BATTERY POWER SYSTEM

OPERATION & MAINTENANCE
GUIDE

914CF1100000-01

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between 8:00 am and 5:00 pm Mountain time Monday through Friday

1 READ THIS FIRST

This manual covers installation, operation and troubleshooting of SENS model 914CF1100000-01 Battery Power System.

Please follow the installation and use instructions. They are vital to the satisfactory operation of the charger. If you have any doubts about adjusting, maintaining or servicing the equipment, contact SENS service department.

Changing factory-set potentiometers ***voids the warranty***. Contact the factory if you believe that the settings on your charger are incorrect.

Before determining that the charger is not working correctly, check the following:

1. Is AC power available to the charger?
2. Are any circuit breakers tripped?
3. Is the charger connected to a battery of the correct voltage?
4. Was the system damaged in transit or installation?
5. If you determine that the charger is not working because it is not producing any current, check the battery's state of charge. If the battery is fully charged it is perfectly normal for the charger to indicate zero current flow.
6. If the battery is being over- or undercharged, check whether the output voltage settings have been tampered with. The pots should be covered with either white adhesive paper dots or a hard colored varnish.

1.1 Description and Application

<u>General</u>
The Battery Power System supplies uninterrupted 48 volt DC power to loads requiring a filtered source. The system contains a 48 volt 25 amp filtered battery charger/rectifier with alarm system and battery.

The system's cabinet is rated for indoor use, and must be protected from dripping water.

Batteries are installed at the factory, and batteries are connected to the system in the field using factory-wired plugs.

<u>Charger</u>
The charger's rating is 48 volts (nominal), 25 amps. The charger will supply from zero to 25 amps depending on the load current and battery's state of charge. The charger is rated for continuous duty at 25 amps. Charger features include the following:

- Constant voltage output
- Electronic current limiting
- Output filtered to less than 30 mV rms
- Temperature compensation to maximize battery performance and life
- Circuit breakers for AC input, DC output and battery
- High voltage shutdown with automatic restart
- Alarm system with local indicators and Form C contacts for remote annunciation

<u>Battery</u>
VRLA (Valve Regulated Lead Acid, also known as "maintenance-free") lead-calcium, 100 AH. Eight ea. 6 volt, 100 AH batteries are connected in series to achieve the required voltage.

NOTE: The batteries are sealed for life, and no attempt should be made to add water to any battery cells.

1.2 What You Should Receive

You should receive one pallet containing the system cabinet, dimensions of which are shown on the attached drawing. Inspect the Battery Power System for damage caused during transit, and report damage to the carrier immediately. If the unit was damaged, contact SENS to determine how best to repair/replace the damaged unit.

2 Installation

2.1 Mechanical Installation

WARNING: This system is *not* approved for operation in mines or other places with explosive atmospheres!

Refer to the attached dimensional drawings for cabinet size and location of skid mounting holes. If the system is to be installed in an area that suffers earthquakes the system must be bolted with high strength bolts to a suitable concrete pad.

When locating the system, do not obstruct ventilation openings in the bottom, side or top of the cabinet.

Protect the system from construction grit, metal chips, paint or other debris. Clean away debris after installation and before turning on the charger.

2.2 Electrical - System Wiring

WARNING: Heat sinks and many other metallic components inside the charger are LIVE with either line or output voltage. These voltages can be lethal. Do not touch any exposed metal surfaces inside the enclosure while the charger is operating.

All cable entry is through a gland plate located in the bottom panel of the system panel. Cables include AC input, DC loads and remote alarm contacts. The gland plate should be removed and either punched or drilled to accommodate the conduit carrying AC input, DC output and alarm leads. Replace the gland plate and make connections.

Connection should be made by a qualified installer in accordance with national and local electrical codes. The installer should determine the gauge of wire to be used based on the length of cable runs and the ampere requirements of the charger.

AC Connections and Power Requirements
All system connections are made on the field terminations panel in the lower portion of the system cabinet.

BEFORE PROCEEDING: Ensure that all breakers , both external to the Battery Power System and inside the Battery Power System cabinet are in the OFF position

Make input connections direct to the AC input circuit breaker. This breaker is located on the field terminations panel in the lower part of the cabinet. The AC source must be capable of providing continuous power as shown in Table 2.2 below.

