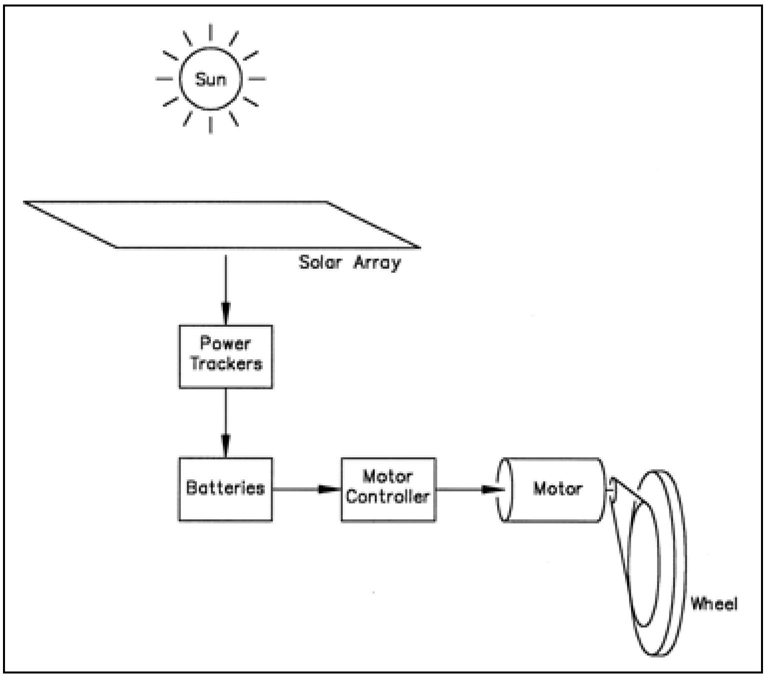
- Introduction
- Components
- Parts Contacts
- Fundraising
- Schematics


Questions? Comments? Email William Shih at wishih@usc.edu.

Please go to the Winston Solar Challenge site for more information.
Special thanks to Jensen Krage, webmaster, for hosting the site and for site development.
Last modified on September 14, 1998.

Building a solar car is a very ambitious goal, but one that is achievable through hard work and commitment. One of the first things to do is to organize a group of people interested in building a car, and planning a specific goal. How much money will you need to build a solar car? If the least expensive parts are used, the cost of a solar car is about $12,000, not including trip costs to the competition. You will need a core group of fundraisers who are willing to spend the year making presentations to businesses and speaking to individuals at their home. You will also need to assess what materials and tools you need and get several people focused on building the car itself. It may be a difficult road the first year, but the things you learn along the way will last a lifetime!




Solar cars are powered by the sun's energy. The main component of a solar car is its solar array, which collect the energy from the sun and converts it into usable electrical energy. The solar cells collect a portion of the sun's energy and stores it into the batteries of the solar car. Before that happens, power trackers converts the energy collected from the solar array to the proper system voltage, so that the batteries and the motor can use it. After the energy is stored in the batteries, it is available for use by the motor & motor controller to drive the car. The motor controller adjusts the amount of energy that flows to the motor to correspond to the throttle. The motor uses that energy to drive the wheels.

Please direct comments and questions to:
William Shih, Northview Solar Racing Team
651 W. Grondahl St., Covina, CA 91722; (213) 764-6794
Last modified: September 2, 1998

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**Solar Array and Power Trackers**

We recommend a solar array created from individual solar cells as opposed to one made of prefabricated solar panels. It enhances the students' learning and can result in a lighter solar array. Cells can be bought from either Siemens or ASE Americas. Both sell the terrestrial-grade cells that are permitted in the Winston Solar Challenge, and the cost for terrestrial-grade cells are much lower than space-grade cells, though terrestrial-grade is less efficient. Each solar cell should produce .5 volts at about 3 amps at peak sunlight. The number of cells to use depends on their size and the allowable solar area per Winston rules. Solar cells should be wired in series on a panel and should be divided into several zones. For example, if you have 750 solar cells, you might want to wire 3 sets of 250 cells, each zone producing about 125 volts. If one zone fails, two other zones are still producing power. The solar array voltage does not need to match the system voltage of the motor if you use power trackers. Power trackers convert the solar array voltage to the system voltage. They are essential in a solar car. Be sure to verify with the power tracker vendor the necessary array voltage to feed the power trackers. If the car drives underneath shade, the power trackers automatically adjusts the power to match system voltage, allowing the system to run as efficient as possible. Power trackers are available from AERL.

**Batteries**

The batteries store energy from the solar array and makes them available for the motor's use. Many different types of batteries are sold. Most high school teams use lead-acid batteries because they are inexpensive, but some teams use lithium-ion or nickel-cadmium. We recommend that you stick with lead-acid batteries because they are readily available and inexpensive. Another choice teams must make is running with flooded-cell batteries or gel-cell batteries. Flooded-cell batteries are the standard automotive batteries filled with liquid sulfuric acid. They are preferred because they can be overcharged without risk of blowing up, but they weigh more than gel-cell batteries. Gel-cell are sealed and lightweight, but when charging the batteries, check the battery voltage often. The number of batteries to choose depends on the motor (system) voltage. If the system voltage is 72 volts, you will need 6 12-volt batteries. Also be sure to check the rules for weight or watthour requirements. Buy batteries with as many amphours as allowed by the rules to maximize the amount of energy you can store.

**Motor & Controller**

Most teams use DC brush permanent magnet motors to drive their solar cars. Inexpensive and easy to hook up, these motors are desirable for high school teams with little financial support. Expect a maximum efficiency of 80-90%. For teams with more money, brushless motors increase the efficiency of the motor to the 94-99% range. Also, some motor and controller setups allow for regenerative braking, which allows the solar car to put energy back into the batteries when going downhill. For the beginning team, DC brush motors would be sufficient to get a solar car up and running. Another variable in choosing a motor is how much power it has. We have found that there is little need to have more than 5hp continuous power output on our motors. There are two manufacturers who supply most teams with motors and controllers: Solectria and Advanced DC Motors. Many college teams buy their motors from Solectria, but Advanced DC Motors have less expensive motors. Controllers usually drive a particular motor. Once you choose the motor that suits your needs, the same vendor would most likely have a matching controller.

**Instrumentation**

One of the most important pieces of instrumentation is a state-of-charge meter. A state-of-charge meter gives information about system voltage, amp draw, battery energy remaining, and estimates the how much time remains until the battery is out of energy. We found that the E-Meter, manufactured by Cruising Equipment, served out purpose well. It has a digital display and accurately counts the number of amp-hours remaining in the battery. The E-Meter is the do-it-all in instrumentation. Another instrument that may be useful is a speedometer. Instead of using a regular speedometer drive, use magnetic contact speedometers, found in many sports equipment stores. This option does not add drag to your car. To ensure that your batteries are running properly, you may invest in getting a voltmeter for each of your batteries. A failed battery may show the proper voltage when the car is not running, but while the battery is under load, the voltmeter will show a lower than normal battery voltage.

**Steering & Suspension**

We strongly recommend front wheel steering as it tends to be more stable and safer. A solar car uses energy frugally if it is to be competitive. If there are two front wheels, it is therefore advisable to work out the geometry so that they run parallel when the car is going straight ahead, but when the car is turning, the front wheels turn at different radii. If the car is turning left, the left front tire is making a smaller circle than the right front tire. If the tires remain parallel while turning, they will cause unnecessary drag, decreasing tire life and overall performance.

The only advice we can offer with respect to suspension is that it should be soft enough to protect the car and solar array from unnecessary jolts and firm enough to provide a stable ride.

**Brakes**

Disc brakes are desirable as they are predominantly hydraulic. Having hydraulic lines running to the wheels can be easier than mechanical brake arrangements. The most significant problem with disc brakes is that the brake pads do not back away from the brake rotors when pressure is released, they just relieve braking pressure. Because the pads don't normally back away from the rotors, they continue to have a small amount of drag. While this drag may not be noticeable on the family car, it is very inefficient on solar cars. Go kart shops now have brake calipers that are spring loaded to move the pads away from the rotors. We have found these very worthwhile.

**Tires & Hubs**

Tire selection will affect rolling resistance which affects how far the solar car will travel with the energy available. Tires with thicker rubber and wider tread tend to have higher rolling resistance (a bad thing). Thinner tires with higher pressuer have less rolling

resistance, but are more susceptible to flats. The best tires we have found are the Bridgestone Ecopia tires made for solar cars. They are very thin and operate at over one hundred pounds/inch pressure. Unfortunately, they need to be mounted on specially made wheels and require custom made hubs. On the good side, these tires and wheels are very light. Some colege teams have experimented with bicycle tires but report limited success (bicycle tires, rims and spokes are not designed for the forces placed on them by non-tilting vechicles that weigh several hundred pounds). Motorcycle tires tend to have more resistance, although there may be high pressure tires with low resistance that we don't know about yet.
Bearing resistance can be reduced by light minimal lubrication. Bearing seals can be cut away at the contact lip to leave most of the seal protection while removing most if not all seal drag. It is a good idea to get the rolling chassis operational months before your schedule gets critical. Run the chassis as many miles as possible to prove that your bearings, axles, steering and suspension can survive.

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Last modified: September 2, 1998

Introduction
Components
Parts Contacts
Fundraising
Schematics

Materials List
Manufacturer's List

Determining what components are needed to put together a solar car is very difficult. Even more difficult is finding where to buy these components. This list of materials and contacts is by no means exhaustive, but may give you a starting point from which to buy materials.

