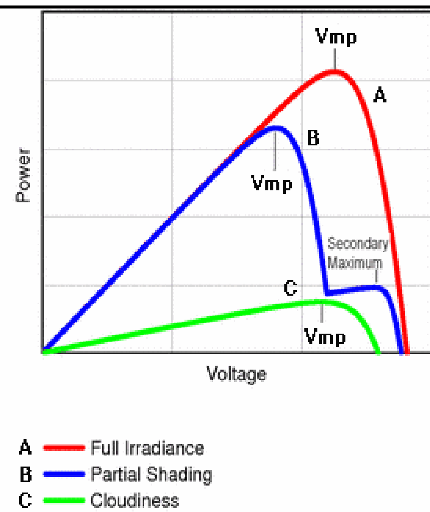
Figure 5.2.1. A typical day of operation for the MPT-3024 with 24-volt nominal array and 12-volt battery bank.

Between the open circuit and short circuit conditions, there is a point at which the array's voltage and current will come together to produce the maximum amount of power. This is called the *maximum power point* of the array, with a voltage of V_{mp} (Figure 6.1.1).

The direct connection of a battery to a PV array causes the array to operate at the voltage of the battery. This is generally well below the V_{mp} of the array. Take, for example, a battery that is being charged at 12.0 volts. The V_{mp} of the array to which the battery is connected is 17.4 volts., which is 5.4 volts above the battery voltage. The array, producing a nearly constant current of, say, 4.0 amps, will generate 69.6 watts (17.4 x 4.0) of power at its maximum power point of 17.4 volts. If connected directly to a battery being charged at 12.0 volts, the array is able to produce only 48.0 watts (12.0 x 4.0) – a 21.6 watt loss.

The MPT-3024 is capable of operating the array at its maximum power point voltage while charging a battery of substantially less voltage. It does this by rapidly switching on and off (many thousands of times per second) the connection between the array and the battery. The on-time (the pulse width) of this switching may be varied according to PV output and the state of charge of the battery. The energy from the PV array is stored in an inductor during the on-time, released during the off-time, and the output filtered. The result is a nearly lossless power converter. It's able to take a higher input voltage at a

Figure 6.1.1. Typical PV array power curve. Notice that the maximum power point (Vmp) changes with the amount, intensity, and type of sunlight received. Partial shading (B) may cause a second, lesser peak to appear on the curve, which can result in a loss of tracking efficiency and a significant loss in output from the array. The curve flattens out as light intensity drops (C). At very low light levels, the power curve will have have no discernable Vmp to track.



lesser current from the array and convert it to a lower output voltage at a higher current for the battery.

For an ideal converter without any losses, the power in equals the power out, or V_{in} x I_{in} = V_{out} x I_{out}. This formula is useful in calculating the approximate relationship between the PV array and the batteries. For example, consider a 75 watt module. It's rated for its maximum output (the full 75 watts) when operating at a V_{mp} of 17.4 volts, and will produce about 4.31 amps of current (17.4 x 4.31 =75.0). V_{in} therefore equals 17.4 volts and I_{in} equals 4.31 amps (the MPT-3024 will automatically find and track these values). If the battery voltage is 12.0 volts while charging, V_{out} equals 12.0 volts. We can easily solve for I_{out}, which is about 6.25 amps (12.0 x 6.25 = 75.0). This is a 45% improvement ("boost") in current over direct connection to the battery.

It can be seen that boost increases as the difference between battery voltage and the V_{mp} of the array becomes greater, so that a highly discharged battery affords much greater benefit when using maximum power point tracking. If the battery was charging at 11.0 volts (almost completely discharged), I_{out} would be 6.82 amps, a 58% improvement.

In reality, external factors such as array temperature and the voltage drop in wiring will produce boost of less than these idealized amounts. The efficiency of the charger will also have a limiting effect on boost. The MPT-3024, like any DC-DC converter, is not 100% efficient. This is due to the resistance of circuit elements, the switching losses of the conversion, and the small amount of energy used in simply powering the electronics that operate the converter. We can approach 99% efficiency under certain conditions. A converter that is 99% efficient would take a 75 watt input and render 74.25 watts at the output, having consumed 0.75 watts of that power in the conversion process and converted it to heat. For the above example, this would leave us with about 6.19 amps for charging our 12 volt battery, which is still a 44% improvement over direct connection to the battery. 99% efficiency is exceptional and may be approached under certain conditions. Typical efficiencies range from 95-97% under most conditions. As a rule of thumb, higher efficiency occurs as PV voltage increases (which causes a corresponding decrease in current for a given amount of power), and as the difference between PV and battery voltage decreases. Typical efficiency for the MPT-3024 is shown in Figure 6.1.2.

The DC-DC conversion process described above is only part of maximum power point tracking. Equally as important, the V_{mp} must be located and then it must be tracked as array temperature and insolation change throughout the day. Most PV modules are rated for their maximum power output at a temperature of 25°C and an insolation of 1kW/m^2. Higher temperatures and lower insolation cause a marked decrease in the V_{mp} of any PV array. Both of these variables can cause fairly rapid and frequent fluctuations in the maximum power point. Even an array located in a very cold environment will quickly heat up 20°C or more above ambient upon exposure to direct sunlight, possibly decreasing the V_{mp} by several volts for a typical 36-cell array over the course of a few minutes. As can be seen, then, most arrays produce their rated power over a very narrow range of operating conditions. The most power, and the greatest boost, is produced by a cold, brightly illuminated array.

The MPT-3024 constantly tracks the array's maximum power point and makes adjustments to the operation of the charger which compensate for any changes detected. If the maximum power point moves due to a change in array temperature, for instance, then the duty cycle of the charger is altered so that it causes the input of the charger to match the corrected power point of the array. This function is fully automatic and does not require any experimentation or guesswork on the part of the user. There are no nominal MPPT adjustments to make or controls to adjust.

The MPT-3024 will conduct a full sweep of the PV array's power curve when the power is first applied, after sleeping, when transitioning from float mode back to MPPT mode, and occasionally when transitioning from equalize mode during an abort. "Collecting Data - Please Wait" will appear on the LCD display during these periods, along with the percentage completed. The sweep and its associated calculations measure and analyze over 1000 points of data, and take approximately 90 seconds to complete with accuracy.

Under some conditions (very low light and shading) the array's power curve will be nearly flat and will have no discernable maximum power point to track. This can be especially evident when using series-wired modules. During these periods, which are common in the morning and evening, and potentially during periods of array shading, the PV array produces little usable energy and the MPT-3024 may operate it at an arbitrary voltage. Sleep mode may be invoked if array current falls below 100mA.

