Operational Manual

Team 2 – Cummins Electric Vehicle Optimization

Members: Samantha Beeler (smb11g), Jakob Consoliver-Zack (jic13), Tyler Mitchell (trm13), Jeremy Randolph (jsr13e)

Sponsor: Dr. Michael Hays

Advisor: Dr. Juan Ordonez

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Abstract

The integrated automatic charging system developed offers the capability to operate an electric golf-cart and simultaneously charge its batteries. The automated nature of the design makes operating the system rather simplistic, however due to the plethora of individual components it is best to be familiar with the how the various sub-systems come together. Additionally despite the best design efforts some problems may occur which require troubleshooting. As such it is best to know the likely methods of failure and how these issues can be fixed. In order to ensure that issues occur less frequently regular maintenance by the user is required. Again in order to prevent user injury during both maintenance and operation it is the responsibility of the user to familiarize themselves with the system as detailed in this manual.

1 Introduction

Many semi-truck drivers sleep in their truck cabins and power the cabins heating and cooling systems off of the truck battery. This forces the drivers to waste fuel by leaving their engine on or to go without the systems. In harsh weather conditions where heating and AC are necessities this presents a safety risk. As such Cummins would like to sell a battery-engine package that would activate or deactivate the engine as needed. Cummins provided an electric golf cart to model a solution. The design developed integrates a battery monitoring system into the golf cart. The system consists of a microcontroller that continuously monitors the voltage of the batteries. Based on these readings the microcontroller will activate a generator that is mounted to the cart. This generator powers the cart's onboard battery charger as well as its DC motor and electrical systems. When the batteries are charged the microcontroller will turn off the generator and switch the motor power supply back to the batteries. In addition to monitoring the voltage of the batteries their temperature will also be continuously measured to ensure that they are at their optimal operating temperature. If the batteries are cold the microcontroller will activate the generator to power heating pads wrapped around the batteries as well as power the cart's motor. When the batteries are warm the microcontroller will shut off the generator and switch the motor back to battery power. Additionally if the batteries become too hot the microcontroller will activate the generator which will then power only the motor. This will ensure that there is no load applied to the batteries, allowing them to cool to an acceptable temperature. Once they have cooled the microcontroller with turn of the generator and switch the motor back to battery power. A more detailed explanation of how various parts of the system operate are outlined in the subsequent section.

2 Functional Analysis

The design developed consists of many different components in order to satisfy the design requirements. A simplified system diagram which includes the major components is given on the following page in Figure 1.

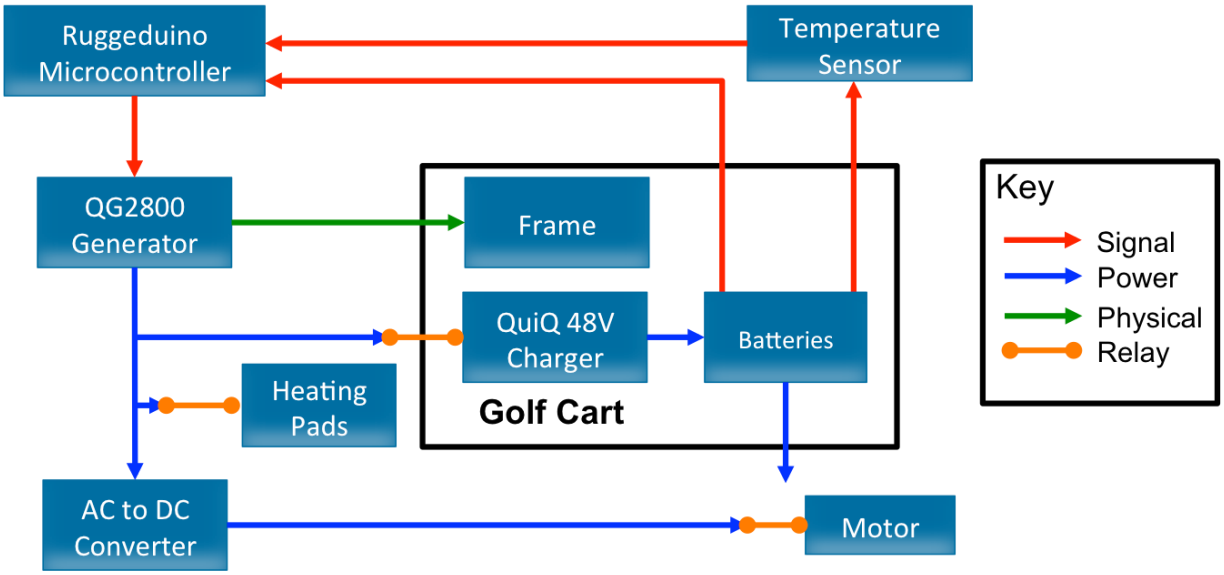


Figure 1. Simplified diagram of how the system operates.

Many of the parts in Figure 1 as well as additional minor components can be categorized into one of four sub-systems, which include the Power System, the Control Circuit, Auxiliary Loads, and Sensor Inputs.

2.1 Power System

As its name implies the power system involves which device(s) power the golf cart's 5,000W DC motor and other electrical systems [1]. The two possible motor power sources are the cart's six 8v lead acid batteries and a Cummins QG2800 Generator. The generator outputs AC power however the motor is DC so two RSP-1500 48V power supplies are used to convert the generator output into the necessary motor input. The motor power source is controlled via two high power double pole double throw relays that are controlled by the microcontroller. When the relays activate during operation there will be a voltage spike that could potentially damage the power supplies and/or batteries. In order to prevent this both the battery and power supply outputs are routed through high power diodes. Relevant technical information regarding the generator and power supplies are covered in the Product Specification section.

2.2 Control Circuit

The control circuit is the heart of the design as it is responsible for controlling power distribution through the system. A schematic of the control circuit is given in Figure 2:

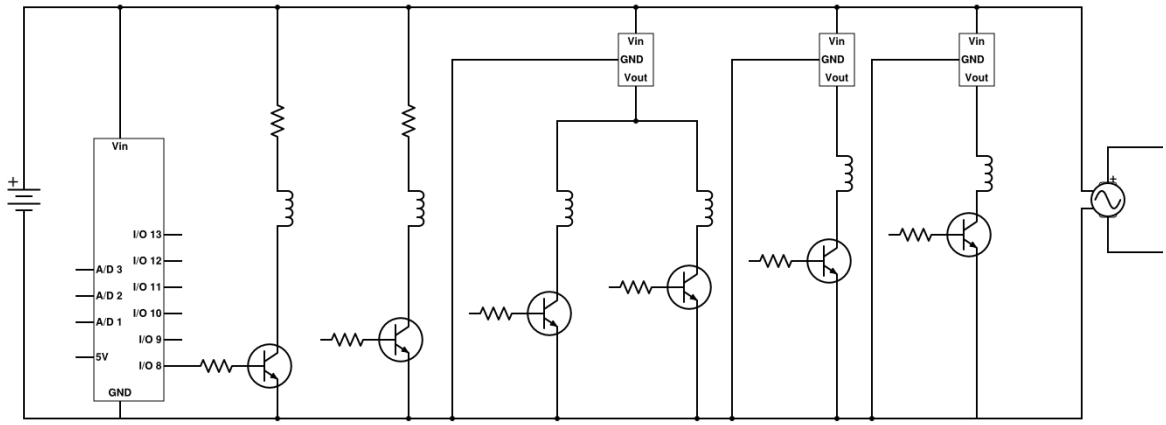


Figure 2. Circuit diagram of control circuit. The relay control coils are represented by the inductors. The leftmost box is the microcontroller while the three leftmost boxes are voltage regulators.

The control circuit consists of a system of transistor-relay pairs that are activated by the Ruggediuno microcontroller. The relays in the design control the activation/deactivation of the generator, the motor's power source, and when power is supplied to auxiliary loads such as the cart's on-board charger and the installed heating pads; these latter two components will be addressed later. When a relay needs to be activated a corresponding pin on the microcontroller applies a voltage to the base of the connected transistor allowing current to flow across it. As can be seen in Figure 2 the relay coil is connected in series to the transistor so that when the transistor is activated the relay coil is energized flipping the relay load switch. All of these relays as well as the Ruggeduino itself are powered off of the generator's 12V battery. In addition to controlling the relays the Ruggeduino is also responsible for powering the sensors as well as reading their respective outputs. The details of these sensors are outlined in the following section. Relevant technical information regarding the microcontroller is covered in the Product Specification section.