**Materials List**

| Material | Vendor |
|---|---|
| **Aluminum, tempered tubing** | **EMJ**<br>For local source call:<br>1-800-3EMJ.EMJ |
| **Amber roof mounted strobe lights**<br>Napa Lighting Model 393A<br>$103.55 | **Pomona Truck & Auto Supply**<br>Dave<br>200 N. Clark Ave.<br>Pomona, CA 91767<br>909-622-1367<br>909-622-5417 (Fax) |
| **Ammeter**<br>KTA Services Model A500-50<br>$40.00 | **KTA Services**<br>Ken Koch<br>944 W. 21st St.<br>Upland, CA 91784<br>909-949-7914<br>909-949-7916 (Fax)<br>http://www.kta-ev.com |
| **Batteries**<br>Trojan Batteries, 12 volts, 70 amp deep cycle<br>Cost varies per model | **Local battery vendor** |
| **Brake calipers, misc. parts**<br>hydraulic, spring loaded<br>Cost varies per model | **Local go-kart vendor** |
| **State-of-charge meter**<br>Cruising Equipment model 900091 - E-Meter<br>Cruising Equipment model 900086 - Prescaler<br>$199 (meter), $69 (prescaler) | **KTA Services**<br>Ken Koch<br>944 W. 21st St.<br>Upland, CA 91784<br>909-949-7914<br>909-949-7916 (Fax)<br>http://www.kta-ev.com |
| **Motor & controller**<br>Advanced DC Motors, Inc. model A89-4001 (motor)<br>Curtis-PMC model 12098-6402 (controller)<br>$525 (motor), $670 (controller) | **KTA Services**<br>Ken Koch<br>944 W. 21st St.<br>Upland, CA 91784<br>909-949-7914<br>909-949-7916 (Fax)<br>http://www.kta-ev.com |
| **Power trackers**<br>AERL<br>Cost varies per model | **Australian Energy Research Laboratories (AERL)**<br>Stuart Watkinson<br>M.S. 660<br>Proston, Queensland 4613, AUSTRALIA<br>011-6171-689308<br>011-6171-689197 (Fax) |
| **Ribbon wire**<br>.080" wide, .005" thk, tinned, fully annealed<br>No cost - donated | **E. Jordan Brooks**<br>Tim Brown<br><br>213-722-8100 |
| **Solar cells** | **Photon Technologies** |

| | |
|---|---|
| **Solar cells**<br>ASE-Americas, Inc. 4" square<br>$6.50 each | **Photon Technologies**<br>Robert Mulligan<br>P.O. Box 790<br>Severna Park, MD 21146<br>410-544-0911<br>410-544-4075 (Fax)<br>photontek@aol.com |
| **Solder for solar cell work**<br>2% silver solder, Kester #NC-740, 25g syringe<br>$10/syringe | **@ONCE**<br>Attn: Catalog Sales<br>4 Sunset Way, Bldg. C<br>Henderson, NV 89014<br>888-428-6623<br>800-950-5679 (fax) |
| **Soldering iron for solar cell work**<br>100 watt pencil, Weller W100PG<br>$60.00<br>Tip for soldering iron, Weller CT6C<br>$9.00 | **@ONCE**<br>Attn: Catalog Sales<br>4 Sunset Way, Bldg. C<br>Henderson, NV 89014<br>888-428-6623<br>800-950-5679 (fax) |
| **Soldering paste flux**<br>Kester #NC-740, in 25 gram syringe, 2% silver, no-clean<br>$10 each/ten syringes<br>$15 each/one syringe | **Marshall Industries**<br>Richard<br>9320 Telstar Ave.<br>El Monte, CA 91731<br>626-307-6000<br>626-307-6173 (Fax) |
| **Tape, acrylic foam, double sided**<br>3M #4945, 1/2" wide, 36 yds/roll<br>$46.98/roll<br>Product info: 800-362-3550<br>L.A. area sales info: 800-241-4819 | **R.S. Hughes Company**<br>Martin<br>San Fernando Rd.<br>Los Angeles, CA<br>818-500-1221 |

## Manufacturer's List

**Advanced D.C. Motors, Inc.**
motors
219 Lamson Street
Syracuse, NY 13206
315-434-9303
315-432-9290 (Fax)

**ASE Americas, Inc.**
solar cells
Ms. Evelyn Bennett
4 Suburban Park Drive
Billerica, MA 01821
508-667-5900 x266
508-663-2868 (Fax)
http://www.asepv.com (Coming soon)

**Australian Energy Research Laboratories (AERL)**
power trackers
Stuart Watkinson
M.S. 660
Proston, Queensland 4613, AUSTRALIA
011-6171-689308
011-6171-689197 (Fax)

**Cruising Equipment**
state-of-charge meters
5245 Shilshole Ave. NW
Seattle, WA 98107
206-782-8100
206-782-4336 (Fax)
http://www.cruisingequip.com

**Curtis PMC**
motor controllers

6591 Sierra Lane
Dublin, CA 94568
510-828-5001
510-833-8777 (Fax)

**E. Jordan Brooks**
ribbon wire
Tim Brown
Los Angeles
213-722-8100

**Kester Solder**
soldering paste flux
515 E. Touhy Ave.
Des Plaines, IL 60018
800-253-7837
http://www.kester.com

**Siemens Solar**
solar cells
Camarillo, CA
805-482-6800
805-388-6395 (fax)
http://www.solarpv.com

**Solectria**
motors & motor controllers
27 Jason St.
Arlington, MA 02174
508-658-2231
508-658-3224 (Fax)
http://www.solectria.com

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Please direct comments and questions to:
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Last modified: May 12, 1999

There are many different ways to fundraise and there is no absolute perfect way. In order to begin, ask yourself what you can offer the contributor. In most cases, we have found that corporations would like to get some public recognition, while individuals want to feel that they are helping a worthwhile project.

**Adopt A Solar Cell**

Many schools have an "Adopt-A-Cell" program in which they ask for contributions in increments of solar cell costs. For instance, if your solar cells are going to cost $6.50 each, you may want to assign an approximate cost of $8 to a cell to cover taxes, shipping, installation materials, etc. So, your Adopt-A-Cell program offers that people can contribute $8 per cell to help your team buy the 750 or 850 cells you need. In return, the contributors know that you have recorded their name and the number of cells they have contributed.

Residential door to door fundraising with Adopt-A-Cell forms works if you have a large number of team members that don't mind spending they day on the street. We suggest door to door only on weekends as too many people aren't home during the week. Remember that people can adopt as many cells as they wish!

**Small Business Sponsorships**

Business door to door also works well, but the initial focus should be on significant contributions ($25, $50, $100, $1000?). You should take an information packet that includes a current list of sponsors, an introduction to the team and the Winston Solar Challenge, the budget, etc. If the business person you are talking with declines any general contribution, we have found that many of these people will still adopt one or more cells. Your information packet should include any interesting information about the team, how it was started, your goals, etc. The cover of the information packet can have a picture of the car or a drawing of what it may look like when completed.

**Corporate Sponsorships**

Remember that it is easier to get smaller donations than large ones. It is not unusual for small businesses to give in the $30 area, but you will have to make your best guess as to waht to ask for with large companies. Be prepared to be asked "How much do you need?" or "What is your budgeted cost and how much have you been given so far?" Set a minimum contribution amount for those companies that will be listed in your packet as contributors. Let them know that the contributors list will be seen by many other business people. Explain why the project is educational. Always ask to speak to the owner and don't give your prepared speech to just anyone. We found success in companies related to automotive and construction as we believe they can more easily relate to the project efforts.

The larger the company, the more professional the presentation should be. A Powerpoint slide show does nicely if you explain it well. To approach a large company, call their corporate office and ask to speak to the person responsible for sponsorships. If they like what you say over the phone, then you will probably be asked to make a presentation to a group of people at their location. Let them know the set price to get their name on your car (we suggest a minimum of $500). It may take several phone calls to get to the point where you can make a presentation, but it will be worth the time.

**Public Presentations**
Community service organizations are one of the very best places to get funding. The local Lion's or Rotary type organizations are concerned for the benefit of their communities -- of which you are a part. Be prepared to make presentations to these organizations.

Large gatherings of people are a good place to fundraise. For example, fairs and city farmers' markets are usually pretty successful. In order to get into city functions, call city hall and ask about an event. They are usually very helpful. At large functions, get a booth or site and set up a table with photos of your progress so far. Have team members there ready to answer questions. The car is the best thing to attract attention, even if it is only partially complete. People like to see what they are contributing for and like to help. You may even develop contacts with companies that can do welding, machining, or furnish wiring, etc. as a result of having your car on display. Make sure you have permission to fundraise at an event.

You may get some companies to contribute things (bicycles, TV's, etc.) that can be raffled off at events. Remember that it is sometimes easier for a company to contribute a product or service that to give cash. Be sure that if you hold a raffle, that you get a hold of the winner! Also, the winner should be drawn at the event so that there is no suspicion regarding how the drawing was performed.

Either before or after the Winston competition, it is a good idea to have some kind of get-together where all of the supportive people (parents, sponsors, etc.) can see the car and be thanked for their support. You can probably get your school to allow the use of a gym or cafeteria. be sure to show off your car. The sponsors who see this may decide that yours is a worthwhile project and donate twice as much next year.

Fundraising is a year long task. Don't wait until late in the year to start. Get organized and divide up work so that it doesn't become overwhelming. Expect to get more people saying no than yes. Think of it as treasure hunting. You will get contributions and some will be significant!

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Last modified: September 2, 1998

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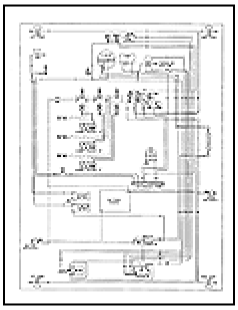
# Technical Schematics



**1998 Northview Solar Racing Team Electrical Schematics**
This drawing describes all of the electrical components on the Valkyrie I, Northview's 1998 entry in the Winston Solar Challenge.

Click on thumbnail to enlarge image. Also available in: PDF format (47.7 KB)
AutoCAD LT 97 format (85.4 KB)

**Documentation for E-Meter**
Dimensions and instruction manual for the E-Meter, a state-of-charge meter manufactured by Cruising Equipment.

Click on picture for dimensions of the E-Meter.
Instruction manual available in
PDF format (451 KB)


**Documentation for AERL Power Trackers**
Contains documentation and technical schematics for AERL power trackers.
In PDF format.
Documentation, page 1 (121 KB)
Documentation, page 2 (131 KB)
Technical Schematic (41.3 KB)

