

SC-2030 Solar Charge Controller User’s Manual (Preliminary)

12-24 V systems, 30Amps max. Document revised May 1, 2014

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1. Description of the SC-2030 Solar Charger

What a solar charge controller does: The purpose of a solar charge controller is to regulate the power from a set of solar panels to provide proper charging to your batteries—not over or under charging them.

The SC-2030 Solar Charger is a precision, high efficiency PWM (pulse width modulated) Solar Array Battery Charge Controller. The objective of this design is to maximize the life of your batteries by allowing the flexibility to adjust solar charging closely according to the way your battery manufacturer has specified.

High performance depends on being connected to a TM-2030 TriMetric Battery System Monitor. With this combination you get both high performance monitoring and charging of your battery system.

- For 12 or 24 V battery systems: AGM, Gel or Liquid Electrolyte batteries.
- Up to 30 amps maximum solar current. It will reduce output sufficient to protect charger if the solar output is greater. Four 135 watt solar panels for 12V systems (eight at 24V) can be accommodated. It's also possible to simultaneously use other chargers of the same batteries with additional solar panels.
- Optional Temperature compensation. For this, order the TS-2 Bogart Engineering temperature sensor.
- Recommended for use with “12V” or 24V solar panels. (see below on page 2 **Where this controller is not recommended**)

- Eight adjustable parameters to allow charging closely according to the way the battery manufacturer specifies. Technical details are shown on graphs on pages 14 and 15.
- If the TriMetric TM-2030 is disconnected from the SC-2030, it will do a much less flexible, but minimal, level of charge regulation without receiving information from the TM-2030. See p.12, Table 3.

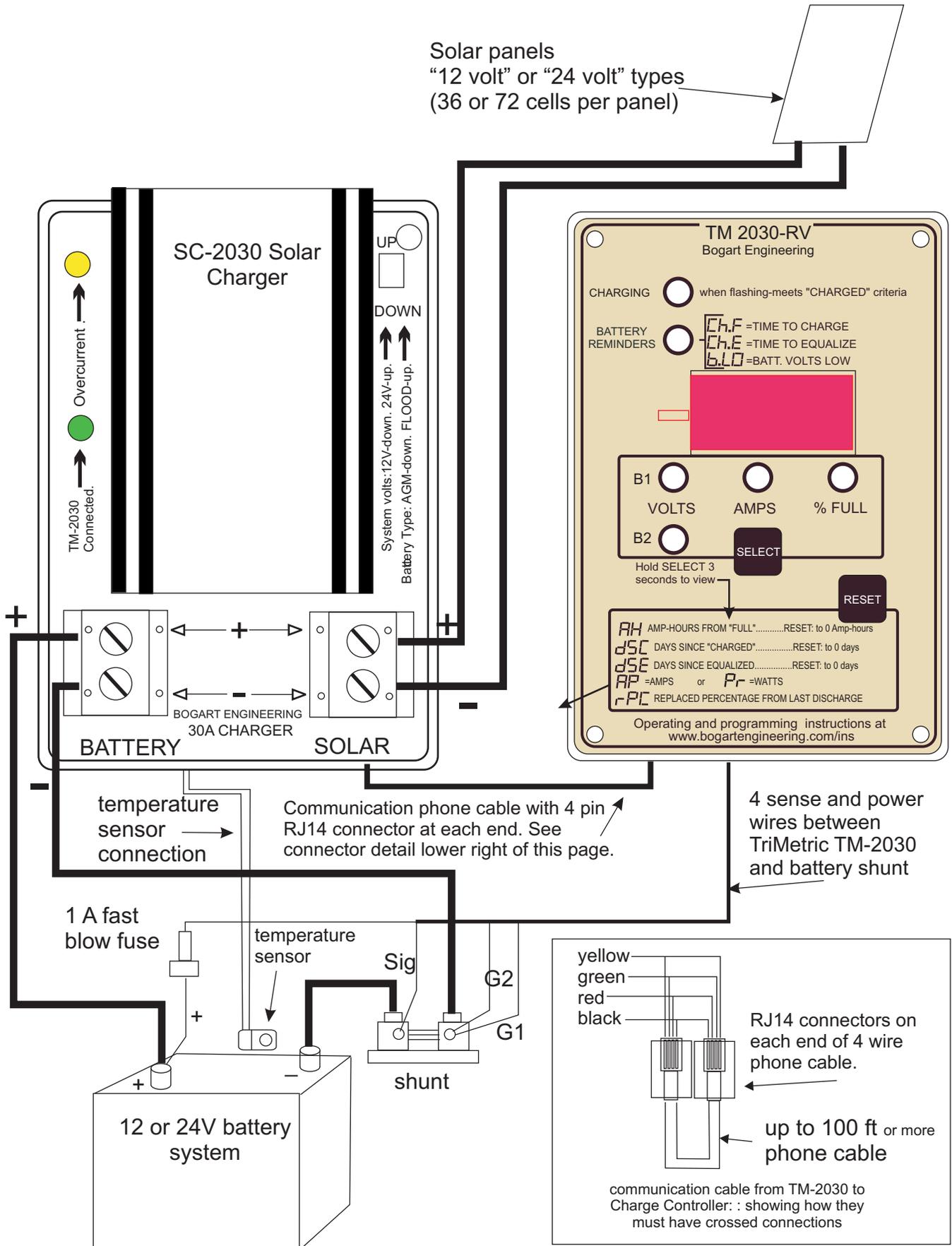
In addition, it has two advantages not usually offered in solar controllers to better preserve the capacity of your battery system.:

- 1. Amp hour counting:** Many battery companies recommend that when batteries are recharged they should be overcharged, so that 104 to 115 percent of the charge that was previously removed should be replaced before going into “float”. Most controllers don't measure this. When connected with the TriMetric, this controller measures the amp hours used, and allows you to specify the correct amount of amp hour overcharge when recharging.
- 2. Finish current charging:** After the batteries are mostly charged, this controller has an optional “fourth” stage that is beneficial for liquid electrolyte lead acid batteries, and this is also sometimes recommended for some AGM types. This stage allows the voltage to go unusually high while it regulates the current to a specified level, to safely get more charge into the batteries. This helps to maintain the capacity of the batteries, which often begins to degrade with solar charged batteries because they don't get sufficiently charged.