Fluctuation of the PV array voltage by several tenths of a volt below or above

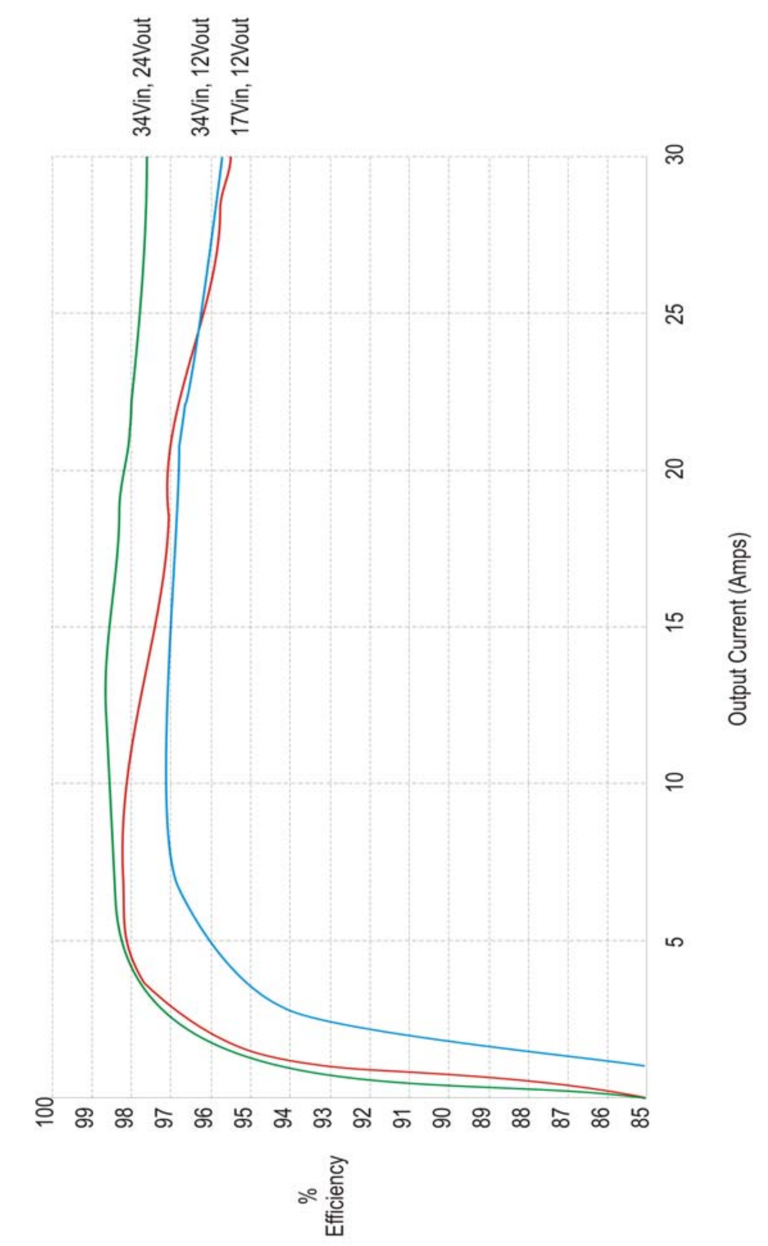


Figure 6.1.2. Efficiency curves for various PV / battery combinations at 25°C .

the V_{mp} may occur during MPPT mode. This is normal and is caused by small changes in the array's V_{mp} and V_{oc} due to environmental conditions, coupled with the limited resolution of analog-to-digital conversion and the dither used by the MPPT algorithm to locate and track the maximum power point.

7. Remote Battery Temperature Sensor

The remote temperature sensor included with the MPT-3024 will automatically alter absorb and float setpoints based on the temperature of the batteries being charged. For each degree Celsius above 25 degrees, the setpoints will be lowered approximately 5mV per 2 volt cell (30mV for a 12-volt battery, or 60mV for a 24-volt battery). For each degree Celsius below 25 degrees, the setpoints will be raised approximately 5mV per 2 volt cell, up to a maximum charging voltage as defined by the TCMAX setpoint. At 25°C, there will be no change. The remote temperature sensor does not affect any setpoints other than absorb and float. The temperature sensor will not function accurately below -20°C (-4°F).

⚠ It is recommended not to charge, use, or store batteries at temperatures less - or greater - than necessary. While a lower temperature will increase the life of the battery, capacity is reduced and there is a risk of the battery freezing at very low temperatures. A higher temperature increases battery capacity, but will shorten its life. Batteries which regularly operate at 49°C (120°F), for example, will incur an almost-80% reduction in useful life versus a battery that operates at 25°C (77°F).

Since the LCD display is capable of 0.1 volt resolution, small changes made to the absorb and float setpoints due to battery temperature might not be reflected in the battery voltage as displayed on the LCD during absorb and float modes. For instance, a two degree increase in battery temperature beyond 25°C will cause the absorb and float setpoints to be decreased by approximately 0.06 volts (60mV) for a 12-volt battery bank. This is less than the resolution of the display, and so the battery voltage as read on the display at the time of transition to float or absorb modes may not register the decrease.

The actual battery temperature will be displayed on the LCD when the remote temperature sensor is plugged in. Below 0°C (32°F), the temperature reading will cease to display actual temperature, and will instead read "< 0°C".

The remote temperature sensor also monitors maximum battery temperature, and will suspend operation of the charger if the battery temperature increases beyond 49°C (120°F).

8. Installation

8.1 Mounting & thermal considerations

With the preceding guidelines in mind, choose a suitable location to mount the MPT-3024. The unit must be mounted vertically against a hard, flat surface (i.e. drywall or plywood) for proper ventilation and cooling. This will also discourage foreign matter from entering the controller through the vents on the front panel. Make sure that the vents are unobstructed. At higher outputs and high ambient temperatures, the metal enclosure of the MPT-3024 may become warm. To prevent overheating and failure, the controller will shut down if the internal heatsink temperature exceeds 85°C (185°F). Overheating and shutdown may occur if the controller is installed in an enclosure, in direct sunlight, or where the ambient temperature is above 40°C (104°F). It must be manually powered down and restarted if overtemperature shutdown occurs.

⚠ The MPT-3024 is not designed for damp locations, nor is it to be installed outdoors, in unventilated enclosures, inside a wall cavity, in direct sunlight, or near a source of heat (stove, radiator, register, etc.). Any of these situations may cause controller failure and will void the warranty. Mounting the MPT-3024 in a cool, dry location will increase operating efficiency and will extend the life of the unit.