2.3 Input From Sensors

As previously mentioned the system will monitor the battery voltage and temperature. The voltage is monitored using a voltage divider that proportionally scales down the sum voltage of the cart's batteries to a voltage that the microcontroller can safely measure. The Ruggeduino then uses this value to calculate the actual voltage of the batteries. Due to the simplicity of this monitoring method there is little chance of hardware failure. The temperature is monitored using a TMP36 temperature sensor that is placed near the battery terminal connected to the motor. In addition to the voltage and temperature monitoring the output current of the charger is also monitored using DFRobot 50A Current Sensor. The current is monitored in order to confirm that the batteries are being charged. The measured current is a critical parameter that has a significant effect on the operation of the installed system, due to how the software on the microcontroller was programmed. As such relevant technical information regarding the current sensor can found in the Product Specifications section.

2.4 Auxiliary Loads

The auxiliary loads in this design are the cart's onboard 1200W QuiQ 912-48xx charger and the two 160W heating pads [2-3]. Both the charger and heating pads run off AC power so they are connected in parallel to the generator output as they do not need to be converted to DC via the power supplies. The load ends of the relays used to control the charger and heating pads are connected to the positive AC input wires of the respective devices. The charger datasheet can be found in Appendix A.

3 Project Specification

Careful consideration had to be taken when selecting the various components for the design. The operational parameters of the critical design components, which include, the generator, the power supplies, high power relays, the microcontroller, and the current sensor are outlined in the following sections.

3.1 Generator

The Cummins QG2800 outputs a maximum current of 20.8A at $120V_{ac}$, this equates to 2,500W of power [4]. The power supplied to the motor will be approximately equal to this value if the batteries have overheated, however if they require charging or if they are too cold the supplied power will be less. This is because the generator simultaneously powers the motor and either the 1,200W charger or the combined 320W heating pads. It was previously mentioned that the cart's motor is 5,000W therefore when the cart is operating off of generator power it will have a reduced maximum speed. This is a concession made due to the fact that a generator that could fully power the motor and charge the batteries, 7,200 W total, would be far too large to mount to the golf cart. If additional information on the generator is needed its operational manuals can be found online.

3.2 Power Supplies

As previously mentioned the motor in the cart is 5,000W, this means that when operating off of the combined cart battery voltage of 48V the maximum current to the motor will be about 104A, however during normal operation the actual current supplied to the motor will be about 70A [5]. The most amount of power supplied to the motor when operating off of generator power will be the generator's full output of 2,500W, assuming ideal conditions with no power loss. This power if supplied to the motor at $48V_{DC}$ corresponds to a conservative current estimate of about 52A going through the motor. The power supplies must be able to output current of this magnitude, however the RSP-1500 power supplies used can only output a maximum current of 32A [6]. In order to reach the necessary amperage the power supplies are arranged in parallel for a combined maximum output of 64A @ $48V_{DC}$. The actual nominal operating current will depend on what systems the generator is powering and will range from ~25A to ~47A. If additional information on the power supplies are needed the datasheet is in Appendix A.

3.3 Microcontroller & Current Sensor

The Ruggeduino analog pins are used to measure the inputs from the various sensors in the design. The AD channels are 10-bit and can handle an applied voltage up to 5.0V, yielding an

effective resolution of ~0.005V. The current sensor has can measure current ranging from -50A to +50A with an output of 0.04V per 1A. The overall resolution accounting for both that of the Ruggeduino and the sensor itself is about 120mA. This is an acceptable value since the charger outputs a current ranging from ~3.4A to ~20A, both well above the minimum resolution.

4 Project Assembly

The integrated system utilizes a QG 2800 Cummins generator to power the golf cart, via power supplies, when the batteries need charging or heating. This generator is fueled by propane and utilizes a 12 volt battery to operate. Mounts for these components were developed and their assembly is outlined in the following sections.

4.1 Generator

The generator and propane tank mount was fabricated out 2 in x 2 in x 1/8 in steel angle iron. The generator mount is composed of two U shaped brackets and two support pieces. With a U shaped bracket bolted to each side of the generator with 5/8” bolts. Each U shaped bracket is connected to a piece of steel angle with a 5/8” bolt. This steel angle runs across the rear seat support ensuring that the generator is secure under the back seat.

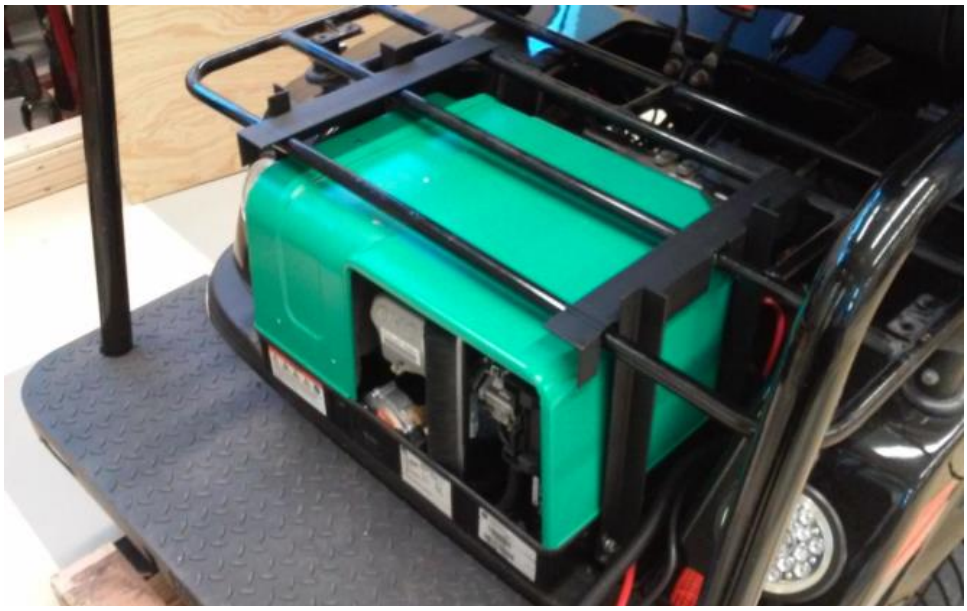


Figure 3. Photograph of the generator mount.

4.2 Propane Tank

The propane tank mount was designed to mount to the rear hand-rail that hangs off the back end of the cart. Utilizing the steel angle iron that was purchased for the generator mount, the team designed a mount to securely fasten the propane tank to the back of the cart. This design

Figure 4. Photograph of the propane tank mount with the tank inserted.

also allows for easy removability of the tank. The mount is secured to the golf cart's frame with 5/8" bolts. Protective material was added to the mount to ensure the metal does not rub against the tank and possibly cause sparks while in motion.

4.3 Power Supplies

These power supplies as well as the 12 volt generator battery are mounted in the golf cart's battery compartment underneath the front seat. The housing, see Figure 5, for the power supplies and generator battery was constructed using steel sheet metal that was cut to fit in the region between the cart's six 8V batteries and the wall of their enclosing compartment. A portion of the metal was cut out to allow the power supplies to slide into the plate. Brackets were added

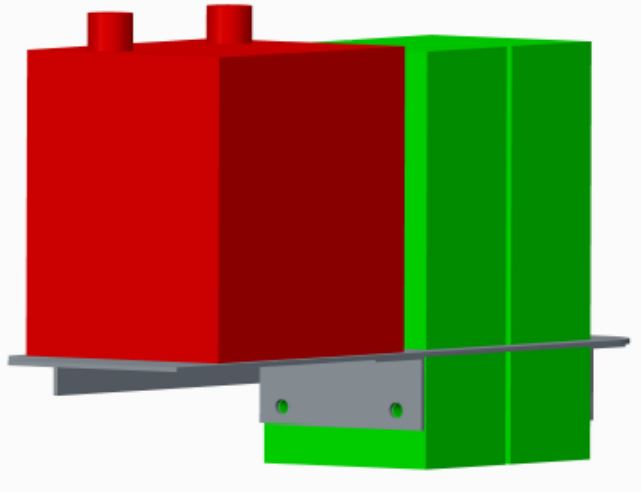


Figure 5. Assembly showing how the power supplies (green) are fastened to the plate and how the battery (red) rests on the plate.

to secure the supplies to the housing. Additionally the supplies are joined together with steel strips, one on either side, that are bolted to the supplies with M4 screws, as seen in Figure 6.