Where this controller is NOT recommended: For 12V systems for best efficiency this “PWM type” charger requires what are often called “12 volt” solar panels that have 36 cells per panel. Or, with 24V systems you should use “12 volt” or “24 volt” solar panels with 36, or 72 cells per panel. Many solar panels manufactured recently are mainly intended for “on grid” application that have 60, 80, or other number of cells—that have voltages that don't well match 12V or 24V battery systems. These panels are not suitable for high efficiency battery charging with a PWM controller such as this one. For good efficiency, they will require a more sophisticated controller with “MPPT” (Maximum power point tracking) capability.

The SC-2030 is a “PWM” (Pulse width modulated) type that is simpler and less costly than a “MPPT” (Maximum Power Point Tracking) type charger. It can be as efficient—provided it is used with panels properly matched to the batteries as described. With this charger you may be able to get more solar performance at the same cost by purchasing another solar panel instead of a more expensive MPPT solar charger.

The high performance mentioned above requires the TM-2030 Battery Monitor to be connected to it, although it will do minimal job of regulation if temporarily not connected.



Wiring for TriMetric TM2030 and charge controller--not showing circuit breakers to battery or solar panels
Figure 1

2. Technical Specifications:

Regulation type.....	PWM
Solar panel open-circuit voltage.....	55V maximum
Solar panel nominal voltage.....	12V - 24V, matched to the battery voltage
Nominal Battery voltage.....	12V - 24V
Required operational current.....	While sun shining: 25mA. Solar dark: 1mA max
Maximum Battery voltage.....	35V
Battery type.....	AGM, Gel, or flooded lead-acid
Solar-panel peak current.....	Up to 32A (higher currents reduce output)
MINIMUM in/out power efficiency at 30A: ...	97.5% (12V systems) 98.5% (24V systems)
MINIMUM in/out power efficiency at 15A: ...	99%
Battery capacity.....	10 to 10,000 amp hours
Terminal block wire gauge.....	Up to 6 AWG
Charging profiles.....	Three stages and optional fourth stage
Ambient temperature.....	0 °F to +140 °F (-18 °C to +60 °C)
Dimensions.....	in.: 3 width X 4 1/4 length X 2 3/4 depth; cm: 7.6 width X 10.8 length X 7 depth

3. General Solar Charging system suggestions and considerations

Balancing batteries with solar: If you intend to charge your batteries mainly or only by solar panels, it's recommended by many battery companies to properly balance the battery storage capacity with adequate solar. Too much battery for solar energy provided can result in undercharging that can reduce battery performance and life. Peak solar panel currents of from 1/10 to 1/4 of the battery "C/20" ampere hour value are often recommended. For example, solar panels that deliver up to 24 Amps could be optimally paired with a battery of 100 to 240 amp-hour capacity system. Otherwise you might want to provide an additional source such as generator or grid tied charger to insure that your batteries frequently get a full charge.

Solar as excellent adjunct to generator charging: A generator can put a lot of energy into the batteries in a relatively short time when they are not too close to being fully charged. As they become more fully charged, batteries gradually accept energy at a lower rate—So charging them to full requires more hours than is usually desirable to run a generator. Solar panels are well suited to do the last 20% of charging—which would otherwise require long generator times running inefficiently at a low charging rate. This will enhance your battery life and reduce generator wear.

You can use other chargers along with this one: If other chargers are also used with your system, they can be compatible with this system. It is important that the charging current from these shows on the TM-2030 amps display— (see section 4.2 below) then the system will properly account for the charging of these others. If you have another solar controller it should have a separate set of panels from which it is charging—you should not attempt to have the same set of panels go to two different controllers.

4. Installation of the SC-2030: Explained in five sections:

4.1 Planning the installation

4.2 Verifying that TM-2030 reads volts and amps correctly

4.3 Tools required

4.4 Installing SC-2030 and connecting solar panels, Batteries, Temperature sensor

4.5 Verifying operation and installing correct charging profiles

4.1. Planning the installation

Installation must be performed by a person knowledgeable of proper electrical wiring, best practices, safety and applicable electrical codes. If you do not meet these

qualifications, please ask someone qualified to perform, supervise, or inspect the installation.

4.1.1 Normal configuration—Paired with a TM-2030 For best performance, the SC-2030 should be paired with a TM-2030 (TriMetric) monitor. The charge controller and the monitor are connected together using a low-cost telephone wire, which can be over 100 ft. long.

4.1.2 Minimal configuration—Standalone. Without the TM-2030, the SC-2030 Solar Charge Controller can perform only basic charge regulation. There are two jumper selected parameters located on the SC-2030 that are then used to regulate the charging: The system voltage can be set to 12 or 24V. The battery type can be designated "AGM" or "liquid electrolyte." These determine the charging only when the TM-2030 is not connected—otherwise they are ignored. In this case, there is an "absorb" stage set to 14.6 or 29.2 volts (for 12 or 24V liquid electrolyte systems) or 14.3 or 28.6 (for AGM systems) which runs for two hours, followed by a float stage of 13.2 or 26.4 volts.

4.1.3 Temperature Compensation: The optional temperature sensor is recommended especially when using AGM or Gel batteries, unless the batteries are kept at a fairly constant ambient temperature.

4.1.4 Review wiring diagram on page 3.

4.1.5 Can more than one charge controller be used?: If the TM-2030 and SC-2030 are connected together, other charge controllers may be added for additional charging current, while still retaining most of the benefits gained by using this paired system. They must be connected so the TM-2030 "sees" this current when they are charging. Also, though all chargers go to the same battery set, the solar panels should be segregated into groups—with each group being controlled by only one charger.

4.1.5 Locating TM-2030 monitor and SC-2030 charger. The TM-2030 is usually placed somewhere with access in the living area to allow easy viewing and control of the SC-2030. Four small wires usually 22 or 24 gauge connect the TM-2030 to the batteries and required shunt. In addition a four wire telephone cable will need to be installed that sends control information from TM-2030 to SC-2030. These wires can be at least 100 feet long (30 meters). The SC-2030 will usually be located in the wire path from panels to batteries to minimize wire length from panels to batteries. Unless the SC-2030 will be used without the TM-2030, it is not required that the SC-2030 be located right near the batteries.

