



ELECTRONIC CONTROL CONCEPTS

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INSTRUCTION MANUAL

MODEL 510

Model 510-24, 510-36, 510-48

SOLAR CONTROLLER

Electronic Control Concepts

Model 510 Solar Controller

Model 510 Version -15

Description

The ECC Model 510 Solar Controller is much more than an intelligent battery charge controller. The Model 510 is used for a wide variety of applications involving smart control of DC loads.

Safety Information

Please read all the instructions and cautions in the manual before starting the installation.

Before making connections to the Model 510 Solar Controller, make sure that both the battery and photovoltaic panel wires are disconnected. They both supply active power. Make the connections to the Model 510, and then connect the battery and PV wires.

Be very careful when working with batteries, particularly lead-acid batteries. Wear eye protection and have fresh water available in case there is contact with the battery acid. If battery acid contacts the skin, wash with soap and water. If the acid contacts the eye, flood with fresh water and get immediate medical attention.

Always remove rings and jewelry when working with batteries.

Use insulated tools and avoid placing metal objects in the work area.

When working with battery wires, make sure that battery leads never contact each other. The battery is capable of supplying a lot of current, and a short circuit could cause sparking or melting of wire insulation.

Explosive battery gasses can be present during charging. Make sure there is enough ventilation to release the gasses.

Be sure the battery electrolyte level is correct before starting charging. Do not attempt to charge a frozen battery.

There are no user serviceable parts in the ECC Model 510 Solar Controller. Contact ECC if service is required.

Do not allow water to enter the controller.

Make sure that the screws that hold the power and load wires are tightened to avoid intermittent connections.

Modes of Operation

There are five major modes of operation. The Modes of Operation only refer to the operation of the DC Load. In each mode the battery(s) will be charged appropriately.

Duty Cycle On-Off Control (On On On)

In this mode of operation, a motor or other DC load is turned on and off based on the state of a battery and the amount of sunlight available. The prime application is for a pond aerator or pond fountain where it is important that the motor run frequently during the day. The Model 510 will determine the on-time and off-time that the DC motor can run as determined by the battery, charge current and motor current. Note that the motor or DC load will be switched off for a short interval to test the battery with no load.

Deep Cycle Control with test (On Off On)

The Battery will be charged to the Bulk Voltage, and then the motor or DC load will be turned on until the battery reaches the Low Battery Cutoff point. Note that the motor or DC load will be switched off for a short interval to test the battery with no load.

Deep Cycle Control without test (Off On On)

The Battery will be charged to the Bulk Voltage, and then the motor or DC load will be turned on until the battery reaches the approximate Low Battery Cutoff point. Note that the motor or DC load will not be switched off for testing the battery voltage. The battery will be tested under load. This method of testing is not as accurate as testing the battery under no load conditions. This mode should be used for applications where any disruption of the switched load would be a problem such as operation of a marine radio or any appliance that would be reset or not work correctly.

Night (Off Off On)

When the Model 510 is set for "night" operation, the battery will be charged all day by the sun, and the DC load will be turned on at dusk. This is used for indoor or outdoor lighting, garden lighting, DC Christmas lights and so on. The lights will remain on until the battery voltage drops to a certain level.

Always On (On On Off)

When the Model 510 is set for "Always On" operation, the load will be switched on, and will be shut off only when the battery drops below the low voltage cutoff value. The

load will be switched on again when the battery recovers either from charging or self-recovery. Use this mode for applications where there is a light load or the load is switched on and off by external switches such as indoor lighting.

Charge Controller Features

- Intelligent control of battery charge
- Blocks reverse current to prevent battery discharge
- Prevents battery overdischarge
- Protects battery from electrical overload
- Display of battery status
- Display charging current

The Model 510 is rated for 10 Amps. It is important to match the solar panel's maximum current to the battery's amp-hour rating (C). There is more information available in Appendix A, which contains a detailed discussion of batteries. There are several variables that need to be considered including:

- Maximum current available from the solar panel
- DC load current
- Battery type
- Battery capacity
- Battery charge rate
- Hours of sunlight available
- Temperature variation

In general, it is advisable to use a deep cycle battery, and to "oversize" the battery. When a battery is charged at lower rates, battery capacity is increased and battery life will be longer. Refer to Appendix A for more information.