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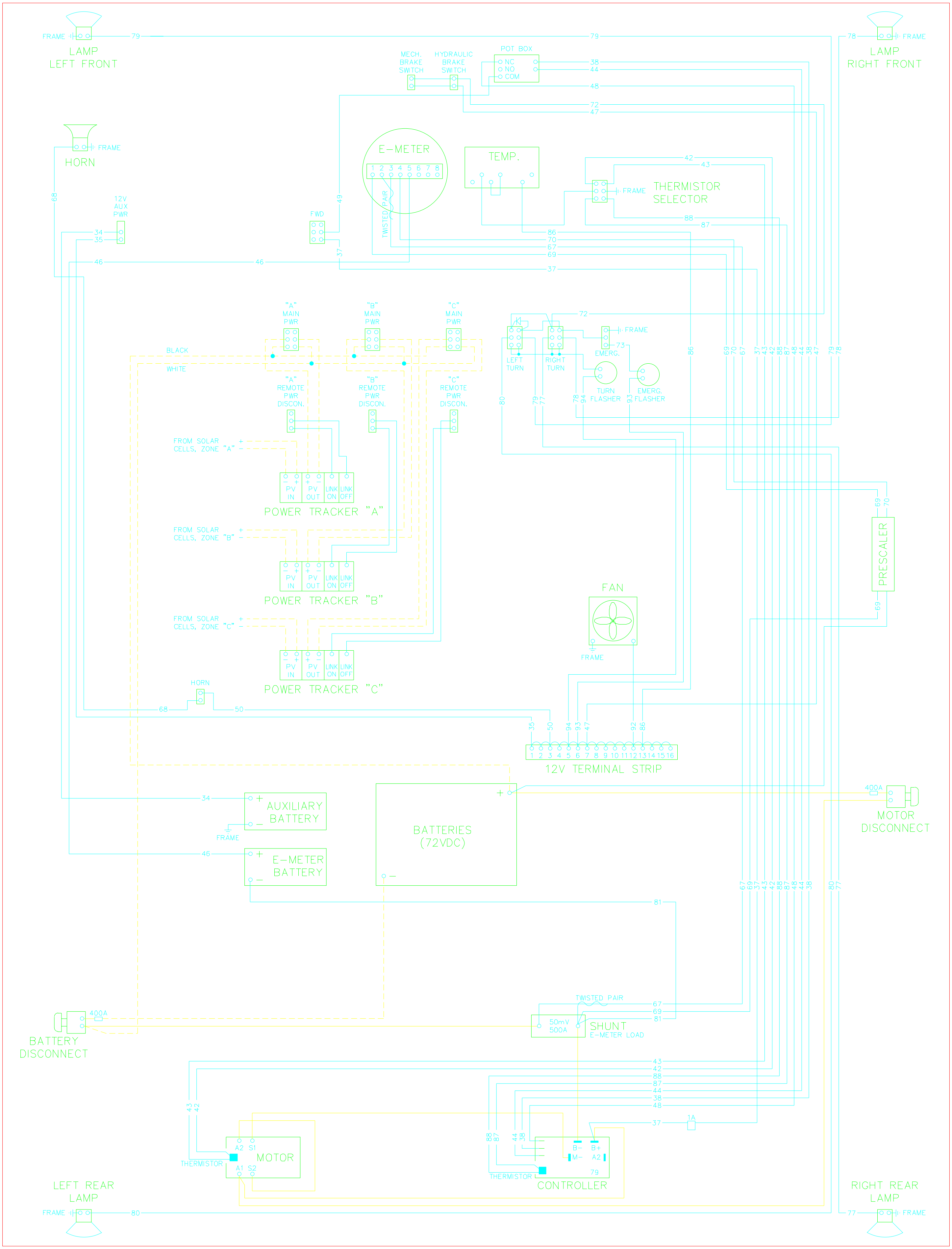
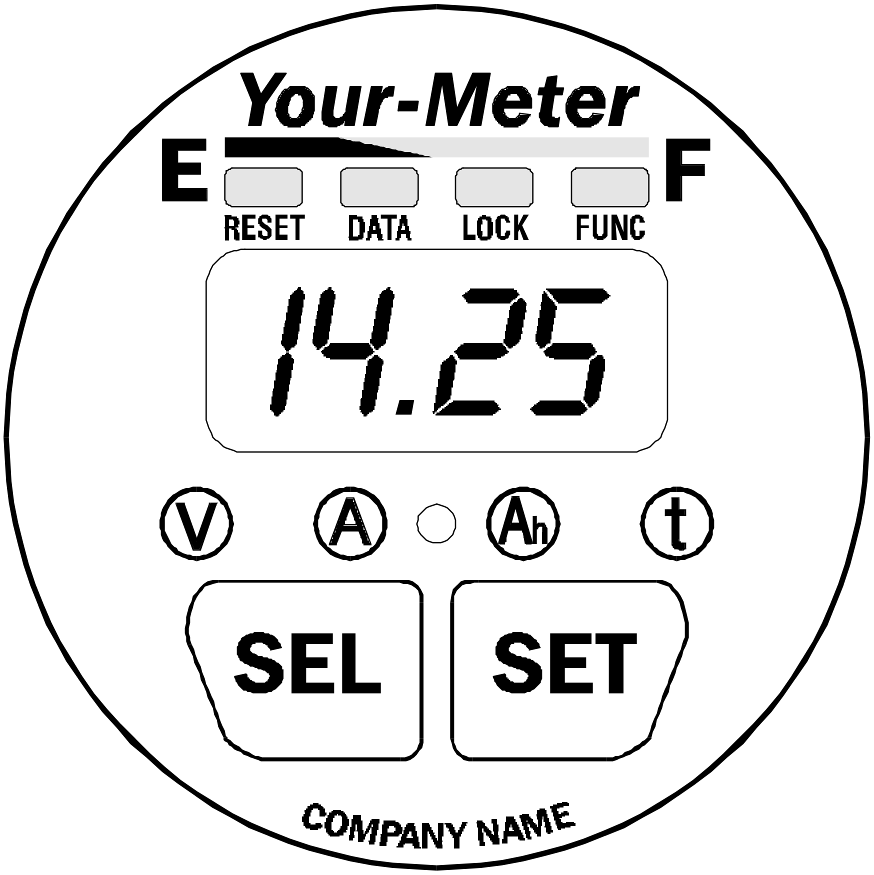


LAMP LEFT FRONT
FRAME
LAMP RIGHT FRONT
MECH. BRAKE SWITCH
HYDRAULIC BRAKE SWITCH
POT BOX
NC
NO
COM
HORN
E-METER
TWISTED PAIR
TEMP.
THERMISTOR SELECTOR
12V AUX PWR
FWD
"A" MAIN PWR
"B" MAIN PWR
"C" MAIN PWR
BLACK
WHITE
"A" REMOTE PWR DISCON.
"B" REMOTE PWR DISCON.
"C" REMOTE PWR DISCON.
LEFT TURN
RIGHT TURN
EMERG.
TURN FLASHER
EMERG. FLASHER
FROM SOLAR CELLS, ZONE "A"
FROM SOLAR CELLS, ZONE "B"
FROM SOLAR CELLS, ZONE "C"
PV IN
PV OUT
LINK ON
LINK OFF
POWER TRACKER "A"
POWER TRACKER "B"
POWER TRACKER "C"
PRESCALER
FAN
12V TERMINAL STRIP
AUXILIARY BATTERY
E-METER BATTERY
BATTERIES (72VDC)
400A
MOTOR DISCONNECT
BATTERY DISCONNECT
50mV 500A
SHUNT
E-METER LOAD
MOTOR
THERMISTOR
CONTROLLER
1A
LEFT REAR LAMP
RIGHT REAR LAMP

# Owner's Manual

*Copyright 1995, 1996* *Manual Part # 890015 Rev. 4* *6/1/96*




## ***Graphic*** *and* ***Digital*** *Displays!*

**Ideal battery monitor for...**

***...Marine Systems***
***...Alternative Energy Systems***
***...Recreational Vehicle Systems***
***...Industrial Lift Truck Applications***
***...Electric Vehicles and many more!***

# The world's most accurate state-of-charge monitor!

EINSTAL4.PM5

# Specifications

**Voltage**: **For 12V and 24V battery systems. Prescaler required for hgher voltages.**

**Standard Model:** Two Auto-ranges: 0 to 19.95V (0.05V resolution)
20.0 to 50.0V (0.1V resolution)

**Optional Prescalers:** 0-100V, 0-500V (Used with standard model)

**Amperage:**

**Low Range:** ± 0 - 40.0 Amps (0.1 Amp resolution)

**High Range:** ± 500 Amps (1 Amp resolution)

**Amp-Hours:**

**Low Range:** ±0 - 199.9 Amp-Hours (0.1 Amp-Hour resolution)

**High Range:** ± 200 - 1999 Amp-Hours (1 Amp-Hour resolution)

**Time Remaining:**

**Low Range:** 0 to 199.9 Hours (0.1 hour resolution)

**High Range:** 0 to 255 Hours (1.0 hour resolution)

**Power Requirements:**

**9.5-40 Volts DC**

**Current:** 50-150 mA (Depends on Ambient light. Display Auto Dims.)
28 mA (Sleep Mode - Bar Graph Display Only)

**Shunt type required:** 50 mV @ 500 Amp

**Accuracy:**

**Voltage:** ± (0.6% of reading + 1 least count of resolution)

**Amperage:** ± (0.8% of reading + 1 least count of resolution)

**Amp-Hours:** Ahr Error ≃ (Time of measurement x current error)

**Physical:**

**Max. Outer Bezel Diameter:** 2.5 inches (63.5mm)

**Max. Barrel diameter:** 1.95" (50mm)

**Max. Depth:** (from back of bezel) 3.15 inches (80mm)

**Hole Cutout Size:** Use 2" or 2 1/16" hole saw (52mm)

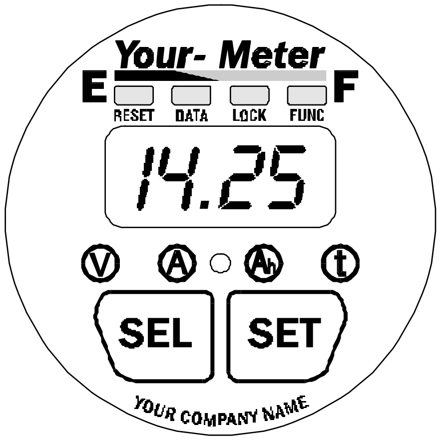
**Water Resistance:** Splashproof front panel.

**Weight:** 8 Ounces (227g)

# Operation

Although Your Meter is a very sophisticated device, obtaining basic battery information from it is simple. With the unit turned on and the Ⓥ (**V**olts) LED on, let's learn how to display the four most important DC system parameters .

When you touch the **SEL** button, you are ***SEL***ecting the display you wish. Each time you touch ***SEL*** in normal operation, you will toggle to the next item to the right Ⓥ (Volts) goes to Ⓐ (**A**mps) to Ⓐh (**A**mp-**h**ours) to ⓣ (**t**ime).




Now press ***SEL*** to bring up these functions.

Ⓥ **Volts** is the electric *potential to do work*. Voltage is useful to assess the approximate state-of-charge and to check for proper charging. Examples: An at rest, fully charged battery will show about 12.8V. A 12 V battery is 100% discharged when it reaches 10.5Volts with a 20 hr. rated load applied. A typical charging voltage would be 14.2V.

Ⓐ **Amps** is the present *flow* of current in or out of the battery. For example, a refrigerator may draw 6 Amps of current. This is displayed as `- 6.0` (6 amps are being *consumed*). Discharge is shown as a negative number and charging is shown as a positive number (unsigned).