TABLE 1: Required minimum copper wire size for 3% loss.													
One way total length from solar panels to SC-2030 plus SC-2030 to batteries													
		Length for 12V systems: For 24V systems double all distances											
Maximum amps from panels→		5 Amps		10 Amps		15 Amps		20 Amps		25 Amps		30 Amps	
Wire gauge (AWG)	Diameter (mm)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)	(ft)	(m)
2*	6.544	230	70	115	35	76	23	57	17	46	14	38	11
4	5.189	144	44	72	22	48	14	36	11	28	8	24	7
6	4.115	91	27	45	13	30	9	22	6	18	5	15	4
8	3.264	57	17	28	8	19	5	14	4	11	3	9	2
10	2.588	36	10	18	5	12	3	9	2	7	2	**	
12	2.053	22	6	11	3	7	2	**		**		**	

*This wire gauge exceeds the terminal block’s maximum wire size and requires adapting.

** Not recommended

4.1.6 Determine wire size required from solar panels to charger and batteries from Table 1 above. Wire size from solar panels to SC-2030 and from SC-2030 to batteries must be much larger for

low voltage systems compared to 120V house wiring to minimize power loss. The required size depends on (1) total maximum amps to be delivered by the panels, (2) the system volts (12 or 24), and (3) the wire length. The recommended maximum lengths assume a 3% maximum power loss using copper wire in a 12V system. Doubling lengths will increase loss to 6%. For 24V systems double all lengths (for 3% loss). All wiring must meet applicable electrical code requirements with respect to maximum current versus gauge. With less than 3% power loss, this is normally not a problem.

4.1.7 Install TM-2030 monitor if not already installed according to "Installer's instructions for TM-2030"

4.2. Verifying that TM-2030 reads volts and amps correctly

Proper charging depends critically on accuracy of TM-2030 voltage and current (amps) readings.

Check volts: For accurate battery-voltage measurement, the TriMetric's voltage-measurement wire (called "B1" in TriMetric wiring diagram) must be connected directly, or close to the battery's positive terminal.

Check amps on the AMPS TriMetric display:

- Under zero-current conditions when all loads and charging sources are off, the TriMetric's ampere indicator must show 0.0A, or $\pm 0.1A$ at most when using the standard 500A/50mV shunt. When using the less common 100A/100mV shunt, the zero-current value should be between minus 0.02-0.04A—which represents the current drawn by the TriMetric.
- The discharge current should be measured reasonably. For instance, a 12V, 12W light bulb connected to a 12V battery should display approximately $-1A$. This assumes no charging is going on, since the amps display shows charge minus discharge. The formula for Amps = Watts ÷ System Volts (12V or 24V).
- Verify that ALL charging sources should be shown as positive amps on the TriMetric TM-2030 when charging. All loads on the batteries should show as negative values when they are operating. This is a check to make sure that the shunt is connected properly—as shown in figure 1 of the TM-2030 INSTALLATION INSTRUCTIONS.

4.3 Tools and hardware required

- Drill with bits of suitable sizes for entry of telephone cable and/or Temperature sensor into SC-2030 plastic enclosure
- Medium Phillips screwdriver for the terminal blocks
- Small Phillips screwdriver for the enclosure
- Wire cutters, wire strippers, and a lug crimper for the battery wire, the solar panel wire, etc.

Hardware Required

- SC-2030 charge controller
- TM-2030 (TriMetric) battery monitor with sensing and power wires (assuming the TM-2030 will be connected)
- Mounting hardware for the above, if required
- Wire of suitable size and length (as determined in section 4.1.6) to go from panels to SC-2030 and from SC-2030 to batteries
- Four-conductor telephone wire up to 100 ft. long—sufficient to go from SC-2030 to TM-2030. The wiring must be crossed (reversed) between the two connectors, as shown in the lower right-hand corner of Figure 1 on page 5.
- Temperature sensor (optional but recommended unless batteries will remain at same temperature)

4.4 Installing the SC-2030, connecting solar panels, batteries, and Temperature sensor

Plan to mount the SC-2030 in a well-ventilated and shaded area to prevent overheating, and protected from direct rainfall. The heat sink can get hot during charging; therefore the charge controller must be installed beyond the reach of animals and young children. The black heat sink fins should be vertical—not horizontal, which means the printing of "SOLAR" or "BATTERY" will be right side up or upside down (not sideways).

- 4.4.1 Run wires (size determined as described section 4.1.6) from solar panels to location for SC-2030, and from batteries to SC-2030 location with enough extra length to easily connect to large green terminal blocks. Carefully mark on the ends of the wire which are positive and which are negative—both to batteries and to solar panels.
- 4.4.2 If communication (phone) cable has RJ11 connectors attached at both ends, check that connectors are "crossed" as shown in figure 1. Run phone cable from TM-2030 to SC-2030 location with sufficient length. If you have a RJ11 crimp tool and correct RJ11 connector, to avoid drilling a larger hole you could pass wire through a small drilled hole through TM-2030 enclosure then use crimp tool to install connector (carefully observing polarity Fig 1). Don't yet connect the communication cable to the TM-2030 (unless connectors at each end are attached and you don't intend to put them on or change them later.)

- 4.4.3 Remove front panel and circuit board from SC-2030 enclosure by removing 4 screws and put it aside. Drill one or more holes in the SC-2030 enclosure to allow the communication cable and the temperature sensor wire (if used) to pass through in a location suitable to the positioning of the controller, wires and the rest of the system. The temperature sense connector requires a 5/16 diameter hole to pass through. For the communication cable, as described in 4.4.2 you could pass the wire through the hole and attach the connector similarly to 4.4.2 if you have the appropriate connector and crimping tool. Reminder: be sure the connectors are attached "crossed" as shown figure 1.
- 4.4.4 Mount the enclosure on vertical surface so the heat sink fins go up and down. Use two screws on flanges, or you may drill your own holes internally and use those.
- 4.4.5 Connect the temperature sensor connector (if used) and the communication cable to the two connectors on the back of the SC-2030 (inside the box). Place the circuit board back onto the enclosure board and secure with four screws.
- 4.4.6 Place the temperature sensor (if used) near the batteries. The hole in the sensor could be connected to a battery terminal—but this is not necessary for it to measure temperature.

For safety, turn off power from batteries and solar panels before doing next step

- 4.4.7 Connect the wires from batteries and the solar panel wires to the controller. **For the following steps, refer to wiring diagram, Figure 1 on page 3. For safety, turn all switches and circuit breakers off while making the connections. While voltages in a 12V or 24V solar system are generally considered safe from electrical shock, amperages can be very high and can create powerful arcs if accidentally shorted, or when connections are made or unmade.**
- Connect two solar panel wires to the controller. Be sure to observe correct polarity.
 - Connect the wire from battery's negative terminal to the controller.
 - Connect the shunt's most positive terminal (i.e. the terminal not connected to the battery's negative) to the controller.
- 4.4.8 Connect communication connector at TM-2030 end if not already connected.
- 4.4.9 Verify all wiring and polarities (plus and minus not reversed). Then close the switches or circuit breakers.

