

Set of Five Smart Gauges™ with Data Recording & Sensor Boards

GCG1-A

Green Cycle designers collected feedback from electric vehicle (EV) owners to develop gauges without compromise for BEVs. To help improve a vehicle's range performance, critical performance data can be recorded on a removable SD memory card for downloading to a PC or Mac for review. The *Green Cycle Data Analysis Tool* analyzes trip performance parameters such as distance traveled, changes in altitude, ambient air temperature and driving style. The analysis of this data can be used to significantly enhance driving efficiency while increasing a BEV's range.

System Diagram

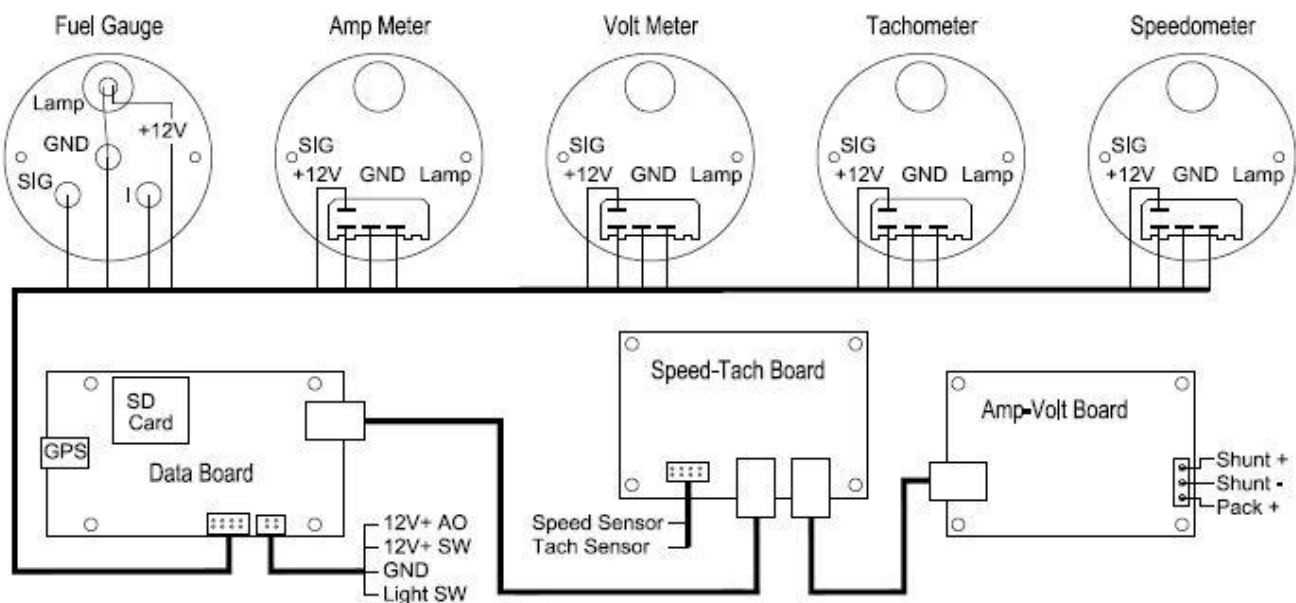


Figure 1

Rev. 0

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Gauges

The Fuel, Volt, Amp, Speed and Tach gauges are electrically programmable. Signals from vehicle sensors are received by the Speed-Tach and Amp-Volt boards and are transmitted to the Data Recording Board for processing and recording. The Data Recording Board sends variable frequency square waves to each gauge which causes the needle to point to the appropriate location on the dial face.

Circuit Boards

The Speed-Tach and Amp-Volt Boards receive data from pulse-type sensors (for speed and RPM), main pack voltage and a current shunt. This data is transmitted via CAN bus over RJ45 cables to the Data Recording Board for processing, storage, and distribution to the appropriate gauge. Incorporated on each of the three circuit boards are RJ11 programming ports. (Other than for the RJ11 port on the Speed-Tach Board being used for calibrating the speedometer, these ports are for factory use-only.)

Amp-Volt Board

Measurement of voltage, current and ambient air temperature are performed by the Amp-Volt Board. This board has three connections to the main battery pack and should be located outside the passenger compartment to isolate the pack's high voltage from the passengers. Since a temperature sensor is included on this board, it should be mounted out of direct sunlight. This board's design requires the use of a 50mV shunt with either 500A or 1000A current rating. This board is factory-configured for a 1000 Amp shunt and in the Amp-Volt Sensor Board section are instructions for accommodating a 500 Amp shunt.

Speed-Tach Board

The Speed-Tach Sensor Board reads pulses per revolutions from speed and RPM sensors (not included). Many motors and transmissions now include these sensors. If assistance is needed to develop custom sensors for a vehicle, email to support@greencycleddesign.com for help in selecting or building speed and tach sensors.