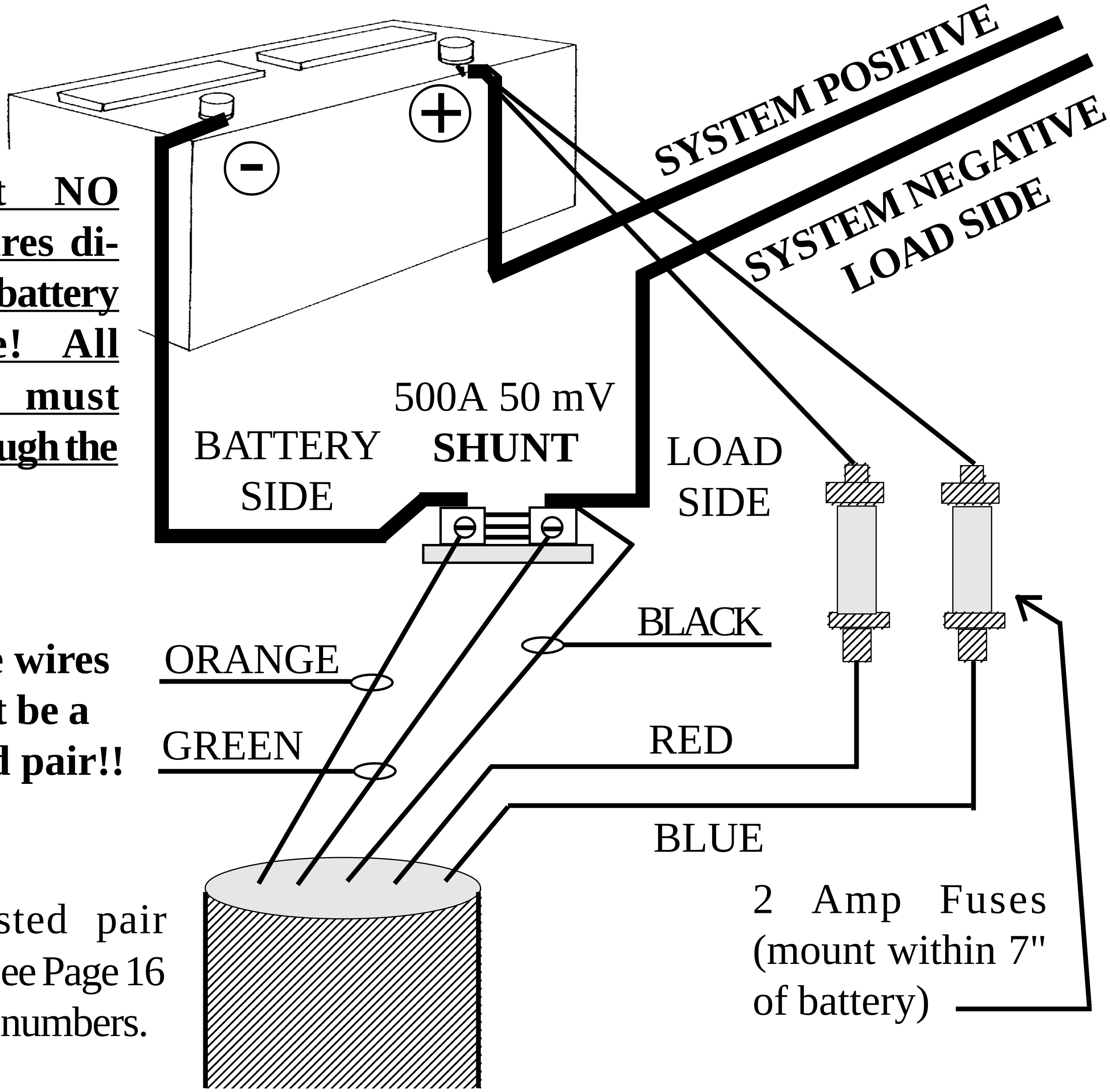
Ⓐh **Amp-hours** consumed represents the *amount of energy removed from* the battery. If you run a 10 Amp load for one hour then ten Amp-hours are consumed. Your Meter will show `-I0` in the Ⓐh display. During chargingYour Meter will compensate for charging efficiency and count back up toward `0` .

ⓣ **Time** is an estimate of how long (in hours) the battery will sustain a load. It is based on a selectable, time averaged, rate of discharge. Default is the average of the last four minutes of use. (See Page 23)

# Shunt & Battery Wires

The shunt is the current sensor for Your Meter. Its 500A 50mV rating means that when 500 Amps flows through it there is 50mV generated across it. The millivolt signal is translated into an Amps display in the meter. For example: A 50A load would generate 5mV across the shunt and would be displayed as 50 Amps. **Caution:** In the diagram below, the **darker wires** represent primary wiring and should be able to carry full battery load current. Size appropriately!

**<u>Connect NO other wires directly to battery negative! All current must flow through the shunt!</u>**




**These wires must be a twisted pair!!**

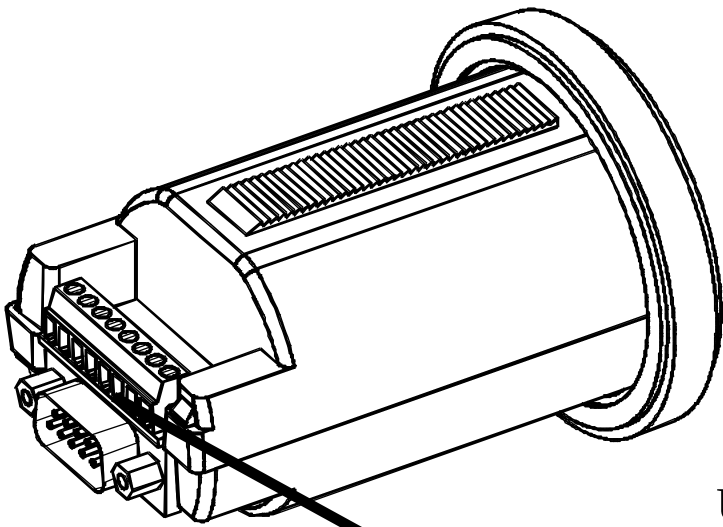
4 Twisted pair cable. See Page 16 for part numbers.

# Meter Wiring Detail

Make the necessary wire connections to Your Meter as shown in the following diagram:

Color code shown for CECO 4 twisted pair cable. Part #s below:

PN 910007 -15'
PN 910009 -25'
PN 910010 -50'

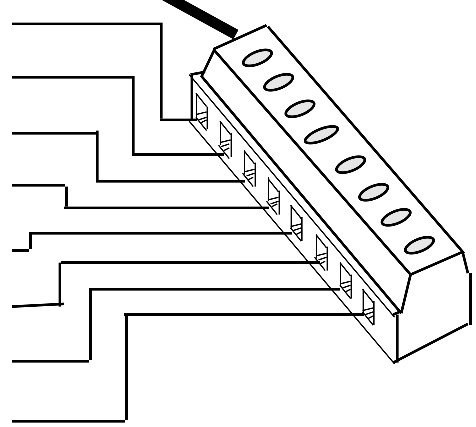


**CAUTION**

Use correct sized screwdriver for terminal screws. Tighten firmly but do not over-tighten to avoid damage

<u>Top Rear View</u>

-DC Meter Negative (BLACK) [1]
Shunt Sense Lead Load Side (GREEN) [2]
Shunt Sense Lead Battery Side (ORANGE) [3]
Battery Volt Sense (0-50V DC[1])(BLUE) [4]
+DC Meter Power (9.5-40V DC) (RED) [5]
Optional Temperature Sensor [6]
Optional Low Battery Alarm [7]
Not used [8]



1) For Voltages above 50V a Pre-Scaler must be used. See Options and Accessories Manual which supplied only if you have ordered an option.

# Setting Battery Capacity

The first time you use Your Meter, it assumes you have 200 Amp-hour lead acid batteries. If your battery capacity is different you must change the declared battery capacity. Follow these instructions to declare a new capacity:

A. Press and hold the **SET** button for 3 seconds to enter SET UP (and Advanced Functions) menu. SEL appears in the display. Press **SEL** and notice that the green V LED is on.

B. Press **SEL** again and note that the A light comes on. Press again and now the Ah LED is on and 200 appears in the display. This is the default battery capacity.

C. Now press and hold the **SET** button to scroll through battery size options. The display will show 1 Amp-hour increments from 10-40 Amp-hours of capacity, 5 Amp-hour steps from 40-100 Amp-hours capacity and 20 Amp-hour steps over 100 Amp-hours of capacity. If you continue to hold **SET**, after 4 increments the display scrolls faster. When the value you want appears, release the **SET** button. If you overshoot your capacity you will have to scroll all the way to 1980 Ahrs after which the display will roll over and begin scrolling up starting from 10 Amp-hours. NOTE: Versions of Your Meter prior to serial number 05000 increment only in 20 Amp-hour steps from 20 - 1980 Amp-hours .

D. After 10 seconds the meter exits the Set Up mode and the selected value is stored as the new battery capacity and the display returns to V (Volts).

Tip: All SET UP and ADVANCED FUNCTIONS begin with the **SET** button. SET UP is normally done at installation. The **SET** button may be **LOCK**ed to prevent unauthorized personnel from tampering with the **SET** functions. See "LOCK" on Page 25.

# Setting Up

There are four different ways that Your Meter can calculate the time of operation remaining. You may select present consumption level, a four minute rolling average, a sixteen minute, or a 32 minute rolling average.Which method is best for you depends on your installation. Most installations will find the four minute average appropriate. To SET UP follow the procedure outlined on Page 19. As you press the **SET** button the following values will appear, use the table below to choose the appropriate averaging period.

| | | |
|---|---|---|
| **Instantaneous:** | Time Remaining Set Up Display: | 000 |
| **4 Minute Average:** | Time Remaining Set Up Display: | 001 |
| **16 Minute Average:** | Time Remaining Set Up Display: | 002 |
| **32 Minute Average:** | Time Remaining Set Up Display: | 003 |

Operating Tip: Use the longest period of time you can to insure long term load variations are considered. If you want instant feedback, use the instantaneous display (no averaging) 000 display.

Caution: The time of operation display is an estimate of how long your battery can sustain a load. Wild variations in battery current, erroneously declared battery capacity, Peukert's exponent, temperature, and prior charge and discharge history may affect the accuracy of this estimate. Please use this display only as a guide. Remember Your Meter provides you with several important battery parameters. Using all of them, i.e. Voltage, Current, Amp-Hours consumed, and Time remaining should allow you to make an informed decision about the state-charge-of your battery. Do not rely on a single value to determine battery status or performance.

# Setting Puekert's Exponent

Pages 32-35 of this manual discuss Puekert's equation and its effect on battery capacity. The exponent used in Puekert's equation is critical to the proper operation of the bar graph state-of-charge display and the time remaining function. The default value of Peukert's exponent is 1.25. You may use the techniques described on pages 32 and 33 to calculate the appropriate exponent for your battery or you may use the tables on pages 34 and 35. Follow the instructions below to change your Peukert's exponent.

A. Press and hold the **SET** button for 3 seconds to enter SET UP (and Advanced Functions) menu. SEL appears in the display. Press **SEL** and notice that the green V LED is on.

B. Press **SEL** again and note that the A light comes on. Continue to press the **SEL** button until the letters F8 appear in the display. This will require eighteen presses of the **SEL** button . The right most LED of the bar graph with the legend **FUNC** under it will be lit.

C. Now press and hold the **SET** button. The default value of 1.25 (or the previously programed value) will appear in the display. The range of values is from 1.0 to 1.50. Holding down the **SET** button will cause the display to increment in 0.01 steps, after 4 increments the display scrolls faster. When the value you want appears, release the **SET** button. If you overshoot your capacity you will have to scroll all the way to 1.50 after which the display will roll over to 1.00 and continue incrementing. You also have to scroll all the way through to declare exponents between 1.00 and 1.50.

D. After 10 seconds the meter exits the Set Up mode and the selected value is stored as the new Peukert's exponent and the display returns to V (Volts).

# Low Voltage

## Low Voltage Sleep Mode

If the voltage on terminal #4, the Voltage sense terminal, falls below 10.0 Volts, the meter automatically goes into the sleep mode. The V function LED flashes to indicate the voltage is below 10.0V. When the Voltage rises above 10.0V the LED stops flashing. This feature reduces the power consumption of Your Meter which reduces the load on the battery, extending the operating time before the battery is completely dead. Also by reducing the power consumption, the meter is able to operate to a lower voltage without a reset of Amp-Hours. With this feature Your Meter will not reset unless the voltage falls below 9.2V if it falls very fast, or 7.15V if the Voltage drops slowly. **Electric Vehicle Users Note:** The Low Voltage sleep feature is defeated when Advanced Function F13 is used to activate the Voltage scaling to 100V or 500V.