4.5 Verifying SC-2030 operation and programming charging parameters.

- 4.5.1 **If the SC-2030 is connected to a TM-2030:** You must do this when there is at least a little sun shining on the solar panels (more than 0.5 amp of current). Check the green light on the SC-2030 Solar Charge Controller. If the two units are communicating it should be on most of the time—but possibly occasionally blink off. If the green LED is off or mostly off, except for occasional blinks on, check the communication cable again, check that the TriMetric is powered and operating properly, and also verify that the phone cable contacts are crossed as shown in the lower right-hand corner of Figure 1. Also, there must be at least a small amount of solar current coming from the solar panels.

4.5.2 **If the SC-2030 is operating without the TriMetric:**

If at least a little solar energy is coming in, the green LED will be usually off—but will occasionally blink on to indicate the following:

- Flashing once, the charger is in the first charging state — first stage or "bulk" charging.
- Flashing twice, the set voltage has been reached, but the charger has not switched to floating mode yet.
- Flashing three times indicates floating mode.
- The amber LED indicates a normal charging state when it is ON. When flashing every half second, it is in over current protection and charger is limiting current to a safe value for charging.

4.5.3 **Last step: Programming the SC-2030 for your battery system when TM-2030 is connected.**

Easy way: Most people will choose the easy way to enter this data. This method automatically enters 8 charging parameters to control the charging, and also provides proper monitoring in most cases. This requires the following two steps, which are outlined in more detail below the table:

STEP 1. Find the "charging profile number" from the table below depending on the type of batteries and system voltage you have, 12 or 24. . Enter this "profile number" number into program P22 in the TM-2030. Our web site will (eventually!) have an expanded table if your batteries are not listed here. If yours is not on the chart, and you have liquid electrolyte batteries (with caps on top for watering) you could start with "Generic" profile 1 or 2 (depending on your system voltage.) If you have AGM batteries, start with profile 7 or 8. (See "Concorde" on chart) Detailed instructions for entering this is just below the table.

Table 2: Find P22 profile number for your battery type and system voltage				
Manufacturer	Models	System Voltage	System capacity	Enter profile number in P22
"Generic" wet cell batteries		12	220	1
		24	220	2
Concorde	Lifeline AGM Sun-Xtender AGM	12	220	9
		24	220	10
Crown	All wet cell	12	220	5
		24	220	6
Deka	Monobloc example 8C11	12	220	11
		24	220	12
GNB /Excide	Absolyte AGM	12	220	15
		24	220	16
Interstate	All wet cell Example GC2 types	12	220	13
		24	220	14
Trojan	All liquid 6V types: example T-105	12	220	3
		24	220	4
US Battery	All liquid 6V types: example T-105	12	220	7
		24	220	8

STEP 2. Determine the system capacity, in amp hours. To determine the system capacity you need to know the capacity of each battery in amp hours—then multiply by the number of series strings in your system. The 20 hour value specified for capacity would be appropriate. The default value automatically entered by step 1 is for 220 amp hours. If your system capacity is not between 200-240 amp hours, change that value by entering the correct value into program P3 in the TM-2030. Always do this *after* step 1 or this data will get overwritten.

Harder way is for experts that know exactly how they want to charge. Entering a profile number automatically overwrites all values. After a profile is installed any of the eight parameters may be individually modified. See the profile graphs on pages 14-15 to understand the function of each of these eight parameters.

Detailed description for entering "charge profile" step 1 above: After getting profile number from table do this:

- a. Press "SELECT" and hold it down until "P1" appears in display. Release.
- b. Press SELECT repeatedly to get to "P7" ("operational level").
- c. Press SELECT and RESET together, momentarily, to get 3 lights to flash.
- d. Use RESET to change until "L3" shows.
- e. Press SELECT repeatedly to get to program "P22".
- f. Press SELECT and RESET together, momentarily to get 3 lights to flash.
- g. Use RESET to enter profile number from table above into display.
- h. Press SELECT once, to get out of program mode—but remaining in P22 with profile number showing.
- i. Hold RESET down—watch as number go 5,4,3,2,1, 0. Nothing gets entered until you reach "0".

Then do step 2 above. Enter P3 program mode and enter the amp hour capacity of your system. This completes the entry of necessary data for charging and monitoring.

5. Useful Information for everyday users

5.1 The best place to find information about the SC-2030 and TM-2030 system

is the "**Quick Reference Guide to TM-2030 and SC-2030**" included with the SC-2030. It has brief descriptions of all functions and also has references to this **SC-2030 User Manual** and the **TM-2030 User's** and **TM-2030 Installation manuals** for greater detail. These manuals will be occasionally updated and posted on our web site as we receive questions from customers that we think haven't been adequately covered in those documents. We always welcome comments for improvements.

5.2 A useful display item for seeing if your batteries are being properly charged

If you partially drain your batteries on a daily basis, we suggest understanding the new display function on the TM-2030 called "**Replaced Percentage from Last Discharge**". This is listed as a secondary display shown near the bottom of the TM-2030 front panel, identified as "**rPC**". This will be of lesser importance if your batteries are charged most of the time, and only occasionally discharged. Many battery companies recommend that when recharging your batteries that you completely replace the amount of charge most recently discharged by your batteries, plus add an additional percentage. For "wet cell" lead acid batteries it is often recommended that 106-115% be replaced. For AGM type (sealed) batteries 104-108% is often suggested. At the end of a day of solar charging, the "**rPC**" ("replaced percentage") display will tell you how much you have replaced. This level of charge may not happen every day—however if less than the ideal is achieved for a day or two, it would be good to go even higher on subsequent days if possible. (Soon after you start discharging your batteries again this will read 0%—to anticipate the next day's recharge.)

5.3 A useful display item to see if you have extra solar power in the afternoon

When charging with solar, often in the afternoon the batteries will begin to accept less solar energy—and as a result this energy may be wasted although it could be used for some extra loads, such as a dishwasher or vacuum. With the TM-2030 connected, there is a "secondary display" item that is not shown on the front panel called "**UPr**" (Unused power) which displays this. If most of the solar power is now surplus (because the batteries are getting well charged), "**YES**" will show on the display. If a lesser amount, the display will indicate the approximate number of watts that are being wasted. Refer to the **Quick Reference Guide**, section 2.1 Also listed there is information about observing solar amps ("**SOL**") and battery temperature ("°C").