Vehicle speed data collection requires a pulse sensor connection to the transmission, drive wheel, or drive shaft between the transmission and differential. The Speed-Tach Board receives, processes, and transmits the sensor data to the Data Recording Board. Calibrating the vehicle's speed is as simple as locating a measured mile, pull the vehicle up to the start point, insert the supplied Speedometer Calibration Key into the RJ11 port, drive one mile at any reasonable speed, stop the vehicle, and remove the calibration key. Next, make a test drive and compare the distance traveled to either a GPS receiver or friend following you in another vehicle to confirm this calibration was done properly.

RPM data collection requires a pulse sensor connection to the motor. The Speed-Tach Board receives this signal and transmits the sensor data to the Data Recording Board. Four DIP switches need to be set by the user based on the type of sensor used. (Only DIP switches 1 and 2 are used, switches 3 and 4 are reserved and should always be in the OFF position.) Reference Table 2 for configuration settings (2, 4, 6, or 8 pulses per revolution) based on the type RPM sensor used.

Data Recording Board

The Data Recording Board receives packet data from the sensor boards, distributes this data to the appropriate gauge for display, and records key vehicle performance parameters. The Data Recording Board measures the vehicle's energy consumption and stores critical performance information on a 4GB SD memory card. Data transfer from each of the three gauge boards takes place at the rate of about 20 times per second via CAN bus.

Once the vehicle has completed a trip and is turned off, the driver can remove the SD memory card and upload the trip data into the *Green Cycle Data Analysis Tool* at www.GreenCycleDesignGroup.com/data/gallery2. This powerful tool for analyzing their vehicle's performance is available free of charge to Green Cycle customers.

Users are required to create an account to store and analyze their vehicle's performance data. The *Green Cycle Data Analysis Tool* is configured to protect private information via password protected user accounts. The user has the option to keep their data completely private, share their data with other Green Cycle customers, or provide unlimited access of their data to all visitors.

Green Cycle's Data Recording Board stores information with the file name as an incremental number from 0 through 255 on the SD memory card. When uploading the SD memory card data to the *Green Cycle Data Analysis Tool* website, the data is normalized to reduce file size and reviewed for duplicate file information. Each trip file begins on ignition start-up and ends when ignition is turned off. Information collected includes time, vehicle speed, motor RPM's, ambient air temperature, amperage going into the pack and amperage exiting the pack, voltage, and GPS longitude, latitude and elevations. Charts can be easily displayed on the Data Analysis Tool using the above static data. GPS coordinates and timing are written to the SD memory card once per second. The GPS data utilizes the National Marine Electronics Association (NMEA) sentence statements.

Below are examples of one of the many performance graphs and a route plotting, using Google Maps. All are available free to customers for use on the *Green Cycle Data Analysis Tool*.

Amp vs. Speed

Max Speed (mph): 31.06
 Avg Speed (mph): 9.22
 Time moving (sec): 322
 Time moving (prct): 51
 Time stopped (sec): 300
 Time stopped (prct): 49
 Max current (Amp): 520
 Avg current (Amp): 21