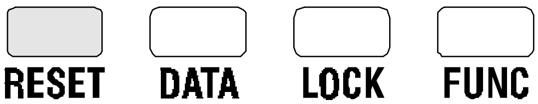
# Low Voltage

## Power Loss & Reset Annunciation

If the Voltage supplying terminal #5 falls too low an automatic shut down occurs. This voltage varies from a low of 7.2V to about 9.2 Volts depending on how fast the Voltage drops. When power is restored, the display defaults to the V function and the digital display flashes. Pressing either the ***SEL or SET*** buttons cancels the flashing display. If the meter is in the sleep mode when power loss occurs, the display will flash for ten minutes and then go to sleep if no buttons are pressed. Once asleep the first button press will wake the display in the flashing mode to annunciate the power loss. The second button press will cancel the flashing display.

# Reset and Lock

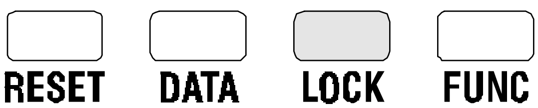
In addition to reporting primary system values, Your Meter is capable of many other front panel functions and will also display important historical battery data. The words below the bar graph display indicate which of these functions you are accessing. To use these functions you must read and understand the following section of this manual.




## Resetting Your Meter

**RESET** Resets Amp-hours to Zero and Resets Your Meter to Factory Values.

To **RESET** the Amp-hour display to Zero, **SEL**ect the **RESET** function as previously described. The letters A H will appear in the display. Press and hold the **SET** button. After 5 seconds the Amp-hour display will be reset to 0 and the letters A L L will appear. If you continue to hold down the **SET** for another 5 seconds all variables and functions are reset to the factory defaults.

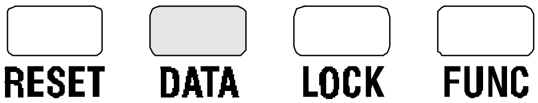



## Front Panel Locking

**LOCK** Prevents user access to Set Up and Advanced Functions.

To **LOCK** Your Meter, **SEL**ect the **LOCK** function as previously described. The letters L O C will appear in the display, indicating you are in the **LOCK** function. Press **SET** and the letters O F F appear indicating the front panel is not Locked. Press **SET** again and the letters O N will appear indicating the front panel is locked. Repeating this procedure toggles the lock off and on, the display will report O F F or O N, indicating Lock off or on.

# Historical Data




## Key Battery Data Displayed

**DATA** Key historical battery information is available through this function. Each time the **SEL** button is pressed while in the **DATA** mode the next piece of data is displayed. Select **DATA** as previously described to see **DATA**.

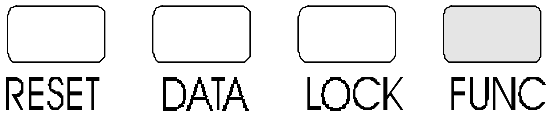
**CEF (**Displayed as `E99`): The Charging Efficiency Factor (CEF) is displayed. A display of `E99` indicates a 99% CEF. This number sets the rate at which Amp-hours are counted back up during charging. This is an Amp-hour CEF, not Kwhr efficiency. The Default setting is 90%. **NOTE:** If the CEF display has a `u` in front of it, this means the CEF has been selected by the user. See Advanced Function F06 for details.

**#CEF Recalculations** (Displayed as **`+I999`**): This is the number of times that the battery has been discharged more than 10% and then recharged until the Charged Parameters have been met. May be considered as the number of charge/discharge cycles the battery has experienced.

**Deepest Discharge** (Displayed as **`-i999`): **Shows the deepest discharge in Amp-hours recorded by the meter since its last **RESET** to factory defaults.

**Average Discharge** (Displayed as `i999`): The running average of all discharges as an Amp-Hour value since last **RESET** to factory defaults.

# Advanced Functions




## Advanced Functions

**FUNC** Allows setup of Advanced Functions.

To access the **FUNC** mode, **SEL**ect the **FUNC** mode as previously described. The letters F01 will appear in the display and the **FUNC** LED will be lit indicating you are in the **FUNC** mode. Continue pressing the **SEL** button until the function you wish to setup appears. Now press **SET** until the desired value or mode appears. Repeat this procedure until you have setup all of the desired advanced functions. Whatever functions you have setup will become active when the display reverts to its normal mode.

F1 **AUTO DISPLAY SCANNING**

Automatically scans through display with each value displayed for 4 seconds.

**DEFAULT: OFF** RANGE: OFF or ON

F2 **DISPLAY SLEEP**

Turns off everything except bar graph if there have been no keystrokes for 10 min. Touch **SEL** or **SET** to wake up unit.

**DEFAULT: ON** RANGE: OFF or ON

F3 **DISPLAY OR SET BATTERY TEMPERATURE**

If there is no external temp sensor and F-16 is OFF (factory default), this function sets ambient battery temperature used to caluculate *rate corrected* battery capacity which drives the LED bar graph and the Time remaining display. Feature not available on units with serial numbers prior to 05000.

**DEFAULT: 20C** RANGE: 0-40C STEP: 1C

If F-16 is ON and an optional external temperature sensor is connected between Pin 6 and Pin 8 (ground), F-3 will display temperature (0-99 C). Temperature will continue to be displayed until one of the two front panel buttons is pressed. Active Temperature display is annunciated by the absence of front panel status indicators. If 0 is displayed at normal (~ 20 C) temperatures, an open temperature probe should be assumed. If >99 is displayed at normal temperatures, a shorted probe should be suspected.

F4 **TURN ON KWHRS DISPLAY**

Kilowatt-hours are displayed in the Ah mode. (Note: The Kwhr display does not take into account Charging Efficiency. As a condition for a recalculation of the CEF and an automatic reset of Amp-hours to zero, 100% of the energy removed from the battery must be returned. The number in the Kwhr display must be zero or positive to allow a recalculation of the CEF and an automatic reset to zero. You may use this function to verify that this condition has been met.)

**DEFAULT: OFF** RANGE: OFF or ON

F5 **USE ALTERNATIVE ENERGY (AE) DEFAULTS**

Changes time to meet Charged Parameters to 1 minute from normal 5 minutes. (Also consider changing Charged Current to 4%)

**DEFAULT: OFF** RANGE: OFF or ON

F6 **MANUALLY SET CEF (Not Recommended)**

Allows manual set up of CEF. Displayed as two digits. Default display A90 indicates automatic CEF recalculation feature active. Returning to A90 from a user CEF turns the automatic CEF feature back on. If a user set up CEF has been selected it will appear as a UXX in the **DATA** mode. See Page 25.

**DEFAULT: A90** RANGE: 65-99 STEP: 1

F7 **SET TEMPERATURE COEFFICIENT**

Compensates for capacity change with temp. ~ 0.5% Cap/$^{o}$C. This coefficient must be supplied by the battery manufacturer. The default value is typical for lead acid liquid or gelled batteries.

**DEFAULT: 0.5** RANGE: .1-0.9 STEP: 0.1

F8 **SET PEUKERT EXPONENT**

Sets exponent for Peukert's equation. A setting of 1.0 defeats Peukerts calculation. See *Owner's Manual* pages 32-35 for a discussion of Peukert's equation and typical values for various batteries.

F9 **SET DISCHARGE FLOOR**

Sets the discharge floor used to calculate bar graph status and time of operation remaining functions. The factory default is to calculate time remaining, and bar graph based on a rate corrected discharge of 100% of declared Amp-Hour capacity. In other words, the bar graph will flash red when less than 20% of your rate corrected (Peukert Amp-Hour) capacity remains. Default time remaining is essentially "time till dead battery".

To ensure a margin of safety you may wish to set a different discharge floor. You may wish to set 80% or some other discharge floor for your bar graph.

**CAUTION:** If you set the discharge floor high, such as 50%, and continue to discharge well beyond this point, you will notice that the bar graph does not "fill up" until you have charged the battery above the discharge floor. In other words, if you set the discharge floor at 50% and discharge 75%, you must recharge back up to the 50% level before your bar graph and time of operation will again give you meaningful information.

**DEFAULT: 100%** RANGE: 50-100% Step: 5%

F10 - F13 **SEE OPTIONS MANUAL**

F14 **ENABLE LIFT LOCKOUT (Low Battery Contact Line)**

In versions of Your Meter equipped with the Lift Lockout (low battery contact line) Option, this function allows the Lockout to be disabled.
**DEFAULT: ON** RANGE: ON, OFF

F15 **<u>SOFTWARE REV.</u>** Displays revision of software.

Please note that the software changes incorporated in Your Meter now may not be retrofitted into earlier versions of this product. If Your Meter is serial number 005000 or larger, it will come with software version E05 or greater installed. Earlier versions of Your Meter do not support temperature sensing, small Amp-hour increments, separate sensing of meter power and battery voltage, and display 255 instead of CCC when the monitored battery is being charged.

F16 **<u>TEMPERATURE SENSOR ON/OFF</u>**
This function allows you to turn the optional external temperature sensor on or off. This feature is only operable when a temperature sensor has been connected between Pin 6 and Pin 8 of Your Meter. To fully understand this feature, please refer to F3 on pages 4-5 of this document. This feature not available on serial numbers prior to 05000.

**DEFAULT: OFF** RANGE: ON, OFF

F17 **<u>LIGHT TEST</u>**
This function confirms proper operation of Your Meter's front panel display. When the SET button is pressed in the F-17 mode, the two top left LEDs of the Bar Graph will display Orange/Yellow color, the numeric LED display will report -188.8 and all four FUNCTION indicators will be on. The display returns to normal when the SET button is released. Operation of the two top right (green) LEDs is confirmed when power is initially applied to Your Meter.

**DEFAULT: OFF** RANGE: ON when SET button is depressed. OFF when SET button is released.

# Peukert's Equation

Peukert's Equation describes the effect of different discharge rates on battery capacity. As the discharge rate increases the available battery capacity decreases. The table and examples on the following page illustrate this effect and how to use the table to estimate the exponent "*n*". The tables on pages 34 & 35 have typical values of "*n*" for common batteries.

Making two discharge tests, one at a high discharge rate and one at a low rate, that bracket your normal range of operation, allows you to calculate an "*n*" that will describe this varying effect. Your Meter uses an *"n"* equal to 1.25 which is typical for many batteries.

At some low to moderate discharge rate, typically a battery's 20 hour rate, the logrithmic effect of Peukert's Equation is greatly reduced. The effect of discharge rates smaller than this is nearly linear. Battery manufacturer specifications of battery capacity in Amp-hours is typically given at the 20 hour rate. From this description, if a battery is discharged at this rate for the period of time called out, you will be able to remove the rated capacity.