5.4 For information about the meaning of the LED lights on the SC-2030 charger

Refer to section 4 of the "**Quick Reference Guide**" referred to above. Section 6 in this **SC-2030 User's Manual** describes in detail the meaning of the various charging modes referred to there.

5.5 There are two different standards you can select to define a "full charge."

The highest (more stringent) standard is selected by using TM-2030 program P7 to choose **L4** instead of **L1**, **L2**, or **L3** which use a lower standard, which requires only that the battery voltage exceed the value in P1, and that the charging amps be less than P2. The **L4** level requires that in addition either the required "absorb time" or "percent overcharge" be achieved, such that the "float" state has been reached. This establishes a better, but more difficult, level to reach. Refer to the **TM-2030 User's Instructions**, section 6.2 for details.

5.6 Using History Data to diagnose system problems

The TM-2030 (TriMetric) makes history data available when the user level P7 has been set to "L2," "L3," or "L4" in programming code "P7." History is recorded daily for the past five days or the last five charge cycles, depending on the parameter. This data can be used to diagnose some system problems. Please refer to the **TM-2030 User's Instructions**, section 6.3 for instructions on interpreting this data.

6. Technical information for interested and advanced users

6.1 Charging lead acid batteries—basic information

Charging a battery is very different than loading a tank with gasoline. First, when filling a tank it is very clear when the tank is full, and trying to overfill simply results in gasoline being spilled without any damage to the tank. Second, using up the gasoline until the tank is completely empty may be inconvenient, but again that does not damage the tank, even if the tank remains empty for a long time. Thirdly, filling the tank slowly or fast, whether the weather is hot or cold, or whether one is starting from a nearly-empty or nearly-full tank, does not affect the eventual amount of gasoline in the tank. Finally, a fuel tank's capacity does not vary over time.

None of these analogies apply to batteries. Lead-acid batteries can accept higher charge currents when they are nearly empty, but must be charged more slowly when they are nearly full because then they will not readily accept the charge. Batteries need to be frequently fully charged. If a battery is allowed to operate consistently at a low charge level, its capacity to hold charge decreases over time. This means that a battery needs to be fully charged every now and then for the proper maintenance of its capacity. In solar applications, this sometimes cannot be achieved in the course of a single day, depending on sunshine and energy usage.

Sometimes a generator is used instead of sunlight to charge the battery at a high current for one or two hours each day. This can easily shorten the life of lead-acid batteries, which cannot get fully charged in two hours even with a very powerful generator. If only charged with very high currents over a short time, a battery's charge capacity will decline over time. A "hybrid" generator-solar system would be preferable with a strategy of using the generator to provide a fast charge early in the morning, when the battery is at its lowest charge level, and stop when the battery can no longer accept high charging currents. By the time the sun is high enough, the solar panel can take over the charging at a lower current for the following six to nine hours. Alternatively, a surplus of solar panels can accomplish something similar, but that means the peak solar power in the afternoon, when batteries are accepting less current, may not be used. To overcome this, plan to use heavier loads, such as laundry, dish washing or well pumping, during the mid afternoon, when batteries accept less solar energy.

6.2 Specifically how solar chargers, including the SC-2030 charge batteries

The following charging description applies when the SC-2030 Solar charger is connected with the TM-2030. If for some reason the TM-2030 is not connected, it uses a basic charging procedure, to be described in section 6.4.

This discussion refers to 12V systems—for 24V systems multiply voltages by two.

To charge batteries, a charger supplies electrical energy to the battery with a certain "voltage." "Volts" is a measure of how hard the charger is attempting to push the energy (electrons) into the battery. The battery always tends to resist the tendency to push the electrons in—the voltage of the charger must be high enough to overcome the resisting force of the battery. This is a little like pushing water into a pipe which is under pressure—enough force must be provided to push it in or it will not go. The "current" or "amperes" is a measure of how much (charge) energy is actually flowing in. The actual flow ("amps" or amperes) depends on two factors: how hard the charger is pushing (voltage) and how much the battery is resisting.

When batteries are at a lower state of charge they do not push back very hard, and the battery will easily absorb all the charge (amperes) that the charger can supply. This is called the "bulk" stage of charging, and the "voltage" from the charger during charging will be below 14 volts or so. This is when most of the charge can go into the battery, and is the simplest part of the charging process; usually the batteries will be able to absorb all the energy the charger is capable of delivering.

When the batteries reach about 85% full, the job of the charger gets more difficult. The batteries begin to resist more, and absorb amps at a lower rate, meaning that it takes a longer time to do the rest of the charging. One might say, "why bother, then to go beyond 85% full? Wouldn't this make the job easy on the charger? Just always operate the batteries from 55%-85% charged." Well, yes it would, but the reason this is not a satisfactory strategy for a lead acid batteries is that if you don't fully charge them regularly, it makes it harder in the future to charge them as much. It is remarkable how often even authoritative sources on lead acid battery charging repeat the phrase that "lead acid batteries do not have memory." Lead acid batteries DO have a memory—if you do not fully charge them, they will remember that, and if this is repeated often their capacity will gradually "walk down" as is correctly described in charging information from the Concorde battery company.

This presents a challenge to solar charging—because the solar day starts to end as the batteries become more resistant. This can result in a battery that is not fully charged when the day ends. It is frequently observed that batteries being charged only by solar tend to lose capacity to hold energy—described as batteries becoming "sulfated". This conveys the fact that the lead sulfate, which is the byproduct of discharging gets more difficult to convert back to fully charged lead and sulfuric acid if it sits around too long before recharging.

To continue the charging story, once the batteries become more resistant to charging—when the charger rises to 14.4 volts, (at 77 degrees F or 25 degrees C) liquid electrolyte batteries will begin to "gas" which means that although part of the energy is still doing some slower charging, part of the charger energy is breaking down the electrolyte in the battery into oxygen and hydrogen gases—and in addition a higher amount of the energy begins to go into heating the battery instead of the desirable conversion of the chemical charging. Although the gassing does waste some energy, this turns out to be desirable in liquid electrolyte batteries because the gas bubbles stir up the electrolyte which otherwise can stratify—because without the stirring the heavier acid can sink to the bottom while weaker acid goes to the top causing unequal

charging at the top and bottom. In AGM batteries, the design is different, so gassing typically doesn't occur, which makes them a little more efficient.