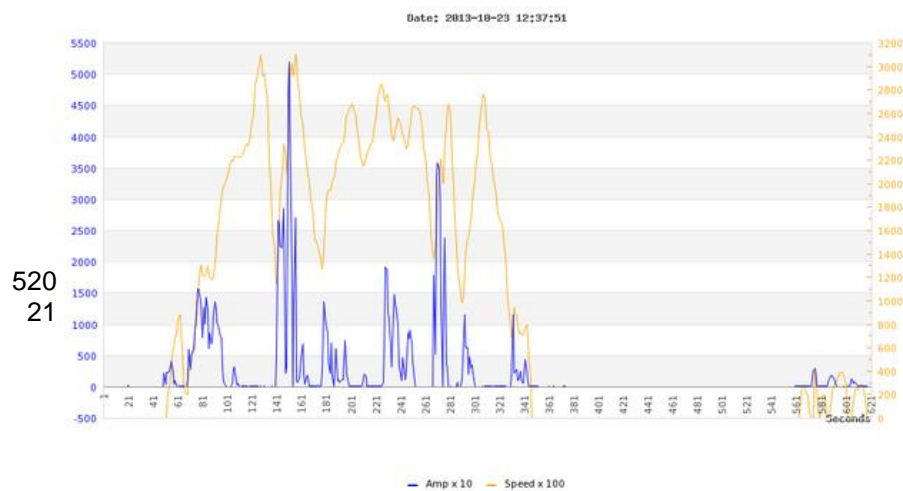


Figure 2

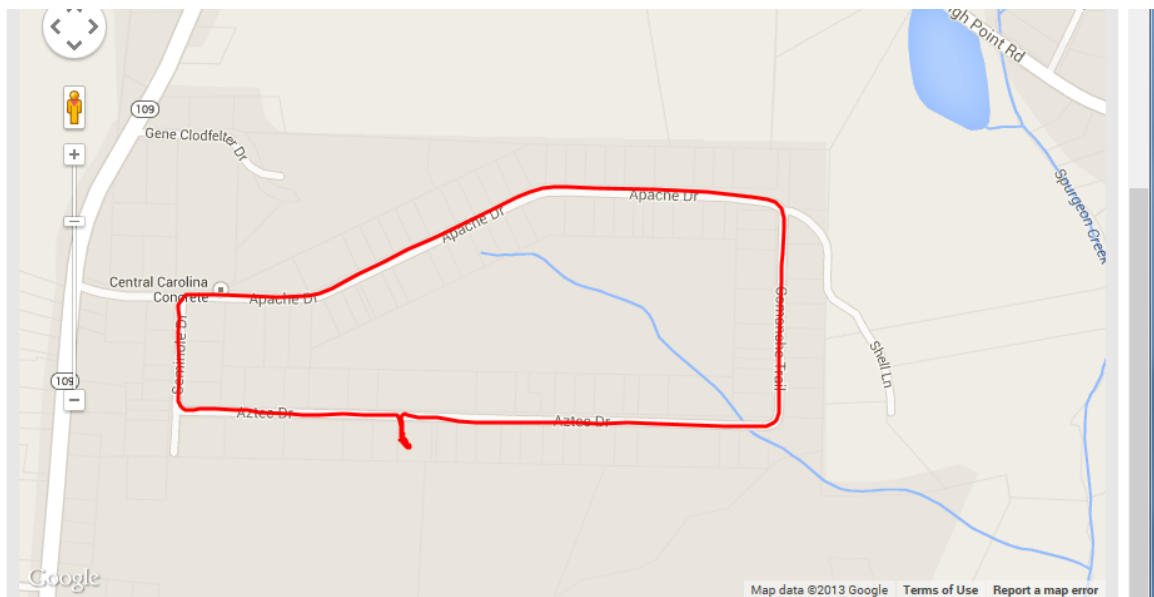


Figure 3

Gauge Installation Instructions

1. Determine a location on your vehicle's dash which is acceptable for easy viewing of each gauge. Take into consideration viewing through the steering wheel or other obstructions.
2. Look behind the dash panel where the holes are to be drilled. Move any wires out before drilling into the dash. Take note of any structural bracing and adjust the gauge location accordingly to miss these obstructions.
3. Drilling the hole for gauge placement requires two different sizes of hole saw bits. The 3" gauges require a 3.125" diameter hole saw bit and 2" gauges require a 2.063" diameter hole saw bit. Drill the appropriate size hole for each gauge and test fit the gauge to the hole. The gauge should fit snugly into the hole. Remove the gauge.
4. Locate a place to mount the Data Recording Board inside the passenger compartment while providing easy access to the SD memory card. Remove the board's box lid and mark the inside of the box in the approximate location of where it will be positioned within the BPV. Two #10 screw holes are adequate for mounting the board's box. (These screws are not included because the material thickness can vary greatly from one BPV to another.) Remove the circuit board to prevent plastic or metal filings from damaging the circuit board. Drill mounting holes in the box and reposition it on the BPV to mark the hole spacing for mounting the box. Clean the box interior and re-install the circuit board inside its enclosure. Be sure to provide easy access to the SD memory card and for inserting the speedometer calibration key during the gauge calibration procedure.
5. Another consideration when mounting the Data Recording Board is for good reception for the on-board GPS receiver. Minimizing the amount of metal or plastic from the BPV's body or dash above this board box will improve access to GPS satellites. A less than optimal board mounting location may result in longer times for the GPS receiver to acquire the satellite(s) (Note: Data is still usable, but, there may be a slight lag at startup time).
6. The Speed-Tach Board should be located within 36" of the speed sensor and the RPM sensor to reduce electrical noise. While it can be placed further away, the wires from the sensor to the Speed-Tach board could become susceptible to noise and the accuracy of the data may be compromised. We understand sometimes an optimal location may not always be available. Routing wires away from 12 volt or pack voltage will help keep noise levels low and Green Cycle's design also includes safeguards to minimize electrical noise.
7. For passenger safety, the Amp-Volt Board must be located outside the passenger compartment and within 12" of the shunt (Figure 8.B). This board is designed for connection to the high voltage battery pack and is electrically isolated from the other boards and gauges in this kit. Failure to install this board properly could result in serious injury or death due to electrical shock.

NOTE: Minimizing the wire length from the shunt to the Amp-Volt Sensor Board helps ensure noise immunity. Longer wire lengths to the shunt can induce electrical noise and may affect data accuracy. Routing these wires away from 12-volt or pack voltage also help to improve noise immunity. Green Cycle has tested several vehicle configurations with this board and has achieved the designed performance by keeping the wire length within 12" of the shunt. Since a temperature sensor is included on this board, it should be mounted out of direct sunlight.

8. Installing the CAN bus cables.

NOTE: Because each BEV configuration will require different cable lengths, RJ45 cables are not included in this kit. It is recommended to measure the lengths, cut the cables to length, fish the cables through the vehicle and then install the RJ45 connectors. Below are recommendations for configuring the RJ45 cables:

- a. Use a string or scrap length of wire to measure from the Data Recording board to the Speed-Tach board. Allow for a little slack and then cut the RJ45 wire harness to length. Insert RJ45 cable male connectors to each end per the schematic below using the standard RJ45 protocol for wire coloring.