⚠ Compliance with national and local electrical regulations is always recommended to ensure proper installation and safe operation of the MPT-3024.

⚠ Some components within the MPT-3024 are static sensitive and may be damaged by static electricity that has accumulated in your body. Before removing the front cover, briefly touch something grounded (a metal water pipe or conduit, a grounded screw, etc.), and avoid touching any components on the MPT-3024's circuit board.

Remove the front cover from the MPT-3024 and disconnect the ribbon cable that connects the panel to the main circuit board (see Figure 8.1.1). Set the front panel aside and securely fasten the MPT-3024 to your chosen mounting surface through the four holes in the back of the enclosure, using the four screws provided.

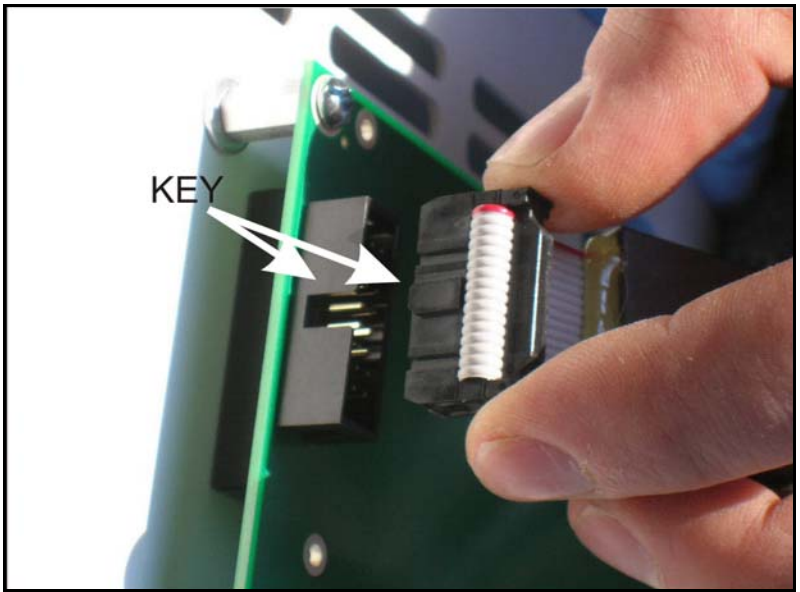


Figure 8.1.1. Disconnecting the ribbon cable from the front panel. When reconnecting, make certain that key on connector aligns with keyslot in the socket.

8.2 Wiring

With the unit firmly mounted to a hard surface, **carefully** remove knockouts from the enclosure as necessary and secure the requisite cable clamps or conduit fittings.

⚠ Careless removal of knockouts may damage the unit if too much force is used, or if components inside of the enclosure are struck. Be certain that no metal particles are left inside of the enclosure once the knockouts are removed. Lightly blowing out the enclosure (with low-pressure air, for example) is recommended.

➔ Each connection to the terminal block of the MPT-3024 will accept up to 4-gauge wire; however, for ease of installation and compliance with code, it's best to use wire no larger than 6-gauge within the enclosure. If it is determined that a size of wire larger than 6-gauge is required to meet the maximum voltage drop, a junction box may be used, in which a short run of 6-gauge wire from the MPT-3024 is terminated at the larger gauge wire.

⚠ Before connecting any wires to the MPT-3024, check the voltage present on each pair. Voltage should not exceed 60 volts under any circumstances.

For code-compliant installations, the use of conduit will be required. It is best to choose knockouts from the bottom of the enclosure. Doing so will allow easy and direct access to the terminal block on the circuit board, and will not cause the wiring to interfere with internal components on the circuit board.

With all external disconnects in the "OFF" position, securely fasten each wire in its proper location on the terminal block and tighten screws. See Figures 8.2.1 and 8.2.2 for assistance with correct wiring. Note that the PV array must have its negative wire connected directly to the **PV-** screw on the terminal block. Using one common negative wire for both **PV-** and **BAT-** connections may cause the MPT-3024 to make erroneous current measurements.

⚠ To increase efficiency and reliability, the MPT-3024 does not use any relays, mechanical contacts, or blocking diodes to ensure correct polarity of any wires connected to the terminal block **BAT** connections. As a result, there is no reverse battery protection offered on this unit. Connecting a battery backward across the **BAT** or **PV** terminals will cause immediate and irreversible damage to the controller, which is not covered under warranty. This can be easily avoided by double checking the polarity of the battery wires with a multimeter prior to connecting them to the MPT-3024, double checking them again before any external disconnects are moved to the "ON" position, and ensuring that all wires are connected to their proper terminals. Reverse PV protection of 30 amps under short circuit conditions is provided.

Miswiring the controller with a reverse battery connection may cause the output filter capacitors inside of the MPT-3024 to bulge, leak, or rupture, which could create a risk for personal injury. **Always** fasten the front panel securely to the unit **before** applying power.

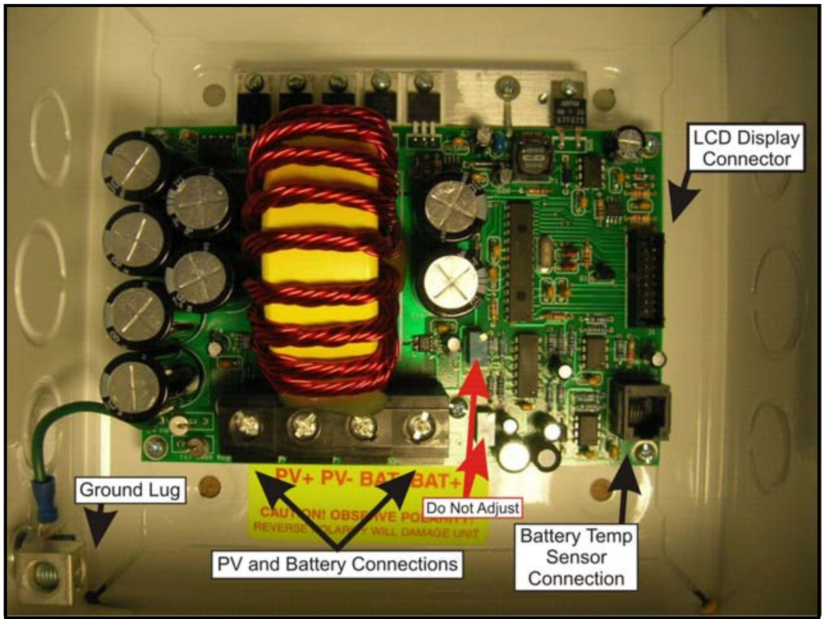


Figure 8.2.1. Wiring connections inside of the MPT-3024.