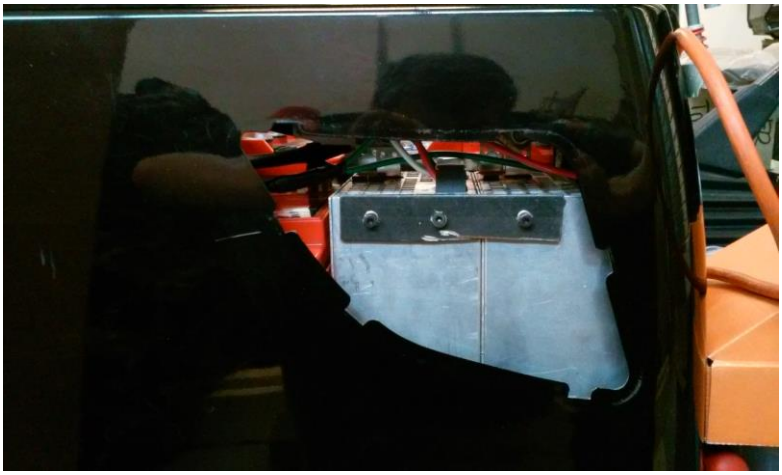


Figure 6. Side view of the power supplies mounted in the cart.

5 Operation Instruction

5.1 Starting the System

Due to the passive nature of the design operating it is quite simple as the majority of the processes are conducted by the system automatically. In addition to the instructions detailed in this section please consult the golf cart's manual for additional safety and operational instructions. **Before activating the system please ensure the following are true:**

1. The golf cart key is turned to the OFF position.
2. The FORWARD/REVERSE switch is in the NEUTRAL position.
3. The parking brake is on.
4. The cart's TOW/RUN switch is set to the RUN position.
5. The propane tank is secured to its mount.
6. The propane tank connections are secure and the valve is open.

If all of the above criteria are true the system can be safely activated. The systems ON/OFF switch is located in the center of the cart between the front and rear seats. To activate the system simply turn the switch to the ON position. When the system activates you should hear audible clicking which indicates that the various relays in the system are functioning properly. If the batteries are below 50% in charge or are too cold the generator will activate. If the batteries are fine in terms of temperature and charge then the cart will continue to operate off of battery power. An LCD screen located next to the charger will display the voltage of the batteries as well as their temperature. In addition if the batteries are being warmed, charged, or have overheated this will also be displayed on the screen. Once you are ready to drive the cart follow these steps:

1. Turn the golf cart key to the ON position.
2. Set the FORWARD/REVERSE switch to the desired setting.
3. Release the parking brake.
4. Drive

5.2 During Operation

Due to the generator outputting less than what the motor requires to fully power it the cart will have a reduced maximum speed of about 6 mph when operating off of generator power. If the cart is moving faster than this speed when the system switches from battery power the generator could be overloaded. When the generator starts there is a 30 second delay before the relays activate and change the motor's power source to the generator. So as not to damage the system, reduce cart speed to less than 5mph upon activation of the generator. For the best results and to further extend the lifetime of the system bring the cart to a complete stop before the power source changes.

5.3 Stopping the System

In the event that the automatic activation of the generator is not desired or if the cart is going to be stored for an extended period of time the system can be deactivated.

If the generator is **OFF** when attempting to deactivate the system follow these procedures:

1. Turn the golf cart's key to OFF position
2. Set the FORWARD/REVERSE switch to the NEUTRAL position
3. Ensure the parking brake is on.
4. Turn the systems ON/OFF switch to the OFF position.
5. Close the propane valve.
6. Set the cart's TOW/RUN switch to the TOW position.

If the generator is **ON** when attempting to deactivate the system follow these procedures:

1. Turn the golf cart's key to OFF position
2. Set the FORWARD/REVERSE switch to the NEUTRAL position
3. Ensure the parking brake is on.
4. Turn the systems ON/OFF switch to the OFF position.
5. Press the generator OFF button located on the right side of the generator housing.
6. Close the propane valve.
7. Set the cart's TOW/RUN switch to the TOW position.

6 Trouble Shooting

There are several possible reasons that the system may not start the most likely causes and their respective solutions are listed below:

NOTE: Before troubleshooting ensure the following:

1. The golf cart key is turned to the OFF position.
2. The FORWARD/REVERSE switch is in the NEUTRAL position.
3. The parking brake is on.
4. The cart's TOW/RUN switch is set to the TOW position.
5. The system switch is in the OFF position.
6. The generator is OFF.

1. Generator does not start.

a. Ensure that the propane valve is open and there is propane in the tank
b. Ensure that the generators circuit breaker is not tripped.
c. Ensure that the relay connections mounted on the generator are secure
d. Ensure the generator battery connections are secure
e. Ensure the generator has sufficient oil.
f. If problem persists consult the online generator manual.

2. Charger will not charge batteries

a. Ensure the charger is plugged into the power cord.
b. Ensure the charger terminals are connected to the carts batteries.
c. Ensure the charger relay connections are secure.
d. If problem persists consult the charger manual in Appendix A.

3. Cart won't move when the generator is on

a. Check that the relay connections are secure.
b. Check that the power supplies connections are secure.
c. Check that the high power relays are functioning when 12V is applied to the coil.

d. If problem persists do **NOT** attempt to fix the problem in ways other than those listed in this section. Consult a trained golf cart technician.

7 Regular Maintenance

The operator of the vehicle should routinely inspect the oil level of the generator. Low oil levels will cause the generator to be unable to start and render the system unable to function at its full capacity. The generator runs using 5W-30 weight oil and should not be overfilled as this can cause damage to the seals which in turn will make the generator inoperable as well. In addition to this general generator maintenance, the operator should check electrical connections and wiring for any loose connections or cracks in the wiring which could hinder system performance. The batteries of the golf cart should be checked monthly in order to ensure that there is a sufficient amount of acid in each one and if there appears to be a deficit, water should be added to get the levels back to a proper amount. The frame of the golf cart should be inspected for rust periodically as well. The brake fluid lines should be periodically inspected along with the brake fluid reservoir tank for leaks or low fluid levels, respectively. Lastly, the user should always ensure that the tires are properly inflated by using a pressure gauge and inflating the tires to the recommended levels in order to obtain the maximum efficiency and performance of the golf cart.

8 Spare Parts

The system was designed to robust in order to extend the overall lifetime, however there may be situations that would require a component to be replaced due to damage. As such a set of spare parts has been assembled and includes:

1. 4 power cable end connectors
2. 10 zip ties
3. An assortment of transistors and voltage regulators
4. An assortment of nuts for the high-power relays
5. The original generator activation/deactivation switch

If a component not found in this list of spare parts requires replacement please contact a trained technician for the required replacement specifications.

References

[1] Tomberlin. *E-MERGE 48SS*. Augusta: Tomberlin, n.d. Print.

[2] Product Manual For Quiq 912-48Xx. 1st ed. Burnaby: Delta-Q Technologies. Web pdf.

[3] "Zerostart 2800071 - Battery Heater | O'reilly Auto Parts". *Oreillyauto.com*. N.p., 2016. Web. 30 Mar. 2016.

[4] "*RV Generator Set Quiet Gasolinetm Series RV QG 2800*. 1st ed. Cummins, 2013. Web pdf.

[5] *E-Merge Service Manual*. 1st ed. Augusta: Tomberlin, 2010. Web pdf.

[6] *1500W Single Output Power Supply*. 1st ed. Mean Well, 2016. Web pdf.

Appendix A

QuiQ™ HF/PFC Battery Charger

Product Manual for:
QuiQ 912-24xx / 36xx / 48xx / 72xx

delta-q TECHNOLOGIES
Unit 3 – 5250 Grimmer St.
Burnaby, BC, Canada V5H 2H2
Tel: 604.327.8244 Fax: 604.327.8246
www.delta-q.com

SAVE THESE IMPORTANT SAFETY INSTRUCTIONS

This manual contains important safety, operating, and installation instructions – read before using charger.

Battery Safety Information

Warning: Use charger only on battery systems with an algorithm selected that is appropriate to the specific battery type. Other usage may cause personal injury and damage. Lead acid batteries may generate explosive hydrogen gas during normal operation. Keep sparks, flames, and smoking materials away from batteries. Provide adequate ventilation during charging. Never charge a frozen battery. Study all battery manufacturers' specific precautions such as recommended rates of charge and removing or not removing cell caps while charging.