(The pin out shown below for Ethernet wire colors follows EIA/TIA 568B)

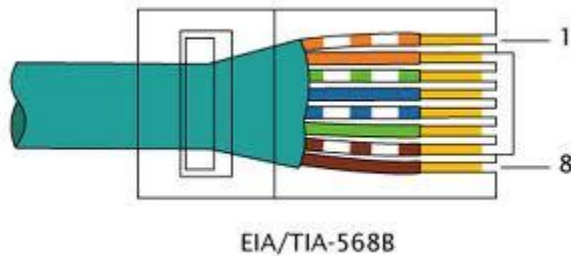


Figure 4

EIA/TIA 568B Wire Map	
1	White/Orange
2	Orange/White
3	White/Green
4	Blue/White
5	White/Blue
6	Green/White
7	White/Brown
8	Brown/White

Figure 5

- b. Use a string or scrap length of insulated wire to measure from the Speed-Tach Board to the Amp-Volt Board. Allow for a little slack and then cut the RJ45 wire harness to length. Insert RJ45 cable male connectors on each end per the schematic above using the standard protocol for wire coloring. These cables carry high-speed serial data. Splicing is not recommended as splices can induce noise which could introduce errors into the data being transmitted.

NOTE: Green Cycle has designed the gauge boards to be connected in a certain order to process, transmit, and record data properly. Locate these boards to allow easy access and plan your RJ45 cable routing per these instructions.

9. Connect the Data Recording Board (Figure 6.A and 6.B) to the gauges and the ignition switch, using the wire harnesses provided. Route the wires to follow a clean and neat path and allow 3" beyond the gauge hole. This extra wire length allows the installer to easily connect or disconnect the gauge. The wire harnesses contain 20AWG wire and may need to be extended due to distance from the Data Recording Board to the gauges. When splicing, use 20AWG wire of the same color and use an appropriate method of making a secure splice connection.. (See [Tips for Splicing Wires Guide](#) found under Support on the Green Cycle website.) The +12V SW, Light, and GND wires on the eight wire harness are designed to be daisy chained together using in-line splice connectors.
10. To complete a gauge installation, the system needs to be initialized. Table 1 displays the files that need to be created for initializing the gauges (and document the system's values in Table 1 under "Your Setting" for future reference. This information will be helpful should the BEV sustain a damaged cell or the user reconfigures the main battery pack's amperage/voltage.) The lithium cell manufacturer's recommendation for nominal voltage and cell amperage are needed along with a PC or Mac to create the initialization files. The Data Recording Board scans the SD memory card for these specific file names. The Data Recording Board recognizes the file name and then verifies the file with the same file name stored (by the factory) in on-board EEPROM. The new file values on the SD memory card will replace the previous values in the EEPROM. The Data Recording Board removes the file from the SD memory card. As long as these files are unavailable on the SD memory card, your system will default to the stored values in the EEPROM each time you start your vehicle.

Table 1

File Name	Your Setting	Description
AMPHOUR.TXT		Enter the standard amp hour rating of the battery pack configuration. For example, two 100Ahr cells in parallel would be a 200 Ahr pack configuration. Enter only integer values (for example "200").
CELLVOLT.TXT		The lithium cell manufacturer has provided you with a nominal cell voltage value. (Most lithium cells have a 3.20 nominal voltage.) Enter as a two point decimal (for example: "3.20").
CELLQTY.TXT		Enter the number of cells used to create the battery pack. Note: if cells are wired in parallel, do NOT count each cell, but, consider the cells in parallel as a single cell. (For example: If there are two 100 Ahr cells in parallel this would be considered as only a single cell. Another good way to calculate this is to count the number of battery management boards used in your battery pack. Enter only integer values (for example: "48").
DOD.TXT		Depth of Discharge (DOD) parameter defines the percent of stored energy which can be removed from the lithium cell per cell manufacturer's recommendation. Most lithium cells can achieve an 80% DOD. This is the theoretical amount of energy available for use. The default value is set to 80 and any new values should be set to a two-digit integer (for example: "80"). As the battery pack ages, DOD can be adjusted to account for any cell degradation. DOD can also be adjusted to compensate for driving in a region with adverse weather climate.

(Note: use a text editor such as Notepad, Word or TextWrangler to read these files. The files in the table above must be named as shown and saved in .TXT format.)