8.3 Grounding

The enclosure of the MPT-3024 is floating with respect to all circuit voltages and may be used with either negatively or positively grounded systems. It may also be used with systems in which neither negative or positive are grounded, as allowed by NEC 690-41 for systems of less than 50 volts. Most systems are negatively grounded, or utilize an isolated ground to which neither negative or positive conductors are grounded. However, it is necessary for a few types of systems to produce a negative voltage when referenced to ground — in this case, ground will be considered positive.

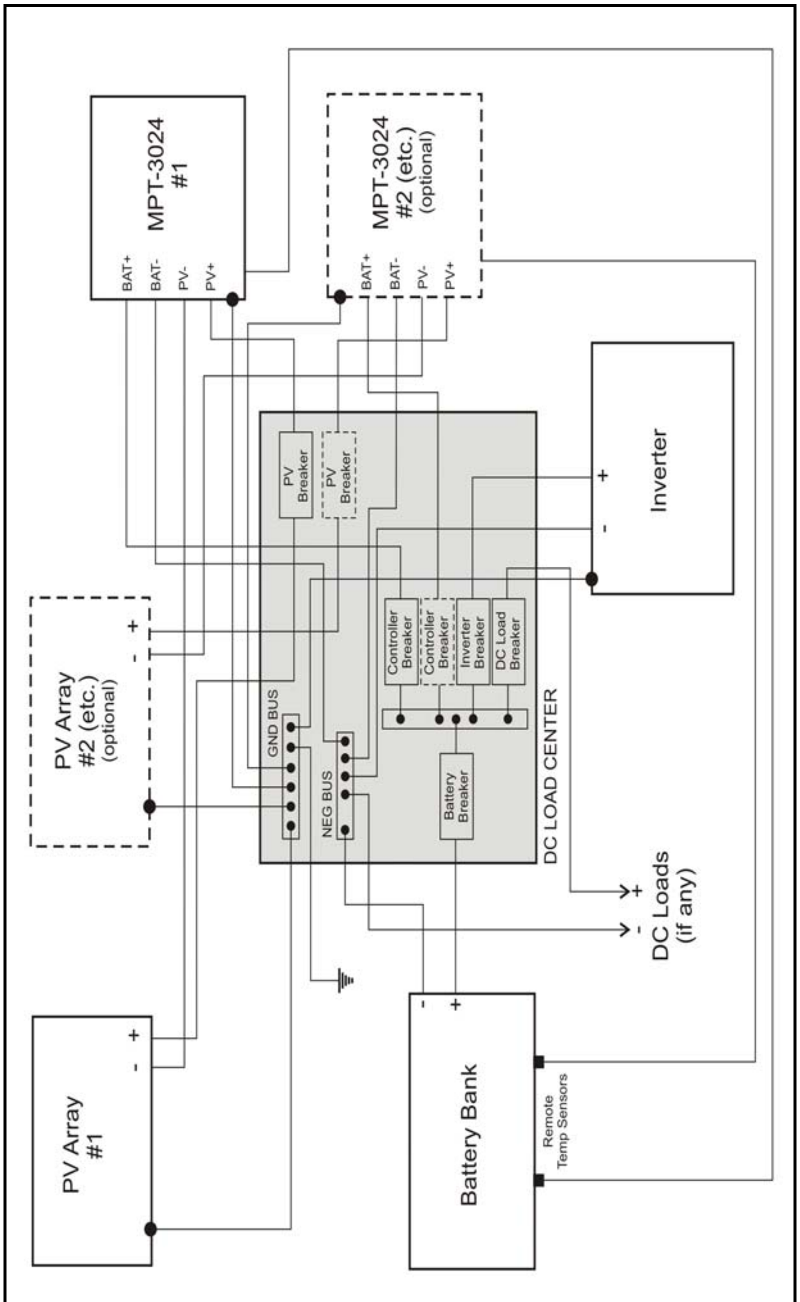


Figure 8.2.2. Suggested wiring diagram.

⚠ In a positively grounded installation, be sure that the **PV+** and **BAT+** terminals are *never* connected together at a common point anywhere in the system.

For code compliance, basic electrical safety, and enhanced EMI shielding, one copper ground wire *must* be securely fastened to the enclosure (at the lug provided, shown in Figure 8.2.1), with the other end connected to the grounded bus bar within your load center.

8.4 Disconnects and overcurrent protection

Pursuant to National Electric Code requirements (and others which may have jurisdiction in your locale), disconnects are required for both the input and output of the MPT-3024. It is recommended that the PV disconnect should be rated for 30 amps to comply with NEC requirements. The recommended disconnect between the MPT-3024 and the battery should be rated for 40 amps. All disconnects should be rated for DC (direct current) use.

8.5 External surge protection

The MPT-3024 includes gas-discharge surge protection on both the **PV+** and **PV-** terminals to ground. This will offer protection against surges, but *will not* be effective against lightning. Additional external protection is highly recommended if your PV array will be roof mounted or otherwise subject to an increased likelihood of lightning strike. Damage from lightning is not covered under warranty.

8.6 External noise filtering

The MPT-3024 includes an adequate amount of capacitance on the input and output for proper charger operation, and also includes noise filtering within the voltage and current sensing circuitry that helps to improve its accuracy. Some sources of power and some types of inverters may introduce unacceptable levels of noise into the power wiring that connects to the MPT-3024. This noise may impair operation of the MPT-3024 under extreme conditions, and must be filtered at the source. Over time, excessive noise may also overwhelm and degrade the filter capacitors within the MPT-3024. Contact the manufacturer of any suspect device for assistance.

8.7 Remote temperature sensor installation

Secure the remote temperature sensor to your battery bank. Choose a site that is likely to experience measurements which accurately reflect the true temperature. The sensor is conveniently encapsulated with thermally conductive epoxy in an isolated copper lug which may be mounted directly to a battery terminal or affixed to the side of a battery. Route the sensor cable to the MPT-3024 and through a knockout in the enclosure, using a cable clamp or suitable bushing. Plug the sensor cable's connector into the matching jack on the circuit board. Although the MPT-3024 includes noise-canceling circuitry, it is best not to run the sensor's cable near any possible sources of electrical noise, such as house wiring or fluorescent light fixtures.