The equation for Peukert's Capacity ($C_p$) is:

$$C_p = I^n t \quad \text{where} \quad n = \frac{\log t_2 - \log t_1}{\log I_1 - \log I_2}$$

By doing two discharge tests and knowing $I_1$ & $I_2$ (discharge current in Amps of the two tests), and $t_1$ & $t_2$ (time in hours for the two tests) you can calculate $n$ (the Peukert coefficient). You will need a calculator that has a Log function to solve the equation above. See example on page 35. After you solve for your Peukert's coefficient you may enter it using Advanced Function F8.

# Peukert's Equation

The table below may be used to understand the effect of high rates of discharge on available battery capacity. It may also be used to estimate the exponent "*n*" for a battery after a single discharge test. The table is based on a 100 Ahr battery but may be used for any capacity battery by using an appropriately scaled current. See the examples below:

**PERCENTAGE OF AVAILABLE CAPACITY FROM A 100 Ahr BATTERY AT DIFFERENT DISCHARGE RATES USING DIFFERENT PEUKERT'S EXPONENTS**

**DISCHAGE RATE IN AMPS**

EXPONENT

| n | 5 | 10 | 16.7 | 25 | 50 | 75 | 100 | 150 | 200 | 250 | 300 | 400 | 500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| **1.1** | 100 | 93 | 88 | 85 | 79 | 76 | 74 | 71 | 69 | 67 | 66 | 64 | 63 |
| **1.2** | 100 | 87 | 78 | 72 | 63 | 58 | 55 | 51 | 48 | 46 | 44 | 42 | 40 |
| **1.25** | 100 | 84 | 74 | 67 | 56 | 51 | 47 | 42 | 40 | 37 | 36 | 33 | 32 |
| **1.3** | 100 | 81 | 69 | 62 | 50 | 44 | 41 | 36 | 33 | 31 | 30 | 27 | 25 |
| **1.4** | 100 | 76 | 61 | 52 | 40 | 34 | 30 | 26 | 23 | 21 | 20 | 17 | 16 |
| **1.5** | 100 | 71 | 55 | 45 | 32 | 26 | 22 | 18 | 16 | 14 | 13 | 11 | 10 |

Example #1: Suppose you have a 200 Ahr battery. Now discharge at a 50 Amp rate until the battery reaches 1.75V per cell (10.5V for a 12V battery). This would be equalivent to a discharge rate of 25A for a 100 Ahr battery. If the battery delivered 67% (134Ahr) the appropriate Peukert's exponent would be 1.25.

Example #2: A 100 Ahr battery with a Peukert's exponent of 1.3 will deliver only 41% of its capacity when supplying a 100A load.

# 1996 MINI-MAXIMIZER™

**MINIATURE, ULTRA LIGHTWEIGHT (350gm) MAXIMUM POWER POINT TRACKERS FOR SOLAR RACING CARS, WITH PLUG-IN REMOTE LCD DIGITAL METERING OPTION.**

**The race-proven AERL MAXIMIZER™ (M.P.P.T.) developed over the last 8 years and now patented around the world, has now been used in more than 150 solar racing cars from all parts of the world. Eight of the first 11 solar cars in the 1990 World Solar Challenge & half of the 55 teams in the 1993 W.S.C. have used the AERL MAXIMIZER™. In response to the continued customer demand, for 1995 AERL added a LCD digital metering module option to its standard range of nine race-proven MINI-MAXIMIZERS™. Typical efficiencies on all units are above 99% and available PV power ranges are 200W, 300W, 400W, 500W & 600Watts.**

## WHY RACE WITH A MAXIMIZER™

The PV output voltage at which maximum electrical power can be delivered from Photovoltaic Solar Panels used in solar racing car applications varies widely with changing sunlight intensities, incident sunlight angles and PV cell temperature levels. The PV cell temperature is greatly affected by the vehicle speed and typically varies over a 25-35 degree celcius range, between a standing and a moving vehicle. This results in a 10%-15% shifting of the PV voltage at which maximum power is delivered.

The battery voltage in solar race cars varies over a wide range also, with the differing charge and discharge levels. For lead-acid batteries, a 25-30% movement between the flat and full voltages is typical. For silver-zinc batteries it is typically 30-35% or greater. With these large variations in PV maximum power output voltage and even larger variations in the battery voltage, if the PV panel and battery are directly connected, the PV panel may unavoidably operate at a voltage (dictated by the battery voltage), that may be up to 25% above or below the ideal PV maximum power voltage. This will result in greatly reduced PV panel power output. To operate the PV panel at its highest instantaneous output power, it is essential to electronically decouple the panel voltage movement from that of the battery voltage movement, with a MAXIMIZER.

The MAXIMIZER™ employs an ultra-high efficiency DC-DC step-down, MOSFET converter and patented control methods to automatically hold the PV panel at its maximum power point voltage, while delivering the resulting maximum PV power to the battery bank at the ever-changing voltage required by the battery.

## 1996 MINI-MAXIMIZER™ FEATURES

1. All of the control electronics are contained in an epoxy sealed, computer tested, plug-in micro-electronic control hybrid.

2. **Ultra-high efficiency:** Typically 98.3%-99.3%. On the MINI-MAXIMIZER units, the 25mA operating current, which is normally supplied via a linear regulator from the PV array input voltage, is now supplied from an auxilary H.F. transformer supply **whenever the unit is actually delivering power to the battery.** Instead of consuming 5 watts at 200V input, for example, to run the control electronics, it now consumes less than 1 watt, greatly reducing total operating losses at desireable higher PV voltages.

3. Optional plug-in LCD Digital metering module for remote dashboard monitoring of PV input amps & volts and output battery charging amps & battery volts. The metering module also includes LED indication of when the battery has entered the fully charged 100% Final Float Mode as well as when it has discharged below 10%-20% state-of-charge, (approximately1.8-1.9V/cell for lead-acid batteries). This low battery LED remains lit until a full 110% equalise charge cycle has been completed following the previous low battery condition.

4. Electronic current limiting and thermal over-load protection provide a high degree of over-load and short-circuit protection.

5. 600A crow-bar diode and fused reverse polarity and input/output short-circuit protection.

6. Two-wire remote ON/OFF control terminals provided.

7. Plug-in, quick-release terminal block for rapid change-over.

8. Any number of units can be operated with outputs paralleled. (Only Mini-Maximizer outputs, **not** inputs can be paralleled.)

9. Tiny size: 145 x 115 x 65 mm. (Light-weight: < 350 grams)

10. All MINI-MAXIMIZERS™ can charge a wide selection of battery voltages up to a nominal 180V (on HV units), with DIP-SWITCH selection and TRIM-POT float level adjustment.

**BATTERY "FINAL FLOAT" VOLTAGE RANGES FOR POSITIONS # 1 to # 10 ON THE SELECTION DIP-SWITCH :**

**'NORMAL" Mini-Maximizers: 200B, 300B, 400B, 500B models**

| #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 |
|---|---|---|---|---|---|---|---|---|---|
| OFF | 13-15 | 26-29 | 39-43 | 52-57 | 62-71 | 75-85 | 87-99 | 99-114 | 111-128 |

**"HV" Mini-Maximizers: 200BHV through to 600BHV models**

| #1 | #2 | #3 | #4 | #5 | #6 | #7 | #8 | #9 | #10 |
|---|---|---|---|---|---|---|---|---|---|
| OFF | 22-27 | 45-53 | 67-78 | 88-103 | 110-129 | 132-155 | 154-179 | -- | -- |

11. **AUTO-EQUALISATION.** On each charge cycle, the battery will charge to a level 8-10% above the **"Final Float"** voltage. This will equalise the charge of each cell and then continue to float charge at the precise, 100%, user selected, **"Final Float"** voltage.

## RACE-TRIM MINI-MAXIMIZER MODELS

**UNITS ARE: NON-ISOLATED, COMMON POSITIVE, DC-DC, STEP-DOWN, HF SWITCHING POWER CONVERTERS.**

**Input open-circuit voltage ranges:** 60-170 Vo/c ("NORMAL")
(25 C. "cold cell" temperature) 99-250 Vo/c ("HV")
**Nominal battery voltage ranges:** Up to 108V ("NORMAL")
(refer to the tables above) Up to 180V ("HV")

**Model numbers designate the maximum rated design power:**

| | | | | | |
|---|---|---|---|---|---|
| **"NORMAL":** | | **200B** | **300B** | **400B** | **500B** |
| **"HV":** | **200BHV** | **300BHV** | **400BHV** | **500BHV** | **600BHV** |
| **I/P AMPS :** | 0-2.5A | 0-3A | 0-3.5A | 0-4A | 0-5A |
| **O/P AMPS :** | 0-2.5A | 0-3A | 0-3.5A | 0-4A | 0-5A |
| **Typ. Loss :** | 2-3W | 2-3W | 3-4W | 3-5W | 3-6W |
| **Price US$ :** | **$490** | **$520** | **$550** | **$590** | **$640** |

**LCD DIGITAL METER MODULE OPTION: Add US$190**
** Please specify length of ribbon cable required for meter. **

**SHIPPING:** Please add **US$20** per unit for air-express delivery.
**TERMS:** Pre-payment only. Please allow 8-12 days delivery.

# USING THE MINI-MAXIMIZER

**Please read the previous page first, before proceeding.**

WARNING: *THE RACE-TRIM MINI-MAXIMIZERS CAN OPERATE AT POTENTIALLY LETHAL DC VOLTAGE LEVELS. INSTALLATION MUST BE PERFORMED BY SUITABLY QUALIFIED PERSONNEL AND ALL APPLICABLE ELECTRICAL SAFETY CODES MUST BE FOLLOWED.*

*The Mini-Maximizer modules are supplied for use as sub-assembly components to form part of a larger electrical power system. As such, they are not supplied in any enclosure and should only be handled in the unenergised state with the plug-in power socket removed.*
***** Many parts of the componentry on the units, when energised, are at high DC voltage levels during operation.*****

*All Mini-Maximizers manufactured by AERL P/L have been thoroughly 100% tested and are guaranteed to meet all of the applicable specifications at the time of shipping. The Mini-Maximizers are supplied by the manufacturer or their agent for charging solar racing car batteries as electrical sub-assemblies only, under the express condition that no lawful responsibility is implied or accepted by the above parties, save those non-excludeable conditions stated or implied by any state or federal legislation, for any damage to any persons, structure, equipment or property associated with the correct or otherwise use of the Mini-Maximizer modules. Use of this product for any purpose other than PV maximum power extraction and battery charging in solar racing cars voids the warranty. AERL guarantees this product against defects of materials and workmanship for a period of 12 months from the date of installation, providing it is used strictly in accordance with the specified voltage & current limits. Damage from external voltage surges (lightning etc), output short-circuits, water / moisture or physical damage sustained while in use is not covered by this warranty. Any defective product should be returned carriage paid to AERL or their agent.*

# CONNECTING THE MINI-MAXIMIZER

**COOLING.** **The MINI-MAXIMIZERS use their own circuit board as a heatsink and although very efficient, should always be mounted in the vehicle so that their air is always gently changing.**

The Race-Trim Mini-Maximizers are fitted with a quick-release plug-in terminal block for rapid and safe change-over. The units can thus be removed in safety without disconnecting individual wires. To remove the terminal block, hook three fingers behind the raised section containing the terminal screws and pull this section firmly, horizontally away from the fixed male pins section. The disconnection requires considerable force as the socket firmly locks in place. The terminal block accepts up to 4.5 sq.mm cables.