Data Recording Board - Measurements and Wiring Schematic



Figure 6.A

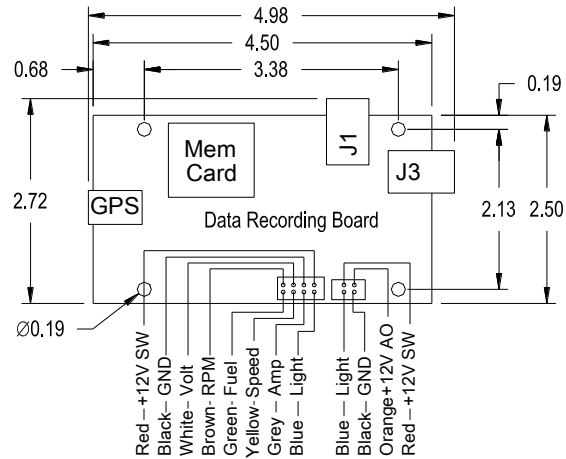


Figure 6.B

Speed-Tach Board - Measurements and Wiring Schematic

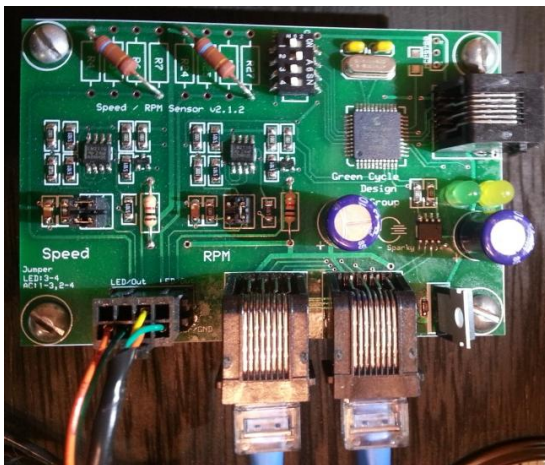


Figure 7.A

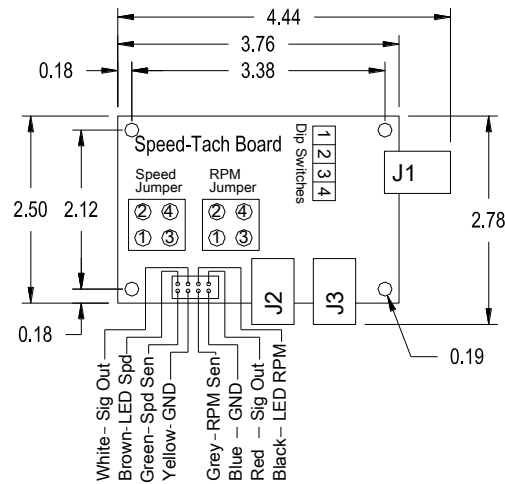


Figure 7.B

The Speed-Tach Board has a set of four DIP switches which require setting based on the number of pulses per revolution of the RPM sensor selected for the motor speed. The #3 or #4 DIP switches are reserved and should always be set to OFF. Settings for these switches should be configured per the Table 2 below.

When connecting the Speed-Tach Board to the Data Recording, it is suggested to use the J2 port and the J3 port for connecting the Speed-Tach Board to the Amp-Volt Board. Choosing either port to make the CAN-bus connection will allow the system to function properly (the suggestion is for consistency and make it easier to debug the system should any issues arise).

Table 2

RPM Sensor Type	Switch #1	Switch #2	Switch #3	Switch #4
2 pulses per revolution	On	On	Off	Off
4 pulses per revolution	Off	On	Off	Off
6 pulses per revolution	On	Off	Off	Off
8 pulses per revolution	Off	Off	Off	Off

(Should you need a different configuration than shown above, please contact Green Cycle for assistance)

The Speed-Tach Board has two sets of four jumper connections which require setting based on the type of sensor selected for either the motor RPM or speed. The Speed-Tach board is able to support two types of sensors. Setting AC supports a generated voltage output such as a sine wave output. The second method or the LED setting performs similar to a switch and can complete a circuit when activated. Examples include phototransistors or Hall effect sensors. Reference the settings configurations per the table below:

Table 3

RPM-Speed Jumpers	Speed Jumper	RPM Jumper
LED setting	Connect #3 to #4	Connect #3 to #4
AC setting	Connect #1 to #3	Connect #1 to #3
	Connect #2 to #4	Connect #2 to #4

Amp-Volt Sensor Board - Measurements and Wiring Schematic



Figure 8.A

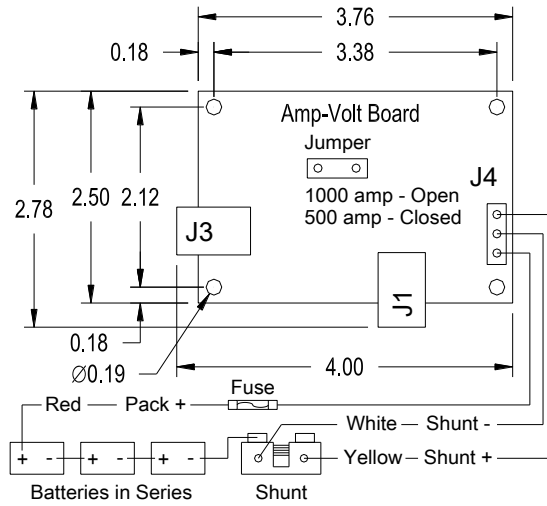


Figure 8.B

The Amp-Volt Sensor Board has a jumper option to support using either a 500 amp or a 1000 amp shunt. This board has been configured at the factory for a 1000 amp shunt.