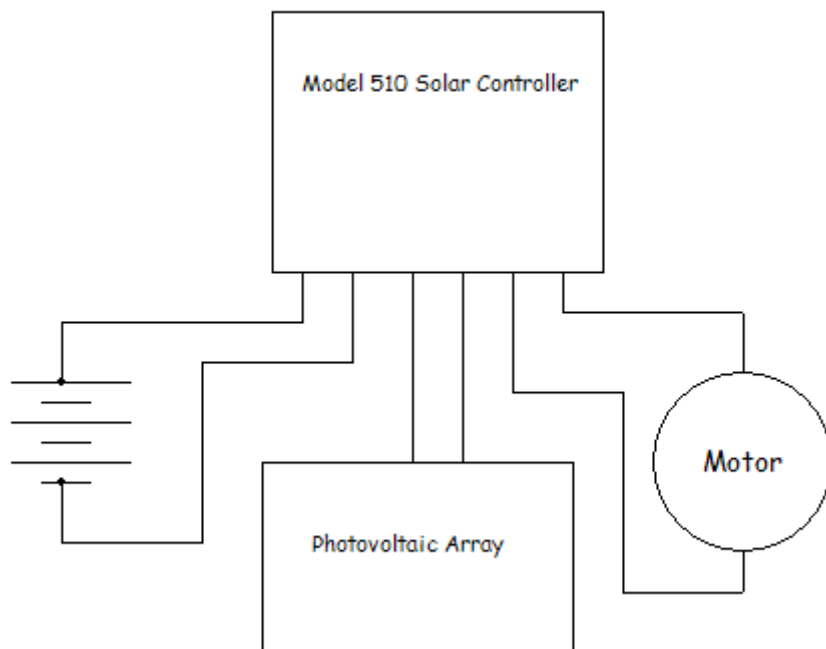
There are factory configurable variations of the Model 510 for different capacity systems.

<u>Model</u>	<u>Nominal Battery / PV Voltage</u>	<u>Batteries</u>
510	12 Volts (standard configuration)	1
510-24	24 Volts	2
510-36	36 Volts	3
510-48	48 Volts	4

For 24, 36 or 48 Volt systems, the batteries should be connected in series. The solar panels must also be wired in series. However, there are solar panels available with higher voltage outputs that can be used for 24 Volt systems.

Interconnection

The diagram below shows an overview of the typical system components.



The components are connected as follows:

<u>Terminal</u>	<u>Function</u>
1	Battery +
2	Battery -
3	PV +
4	PV -
5	Motor +
6	Motor -

Interconnection wires should be 16 AWG minimum, and lengths should be as short as possible. The Terminals on the Model 510 Terminal Strip can accommodate wires as large as 12 AWG. Insert the wire into the hole in front of the terminal and secure firmly with the clamping screw on top of the terminal strip. Tinning stranded wires using a small amount of solder will provide more reliable connections.

Installation Steps

1. Open top cover by loosening Philips screw.
2. Mount the unit using the attached flanges.
 - The unit can be mounted outdoors, but for long term reliability take precautions to either cover the unit or enclose with other system components.

3. Adjust the 4 switches for the appropriate mode using the DIP switch on the lower right side of the printed circuit board. Each switch must be in the correct position.
 - Refer to the description of Modes or the Switch Setting Chart and Figure 1.
4. Wire the unit making the connections as shown on the front panel or the chart above
 - Connect the battery power wires to the Controller.
 - Connect the solar array wires.
 - Connect the load wires.
5. Test
 - Observe the 4 LED indicators for expected function.
6. Seal the wires as they enter the Cable Gland
 - Use a silicon-sealing compound such as RTV or a Plumbers Putty such as *Sta Put Ultra*.
7. Close the cover and tighten using the Phillips screw. The unit must be switched on when the cover is closed.

Switch Configuration

DIP Switch Setting

Switch 1 (top)	Mode	See Mode Configuration
Switch 2	Mode	Chart
Switch 3	Mode	Below
Switch 4 (bottom)	Battery Type	On = wet, Off = Gel