Electrical Safety Information

Danger: Risk of electric shock. Connect charger power cord to an outlet that has been properly installed and grounded in accordance with all local codes and ordinances. A grounded outlet is required to reduce risk of electric shock – do not use ground adapters or modify plug. Do not touch uninsulated portion of output connector or uninsulated battery terminal. Disconnect the AC supply before making or breaking the connections to the battery while charging. Do not open or disassemble charger. Do not operate charger if the AC supply cord is damaged or if the charger has received a sharp blow, been dropped, or otherwise damaged in any way – refer all repair work to qualified personnel. Not for use by children.

INFORMATIONS IMPORTANTES DE SÉCURITÉ

Conserver ces instructions. Ce manuel contient des instructions importantes concernant la sécurité et le fonctionnement.

Information de Sécurité de la Batterie

Attention: Utiliser seulement sur les batteries 72V avec un algorithme approprié au type spécifique de batterie – voire le manuel. D´autres types de batteries pourraient éclater et causer des blessures ou dommages. Les batteries peuvent produire des gaz explosives en service normal. Ne jamais fumer près de la batterie et éviter toute étincelle ou flame nue à proximité de ces derniers. Fournisser la bonne ventilation lors du chargement. Ne jamais charger une batterie gelée. Prendre connaissance des mesures de précaution spécifiées par le fabricant de la batterie, p. ex., vérifier s´il faut enlever les bouchons des cellules lors du chargement de la batterie, et les taux de chargement recommandés.

Information de Sécurité Électrique

Danger: Risque de chocs électriques. Ne pas toucher les parties non isolées du connecteur de sortie ou les bornes non isolées de la batterie. Toujours connecter le chargeur à une prise de courant mise à la terre. Ne pas ouvrir ni desassembler le chargeur – referer toute reparations aux personnes qualifiés. Pas à l´usage des enfants.

Operating Instructions

1. Always use a grounded outlet. When using an extension cord, avoid excessive voltage drops by using a grounded 3-wire 12 AWG cord.
2. The charger will automatically turn on and go through a short LED indicator self-test (Models 912-xx0x will flash all LED's in an up-down sequence and Models 912-xx1x will alternatively flash its LED RED-GREEN) for two seconds. If the charger is connected to battery pack, a trickle current will be applied until a minimum voltage is reached. If the charger is used in an off-board application and the charger is waiting to be plugged into a battery pack, the charging algorithm number will be displayed for 11 seconds (see "Check / Change Charging Algorithm") before ultimately displaying an under-voltage fault (fault disappears when plugged into battery pack).
3. Once a minimum battery voltage is detected, the charger will enter the bulk charging constant-current stage. Models 912-xx0x will display the current to the battery on the bargraph and Model 912-xx1x will flash its LED GREEN off more than on to indicate <80% charge status. The length of charge time will vary by how large and how depleted the battery pack is, the input voltage (the higher, the better), and ambient temperatures (the lower, the better). If the input AC voltage is low (below 104VAC), then the charging power will be reduced to avoid high input currents (Models 912-xx0x 'AC' LED and Models 912-xx1x single LED both flash YELLOW). If the ambient temperature is too high, then the charging power will also be reduced to maintain a maximum internal temperature (Models 912-xx0x bargraph flashes and Models 912-xx1x single LED flashes YELLOW).
4. When the battery is at approximately 80% state of charge, the bulk stage has completed and an >80% charge indication is given (Models 912-xx0x turn on the '80%' LED and Models 912-xx1x will flash its LED GREEN on more than off). In the next phase known as the absorption or constant-voltage phase, the last 20% of charge is then returned to the battery. The charging could be terminated at this point if the vehicle requires immediate usage, however, it is highly recommended to wait until 100% charge indication is given to ensure maximum battery capacity and life.
5. A low current "finish-charge" phase is next applied to return and maintain maximum battery capacity (Models 912-xx0x will flash the '100%' LED).
6. When Models 912-xx0x '100%' LED or Models 912-xx1x single LED is continuously GREEN, the batteries are completely charged. The charger may now be unplugged from AC power (always pull on plug and not cord to reduce risk of damage to the cord). If left plugged in, the charger will automatically restart a complete charge cycle if the battery pack voltage drops below a minimum voltage or 30 days has elapsed.
7. If a fault occurred anytime during charging, a fault indication is given by flashing RED with a code corresponding to the error. There are several possible conditions that generate errors. Some errors are serious and require human intervention to first resolve the problem and then to reset the charger by interrupting AC power for at least 15 seconds. Others may be simply transient and will automatically recover when the fault condition is eliminated. To indicate which error occurred, a fault indication will flash RED a number of times, pause, and then repeat.
   [1 FLASH] Battery Voltage High: auto-recover
   [2 FLASH] Battery Voltage Low: auto-recover
   [3 FLASH] Charge Timeout: the charge did not complete in the allowed time. This may indicate a problem with the battery pack (voltage not attaining the required level), or that the charger output was reduced due to high ambient temperatures.
   [4 FLASH] Check Battery: the battery pack could not be trickle charged up to the minimum level required for the charge to be started. This may indicate that one or more cells in the battery pack are shorted or damaged.
   [5 FLASH] Over-Temperature: auto-recover. Charger has shutdown due to high internal temperature which typically indicates there is not sufficient airflow for cooling – see Installation Instructions 1). Charger will restart and charge to completion if temperature comes within accepted limits.
   [6 FLASH] QuiQ Fault: an internal fault has been detected. If Fault 6 is again displayed after interrupting AC power for at least 15 seconds, the charger must be brought to a qualified service depot.

Maintenance Instructions

1. For flooded lead-acid batteries, regularly check water levels of each battery cell after charging and add distilled water as required to level specified by battery manufacturer. Follow the maintenance and safety instructions recommended by the battery manufacturer.
2. Make sure charger connections to battery terminals are tight and clean.
3. Do not expose charger to oil, dirt, mud or to direct heavy water spraying when cleaning vehicle.

See flip side for **Product Specifications** and **Installation Instructions** for qualified personnel.

Specifications

DC Output – see Operating Instructions

QuiQ Model: 912-	24xx	36xx	48xx	72xx
Voltage-nom (V)	24	36	48	72
Voltage-max (V)	33.6	50.4	67.2	100
Current-max (A)	25	21	18	12
Battery Type	Specific to selected algorithm			
Reverse Polarity	Electronic protection – auto-reset			
Short Circuit	Electronic current limit			

AC Input

All models	
Voltage-max (Vrms)	85 – 265
Frequency (Hz)	45 - 65
Current-max (Arms)	12A @ 104VAC (reduced 20%<104V)
Current – nominal (Arms)	10A @ 120VAC / 5A @ 230VAC
AC Power Factor	>0.98 at nominal input current

Operation

Charger Model: 912-	xx0x (10 LED)	xx1x (1 LED)
AC ON	Solid YELLOW	LED Active
AC LOW	Flash YELLOW	Flash YELLOW
Thermal Cutback	Flash Bargraph	Flash YELLOW
<80% Charge Indicator	-	Short Flash GREEN
>80% Charge Indicator	Solid YELLOW	Long Flash GREEN
100% Charge Indicator	Solid GREEN	Solid GREEN
Fault Indicator	Flash RED	Flash RED
DC Ammeter	LED Bargraph	-
Bat Temp Compensation	Automatic	Optional
Maintenance Mode	Auto-restart if V<2.1Vpc or 30 days elapse	

Mechanical

All models	
Dimensions	28.0 x 24.5 x 11.0 cm (11 x 9.7 x 4.3")
Weight	<5 kg (<11 lbs) w/ standard output cord
Environmental	Enclosure: IP46
Operating Temperature	-30°C to +50°C (-22°F to 122°F), derated above 30°C, below 0°C
Storage Temperature	-40°C to +70°C (-40°F to 158°F)
AC input connector	IEC320/C14 (require ≥1.8m localized cord)
DC output connector	OEM specific w/ 12AWG wire

Regulatory

Safety	
EN 60335-1/2-29	Safety of Appliances/ Battery Chargers
UL2202	EV Charging System Equipment
UL1564 2nd Edition	Industrial Battery Charger
CSA-C22.2 No. 107.2	Battery Chargers- Industrial
Emissions	
FCC Part 15/ICES 003	Unintentional Radiators Class A
EN 55011	Radio disturbance characteristics (Class A)
EN 61000-3-2	Limits for harmonic current emissions
EN 61000-3-3	Limits of voltage fluctuations and flicker
Immunity	
EN 61000-4-2	Electrostatic discharge immunity
EN 61000-4-3	Radiated, radio-frequency, EMF immunity
EN 61000-4-4	Electrical fast transient/burst immunity
EN 61000-4-5	Surge immunity
EN 61000-4-6	Conducted Immunity
EN 61000-4-11	Voltage variations immunity

Installation Instructions

WARNING: The output of chargers with greater than 48V may pose an energy and/or shock hazard under normal use. These units must be installed in the host equipment in such a manner that the output cable and battery connections are only accessible with the use of a tool by qualified personnel.