⚠ Connecting the sensor to the MPT-3024 while the power is on may cause erratic operation, but will cause no damage – plug the sensor in only when power is disconnected from the unit. Use only the supplied temperature sensor with the MPT-3024. Using other sensors, or attempting to plug telecommunications equipment into the temperature sensor's jack may damage the MPT-3024 and will void the warranty.

Reconnect the ribbon cable to the front panel (the connector is keyed so it will fit only one way – do not force it) and reinstall the cover onto the enclosure *before* applying power.

9. Setup and Configuration

With the MPT-3024 properly installed and wired, power may be applied and setup initiated. PV and battery power may be applied simultaneously or separately in any order. The MPT-3024 derives power for its internal circuitry from the battery bank; it will not power up until the battery power has been connected.

➔ The MPT-3024 requires at least 6 volts of battery power to initialize, and will not begin charging unless connected to a battery of at least 10 volts. If it becomes necessary to disconnect the batteries from the MPT-3024, wait at least 30 seconds before reapplying power or the unit may not initialize properly.

9.1 Initialization

With power applied, a welcome screen will appear for approximately five seconds. The MPT-3024 will then verify that a battery of suitable voltage has been connected, and will display the results on the next screen. You may confirm the result and commence charger operation, or you may choose to enter setup.

➔ Battery banks of less than 15 volts will automatically be configured as a 12-volt nominal battery; banks measuring between 20 and 30 volts will automatically be configured as a 24-volt nominal bank. Batteries measuring outside of these ranges will cause a fault to be displayed (see Section 14). The unit must be powered down and the fault corrected before continuing. If the battery bank voltage displayed on the LCD at this point is different than expected, check the wiring of your batteries to make sure they're connected in the proper order.

9.2 Setpoint adjustments

Upon first power-up, default setpoint values will be present (see Table 9.2.1). Check with your battery manufacturer to determine if these are the recommended setpoints for your batteries. To alter these values, press **SETUP**. Three setpoints will appear on the next screen: ABSORB, FLOAT, and EQLZ.

- The ABSORB setpoint defines the voltage at which the battery is considered to be full. Once the battery reaches this voltage, the controller transitions from the MPPT mode to the absorb mode, where the battery is held at the absorb setpoint voltage for a time.

- The FLOAT setpoint defines the voltage at which the battery is kept charged indefinitely upon completion of the absorb mode. The float mode may optionally be disabled by increasing the float setpoint beyond the maximum setting of 14.0v / 28.0v, at which point the display will read DSABL. If the float mode is disabled, the charger will remain in absorb mode indefinitely after reaching the absorb setpoint voltage, unless triggered back into MPPT mode.

- The EQLZ setpoint defines the target voltage for the equalize mode.

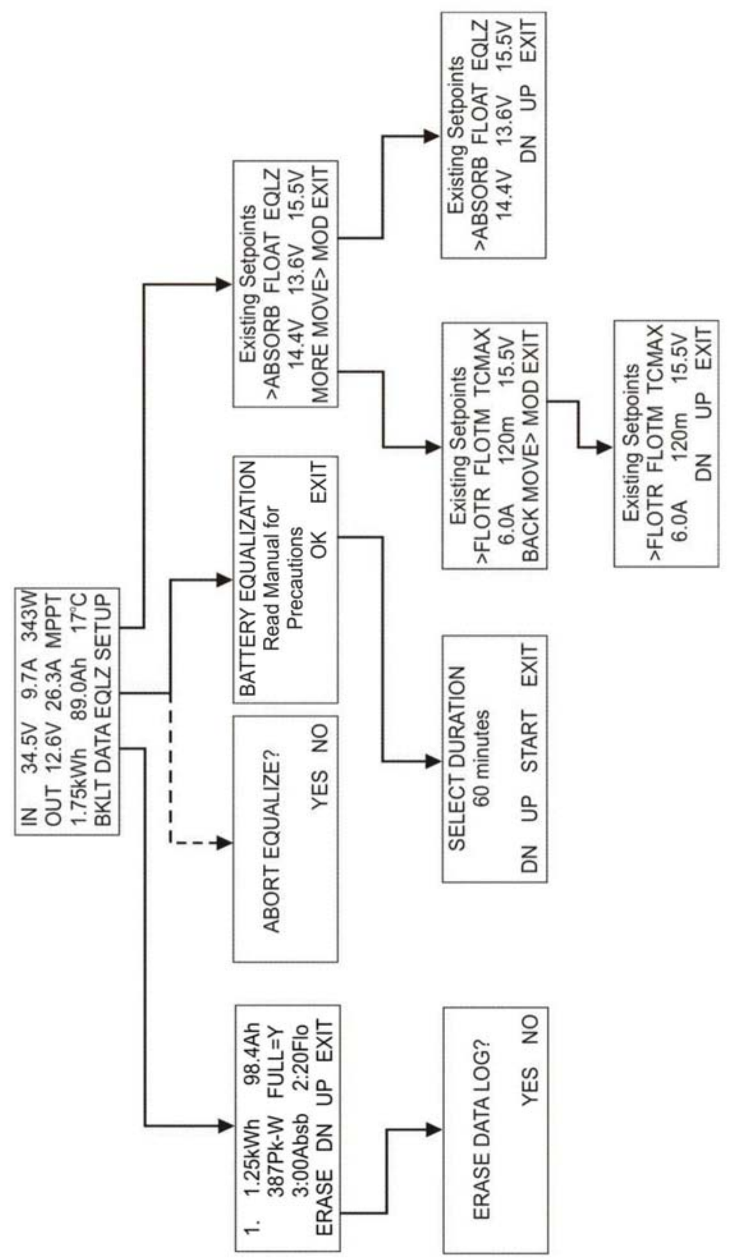


Figure 9.1.1. Operational flowchart.

	Default 12v	Default 24v	Range 12v	Range 24v
ABSORB	14.4v	28.8v	14.0v - 15.2v	28.0v - 30.4v
FLOAT	13.6v	27.2v	12.8v - 14.0v	25.6v - 28.0v
EQLZ	15.5v	31.0v	15.0v - 16.0v	30.0v - 32.0v
FLOTR	6.0A	6.0A	0A - 30A	0A - 30A
FLOTM	180 min	180 min	0 - 255 min	0 - 255 min
TCMAX	15.5v	30.0v	14.8v - 16.0v	29.6v - 32.0v

Table 9.2.1. Default values and range for adjustable setpoints.

Pressing **MORE** will bring you to the second setpoint screen. Three more setpoints will appear here: FLOTR, FLOTM, and TCMAX.