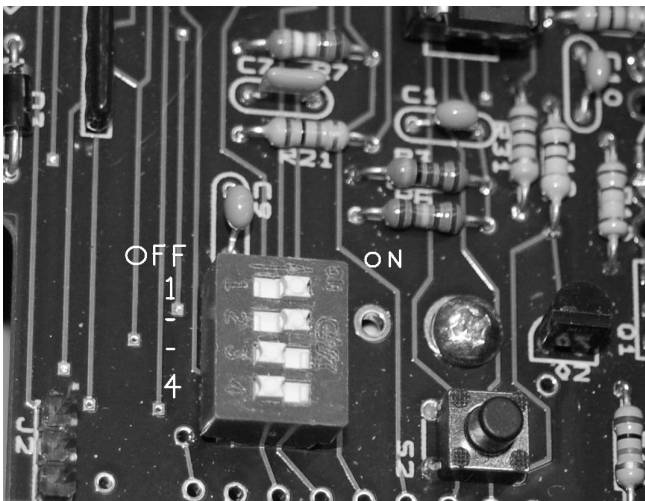


Figure 1
DIP Switch Location

Mode Configuration

Mode	Switch 1 (top)	Switch 2 (2nd)	Switch 3 (3rd)
Duty Cycle On-Off	On	On	On
Deep Cycle with Test	On	Off	On
Deep Cycle no Test	Off	On	On
Night (Lighting Mode)	Off	Off	On
Always On	On	On	Off
Reserved (reverts to Deep Cycle with Test)	On	Off	Off
Reserved (reverts to Deep Cycle no Test)	Off	On	Off
Reserved (reverts to Night mode)	Off	Off	Off

Specifications

- Batteries - wet or sealed lead acid, lead calcium, lead antimony battery, 12 Volt nominal or multiples (For example bank of 4 batteries for 48 Volt system)
 - Refer to Appendix A for information about batteries that are compatible with the Model 510
- Reverse Polarity Protection - protects against reverse polarity connection of PV panel or battery
- Diode Protection to prevent battery discharge when Battery is higher than PV panel
- Photovoltaic Panels - Suitable for PV panels with Open Circuit Voltage from 17 to 25V
 - Appendix B lists several panels that are compatible with Model 510
 - Note that for 24 Volt systems, use two Photovoltaic panels or a panel with an output of 30 to 48 Volts or two panels in series.
- Rated charging/load current 10A
- Pulse Width Modulation Charging with 3-stage Charge Control (to allow battery be left unattended for long periods of time)
- User Adjustable Charge Control Settings for Gel or Wet types of batteries,
- Low Voltage Disconnect
 - 11.5 Volts
- Low Voltage Reconnect
 - 11.8 Volts
- Built-In Microprocessor for PV charge control to maximize the charging efficiency and motor operation
- Overcharge and Over-discharge Protection
- Tri-Color LED indication of system conditions
 - Battery
 - Green - above 13.2 Volts
 - Orange - 11.8 to 13.2 Volts
 - Red - Below 11.8 Volts
 - Photo Voltaic Panel
 - Green - above 18.0 Volts
 - Orange - 14.0 to 18.0 Volts
 - Red - 10.0 to 13.9 Volts
 - Off - below 10.0 Volts
 - Charge Current
 - Red - above 8.0 Amps
 - Orange - 4.0 to 7.9 Amps
 - Green - 1.0 to 3.9 Amps
 - Off - below 1.0 Amps

- Load Current
 - Red - above 8.0 Amps
 - Orange - 5.0 to 7.9 Amps
 - Green - Less than 5.0 Amps
 - Off - Load switched off
- Range / Accuracy (Accuracy applies to internal readings, LED outputs and optional display)
- Battery, 8 to 16 Volts, 2% +/-0.1V
- Photovoltaic Cell, 0 to 27 Volts, 2% +/-0.1V

Batteries

Selection, Sizing and Care

In electrical terms, the word "battery" is defined as an electrochemical device that converts chemical energy into electricity, by a galvanic cell. A galvanic cell is a fairly simple device consisting of two electrodes (an anode and a cathode) of different metals or metal compounds and an electrolyte (acid or alkaline) solution. A "Battery" is two or more of those cells in series, although many types of single cells are referred to as batteries - such as camera batteries. Batteries do not make electricity they store it. As chemicals in the battery change, electrical energy is stored or released. In rechargeable batteries this process can be repeated many times. Batteries are not 100% efficient - some energy is lost as heat and chemical reactions when charging and discharging. The lost energy can be minimized with slower charging and discharging rates. A battery rated at 100 amp-hours over 6 hours might be rated at 120 AH at the 20-hour rate, and 140 AH at the 48-hour rate. Practically all batteries used in photovoltaic applications are Lead-Acid type batteries. They still offer the best price to power ratio. Typical efficiency in a lead-acid battery is 85-95%.