Good solar chargers will then go into what is often called "absorb" stage—where the charger holds the voltage just above the gassing point (voltage ideally temperature compensated). The batteries then absorb gradually less and less energy as they further charge. Most manufactured solar chargers maintain the "absorb" voltage for a set amount of time—perhaps one to four hours before they go into the "float" voltage of about 13.2 volts. Often the better chargers allow you to set the exact absorption voltage, the holding time, and the exact float voltage. The float voltage is a maintenance voltage which is intended to be the ideal voltage to keep a battery at minimum wear for the longest time once it's fully charged.

Although just maintaining the "absorb" voltage for a fixed time is not a bad way to decide when to go into "float", many battery companies suggest that it is better to monitor the amount of current (amperes) going into the battery during this time and then go into float based on this. There are three variations on this method:

- (1) Charge above the gassing voltage until the amperes drop to a sufficiently low value, say an "ampere" value that is 1% or 0.5% of the amp hour "capacity" of the batteries.
- (2) Charge until the value of amps into the batteries stops decreasing for a specified period of time—and stays at this constant value for perhaps a couple of hours.
- (3) Charge until the charger has replaced a specified percentage of charge amp hours than was last removed from the batteries during its last discharge cycle.

These options are unusual with most solar chargers, but the first or third is possible with the SC-2030 solar charger when used with the TM-2030 monitor. The TM-2030 measures the previous amount of discharge (typically the night before), then when recharging requires returning 105-115% (or even more) of that amount, adjustable by the user. The problem for many chargers is that they do not measure or know the exact value of amperes or amp hours going into the batteries. They may measure the amps from the charger going into the battery loads together, but they don't know what percentage of this is going into the battery compared to the loads, so these methods of observing battery amps are not available.

By returning a constant additional percentage, excess charge that is returned depends on the amount that was previously removed. This has the effect that the "absorb" time is not always the same, but is adjusted to the previous day's usage to avoid overcharge or undercharge—however, as said previously, the more common problem with solar charging is under charging, not over charging.

An additional method the SC-2030 uses to get in sufficient charge is that it has an (optional) finish charge stage to try to increase the intake of current into the battery by boosting the voltage when the current has declined to a safe enough value. This is explicitly recommended by some battery companies for liquid electrolyte batteries (not sealed AGM or gel types). If the SC-2030 is programmed to do this, after the charging current decreases to a safe value while in "absorption" state the SC-2030 then increases voltage (while regulating current) to attempt to put more charge at the end when the battery is becoming extra resistant so as to attain the overcharge amount that was specified by the overcharge amount. The overcharge percentage, maximum voltage, and maximum permitted current are all values that can be programmed into the TM-2030.

The effect of temperature on charging: The ideal temperature for a lead acid battery is often considered to be about 25 degrees C (77 degrees F). When batteries are cold, the charging process is slower, so they take longer to charge. The gassing voltage of the battery increases with lower temperature—and therefore the recommended "absorption" voltage should rise as temperature goes below the usual reference temperature of 25 degrees C (77 degrees F). If the battery temperature varies much, the charger should have the capability to adjust its voltage to temperature, especially for sealed AGM or gel types.

6.3 Description and graph of exact SC-2030 charging profiles

Standalone operation-without the TM-2030: With the TM-2030 not connected, there are only two charging selections available (by two jumpers you set on the SC-2030 circuit board.) They allow choice for "AGM or liquid electrolyte" and "12 or 24V" system. These are intended to be for "backup" charging if for any reason the TM-2030 is not connected. When the TM-2030 is connected, these values are ignored.

The chart below shows the voltages used depending on how the jumpers have been set. It begins charging at maximum solar current until it reaches the limiting "absorb" voltage shown. After that it charges for an absorb time of two hours. Then it regulates at the float voltage shown.

Table 3: Shows “absorb volts” and “float volts” for jumper settings –TM-2030 not connected

SC-2030 Battery type jumper setting	System Voltage jumper setting	Absorb voltage (temperature compensated to 25° C if sensor is connected)	Float voltage
Liquid electrolyte	12V	14.7V	13.2V
Gel or AGM	12V	14.2V	13.2V
Liquid electrolyte	24V	29V	26.4V
Gel or AGM	24V	28.4V	26.4V

6.4 Charging profiles showing all programmable values for SC-2030 when TM-2030 is connected

Two profiles are shown: the first on page 14, figure 2 is more typical of most good solar chargers. However the SC-2030 has an additional unusual option of setting a "percentage of overcharge" value from 100 to 120%.

The second profile (page 15, figure 3) shows the addition of a higher voltage "finishing absorb," current limited charging to encourage the batteries to get safely more fully charged as the batteries become more resistant to charging, specifically intended for lead acid liquid electrolyte (wet cell) types.

The profiles show the program values that you use with the TM-2030 to adjust the charging; these are identified by the "P1, P2, etc values that identify the TM-2030 program numbers.

Important note about settings for P2, P20, and P21. These are all percent settings that refer to the percentage of the value programmed into P3. For example, for P2 the "amps" set point equals the value in P2 (in percent) times the P3 value. Similarly, P20 and P21 are also referenced as a percent of the P3 setting.

The P22 "battery install profile" setting automatically writes all of the 8 values shown below as shown in Table 4 below. If it is used, P22 should be entered first. After that any other values may be changed individually if desired. If you find a profile set that has most of the values you want, first enter that profile, then change the ones that you want to be different. Presently there are 16 profiles available. It is likely that more will be added in the future in later revisions of the TM-2030.

- P1: Absorb volts:** When charging begins, the maximum solar current is sent to the batteries until this voltage is reached. Then the charger limits voltage to this value. (10.0-65.0)
- P2: Charged setpoint.** Amps value, expressed as a percentage of P3: from 0.0-10.0%. When the amps drops to this value with voltage equal or just greater than P1, and the TM-2030 is in Levels 1-3, the batteries are signaled as "charged." (In Level 4, the standard is much higher: batteries must go into float mode before they are signaled as “charged”.)
- P3: Total battery** system capacity (in amp hours). (10-10,000 amp hours)
- P14: Limit timer** for charging, before going into "Float" described in the profile graphs. (0.0-25.0 hours)
- P15: Finish charge (high) voltage limit**—allowed only after the amps drop below the P21 current limit. (10.0-65.0)
- P16: Float** voltage (10.0-65.0)
- P20: Percent of** overcharge before going into "float" (0-20%).
- P21: Finish charge Amps** limit (expressed as a percentage of P3) below which amps must be to rise to P15 voltage.
- P22: The "charge profile"** entry program: simultaneously programs all of above eight values based on system voltage and the battery type selection.