- The FLOTR setpoint defines the current at which the battery is considered to be full. Once the charging current reaches this point in the absorb mode, the controller turns off and enters the full stage. It is adjustable from 0 to 30A. This value is typically set to equal the battery capacity divided by 100. For a 600A-H battery bank, this would be 6.0A, which is the default setting. If the absorb mode is disabled, the charger will transition immediately to the full state once the ABSORB setpoint is met.

- The FLOTM setpoint specifies a timer value in minutes which will override the FLOTR setpoint once the timer has elapsed. This timer is reset and reinitialized every time the charger enters the absorb mode. It is adjustable from 0 to 255 minutes. Consult your battery manufacturer to determine the proper setting for your batteries. The absorb mode may optionally be disabled by setting the FLOTM value to its minimum value of zero minutes. The absorb mode will be re-enabled (FLOTM will be reset to its default of 180 minutes or 3 hours) if power is disconnected from the MPT-3024 while absorb is disabled. Changing the value of FLOTM while the charger is operating in the absorb mode will have no effect until the next time the charger transitions into the absorb mode.

- The TCMAX setpoint establishes a maximum voltage for the temperature compensated absorb and float setpoints. A very cold battery may prompt the controller to alter the absorb and float setpoints beyond a safe charging voltage when using the remote temperature sensor. However, the controller will never attempt to charge the battery at a voltage greater than that defined by the TCMAX setpoint (except when equalizing).

Any of the setpoints may be changed by first pressing the **MOVE>** key. The ">" character will appear next to the setpoint to be changed. Once selected, pressing **MOD** will allow you to either increase or decrease the setpoint using the **UP** or **DN** keys. After the desired value is chosen, pressing **SAVE** will store the setpoint in memory and will then allow you to alter other setpoints, if necessary. The first setpoint screen may be accessed from the second screen by pressing **BACK**. Pressing **EXIT** will bring you back to the battery voltage confirmation screen, at which point you may press **OK** to begin charger operation. See Figure 9.1.1.

9.3 Compensating for voltage drop with setpoints

A voltage drop is to be expected across all wiring, but should be kept as small as possible for best system efficiency (see Sections 4.1 and 4.2). In cases of moderate voltage drop between controller and battery, the voltage at the controller (as determined by setpoint adjustments in float and absorb modes) may be somewhat greater than the actual battery voltage. This can lead to undercharging of the battery. For example, the controller may be set to absorb at 14.4 volts, but with a 0.2 volt drop between the controller and battery, the battery will measure only 14.2 volts at its terminals. The problem can be mitigated by raising the setpoint voltages slightly (not more than 0.2 volts) to compensate for the voltage drop. Keep in mind, however, that voltage drop increases with current, and so the problem may not manifest itself at lower currents. If the voltage drop is greater than 0.2 volts at maximum operating current, then a larger wire size should be selected, or the batteries should be located closer to the controller. In general it's a good practice to place the batteries no further than 20 feet from the controller.

10. Operation

The normal operation of the MPT-3024 is fully automatic and requires no user intervention, except for battery equalization (see section 12).

Setpoints may be changed at any time while the charger is operating by pressing the **SETUP** key. The data log (see section 11) may be accessed by pressing the **DATA** key. The charger will continue to operate in the background while either setup or data information is being accessed and displayed. Altering setpoints during operation may cause the charger to transition between modes during setup or once setup has been exited, depending on the new setpoints chosen. Once float mode has been reached, altering any setpoints related to the absorb or MPPT modes will not take effect until the next time the charger enters those modes.

10.1 Backlight and autoexit features

The backlight may be turned on or off at any time during charger operation by pressing the **BKLT** key. The backlight will automatically turn on when power is first applied to the MPT-3024, and when accessing the setup, data, or equalize menus during normal operation. It will also turn off automatically after 30 seconds upon returning to the main status display.

All menus will automatically exit to the main status display after 60 seconds of inactivity, and the backlight will turn off. If coming from a setpoint adjustment, the value of the setpoint will be saved before exiting and returning to the status display. If accessing the data log from the sleep mode, the controller will revert to sleeping after about two minutes of inactivity.

11. Data Logging

The MPT-3024 allocates memory for the storage of accumulated Amp-hours, accumulated Watt/kW-hours, peak watts, the amount of time spent in the absorb and float modes, and battery full status. It stores these values in the form of a 30-entry log. Under normal circumstances, each log entry will correspond to one wake/sleep cycle (i.e. one day’s worth of data).

> ➔ Data logging will not operate properly in regions that receive 24-hour sunlight during the summer months, if there is insufficient darkness to cause the MPT-3024 to sleep once in a 24-hour period. In these situations, data will continue to accrue until the maximum values have been reached (9.99kWh and 999.9Ah), and no log entries will be made.

Data is logged with the most recent values saved in the 1st entry, and the oldest values saved in the 30th entry. Each new entry will shift the existing entries one down (i.e. 1st will become 2nd, 2nd will become 3rd, etc.). After 30 entries have been made, subsequent entries will push the oldest (30th) entry off of the log to make room for the newest (1st). Log data is stored in non-volatile memory, which is retained even when power to the controller is off.

The data log is updated upon entry into sleep mode. In some instances (during wakeup in the morning and during shutdown at night), the MPT-3024 may enter and exit sleep mode several times before settling into a steady state. In order to prevent spurious log entries during these periods (which contain negligible data, and which do not correspond to a genuine day's worth of data), the log will not be updated unless the Amp-hour meter has accumulated more than 0.5Ah. It should be noted that excessive clouds or anything that obscures the PV array during daylight (snow, for example) may invoke the sleep mode with enough accumulated data to cause a log entry to be made, even though a full day's worth of data has not been logged.

When comparing log data from one day to another, keep in mind that the output of the controller for any given day will depend largely on the state of the batteries being charged that day and the demands of any active loads, in addition to the amount of sunlight. Batteries that are almost fully charged will cause much less accumulation for the watt-hour and amp-hour meters than batteries which are discharged. Likewise, heavier loads will delay a full state of charge in the batteries and will cause a greater accumulation in the watt-hour and amp-hour meters. A more accurate comparison between log entries may therefore be made by taking the amount of time spent in the absorb and float modes into consideration. Less time spent in these modes means that more time has been spent in the MPPT mode, which will generally result in a greater accumulation of watt-hours and amp-hours for a given amount of solar insolation.

The data log may be accessed from the main status display at any time by pressing the "DATA" key. It may also be accessed once the MPT-3024 has entered sleep mode by pressing any key.