There are many different types of batteries. Most solar applications use a type of battery called deep cycle. These batteries are specifically designed to be able to tolerate discharging the battery to low capacities without compromising the useful life. Deep cycle batteries are designed to be discharged down as much as 80% and have much thicker plates. The common construction types are flooded (wet), gelled, and AGM (Absorbed Glass Mat). AGM batteries are also sometimes called "starved electrolyte" or "dry", because the fiberglass mat is only 95% saturated with Sulfuric acid and there is no excess liquid.

Gelled batteries, or "Gel Cells" contain acid that has been "gelled" by the addition of Silica Gel. The advantage of these batteries is that it is impossible to spill acid even if

they are broken. A disadvantage of the Gel Cell is that they must be charged at a slower rate (C/20) to prevent excess gas from damaging the cells. They cannot be fast charged on a conventional automotive charger or they may be permanently damaged. This is not a problem with the Model 510 since the unit has a mode specifically for Gel Cell batteries.

The newer AGM batteries have all the advantages of Gel Cell batteries, but can take much more abuse. These are also called "starved electrolyte", as the mat is about 95% saturated rather than fully soaked. That also means that they will not leak acid even if broken.

AGM batteries have several advantages over both gelled and flooded, at about the same cost as gelled: Since the electrolyte (acid) is contained in the glass mats, they cannot spill, even if broken. Since there is no liquid to freeze and expand, they are practically immune to freezing damage. The charging voltages are the same as for any standard battery. Also, since the internal resistance is very low, there is almost no heating of the battery even under heavy charge and discharge currents. AGM's have a very low self-discharge, typically from 1% to 3% per month. This means that they can sit in storage for much longer periods without charging than standard batteries.

The lifespan of deep cycle batteries vary considerably with how it is used, how it is maintained and charged, temperature, and other factors. The deep cycle batteries used in renewable energy systems are designed to be discharged a maximum of 80 percent (20% state of charge). If they are discharged 100 percent, they are immediately damaged.

Sizing a battery

To figure the size of battery, the key specification is Amp-hours. Amp-hours are a rough indication of how much energy a battery can store. A battery's Amp-hour rating indicates the total amount of energy it will deliver at a constant rate of discharge. For example a 50 Amp-hour battery theoretically could deliver 50 Amps for one hour or 1 Amp for 50 hours. This is not true in practice. At different rates of discharge, a battery's actual Amp-hour rating will change. In order to standardize, manufacturers now specify the Amp-hour rating over a period of 20 hours before it reaches a voltage at which it is discharged. For the 50 Amp-hour battery can deliver 2.5 Amps for 20 hours. (50 Amp-hour divided by 20 hours = 2.5 Amps.) A 12-volt battery, the most common nominal voltage, is fully discharged at about 10 Volts. A 100 Amp-hour, 12 Volt battery will run a 5 Amp load for 20 hours, and a 200 Amp-hour battery will run a constant 10-amp (120 watt) load for 20 hours. In general, when a 100 Amp-hour battery is discharged at a rate greater than 5 Amps, it will not deliver all the advertised Amp-hours before it goes dead. On the other hand, if you discharge it at a

steady rate of less than 5 amps, you'll get slightly more Amp-hours than the manufacturer's rating shows. That principle applies to most lead-acid batteries, the faster the discharge rate, the fewer Amp-hours delivered. The slower energy is taken from a battery, the longer it will last.

We can calculate the desired Amp-hour rating for a battery based on the current needed for a specific application. As an example, suppose we were designing a lighting system that drew 5 Amps and we needed the lights on for 10 hours each night. The calculation would be (10 hours / 20 hours) X 5 Amps = 2.5 Amps which would indicate a 50 Amp-hour battery. A 50 Amp-hour battery would work for most conditions. The battery would charge fully during the day when there was sunlight, then run to depletion in 10 hours each night. In fact, the 510 Controller would shut off the load (lights) when the battery approaches full discharge. Since we can't depend on having sun each day, it would be better to oversize the battery, so that there is additional capacity. We would recommend an 85 or 100 Amp-hour battery.

DAYS of AUTONOMY:

The sun does not shine with equal intensity every day, at night and during inclement weather. Cloud cover, rain, snow, etc, diminish the daily Insolation (*Insolation* is the amount of solar energy delivered to the earth's surface. Insolation is measured in kWatts/meter²). A storage factor must be employed to allow the photovoltaic battery system to operate reliably throughout these periods. In addition, it is desired to obtain the best service life of the battery by limiting its average daily depth of discharge. This storage factor is commonly referred to as "Number of Days of Battery Autonomy". The number of days is established by evaluating the Peak Hours of Sun per Day [(kW/m²)/day] for the lowest Insolation month of the year; with the solar array oriented for maximum output during that month.