Once the shunt type has been selected, set the jumper configuration appropriately. A jumper on the board (see Figure 8.B) allows the installer to switch between the two shunt amperage ratings. To implement the 500 amp setting, place the jumper between the two pins shown in the diagram above. Converting back to the 1000 amp setting can be done by removing the jumper altogether. Figure 8.B illustrates one wire connecting to the shunt (+) positive, one wire to the shunt (-) negative and one wire with an inline fuse (provided in the kit) connecting to the main battery pack (+) positive terminal.

Gauges

FUEL GAUGE



Size: 2" diameter

Dial: Analog, "E" to "F" showing % of pack capacity remaining

Theory of Operation - Battery pack capacity is programmed during initial set-up into the Data Recording Board. As energy is utilized – either consumed while driving or generated during regenerative braking or a charging cycle, the Data Recording Board calculates the battery pack capacity and displays the percentage of pack available on this gauge. The Data Recording Board reads and stores data up to 20 times per second during operation. During the charging cycle, the Data Recording Board logs data once every second and recognizes when the charger has completed its cycle. The fuel gauge is then set to "F" to indicate that the battery pack has been charged to its full capacity. This approach reduces the possibility of error accumulation over time.

NOTE: Whenever a new vehicle configuration is uploaded to the Data Recording Board, the fuel gauge will automatically default to displaying below "E" on the gauge dial. After the changes have been uploaded, complete a full-pack charge cycle to reactivate your fuel gauge for normal operation.

Calibration - Remove the SD memory card and use a PC or Mac computer to create the .TXT files noted in Table 5. Once these files have been created, insert the SD Card into the Data Recording Board. The Data Recording Board will recognize new values upon the next ignition key switch-on sequence and store the new values into its memory. Once the data is stored, these files will be automatically removed from the SD memory card. Should the vehicle's configuration change, recreate these files on the SD memory card and the Data Recording Board will upload the new values into its on-board memory.

AMMETER



Size: 3" diameter

Dial: Analog, 0 to 1500 amps, with geometric scaling

Theory of Operation – Green Cycle’s experience within the market place has led us to develop a custom analog gauge utilizing a large, easy to read dial with a geometric scale. The large spacing between 0 to 100 amps allows drivers the ability to instantly see how modifying their driving habits can maximize battery conservation. As the amperage draw increases, the distance between dial marks decreases. In theory, the higher amperage draw means the faster the driver is going and the greater need to keep their eyes on the road. Some gauge systems use “stylish” digital readouts; however, the large automakers which at one time widely used digital readouts for speedometers, have since gone back to analog readouts. In addition digital displays can suffer have sun washout. Years of research have determined the human brain has difficulty while driving comprehending numbers versus needle locations. Take a look at the new cars on the market today and see how many use digital displays for critical instrument readouts.

Calibration - Remove the SD memory card and use a PC to create the .txt files noted in Table 1. Once these files have been created, insert the SD Card into the Data Recording Board. The Data Recording Board will recognize new values upon the next key switch on sequence and store the new values into its memory. Once the data is stored, these files will be automatically removed from the SD memory card. Should the vehicle’s configuration change, – simply recreate these files on the SD memory card and the Data Recording Board will upload the new values into its memory.

VOLTMETER



Size: 3" diameter

Dial: Analog percent of pack voltage from -20% to 20%

Theory of Operation - Green Cycle has designed this gauge dial for easy reading during operation. We have chosen to use percentage of battery pack voltage instead of actual specific pack voltage. This allows the flexibility to use the same gauge with all types of BPVs. It also allows our customers the ability to change their pack voltage at any time (without having to swap out their gauge) should there be a need to increase/decrease the voltage of their BPV. Earlier you were instructed to enter parameters into the SD memory card. These settings will provide the proper calculations for the volt meter. The Data Recording board will take the number of cells times the nominal cell voltage and sets this value to 0 (zero).

Once the system is fully charged, you will see it show around +13% for a brief time and then drop to about 10%. This is the normal characteristic of the lithium cells. As you are driving, the needle will move constantly as you accelerate or coast. When the needle goes down to minus (-) 10%, upon removing your foot from the accelerator the needle should go back above 0. If it stays close to the minus (-) 10%, then the pack is near empty. Should the needle bounce back up to positive (+) 5%, the pack charge is above half full. (This is a good double check to make sure your system is operating properly.)

Calibration - Remove the SD memory card and use a PC or a Mac to create the .txt files noted in Table 5. Once these files have been created, insert the SD Card into the Data Recording Board. The Data Recording Board will recognize new values upon the next key switch on sequence and store the new values into its memory. Once the data is stored, these files will be automatically removed from the SD memory card. Should the vehicle’s configuration change, simply recreate these files on the SD memory card and the Data Recording Board will upload the new values into its memory.