"Wh" is the accumulated PV watt-hours for that day. If the value is greater than 999, the number will appear as kilowatt-hours (kWh).

"Ah" is the accumulated Amp-hours as output to the batteries for that day.

“Pk-W” represents the peak input power (in watts) recorded for that day. This is the highest power that was measured during operation for the period represented by each entry.

“FULL” will be followed by either a “Y” or an “N” — indicating whether or not the batteries were fully charged for that day.

The third row of data tallies the amount of time that the controller spent in the absorb and float modes for that day, rounded to the nearest five minutes. Up to 16 hours maybe be logged in both timers. In the unlikely event that the 16 hour limit is exceeded, the timer will roll over to zero and will begin counting again. The format for these timers is HH:MM, where H is hours and M is minutes.

Log entries may be scrolled through by using the “UP” and “DN” keys. All log data may be erased by pressing the “ERASE” key. Any request for erase will be confirmed before the erase command is executed.

12. Battery Equalization

As a string of batteries ages, one or more cells may become stronger and attempt to draw more than their share of charging current. In order to force the weaker cells into competition with the stronger cells, the entire string of batteries may be subject to an overcharge. This will also help to eliminate stratification of the electrolyte in each battery and will prolong the life of your batteries if done properly.

The MPT-3024 features a built-in equalize mode which must be initiated by the user. Automatic equalization can be potentially harmful to the batteries if they are not properly prepared to accept the overcharge. It may also damage equipment that is connected to the batteries at the time of equalization if such equipment is not meant for sustained voltages in excess of those they normally operate at. Also, it’s always a good idea to be nearby as the batteries are being equalized so you may be alerted to any problems before they become catastrophic. For these reasons, the MPT-3024 does not provide automatic equalization.

The equalize mode may be initiated at any time. Before doing so, run through the following checklist to ensure that equalization will be most successful:

1) Equalization should be attempted early on a bright, sunny day with batteries at or near full charge. Cloudy days will likely not produce enough charging current to bring the batteries up to the equalize setpoint. Beginning the equalize operation late in the day will probably not allow enough time for the equalize charge to complete fully.

2) Never attempt to equalize a sealed battery, or any battery other than a flooded lead-acid type, unless specifically instructed to do so by the manufacturer. Batteries that are not meant to be equalized may explode or become permanently damaged if subjected to overvoltage.

3) Ensure than each battery in your bank is filled with distilled water to the proper level both before and after the equalize operation.

4) Disconnect sensitive equipment from the batteries if it's possible that it might become damaged by overvoltage, and turn all loads off.

5) Ensure that the batteries are in an adequately vented space, and are far away from any sources of ignition.

6) Ensure that connections to each battery are well-made and in good condition.

7) Check frequently on the batteries once the equalize mode begins. Always wear protective clothing and eye protection when checking on the condition of your batteries.

Initialize equalization by pressing the **EQLZ** key while the charger is in normal operation. You will be prompted to read these instructions; you may then press either **OK** to proceed, or **EXIT** to resume normal charger operation. Upon pressing **OK**, you will be asked to specify the duration of the equalize charge (time will not begin counting until the charger actually reaches the equalize setpoint). You may enter a value of 0 to 255 minutes (the default is 60 minutes); check with your battery manufacturer for help in determining the proper duration. Press **OK** to proceed, or **EXIT** to abort equalization and resume normal charger operation.

The controller will revert to MPPT mode when **OK** is pressed if it is not already in that mode, and will begin to deliver full power to the batteries in an attempt to bring their voltage up to the equalize setpoint. EQSET will appear on the third line of the display, with a scrolling asterisk and the percent sign to the right. With adequate charging current, the equalize setpoint will soon be met and the controller will enter the equalize mode (EQLZ will replace MPPT on the display).

Upon entering the equalize mode, the timer will begin counting down, and the scrolling asterisk on the screen will be replaced by a number which represents the percent of equalization completed. The controller will remain in the equalize mode, and will continue to count down time, even if the battery voltage falls below the equalize setpoint. To ensure that the battery voltage is maintained as close as possible to the setpoint, invoke the equalize mode only when there will be adequate sunlight (and thus enough charging current) for the duration of the procedure.

If equalization is successful, the controller will exit the equalize mode at 100% completion, will resume normal charger operation, and EQEND will be appear on the third line of the display. Pressing the EQLZ key again will clear EQEND from the display.

If equalization is not successful because the controller entered sleep mode before the equalize setpoint voltage was met, or because the equalize operation was unable to complete before sleep mode was entered, EQERR will appear on the third line of the display when the controller reawakens, along with the percentage of equalization that had been completed before the transition to sleep. Pressing the EQLZ key again will clear this from the display, and you may choose to try equalizing your batteries again. Check with your battery manufacturer to learn how often they recommend equalizing your batteries.

The equalize mode may be aborted at any time after it has been initialized by pressing the EQLZ key again.

13. Use of Multiple and Other Charging Sources

The MPT-3024 has been designed for use only with PV modules. Although it may possibly be used with other sources, it has not been tested with them, and will not be warranted when used with non-PV sources.

The MPT-3024 may, however, be integrated into a system in which there exists more than source of power for charging the same bank of batteries. For these installations, each source of power will require a charge controller that is specifically suited for the type of source to which it's connected. Consult a system installer for more information.

For high-power systems with many PV modules, it is recommended that they be divided into multiple arrays, each with its own dedicated charge controller. This will improve tracking and overall system efficiency in most instances.

⚠ Always ensure that each MPT-3024 has its own dedicated array: do not connect the **PV** terminals of multiple controllers in parallel. The **BAT** terminals should be connected in parallel when using multiple charge controllers (always observe proper polarity and ensure that **+** and **-** terminals are never connected together). See the diagram in Figure 8.2.1.

⚠ Since the input to the MPT-3024 operates as an open circuit when the batteries are full (and also during sleep mode), the source of voltage connected to the MPT-3024 must be capable of open-circuited loading without damage. The source must also never exceed 60 volts under any circumstances.

➔ Sources of power which do not continually produce at least 100mA of current will cause the MPT-3024 to enter sleep mode.

14. Fault Messages

The MPT-3024 is designed with a variety of sensing capabilities that are meant to make the microprocessor aware of a fault condition and allow it to shut the controller down before damage results. On the rare occasion that the controller shuts down due to the presence of a fault, an alert will appear on the LCD display so that the user can take appropriate action before resuming operation of the controller. Table 14.1.1 lists possible fault conditions, their corresponding alerts, and the action required by the user for each. After correcting the fault, power down the controller for 30 seconds before reapplying power.