1) Determine Mounting Location:
While its sealed nature allows the charger to be mounted virtually anywhere, the choice of mounting location and orientation is extremely important. For optimum performance and shortest charge times, mount the charger in an area with adequate ventilation. The charger should also be mounted in an area that will be relatively free of oil, dirt, mud, or dust since accumulations within the fins of the charger will reduce their heat-dissipating qualities. Optimal cooling also occurs when the charger is mounted on a horizontal surface with the fins vertical. More airflow from below the charger will help cool the fins, so mounting above open areas or areas with cut-outs for airflow is desirable. Contact Delta-Q for information on other mounting orientations. As the charger may get hot in operation, the charger must be installed such that risk of contact by people is reduced. The charger's AC plug must be located at least 18" above the floor/ ground surface and the status display must be visible to the user.

2) Mounting Procedure:
Mount the charger by the mounting plate using appropriate fasteners (i.e. 1/4" or M6 with locking hardware). For UL2202 compliance, a 12AWG green bonding wire with ring terminals must be attached from the bonding stud located on the front of the charger (identified by ⏚) to the vehicle frame. The vehicle connection must be made using corrosion resistant hardware (e.g., a #10 stainless steel machine screw with at least two threads of engagement and, if required, a paint piercing washer).

3) DC Battery Connection Procedure:
a) The green wire outputs battery voltage when the charger is not plugged into AC to provide an interlock function – see Fig. 1. **If used, a user-supplied 1A fast-blow external fuse must be installed inline to prevent damage. Shorting or drawing more than 1A may damage charger and void the warranty.**
b) Securely fasten the black ring terminal from the charger to the negative terminal ("-", "NEG", NEGATIVE") of the battery pack.
c) Check that the correct charge algorithm is being used – refer to section 4). Securely fasten the red ring terminal to the positive terminal ("+", "POS", "POSITIVE") of the battery pack.

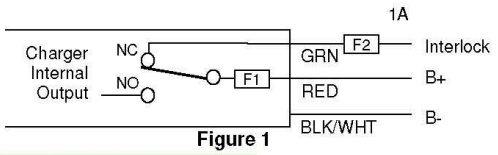


Figure 1

4) Check / Change Charging Algorithm:
The charger comes pre-loaded with algorithms for batteries as detailed in Table 1. If your specific battery model is not listed, please contact Delta-Q.
Each time AC power is applied with the battery pack NOT connected, the charger enters an algorithm select/display mode for approximately 11 seconds. During this time, the current Algorithm # is indicated on the '80%' LED (Models 912-xx0x) or on the single LED (Models 912-xx1x). A single digit Algorithm # is indicated by the number of blinks separated by a pause. A two digit Algorithm # is indicated by the number of blinks for the first digit followed by a short pause, then the number of blinks for the second digit followed by a longer pause.
To check / change the charging algorithm:
a) Disconnect the charger positive connector from battery pack. Apply AC power and after the LED test, the Algorithm # will display for 11 seconds.
b) To change algorithm, touch positive connector during the 11 second display period to the battery pack's positive terminal for 3 seconds and then remove – the Algorithm # will advance after 3 seconds. Repeat until desired Algorithm # is displayed. A 30 second timeout is extended for every increment. Incrementing beyond the last Algorithm moves back to the first Algorithm.
After desired Algorithm # is displayed, touch the charger connector to the battery positive until the output relay is heard to click (~10 seconds) – algorithm is now in permanent memory.
c) Remove AC power from the charger and reconnect the charger positive connector to the battery pack. It is highly recommended to check a newly changed algorithm by repeating step 4) above.

Alg #	Battery Type
43	Discover AGM
27	Crown CR-325
21	Exide Flooded
12	Exide/Sonnenschein Gel
7	J305 DV/DT CP
6	DEKA 8G31 Gel
5	Trojan 30/31XHS
4	US Battery USB2200
3	T105 DV/DT CP
1	Trojan T105

Table 1.

Product warranty is two years - please contact dealer of original equipment for warranty service.

Note: This is a Class A product. In a domestic environment this product may cause radio interference, in which case the user may be required to take adequate measures.

POWER IN MOTION

Delta-Q Technologies Corp.

Unit 3, 5250 Grimmer Street
Burnaby, BC Canada V5H 2H2

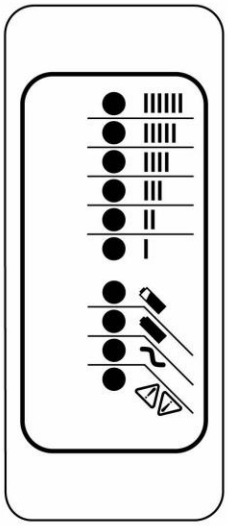
www.delta-q.com
info@delta-q.com

T 604.327.8244
F 604.327.8246

QuiQ Charger Troubleshooting Guide

Delta-Q's QuiQ charger is designed for a long, trouble-free service life. Occasionally, the user may encounter abnormal operation which can usually be corrected by following the procedures in this guide.

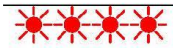
Indications on the Charger 10-LED Display



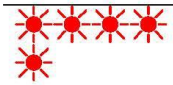
LED indications following "Power-On Self Test":

Ammeter (Amber)	**Solid:**	Displays approximate scale of current output during bulk phase. Also indicates algorithm #1-6 for 11 seconds if no battery is connected.
	Flashing:	High internal charger temperature. Current output reduced. • Provide better airflow to the charger. • Try to move the charger to a cooler location. • Confirm that dirt or mud is not blocking the cooling fins of the charger. Clean the charger. Rinse charger with low pressure hose if required. Do not use high pressure. Do not use a pressure washer.
80% Charge (Amber)	**Solid:**	Bulk charge phase complete, 80% charged. In Absorption phase.
	Flashing:	With no battery connected, indicates algorithm # selected by number of flashes.
100% Charge (Green)	**Solid:**	Charging complete. Charger in Maintenance Mode.
	Flashing:	Absorption phase complete. In Finish phase
AC On (Amber)	**Solid:**	AC Power good
	Flashing:	Low AC Voltage, check voltage and extension cord length (max 100', 12-AWG or 50' 14-AWG).
Fault (Red)	**Flashing:**	Charger error. Check code and refer to troubleshooting guide below.

Fault Indications:

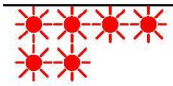
Fault LED Flashes (Red)	Explanation and Solution
	High Battery Voltage Detected • Check that the battery charger voltage is consistent with the battery pack voltage. The first two digits of the four digit model name indicate the battery voltage the charger supports. • Check for wiring errors. • High battery voltage could also occur if there is another source charging the battery. Disconnect any other sources during charging. • If this problem does not clear after the battery voltage is confirmed to be less than 2.4V per cell, return the charger for service. • This fault will automatically clear and the charger will restart charging when this problem is removed.
	Low Battery Voltage Detected • Check the battery and connections to the battery. • Check the nominal battery voltage. The first two digits of the four digit model name indicate the battery voltage the charger supports. Confirm that a nominal battery voltage is the same as the charger voltage. • If this problem does not clear after the battery voltage is confirmed to be higher than 1V per cell and all connections are good, return the charger for service. • This fault will clear automatically when the low battery voltage problem is rectified.
	Charge Timeout - Indicates the battery failed to charge within the allowed time. This could occur if the battery is of larger capacity than the algorithm is intended for. In unusual cases it could mean charger output is reduced due to high ambient temperature. It can also occur if the battery is damaged, old, or in poor condition. • Check the battery for damage such as shorted cells and insufficient water. Try the charger on a good battery. • If the same fault occurs on a good battery, check the connections on the battery and connection to AC power, and AC voltage. • Confirm that the nominal battery pack voltage is the same as the battery charger voltage. • If a charger displays this fault on a battery pack, and the pack is of questionable status, reset the charger by disconnecting AC power for 30 seconds, and then reconnect the AC to start a new charge cycle. After a few charge cycles this problem could stop occurring as the pack "recovers." • This fault must be cleared manually by unplugging the AC, waiting 30 seconds and reconnecting the ac power.
	Check Battery - This fault indicates the battery pack could not be trickle charged up to the minimum level required for the normal charge cycle to be started. • Check that none of the battery pack connections between modules are reversed or incorrectly connected. • Check that one or more cells in the battery are not shorted. • Confirm that the nominal battery pack voltage is the same as the battery charger voltage.