Table 4: Showing programmed values for each P22 charging profile number

Profile number and battery type (with total system volts not battery volts)	Profile number P22	P1 Absorb V	P2 Amps setpt	P3 capacity Ahr	P14 Time hr	P15 high V	P16 float V	P20 Over charge	P21 Finish amps
"Generic" wet cell (12V)	1	14.4V	2%	220AH	4h	15.7	13.2	10%	3%
"Generic" wet cell (24V)	2	28.8	2%	220AH	4h	31.4	13.2	10%	3%
Trojan wet cell (12V)	3	14.4V	2%	220AH	4h	16.2V	13.4	10%	3%
Trojan wet cell(24V)	4	28.8V	2%	220AH	4h	32.4V	26.8	10%	3%
Crown wet cell(12V)	5	14.5V	2%	220AH	4h	15.9	13.5	10%	3.5%
Crown wet cell(24V)	6	29.0V	2%	220AH	4h	31.8	27.0	10%	3.5%
US Battery(12V)	7	14.8V	2%	220AH	4h	15.5	13.0	15%	3.5%
US Battery(24V)	8	29.6V	2%	220AH	4h	31.0	26.0	15%	3.5%
Concorde AGM(12V)	9	14.3 V	0.5%	220AH	4h	14.3	13.3	7%	2%
Concorde AGM(24V)	10	28.6 V	0.5%	220AH	4h	28.6	26.6	7%	2%
Deka monobloc(12V)	11	14.2 V	2%	220AH	8h	14.2	13.5	20%	5%
Deka monobloc (24V)	12	28.4V	2%	220AH	8h	28.4	27.0	20%	5%
Interstate(12V) wet cell	13	14.5 V	2%	220AH	4h	15.3	13.4	15%	4%
Interstate(24V) wet cell	14	29.0V	2%	220AH	4h	30.6	26.8	15%	4%
GNB-Absolyte(12V) VRLA	15	14.3 V	1%	220AH	8h	14.3	13.5	7%	2%
GNB-Absolyte(24V) VRLA	16	28.6 V	1%	220AH	8h	28.6	27.0	7%	2%

Warranty and customer service

Limited warranty

The SC-2030 Solar Charge Controller is warranted for four years against any manufacturing defect. Any controller not meeting the specification or rated performance shall be replaced or repaired, at Bogart Engineering's discretion, provided it has not been subjected to abuse or misapplication. In many cases, if we know or believe a problem is due to a manufacturing defect, we will extend this to 5 years or more. For warranty service, please contact us or your dealer before shipping your SC-2030.

How to obtain customer service

Please contact your dealer, or contact Bogart Engineering, Inc. at 19020 Two Bar Road, Boulder Creek, CA 95006, (831) 338-0616. Contact us or the dealer before returning any item.

www.bogartengineering.com

Three stage charge control: Figure 2. This is closer to how most good conventional controllers charge lead acid batteries--except that this controller also has the capability (if desired) to return a specified **number of amp hours** to the batteries (compared to the most recent discharge) before going into "float". Also, it is best suited for AGM or Gel type lead acid batteries. Liquid electrolyte batteries can usually benefit from four state solar charging (Figure3).

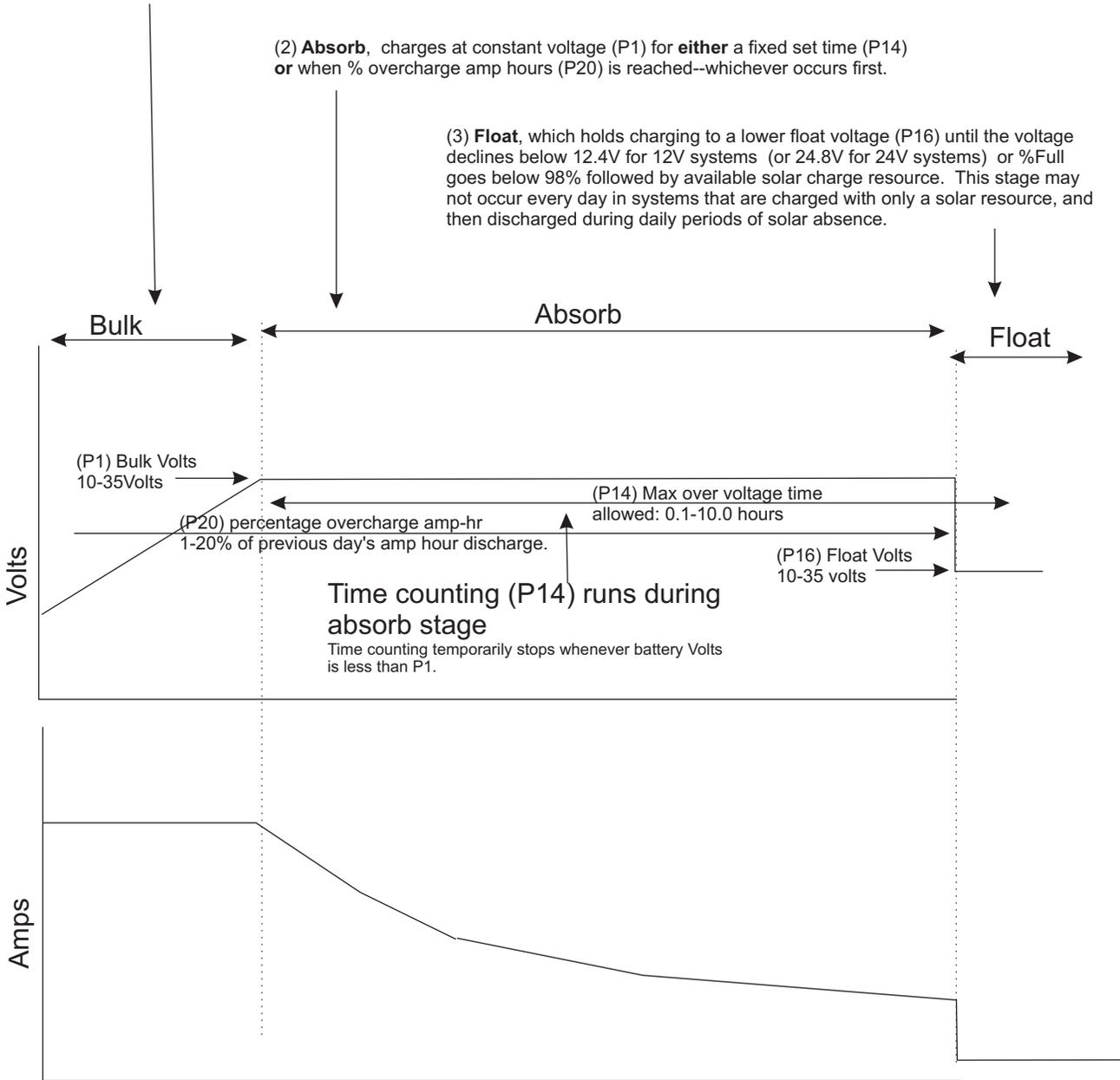
To select three stage charge control, set program P21 (finish amp value in %) to "OFF." Then for charging, set these program values: P1, Bulk volts. P14, max absorb time. P16, float volts and optionally P20 (% overcharge amp hours.)