Fault Message	Cause of Fault	Corrective Action
Battery Out of Range	• Battery voltage is not within proper range as tested during startup. A 12-volt bank must measure between 10 - 15 volts at idle. A 24-volt bank must measure between 20 - 30 volts at idle. A measurement below 10 volts, between 15 and 20 volts, or above 30 volts, is out of range.	• Check batteries for defects and proper wiring. Use only batteries wired for a nominal voltage of 12 or 24 volts.
Input > 60v	• The PV array is producing more than 60 volts open-circuit.	• Verify that array is wired for no more than 60 volts open-circuit. An array with a nominal output of 36 volts or more will generally have an open-circuit voltage of more than 60 volts, and should not be used.
Battery Temp Too High	• The battery, as sensed by the remote temperature sensor, has exceeded 49°C (120°F).	• Check batteries for defects and ensure good air circulation. Lower ambient temperature if possible.
Internal Temp Too High	• The temperature of the heatsink inside of the MPT-3024 has exceeded 85°C (185°F).	• Ensure that the unit is mounted properly, has adequate ventilation, and is not operating in direct sunlight. Reduce ambient temperature if possible.

Table 14.1.1. Fault messages that are displayed on the MPT-3024's LCD when an abnormal condition is detected. Shut down the MPT-3024, correct the fault, and wait 30 seconds before reapplying power.

15. Specifications

Output Current	30 amps
Battery Voltage	12V or 24V nominal [1]
PV Voltage	12V or 24V nominal [1]
Max PV Open-circuit Voltage	60 volts
Power Consumption in Sleep	~200mW (8mA @ 24V)
Power Consumption at Idle w/backlight	~700mW (29mA @ 24V)
Battery Temperature Compensation	5mV/°C per 2-volt cell [2]
Ambient Temperature (Operating)	-20°C / -4°F — 40°C / 104°F
Voltmeter Accuracy Voltmeter Resolution	0.2% at full scale (60V) 0.1V
Ammeter Accuracy Ammeter Resolution	2.0% at full scale (30A) 0.1A
Wire Size for BAT and PV Terminals	4ga - 12ga
Maximum PV Input Power	864W with 24-volt battery [3] 432W with 12-volt battery [3]
Dimensions	8.125” x 8.125” x 4.375” (209mm x 209mm x 111mm)
Weight	7 lbs. (3.2kg)

1. Nominal battery voltage must be equal to or less than nominal PV voltage.
2. When remote temperature sensor is installed.
3. Assumes charge on battery of 28.8v/14.4v, respectively.

16. Troubleshooting

If the MPT-3024 is not operating as expected, please review the following list of conditions and possible causes before requesting technical support from RPT. Many problems can be traced to improper or insufficient wiring, faulty connections, or adverse weather conditions.

Problem	Possible Cause(s)	Possible Solution(s)
Controller will not power up - display is blank	• Battery voltage is insufficient • Improper wiring • Battery disconnect open or tripped	• Ensure that battery voltage is greater than 10 volts • Check integrity of wiring and connections • Reset disconnect and/or determine cause of tripping
Controller is always sleeping	• PV array is disconnected • PV array is connected backwards. • PV array V_{oc} is below battery voltage • PV array is producing less than 100mA	• Check for open wiring and terminal corrosion • Connect with proper polarity • Check for array / battery mismatch. Array voltage must be greater than battery voltage by at least 2 volts. • Check integrity of wiring and connections • Sunlight may be insufficient due to time of day or weather conditions. Wait until conditions improve • Sunlight may be insufficient due to time of day or weather conditions. Wait until conditions improve
Battery voltage as measured at batteries during absorb or float is higher or lower than setpoints displayed on controller	• The battery temperature sensor, if connected, is automatically altering ABSORB and FLOAT setpoints based on battery temperature. See Section 7 for more information. • Wiring may be introducing voltage drop • Wiring connections may be loose or corroded	• Normal operation. • A small amount of voltage drop (<2%) is to be expected and is normal. Larger amounts may suggest that wire size is too small, and should be increased accordingly. Setpoints may be altered slightly to compensate — see Section 9.3 for more information. • Check connections

Problem	Possible Cause(s)	Possible Solution(s)
Controller never enters full mode	• Insufficient current from PV array to fully charge battery	• Array may be undersized for system. Re-evaluate and increase array size if necessary / possible. • Array might not be receiving enough sunlight. Consider relocating array for better exposure. • Weather conditions could be limiting array output (common during winter months). Wait for conditions to improve. • Make sure PV modules are clean. • Check all connections for damage and corrosion.
	• Float mode has been disabled	• Controller will remain in absorb mode with float mode disabled. This is normal. Re-enable float to allow entry into full / float modes.
	• External loads active	• Loading will delay full charge, and in some cases may prevent it altogether. If this is a regular occurrence, consider a larger array if possible, or reduce loading while charging.
Controller charges battery to full, but battery capacity seems lower than it should be	• Controller setpoints are not properly adjusted.	• Check with your battery manufacturer to determine proper values. Reference Section 9.2 of this manual. If the ABSORB and FLOAT setpoints are correct, check the FLOTM and FLOTR setpoints. A FLOTM which is set too low or a FLOTR which is set too high will cause insufficient finishing of the battery's charge.
	• Defective battery	• Test battery condition and capacity, and replace if necessary

Problem	Possible Cause(s)	Possible Solution(s)
Equalize never starts	• PV array output insufficient	• Array may be undersized for system. Re-evaluate and increase array size if necessary / possible. • Array might not be receiving enough sunlight. Consider relocating array for better exposure. • Weather conditions could be limiting array output. Wait for conditions to improve. • Make sure PV modules are clean. • Check all connections for damage and corrosion.
	• Battery in low state of charge	• Ensure that battery is nearly full before initiating equalize
	• Equalize time is set to zero	• Set time for appropriate duration
	• External loads active	• Loads should be turned off or disconnected before initiating equalize
Output boost to batteries is less than expected	• PV array V_{mp} is close to or below battery voltage	• Arrays wired for the same nominal voltage as the battery bank will often have a V_{mp} that is lower than the battery voltage as the temperature of the array rises. A warm 12-volt array, for example, may have a V_{mp} of 14 volts or less — which may be at or below the battery voltage. In these situations, there will be no boost available. Wire the array for 24 volts when using a 12-volt battery, if possible.
	• Battery is nearly full	• As battery voltage increases, boost decreases. This is normal.
	• Controller is not in MPPT mode	• Boost is available only when operating in MPPT

NOTES