- Try the charger on a good battery.
- If this fault occurs the battery pack is likely in poor condition. Try to recover the pack with a charger that can charge the individual cells – such as an automotive charger. Be sure to set this charger to the appropriate voltage – 6V per 6V battery, 12V per 12V string/battery.



Over-Temperature: This fault indicates the charger has become too hot during operation. This extra fault indication (as opposed to the flashing ammeter described above), indicates an even higher temperature was reached inside the charger. Though not damaging to the charger, charge time will be extended significantly

- This fault indication will not clear automatically, but the charger will restart charging automatically when the temperature drops. The fault indication must be cleared manually by unplugging the AC power, waiting 30 seconds and reconnecting the AC.
- If possible, install the charger in a cooler location or increase cooling air flow to the cooling fins.
- Confirm that dirt or mud is not blocking the cooling fins of the charger. If required, clean the charger by rinsing it with a low pressure hose. Do not use high pressure. Do not use a pressure washer.



QuiQ Internal Fault: This fault indicates that the batteries will not accept charge current, or an internal fault has been detected in the charger. This fault will nearly always be set within the first 30 seconds of operation. If it occurs after the charger has started charging normally, be sure to make a note of it.

- Try to clear the fault by unplugging AC power, waiting 30 seconds and reconnecting the AC.
- Check all battery connections. Look for a high resistance connection. The most likely reason for this fault is a fault in the battery such as a bad battery connection, an open cell, or insufficient water.
- This fault will occur if an internal fuse inside the charger blows. If the green wire is shorted to ground even momentarily this fuse will blow. To check the fuse, measure with an ohmmeter between the green and red wires with the AC disconnected. If a short circuit is not measured, the fuse has blown. Return unit to a service depot to have this fuse replaced.
- For software revision 0.81 or older, this fault may indicate that the input or output voltage went out of range. Check input and output connections before returning the unit to a service depot. Charger may need to be brought to a service depot to have its software upgraded. Refer to the lower right hand corner on the back of the Product Manual to determine the software revision.
- If this fault occurs after battery charging has started, confirm that AC power was not interrupted and that all battery connections are good.
- If all battery connections are good, an internal fault has been detected and the charger must be brought to a qualified service depot.

Other Indications:

Indication	Explanation and Solution
AC On LED Lit, Charger won't start charging.	Charger has detected a condition that does not allow it to charge

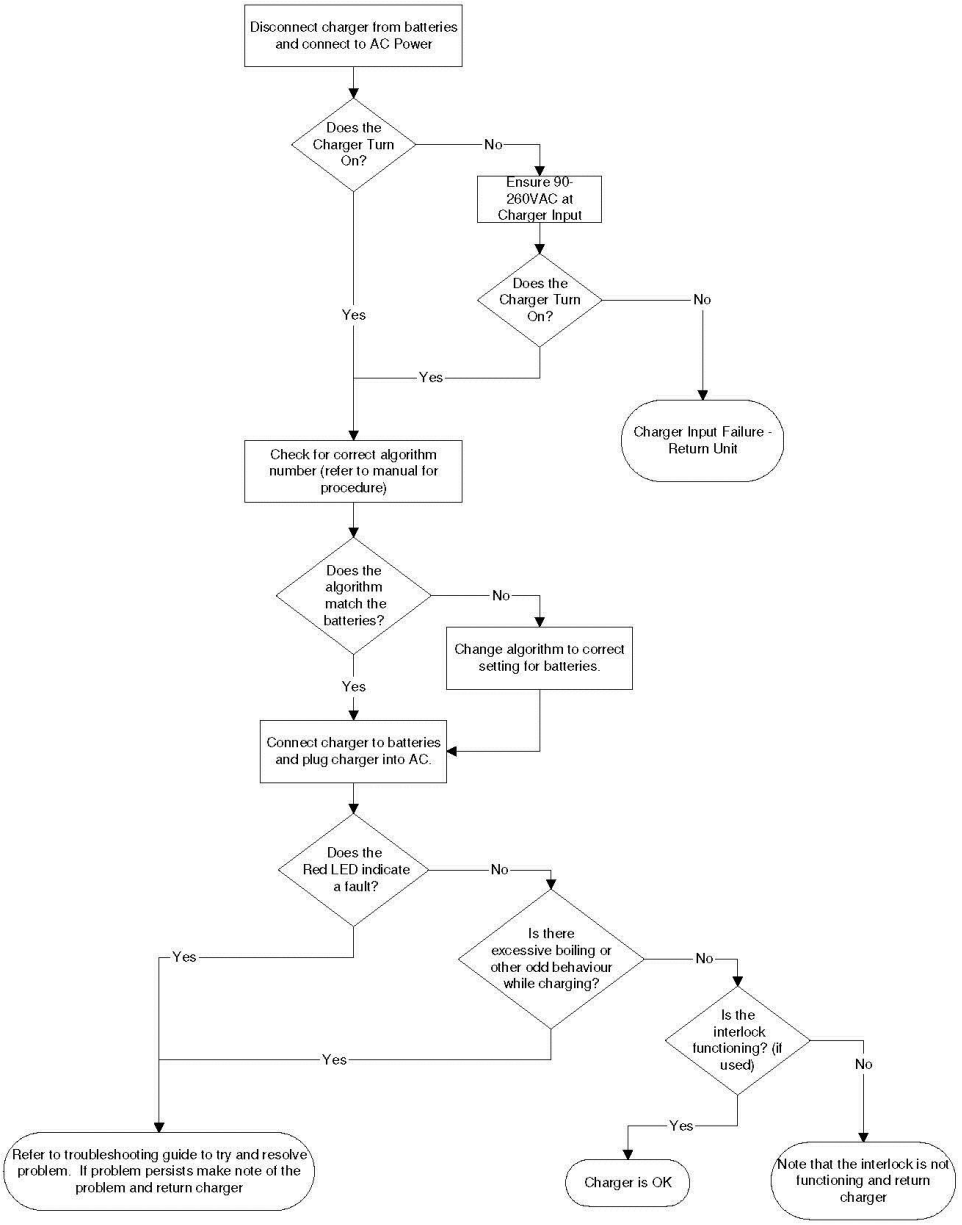
	• Confirm battery connections are good. • The nominal voltage for a lead acid battery is 2 V per cell. For example, a 48V battery will have 48/2 = 24 cells. • If the battery voltage is greater than 2.5V per cell, the charger will not start charging. • If the battery voltage is less than 0.5V per cell, the charger will not start. • For software revisions 0.81 or lower, the charger will not start charging if the battery voltage is less than 1V per cell. Refer to the lower right hand corner of the back of the Product Manual to determine the software revision. • Check for any fault codes that might be set and refer to the descriptions above. • A fully charged battery will draw very little current, but will not show 100% charged immediately. The charger will change to Absorption mode in under 5 minutes once the conditions for the end of bulk charge have been met. The 80% LED will illuminate at this time. During the final phase of charging, the battery will only accept a very small current – the charger is unable to accelerate this portion of the charge cycle without damaging the battery.
Excessive Battery Watering or Strong Sulphur (Rotten Egg) Smell	Overcharging or high battery temperature. These symptoms are unlikely to be caused by too high a charge current since the maximum charge current of the charger will be small compared to even a moderately sized battery pack. The most likely cause for this problem is incorrect charge algorithm setting and/or high ambient temperatures. • Confirm that the battery pack is not too small – usually > 50Ah. • Confirm that the nominal battery voltage matches the charger output voltage. • Confirm the correct battery charge algorithm. If the battery pack is new, the algorithm will need to be changed if the pack is not the same as the old one. Refer to the Product Manual for instructions on how to determine and change the battery charge algorithm. • If the output voltage of the charger seems excessive, return the charger for service. Contact Delta-Q to get the expected battery voltage settings for the charger in question. Be sure to have the charger's serial number and charge algorithm setting available when calling.
Difficulty Changing the Default Battery Charge Algorithm	The mode to change the battery charge algorithm can only be selected during the first 10 seconds of operation. Refer to the Product Manual for instructions. If the 10 second window is missed, cycle AC power by unplugging the charger, waiting 30 seconds, and reconnecting AC power. To extend Battery Charge Algorithm Change Mode by 30 seconds (120 seconds on newer models), connect the charger output to a good battery for approximately 1 second and then disconnect the battery again.