To properly monitor "percent full", also set these program values: P2: charged setpoint % amps (amps =P2% times P3), P3: battery system capacity.

(1) **Bulk**, charges battery at maximum rate until the batteries reach "absorb voltage" (P1).

(2) **Absorb**, charges at constant voltage (P1) for either a fixed set time (P14) or when % overcharge amp hours (P20) is reached--whichever occurs first.

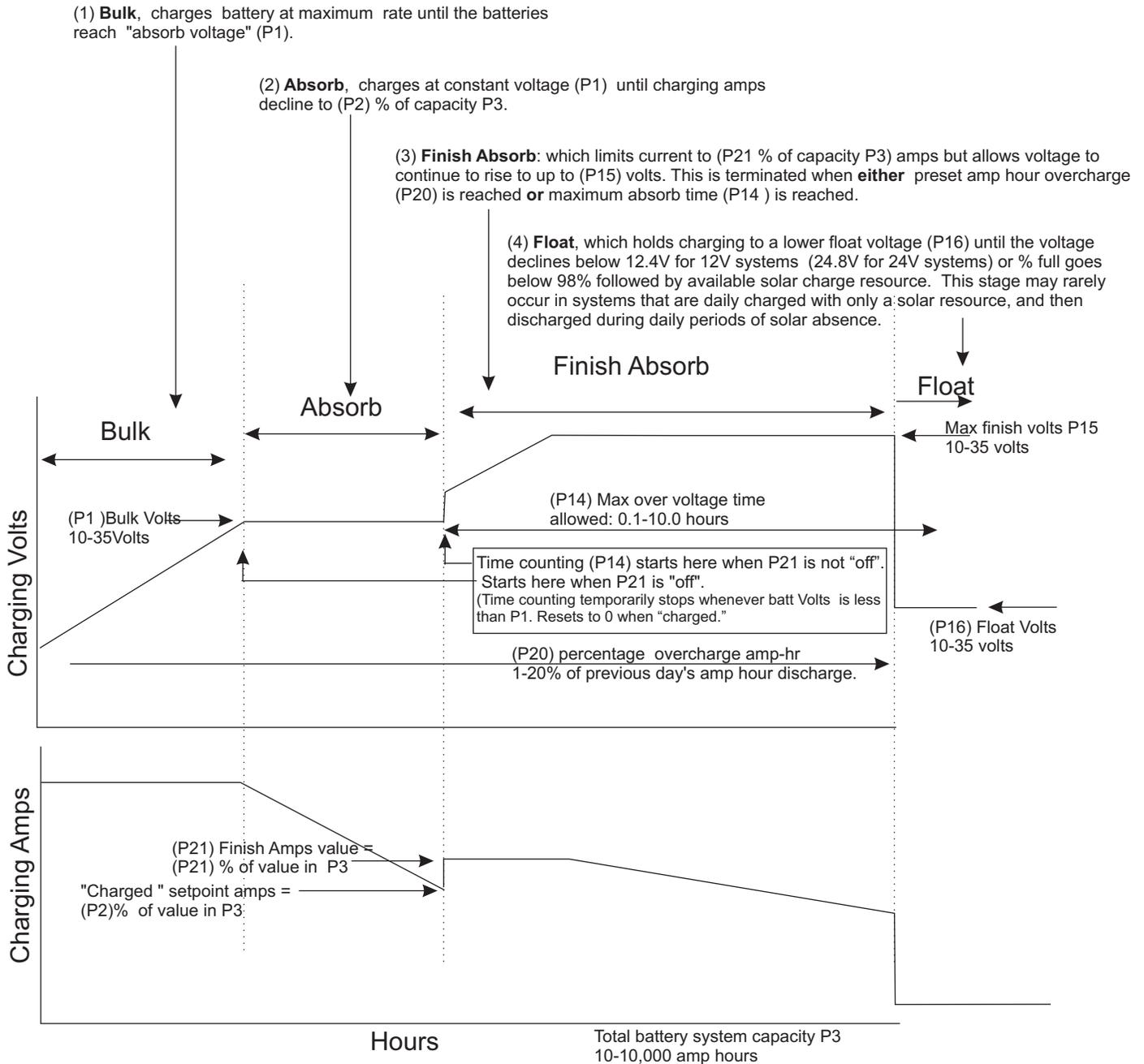
(3) **Float**, which holds charging to a lower float voltage (P16) until the voltage declines below 12.4V for 12V systems (or 24.8V for 24V systems) or %Full goes below 98% followed by available solar charge resource. This stage may not occur every day in systems that are charged with only a solar resource, and then discharged during daily periods of solar absence.



3 state charging profile (AGM or Gel batteries) Figure 2
 Total battery system capacity P3 10-10,000 amp hours

Four stage charge control: Figure 3. This method has four stages, having an additional final higher voltage "finish absorb" stage, also with optional capability to deliver a measured additional amp hour overcharge (compared with the most recent discharge amount). It is suited to do a more thorough charging of liquid electrolyte lead acid batteries. This can better maintain their capacity.

To select four stage charge control, program P21 must NOT be "OFF." Then for charging, set these program values:
 P1: Bulk volts. P2: Absorb end amps value. P3: Battery system capacity, amp-hours. P14: Max absorb time. P15: Max finish charge volts, P16: Float volts. P21: Max finish charge amps and optionally P20: Amp hours overcharge.
 When these values are properly set, the TriMetric will also correctly measure "% Full"



4 state charging profile
 for liquid electrolyte batteries
 Figure 3