***** ALWAYS DOUBLE-CHECK THE POLARITY *****

**MOUNTING.** To avoid damage to the large electrolytic capacitors, the units should be mounted with the circuit board parallel to the plane of the ground. Otherwise excessive vehicle vibration may cause fatigue failures.

**ON/OFF CONTROL.** The remaining 3 terminals, marked "REMOTE CONTROL": "LINK for ON" & "LINK for OFF" are for a remote on/off switch to be connected - if required. This is an electronic ON/OFF control that shuts down the Mini-Maximizer. (It is a 3V logic control with respect to the (-) PV INPUT and involves only 0.1mA of current). ****The first piano DIP switch on the Battery Selector is also an ON/OFF switch.****

**OUTPUT FUSE.** The negative output is fused with a high voltage , low loss 25A fuse, printed on the top side of the PCB. When the "FUSE" blows, the white-ringed section blows away. The fuse will blow if, (1) The battery is connected backwards or (2) The inputs are shorted, while the battery is connected.

REPLACING A BLOWN FUSE. A spare printed circuit board fuse is supplied. If the built-in fuse is blown, unplug the terminal connector socket, rectify the cause of the fault and then remove the top extra set of nuts and spring washers from the fuse mounting bolts. **Place the spare fuse, metal side downwards on the bolts, place the spring washers on the bolts and then the second set of nuts. Tighten firmly to achieve a good electrical connection.**

*** NEVER SHORT THE INPUTS OR OUTPUTS ***

**USING A BLOCKING DIODE or AN OUTPUT CIRCUIT-BREAKER.** A blocking diode is usually used in PV battery charging systems to prevent the battery discharging back into the PV panels at night. This is ideal for unattended PV systems, but wastes valuable power in the diode. In solar racing cars, where every watt counts, it is recommended to connect the outputs from the Mini-Maximizer(s) via an isolating circuit-breaker, instead of using a blocking diode. This circuit breaker can be simply opened at night to stop reverse power flow from the battery. This will also power down the Maximizer(s) and prevent them from drawing their supply current from the battery bank at night and also prevents the panels from remaining electrically "ALIVE" at night. The Maximizers do not have to be switched off before opening or closing this output isolator at night or the next morning as they have an automatic idle-down mode when their output is open-circuited. A single, double pole, miniature circuit-breaker, with one pole in each positive and negative line is recommended. **Place this circuit-breaker after the common output bus connection, if multiple Maximizers are being used.** If a blocking diode is used as well, place an appropriately heatsunk and rated diode after the Maximizer(s) output. This will serve both functions of night-time reverse power blocking and stopping the Maximizer power supply drawing from the battery.

**WARNING: In wet Lead-acid systems, keep circuit-breakers away from the battery, as a tripping breaker represents a possible hydrogen gas ignition source.**

**MULTIPLE L.E.D. INDICATORS.** When voltages are present at the input and output terminals, red "INPUT ALIVE" & "OUTPUT ALIVE" LED's light up to indicate this. When the battery voltage reaches a level corresponding to fully discharged, (eg. 1.8-1.9V/cell for lead-acid batteries), a red "LOW" LED lights and remains lit until the battery is fully equalised and recharged, at which point the red "FULL" LED lights up. **This shows if the battery has been below the "LOW" level on the last discharge cycle.**

# PANEL DESIGN & MAXIMIZER SELECTION

**MINI-MAXIMIZER DESIGN RULE:** The "hot cell", **(that is the 50-60 degrees celcius PV cell temperature), Maximum Power PV Panel Voltage should be selected to be equal to OR above the fully charged & equalised (110%) battery bank voltage level. This will always ensure maximum PV power delivery.**

**IMPORTANT NOTE:** PV Cell open-circuit and operating voltages increase by 0.4% / Deg.C. for decreases in temperature and decrease by 0.4% / Deg.C. for increases in cell temperature.

**When referring to a battery, the following will be used to describe its voltages - REST Volts / FLOAT Volts / EQUALISE Volts.**
e.g. For a lead-acid cell this typically gives **2.06V / 2.34V / 2.55V**
e.g. For a Silver/Zinc cell this typically gives **1.5V / 1.81V / 2.00V**

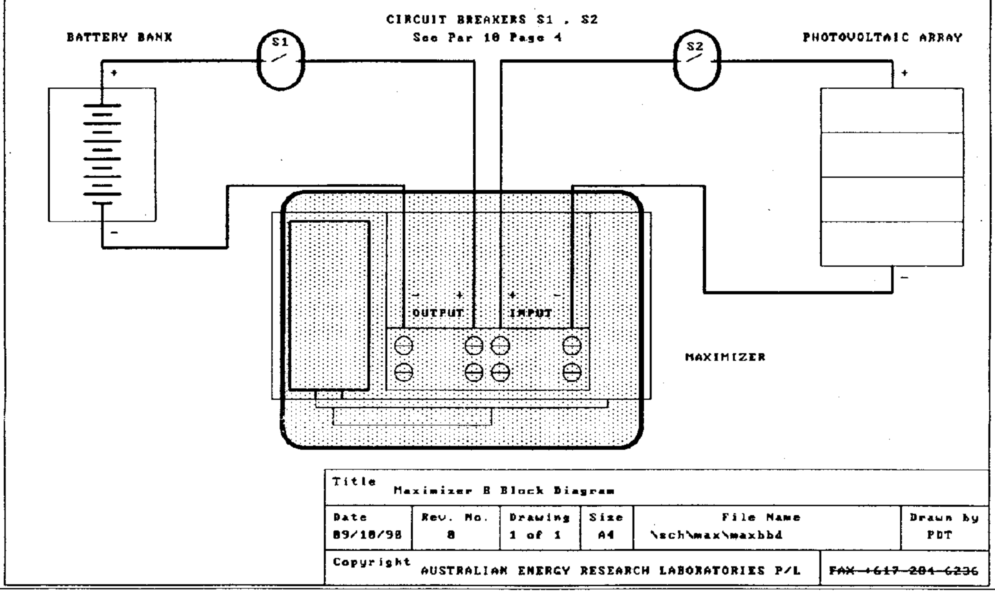
**A TYPICAL RACING CAR DESIGN EXAMPLE**

**THE BATTERY:** 60 x lead-acid Cells (124V / 140V / 153V)
Using the above DESIGN RULE; the "hot cell" PV maximum power voltage should thus be 153V or above. **To obtain the approximate "hot cell" PV open-circuit voltage, multiply this figure by 1.3 times.** This gives a voltage of $199V_{o/c}$ "hot". **To obtain the 25 degree C. ("cold cell") PV open circuit voltage, multiply the "hot cell" $V_{o/c}$ value by 1.15.** This gives 229Vo/c "cold". This would then require the use of an "HV" Mini-Maximizer, with the float selection dip-switch on setting # 7, with the 20 Turn "Final Float" trim-pot adjusted to give a final float voltage of 140V. (The equalise level will then be around 153V, 9% above the 140V).

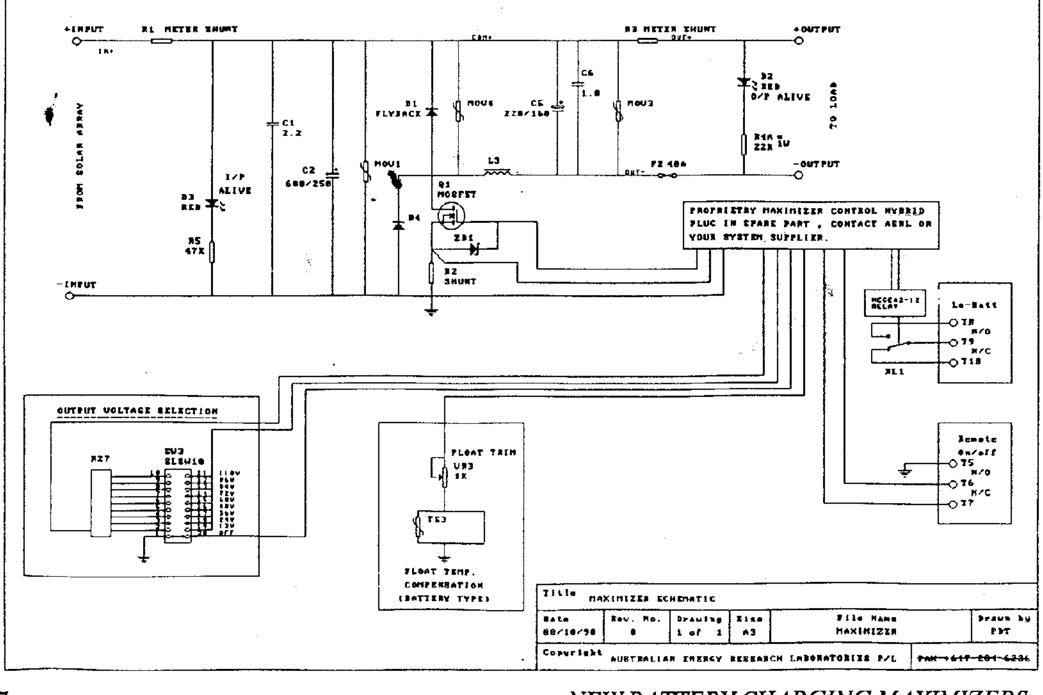
**(NOTE: The Mini-Maximizer samples the PV panels every 30 seconds to update the Maximum Power Point Voltage). FEB1996**

| NOMINAL (lead-acid) BATTERY VOLTAGE | DAILY CYCLED SYSTEMS : (SET THIS FINAL FLOAT LEVEL) | | | | | FLOATING STAND-BY SYSTEMS : (SET THIS FINAL FLOAT LEVEL) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| ACTUAL BATTERY TEMP : | -10C | 0C | 10C | 20C | 30C | -10C | 0C | 10C | 20C | 30C |
| 2V CELL REFERENCE | 2.51 | 2.48 | 2.45 | 2.42 | 2.39 | 2.41 | 2.38 | 2.35 | 2.31 | 2.28 |
| 12 V | 15.1 | 14.9 | 14.7 | 14.5 | 14.3 | 14.5 | 14.3 | 14.1 | 13.9 | 13.7 |
| 24 V (2 x 12V) | 30.2 | 29.8 | 29.4 | 29.0 | 28.6 | 29.0 | 28.6 | 28.2 | 27.8 | 27.4 |
| 36 V (3 x 12V) | 45.3 | 44.7 | 44.1 | 43.5 | 42.9 | 42.0 | 41.7 | 41.1 | 40.5 | 39.9 |
| 48 V (4 x 12V) | 60 | 59 | 59 | 58 | 57 | 58 | 57 | 56 | 56 | 55 |
| 60 V (5 x 12V) | 75 | 74 | 73 | 72 | 71 | 72 | 71 | 70 | 69 | 68 |
| 72 V (6 x 12V) | 91 | 89 | 88 | 87 | 86 | 87 | 86 | 85 | 83 | 82 |
| 84 V (7 x 12V) | 106 | 104 | 103 | 102 | 100 | 101 | 100 | 99 | 97 | 96 |
| 96 V (8 x 12V) | 121 | 119 | 118 | 116 | 114 | 116 | 114 | 113 | 111 | 110 |
| 108 V (9 x 12V) | 136 | 134 | 132 | 131 | 129 | 130 | 129 | 127 | 125 | 123 |
| 110 V (55 x 2V) | 138 | 136 | 135 | 133 | 131 | 132 | 131 | 129 | 127 | 125 |

## Typical System Connection Diagram for the MAXIMIZER




## MAXIMIZER SCHEMATIC ©1992 AERL. (Patent Pending)



# Winston Solar Challenge

## Educational Materials Available

### Video Tapes:

**Instructional Video:** *"How to Build a Solar Car"*
Developed by Dr. Gary Vliet, Professor of Mechanical Engineering, University of Texas at Austin. Presented by the Winston Solar Challenge, Central & Southwest Services, and the Texas Solar Energy Society.