General Troubleshooting

Should the condition of a charger be in doubt, the flow chart on the next page should be followed to check the charger's operating condition.

19Aprr07 chui@delta-q.com

Delta-Q Technologies
QuiQ Charger Troubleshooting Flow Chart



MEAN WELL

RSP-1500 SERIES

1500 Watt Enclosed with Fan Power Supply

Measures: 10.95 x 5.00 x 3.29"

■ Features :

- Universal AC input/Full range
- ZVS new technology
- AC input active surge current limiting
- High efficiency up to 91%
- Built-in active PFC function,PF>0.95
- Protections: Short circuit / Overload / Over voltage / Over temperature
- Forced air cooling by built-in DC ball bearing fan
- Output voltage can be trimmed between 70~100% of the rated output voltage
- High power density 8.3W/inch^3
- Current sharing up to 6000W(3+1)
- Alarm signal output
- Built-in 12V/0.1A auxiliary output for remote control
- Built-in remote ON-OFF control
- Built-in remote sense function
- 5 years warranty

SPECIFICATION

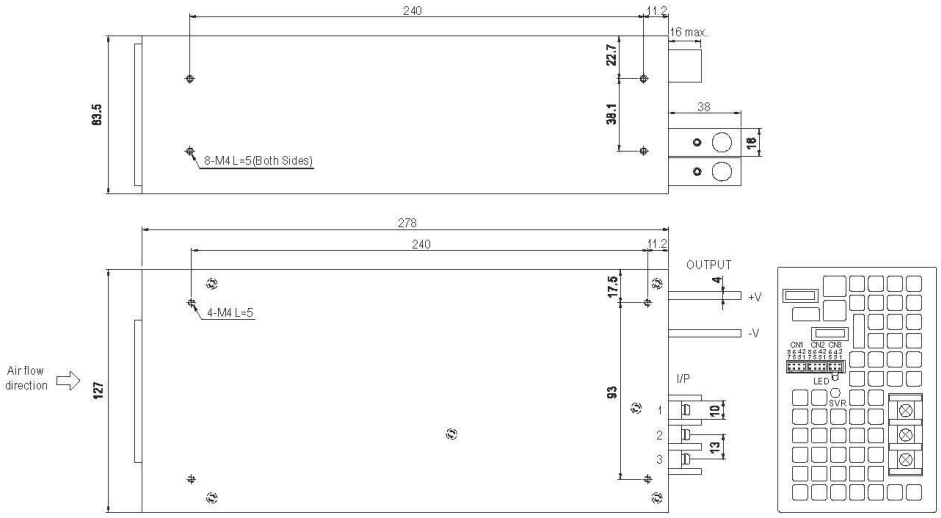
MODEL		RSP-1500-5	RSP-1500-12	RSP-1500-15	RSP-1500-24	RSP-1500-27	RSP-1500-48
OUTPUT	DC VOLTAGE	5V	12V	15V	24V	27V	48V
	RATED CURRENT	240A	125A	100A	63A	56A	32A
	CURRENT RANGE	0 ~ 240A	0 ~ 125A	0 ~ 100A	0 ~ 63A	0 ~ 56A	0 ~ 32A
	RATED POWER	1200W	1500W	1500W	1512W	1512W	1536W
	RIPPLE & NOISE (max.) Note.2	150mVp-p	150mVp-p	150mVp-p	150mVp-p	150mVp-p	200mVp-p
	VOLTAGE ADJ. RANGE	4.5 ~ 5.5V	10 ~ 13.5V	13.5 ~ 16.5V	20 ~ 26.4V	24 ~ 30V	43 ~ 56V
	VOLTAGE TOLERANCE Note.3	±2.0%	±1.0%	±1.0%	±1.0%	±1.0%	±1.0%
	LINE REGULATION	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%
	LOAD REGULATION	±2.0%	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%
	SETUP, RISE TIME	1500ms, 100ms at full load					
	HOLD UP TIME (Typ.)	10ms at full load		14ms at full load		16ms at full load	
INPUT	VOLTAGE RANGE	90 ~ 264VAC 127 ~ 370VDC					
	FREQUENCY RANGE	47 ~ 63Hz					
	POWER FACTOR (Typ.)	0.95/230VAC 0.98/115VAC at full load					
	EFFICIENCY (Typ.)	80%	87%	87%	90%	90%	91%
	AC CURRENT (Typ.)	17A/115VAC 8A/230VAC					
	INRUSH CURRENT (Typ.)	30A/115VAC 60A/230VAC					
	LEAKAGE CURRENT	<2.0mA / 240VAC					
PROTECTION	OVERLOAD Note.5	105 ~ 135% rated output power					
		Protection type : Constant current limiting unit will shut down o/p voltage after 5sec. Re-power on to recover					
	OVER VOLTAGE	5.75 ~ 6.75V	13.8 ~ 16.8V	17 ~ 20.5V	27.6 ~ 32.4V	31 ~ 36.5V	57.6 ~ 67.2V
		Protection type : Shut down o/p voltage, re-power on to recover					
	OVER TEMPERATURE	Shut down o/p voltage, recovers automatically after temperature goes down					
FUNCTION	AUXILIARY POWER(AUX)	12V@0.1A(Only for Remote ON/OFF control)					
	REMOTE ON/OFF CONTROL	Please see the Function Manual					
	ALARM SIGNAL OUTPUT	Please see the Function Manual					
	OUTPUT VOLTAGE TRIM	Please see the Function Manual					
	CURRENT SHARING	Please see the Function Manual					
ENVIRONMENT	WORKING TEMP.	-20 ~ +70℃ (Refer to "Derating Curve")					
	WORKING HUMIDITY	20 ~ 90% RH non-condensing					
	STORAGE TEMP., HUMIDITY	-40 ~ +85℃, 10 ~ 95% RH					
	TEMP. COEFFICIENT	±0.05%/℃ (0 ~ 50℃)					
	VIBRATION	10 ~ 500Hz, 2G 10min./1cycle, 60min. each along X, Y, Z axes					
SAFETY & EMC (Note 4)	SAFETY STANDARDS	UL60950-1, TUV EN60950-1 approved					
	WITHSTAND VOLTAGE	I/P-O/P:3KVAC I/P-FG:2KVAC O/P-FG:0.5KVAC					
	ISOLATION RESISTANCE	I/P-O/P, I/P-FG, O/P-FG:100M Ohms / 500VDC / 25℃/ 70% RH					
	EMC EMISSION	Compliance to EN55022 (CISPR22), EN61000-3-2,-3					
	EMC IMMUNITY	Compliance to EN61000-4-2,3,4,5,6,8,11, EN55024, light industry level, criteria A					
OTHERS	MTBF	62.6K hrs min. MIL-HDBK-217F (25℃)					
	DIMENSION	278*127*83.5mm (L*W*H)					
	PACKING	3.0Kg; 4pcs/13Kg/1.19CUFT					
NOTE	1. All parameters NOT specially mentioned are measured at 230VAC input, rated load and 25℃ of ambient temperature. 2. Ripple & noise are measured at 20MHz of bandwidth by using a 12" twisted pair-wire terminated with a 0.1uf & 47uf parallel capacitor. 3. Tolerance : includes set up tolerance, line regulation and load regulation. 4. The power supply is considered a component which will be installed into a final equipment. The final equipment must be re-confirmed that it still meets EMC directives. For guidance on how to perform these EMC tests, please refer to "EMI testing of component power supplies." (as available on http://www.meanwell.com) 5. Derating may be needed under low input voltages. Please check the derating curve for more details.						