The minimum number of days that should be considered is 5 days of storage for even the sunniest locations on earth. In these high sun locations there will be days when the sun is obscured and the desired battery's average daily depth of discharge is limited to 20%. Therefore, the recommended days of autonomy storage are listed on the following chart:

Recommended Days of Autonomy Storage

<u>kW/m²/day</u>	<u>Days of Storage</u>
4.5+	5
3.5 to 4.5	6
2.7 to 3.5	7
2.0 to 2.7	8
<2.0	Up to 14

Appendix A

Some Suggested Batteries (all 12 Volts unless otherwise specified)

Power Battery Co.	Sealed Gel Solar Batteries		www.powerbattery.com
<u>Battery Model</u>	<u>Ampere Hours</u>	<u>Charge Rate</u>	
PSG-1240	28	0.5 to 3.5 Amp	
PSG-1285	76	.76 to 3.8	
PSG-12120	110	1.1 to 10 ₁	
PSG-12255	220	2.2 to 10 ₁	

Apex Battery	Solar Battery		www.apexbattery.com
<u>Battery Model</u>	<u>Ampere Hours</u>	<u>Charge Rate</u>	
8A22NF	63	.63 to 2.8 Amp	
8A27	100	1.1 to 4.6	
8A4D	200	2.1 to 10 ₁	

Trojan Battery Co.	Deep Cycle Gel		www.trojanbattery.com
<u>Battery Model</u>	<u>Ampere Hours</u>	<u>Charge Rate</u>	
24-Gel	66	not specified	

Notes:

1. Maximum charge rate based on Model 510 maximum charging current

Appendix B

Solar Panels

The Model 510 is designed for a maximum charging current of 10 Amps. For a 12 Volt system a 180 Watt Photovoltaic Panel would be the maximum size. (18V x 10A) Check the maximum output current specification of the panel.

Table 1 contains some suggested solar panels that are suitable for use in systems using the Model 510 Solar Controller. There are many other panels that can be used.

For charging batteries, the key parameter is the current that the panel can deliver. For example, if a panel delivers 5 Amps at 17 Volts it is rated at 85 Watts. A panel that can deliver 5 Amps at 20 Volts is rated at 100 Watts. The battery charging capability of the two panels will essentially be the same.

In order to comply with the National Electric Code (NEC), the current rating of the controller for solar charging must be equal or greater than 125% of the solar array's short circuit current output (Isc). The Model 510 Solar Controller is actually capable of working with up to 12.5 Amps, so an array that supplied 10 Amps short circuit current could be used.

Recommended Solar Panels for use in a Model 510 Solar Controller system.

Mfgr	Part #	Rated Watt	Price	\$/W	Peak V Volts	Peak I Amps	Height in	Width in	Area square in	Watts / sq ft.	Calculated Watts
SunWize	SW60A	60	\$380	\$6.33	16.7	3.6	35.1	22.6	793.3	10.9	60.1
MrSolar.com	BSP65-12	65	\$395	\$6.08	17.4	3.75	58	13.8	800.4	11.7	65.3
BP Solar	BP375J	75	\$418	\$5.57	17.3	4.3	47.1	20.9	984.4	11.0	74.4
Sun Tech Power Co.	STP080-12Bp	80	\$445	\$5.56	16.8	5.12	47	20	940.0	12.3	86.0
SunWize	SW100C	100	\$550	\$5.50	23	4.35	54	22.9	1236.6	11.6	100.1
BP Solar	BP 3125	125	\$640	\$5.12	17.4	7.2	59.4	26.5	1574.1	11.4	125.3
Sharp	ND-130UJF	130	\$685	\$5.27	17.4	7.5	59	26.1	1539.9	12.2	130.5
Sharp	ND-N2ECU	142	\$740	\$5.21	20	7.11	45.9	39	1790.1	11.4	142.2
Mitsubishi	MF165EB3	165	\$785	\$4.76	24.2	6.83	62.3	31.5	1962.5	12.1	165.3
Solarworld-USA	SW175	175	\$805	\$4.60	35.8	4.89	63.4	31.9	2022.5	12.5	175.1
Sanyo	HIP-200BA19	200	\$1,104	\$5.52	55.8	3.59	51.9	34.6	1795.7	16.0	200.3

Notes:

ECC is not responsible for the accuracy of this information, particularly prices which change often.

Modules with more than 25 Peak Volts are suitable for a 2 battery (24 Volt) system.