**Race Video:** *The 1997 Winston Solar Challenge*
The complete five-day story of the 1997 Winston Solar Challenge, a cross-country race from Dallas to San Antonio.

### Instructional Materials:

**Rule Booklets** for the 1998-1999 Winston Solar Challenge

**Race Booklets:**
1997 Winston Solar Challenge - Dallas to San Antonio
1998 Winston Solar Challenge - At the Texas Motor Speedway

**Curriculum Guidelines**

**List of Suppliers**

Contact the Winston Solar Challenge to get copies of these video or print materials.
[972.867.6063 or Email: LehmanM743@aol.com]

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# The History of Solar Car Racing

## Electric Vehicles

The harnessing of electrical energy is one of mankind's greatest achievements. English chemist John F. Daniell was credited with developing the first "primary" cell, even though his work was a continuation of the research carried out in the late 1700's by Italian scientist Alessandro Volta.

Volta's battery (or galvanic cell), called the "Voltaic Pile," consisted of silver and zinc discs separated with cardboard and soaked in salt water. Daniell's primary cell was more efficient, but French physicist Gaston Plante took this discovery one step further in 1959 with the invention of the lead-acid storage battery. The modern "dry cell" battery was developed just a few years later by another Frenchman, Georges Leclanche.

By 1900, 38% of pleasure cars sold in the U.S. were electrically powered, 22% gasoline-driven, and 40% steam-driven. But steam had had its day, and the wealthy showed an overwhelming admiration for the quietness and simplicity of the electric cars.

The French BGS Electric Car held the world's distance record on a single charge - 290km in 1900. Electric-powered taxis plied the streets of New York, but country trips were a constant problem. With no power source at their country estates to recharge the batteries of their carriages, the wealthy found electric transport had its limitations. The development of the automobile starter motor by Charles Kettering in 1911 ended the electric vehicle's hold on the market place.

The year 1912 was the high point for electric vehicles in the U.S. with almost 34,000 cars, trucks and buses registered for road use. This trend for electric vehicles went downhill from here with only limited use in specialized commercial applications.

The 1967 GM Electrovan was one of the most famous examples of the fuel cell electric vehicle. Using NASA technology, GM engineers developed a means of using a non-liquid membrane and platinum electrodes which acted as a catalyst in the presence of hydrogen and oxygen. If was effective, but costly.

Electric vehicles even made it to the moon with the Apollo 15, 16 and 17 missions. Despite this success, the EV has continued to be plagued with problems that restrict its use, namely cost, range, weight and recharging time. Solutions to these problems are within our grasp, and are presently being implemented in the new electric vehicles rolling off the assembly line.

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## Storing the Sun's Energy

Photovoltaic cells are constructed of semiconductor materials which can absorb light and convert it to electricity. The term itself is derived from the Greek "photo" meaning light, and "voltaic" from Alessandro Volta.

The most commonly used semiconductor is silicon (sand), one of the most abundant materials on earth. The manufacture of an active silicon cell, at its simplest level, involves growing a crystal of silicon from reservoirs of molten silicon. Silicon in its pure form is somewhat poor in its ability to conduct electricity, therefore it is necessary to add small amounts of impurities. The type of impurity used in this "doping" operation is dependent on whether we want the semiconductor to conduct positive or negative charges.

As a rule, phosphorous will be added to produce a silicon that will conduct negative charge (electrons) and is referred to as an n-type silicon. The addition of Boron to the silicon will produce the opposite effect, conducting positive charges (hole), and is referred to as a p-type silicon.

Once these two types of silicon have been produced and are layered into a single cell, a junction is formed called a p-n junction. It is at this junction that a voltage potential is developed, similar to that at the terminal of a storage battery.

When sunlight strikes the cell in the vicinity of the p-n junction, each photon generates an electron and a hole. The electron and hole move apart; this movement of charge constitutes and electric current which can be made to do some external work.

Typically, the potential difference in a silicon solar cell is of the order of 0.5 volts, while the current produced depends on the amount of sunlight, area of the cell, etc. By connecting several cells, in series or parallel, the voltage or current output of the array can be increased. The energy is then stored in batteries.

Today's batteries are rated by their ampere-hour capacity. Generally, 5, 10, or 20 hour rates have been common measures. For example, if a battery is rated at 60 amp/hours at the 20 hour rate, it means that the battery can be discharged at 3 amps for 20 hours without the voltage falling below 1.75 volts per cell, or 10.5 volts in the case of a 12-volt battery.

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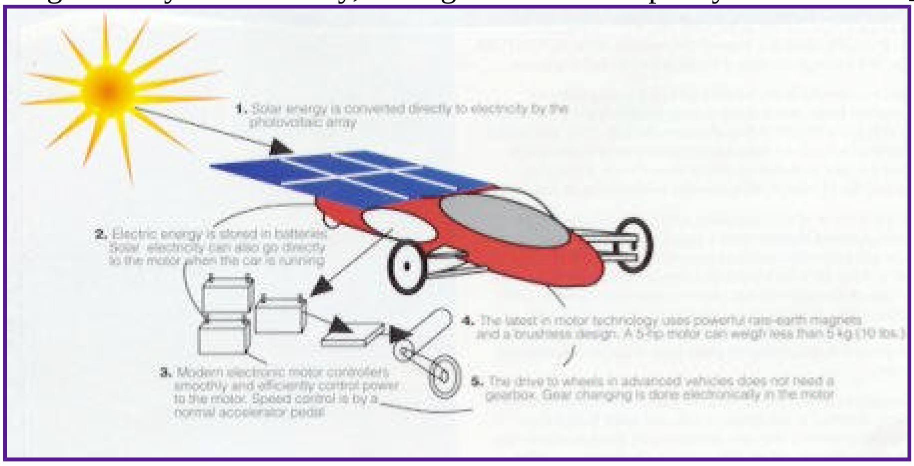
## The History of Solar Car Racing

Hans Tholstrup and Larry Perkins pioneered solar car racing when they completed an epic Solar Trek from Perth to Sydney (Australia) in 1983. What followed was a series of solar car races designed to increase public awareness. .

The 1987 Australian World Solar Challenge saw 23 participants inaugurate the first such race, followed by the European Tour de Sol, the American Tour de Sol, and the SUNRAYCE. Some spectacular corporate and college vehicles adorned these early races and are pictured below.


Like the electric automobiles of the early 20th century, a solar car is powered by electricity. Unlike its predecessor, a solar car uses only sunshine for fuel. Photovoltaic cells on the car collect and convert the energy from sunlight directly into electricity, making the vehicle completely self-sufficient. [See diagram]




The main objective of any solar car manufacturer is to build an efficient, "winning" vehicle. Design considerations included hundreds of tradeoffs, but certain elements are essential.

Reliability is an important design factor. A vehicle which performed well without any major breakdowns would cover the race distance in less time.

The overall shape of a solar car is another important design factor. Teams had to determine how and where they would mount the solar cells for maximum energy grain. They also had to decide how to maintain low weight and minimize aerodynamic drag.

A typical solar car generates 700-1500 watts of power, or about 1-2 horsepower. This makes aerodynamic drag and rolling friction critical considerations.

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## The History of the Winston Solar Car Race

The excitement surrounding solar races eventually filtered down to the high school level. Hawaii's Konawaena Solar Team's early venturing into the World Solar Challenge showed that high school students had the ability to step up to this level of engineering. This was reaffirmed in 1993 when the Winston Solar Car Team blazed new roads when it took part in the '93 SUNRAYCE. Although not an official entry (due to its high school status), the Winston kids showed that high school students have the "right stuff."

After several years of racing, the Winston Team concluded that there were two significant problems facing the world of high school solar car racing:

· There was no race designed exclusively for high school solar car teams. · There was no education program designed to help a high school develop their own solar car programs.

How could a high school with limited funding, materials, and technology hope to successfully compete against corporate or college vehicles. For instance, the winner of the 1996 World Solar Challenge, the Honda "Dream," costs between twenty to thirty million dollars; the average cost of a college-level vehicle is two hundred thousand dollars. The Winston students wanted a way to level the playing field so that money would not produce the "racing edge." This is accomplished by placing limits on the costs of solar car construction through restrictions on solar cells and batteries.

The Winston Solar Challenge is designed exclusively for high school entrants. Rather than being just a race, it is the product of a two-year education program designed to help schools develop their own solar projects. Through curriculum materials, on-site visits, and workshops, Winston students work with 350 schools in 5 countries to share their knowledge, reduce the time it takes to start a project, and help motivate students in science & engineering.

The first Winston Solar Challenge was held in 1995. Ninety schools participated in the project; nine schools actually started the construction of a solar car. By race day, three teams had qualified for the race, a 3-day two hundred mile race around the Dallas/Fort Worth Metroplex.

The 1997 Winston Solar Challenge is a 5-day four hundred mile race from Dallas to San Antonio. Twenty-two schools (from 3 countries) are building vehicles; eight teams have already qualified for this race. The 1997 race is a cross-country event from Dallas to Los Angeles.

The Winston Solar Education Program strives to de-emphasize the intensity of competition, and encourages the sharing of knowledge and the development of new friendships. Our goal is to motivate students in science and engineering.

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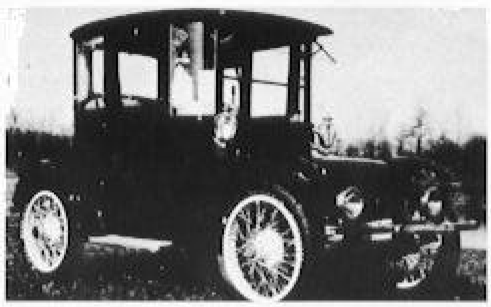
The successful 1983 BP Solar Trek spawned the Solar Challenge.


The 1915 Detroit Electric had a top speed of 40km/h.