File Name:RSP-1500-SPEC 2013-11-01

MEAN WELL
RSP-1500 SERIES
1500 Watt Enclosed with Fan Power Supply
Measures: 10.95 x 5.00 x 3.29"

■ Mechanical Specification

Case No.943A Unit:mm



AC Input Terminal Pin No. Assignment

Pin No.	Assignment
1	FG ⏚
2	AC/N
3	AC/L

Control Pin No. Assignment(CN1,CN2) : HRS DF11-8DP-2DS or equivalent

Pin No.	Assignment	Pin No.	Assignment	Mating Housing	Terminal
1	RCG	4	TRIM	HRS DF11-8DS or equivalent	HRS DF11-**SC or equivalent
2	RC2	6	LS(Current Share)		
3,5,7	-S	8	+S		

RCG: Remote ON/OFF Ground
RC2: Remote ON/OFF
-S : -Remote Sensing
TRIM: Adjustment of Output Voltage
LS: Load Share
+S: +Remote Sensing

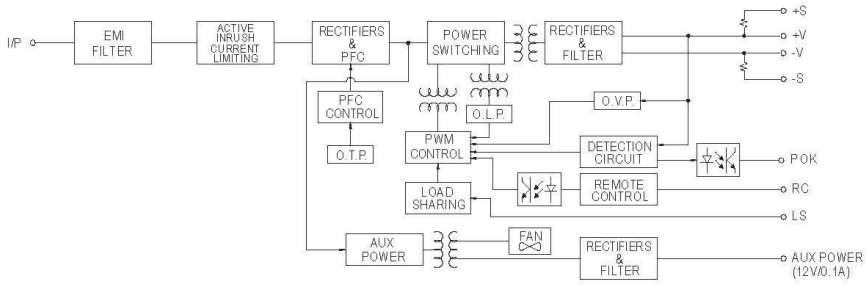
Control Pin No. Assignment(CN3) : HRS DF11-6DP-2DS or equivalent

Pin No.	Assignment	Pin No.	Assignment	Mating Housing	Terminal
1	P.OK GND	4	AUXG	HRS DF11-6DS or equivalent	HRS DF11-**SC or equivalent
2	P.OK	5	RC1		
3	RCG	6	AUX		

P.OK GND: Power OK Ground
P.OK: Power OK Signal
RCG: Remote ON/OFF Ground
AUXG: Auxiliary Ground
RC1: Remote ON/OFF
AUX: Auxiliary Output

■ Block Diagram

PFC fosc : 70KHz
PWM fosc : 100KHz

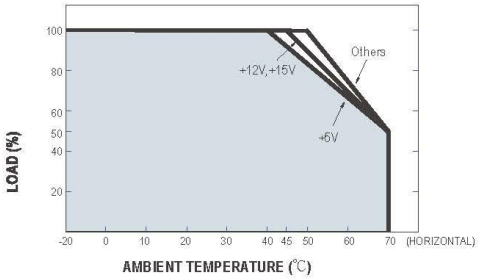


File Name:RSP-1500-SPEC 2013-11-01

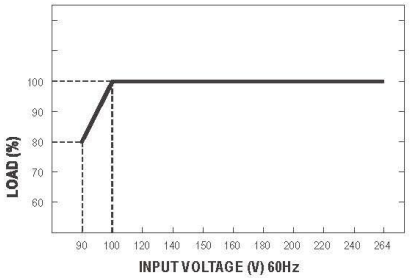
SAGER POWER SYSTEMS

MEAN WELL
RSP-1500 SERIES
1500 Watt Enclosed with Fan Power Supply
Measures: 10.95 x 5.00 x 3.29"

Derating Curve



Static Characteristics



Function Manual

1.Remote ON/OFF

(1)Remote ON/OFF control becomes available by applying voltage in CN1 & CN2 & CN3

(2)Table 1.1 shows the specification of Remote ON/OFF function

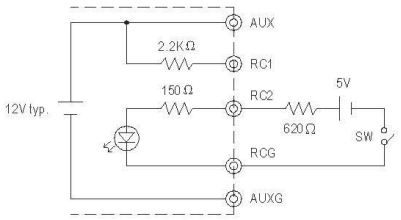
(3)Fig.1.2 shows the example to connect Remote ON/OFF control function

Table 1.1 Specification of Remote ON/OFF

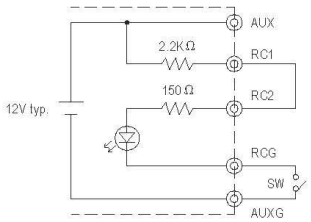
Connection Method		Fig. 1.2(A)	Fig. 1.2(B)	Fig. 1.2(C)
SW Logic	Output on	SW Open	SW Open	SW Close
	Output off	SW Close	SW Close	SW Open

Fig.1.2 Examples of connecting remote ON/OFF

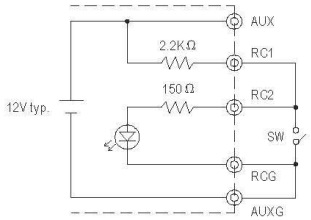
(A)Using external voltage source



(B)Using internal 12V auxiliary output



(C)Using internal 12V auxiliary output



FileName:RSP-1500-SPEC 2013-11-01

SAGER POWER SYSTEMS

MEAN WELL
RSP-1500 SERIES
1500 Watt Enclosed with Fan Power Supply
Measures: 10.95 x 5.00 x 3.29"

2.Alarm Signal Output

(1)Alarm signal is sent out through "P.OK" & "P.OK GND" pins
(2)An external voltage source is required for this function. The maximum applied voltage is 50V and the maximum sink current is 10mA
(3)Table 2.1 explain the alarm function built-in the power supply

Function	Description	Output of alarm(P.OK)
P.OK	The signal is "Low" when the power supply is above 65% of the rated output voltage-Power OK	Low (0.5V max at 10mA)
	The signal turns to be "High" when the power supply is under 65% of the rated output voltage-Power Fail	High or open (External applied voltage 10mA max.)

Table 2.1 Explanation of alarm

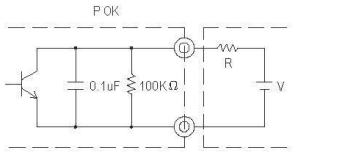


Fig. 2.2 Internal circuit of P.OK (Open collector method)

3.Output Voltage TRIM

(1)Adjustment of output voltage is possible between 70~100% (Typ.) of the rated output which is shown in Fig. 3.1
(2)Connecting a resistor externally between TRIM and-S on CN1 or CN2 that is shown in Fig. 3.2.
(3)+S & +V, -S & -V also need to be connected on CN1 or CN2.

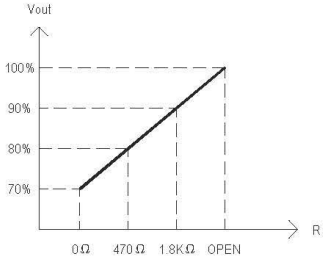


Fig. 3.1 External Resistor (Typical)

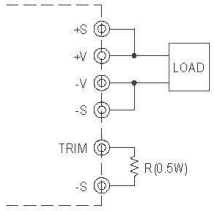
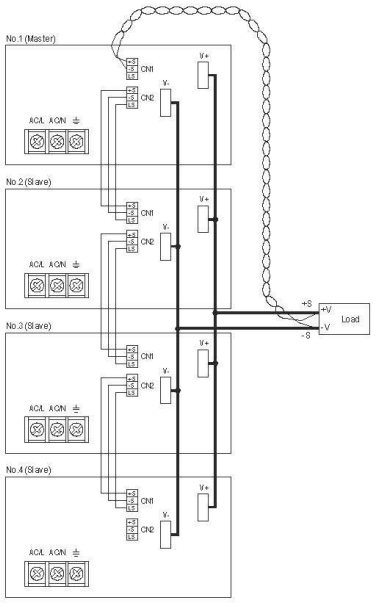


Fig. 3.2 Output voltage trimming

4.Current Sharing

(1)Parallel operation is available by connecting the units shown as below (+S,-S and LS are connected mutually in parallel):
(2)The voltage difference among each output should be minimized that less than 0.2V is required
(3)The total output current must not exceed the value determined by the following equation (Output current at parallel operation) = (The rated current per unit) × (Number of unit) ×0.9
(4) In parallel operation 4 units is the maximum, please consult the manufacture for other applications
(5) When remote sensing is used in parallel operation, the sensing wire must be connected only to the master unit



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