TACHOMETER



Size: 3" diameter

Dial: Analog
0 to 7000 RPM's

Theory of Operation - This gauge is just as important for reading revolutions per minute of an electric motor as it is for reading the RPMs of a gasoline motor. This gauge helps ensure the driver does not over-rev the motor and keeps the motor's RPM's in the "sweet spot" for maximum efficiency and performance.

Calibration – This is a standard tachometer and does not require calibration. However, there are two DIP switches on the Speed-Tach Board which must be configured based on the number of pulses per revolution output of the selected RPM sensor. Reference the Speed-Tach Sensor Board mentioned above (Table 2 and 3) for proper DIP switch settings.

SPEEDOMETER



Size: 3" diameter

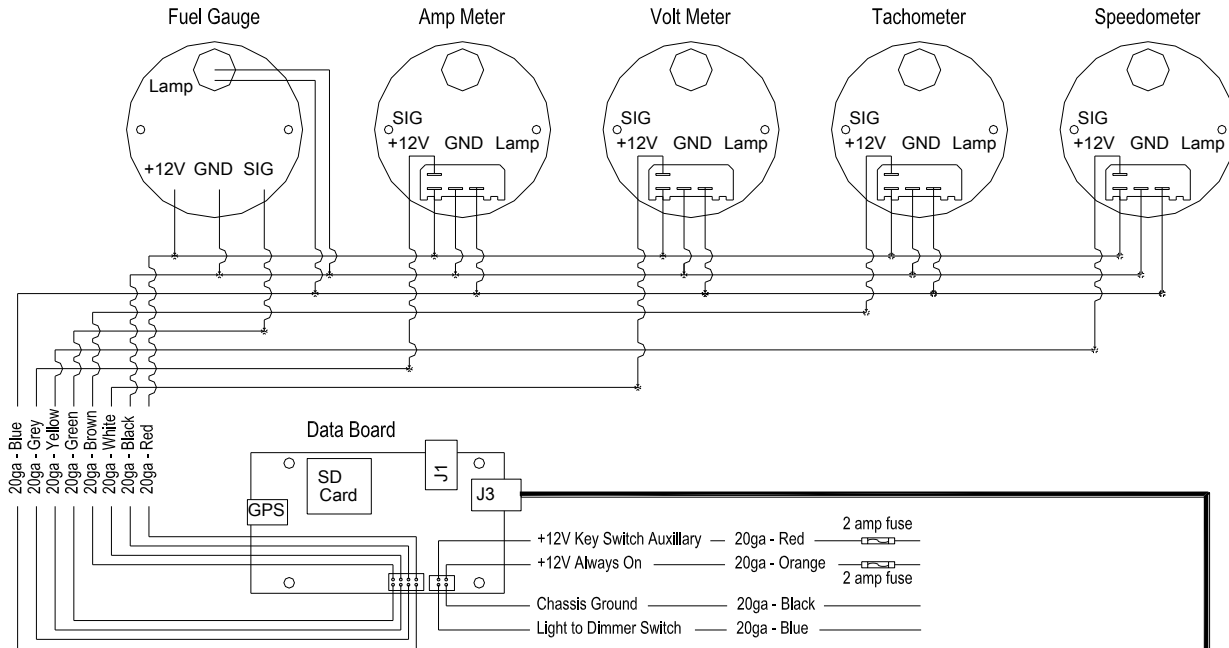
Dial: Analog
0 to 120 mph,
LCD odometer with
trip reset button

Theory of Operation – A speedometer and odometer are required on vehicles licensed for highway use. For vehicles not licensed for highway use, the speedometer can still be useful to let the driver know the speed at which the vehicle is traveling. The odometer is a digital display that includes a trip odometer function which can easily be reset using the push button on the dial face.

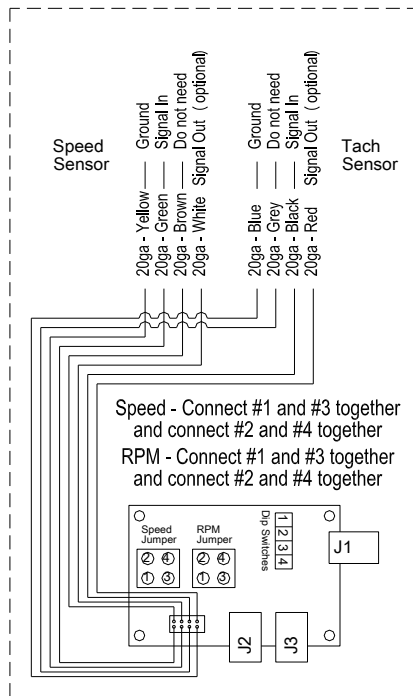
Calibration – Once the gauges have been installed and the system is working properly, the calibration sequence can be implemented for the speedometer.

1. Accurately measure a one-mile course. Choose a course which has little or no traffic and can allow for stopping safely.
2. Pull the vehicle up to the starting line. (Note: Only the number of revolutions per mile will be recorded. Speed, stopping, or starting will not affect the calibration. Avoid spinning tires or backing up as these will affect calibration.)
3. Insert the Speedometer Calibration Key provided in the kit.
4. Drive your BPV to the end of the one-mile course.
5. Stop the vehicle and remove the Speedometer Calibration Key.
6. Validate the calibrated speedometer's performance by following a friend's vehicle and or using a GPS receiver's readout.

System Wiring Diagram



Speed-Tach Board - AC Generator Type Sensor



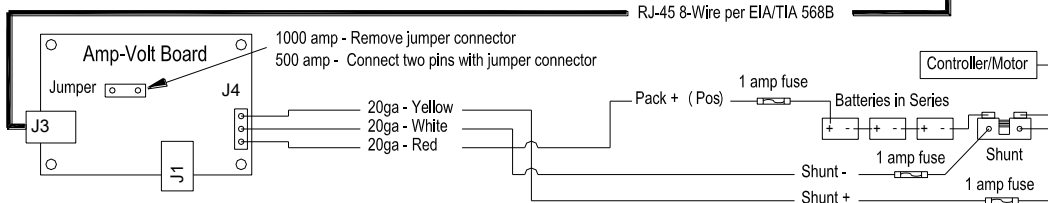
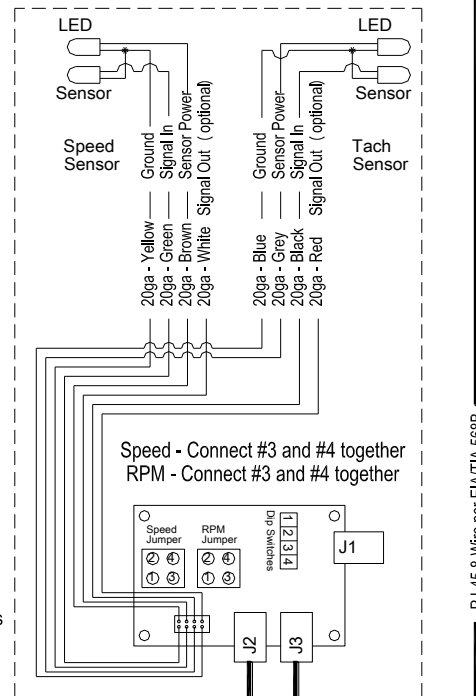
Dip Switch Settings for Tach

- 2 pulses per revolution
Switch 1 = On Switch 2 = On
Switch 3 = Off Switch 4 = Off
- 4 pulses per revolution
Switch 1 = Off Switch 2 = On
Switch 3 = Off Switch 4 = Off
- 6 pulses per revolution
Switch 1 = On Switch 2 = Off
Switch 3 = Off Switch 4 = Off
- 8 pulses per revolution
Switch 1 = Off Switch 2 = Off
Switch 3 = Off Switch 4 = Off

Notes:

- The Speed/Tach board is designed with a resistor (Newark p/n 94C-2460 160 Ohm, 2 watt) to work with LED photosensor from Newark p/n 45J-3438 with forward voltage drop at 1.5 mV, 100 mA or approved equivalent.
- It is acceptable to mix sensor styles using the appropriate jumper settings as pictured in this diagram.

Speed-Tach Board - Photosensor



RJ-45 8-Wire per EIA/TIA 568B

Customer Support

This datasheet has been written to provide owners and installers with necessary information about the operation and installation of these gauges and circuit boards. We have completed dozens of gas-to-electric vehicle conversions and ground-up BPV designs. We know first-hand the challenges of installing gauges. The team at Green Cycle has dealt with incomplete or non-existent information from other suppliers so we hope you find this information useful in getting the most enjoyment out of your GCG1-A gauges.

We want to hear from you should you have any technical questions (or just want to give us feedback on our products). Send us an email at support@greencycledesigngroup.com.

12 Month Limited Warranty

Green Cycle Design Group, LLC warrants to the consumer that all Green Cycle products will be free from defects in material and workmanship for a period of twelve (12) months from date of the original purchase. Products that fail within this 12 month warranty period will be repaired or replaced at Green Cycle's option to the consumer, when it is determined by Green Cycle Design Group, LLC the product failed due to defects in material or workmanship. This warranty is limited to the repair or replacement of parts in the Green Cycle products. In no event shall this warranty exceed the original purchase price of the Green Cycle products nor shall Green Cycle Design Group, LLC be responsible for special, incidental or consequential damages or costs incurred due to the failure of this product. Warranty claims to Green Cycle must be transportation prepaid and accompanied with dated proof-of-purchase. This warranty applies only to the original purchaser of product and is non-transferable. All implied warranties shall be limited in duration to the said 12 month warranty period. Breaking the instrument seal, modifying the circuit boards, improper use or installation, accident, water damage, abuse, unauthorized repairs or alterations voids this warranty. Green Cycle Design Group, LLC disclaims any liability for consequential damages due to breach of any written or implied warranty on all products manufactured by Green Cycle Design Group, LLC.