TABLE 2.2
AC Input Circuit Breaker Ratings

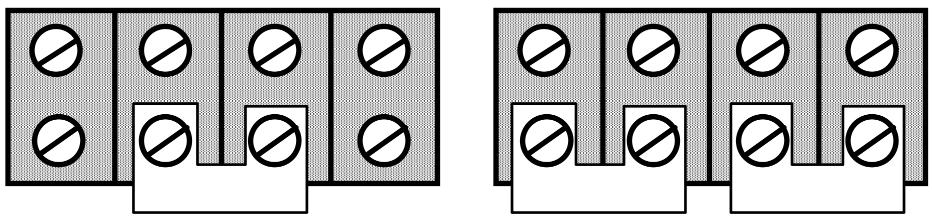
Charger output						Breaker 115 V	Breaker 230 V
V	**A**	**V**	**A**	**V**	**A**	**amps**	**amps**
48	25					30	15

115/230 Volt Strapping

Chargers equipped with field-selectable dual-voltage input are factory-set at 230 volts. If your input supply is 115 volts, change the voltage selection terminal block to the configuration shown below. The input voltage selection block is located on the input/output connection panel inside the system front door

Figure 2.2
115/230 Volt Terminal Configurations

230 volt configuration 115 volt configuration



WARNING: The Battery Power System should be connected to a grounded permanent wiring system. A ground stud or terminal is provided for this purpose, and is located on the field terminations panel in the lower part of the system cabinet.

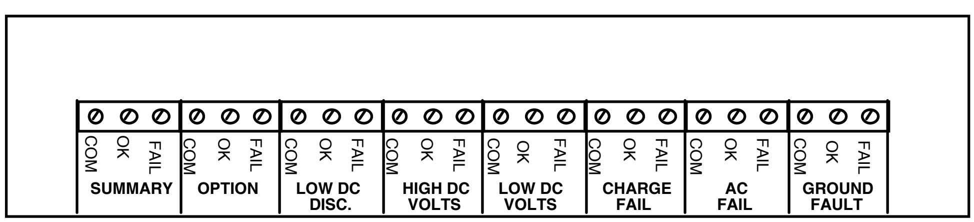
DC Output Connections
Connect DC loads direct to the load circuit breaker as shown in the attached drawing. The load breaker is located on the field terminations panel in the lower part of the cabinet. Use cables that are large enough to carry the required current to the loads with a voltage drop of less than 0.5 volts.

Alarm Connections
The charger's alarm system includes Form C contacts. Connect to these contacts as indicated on the attached customer connection drawing. The contact board is located on the field terminations panel located in the lower part of the system cabinet. Do not exceed the relay maximum current rating of 2A @ 26 volts DC or 1A @ 117 VAC. The contacts are in the "failed" state when de-energized .

See Figure 22. The alarm contacts active in this system include the following:

- AC fail
- Charger fail
- Low battery voltage
- High battery voltage
- Ground fault
- Summary alarm (activates when any one or more of the above activate)

FIGURE 2.2
Remote Contact Terminal Block



Other alarm positions, including "load disc." and "option" are not active in this system. Full alarm description is provided under the manual section "Operation".

Battery Installation and Connection

WARNING: Batteries are live at all times, and can cause severe shock or eye damage if handled improperly. Be particularly careful not to short circuit the battery terminals!

Batteries are installed and wired at the factory. Before commissioning the system, remove the plastic foam dunnage from around the batteries.

2.3Installation Questions or Failure(s)

Contact the factory if you have any problems or questions.

3 Operation

3.1 Start-up

Close the battery breaker, the charger output breaker, then the AC input breaker. The charger will ramp up to maximum required output power over a period of about 10 seconds. The front panel ammeter will indicate current flow.

AC FAIL and CHARGE FAIL lights should extinguish and be replaced by the green AC ON light.

The charger will automatically supply power to the load and maintain the battery without further attention. If the charger does not start as described, or appears to have failed, check the following:

• Verify that AC mains power is available
• Verify that no circuit breakers are tripped
• Verify that contractor-installed AC, DC and alarm connections are correct
• Verify that no components or harness connections are loose or damaged in the battery charger.

If all of the above appear to be in order, contact SENS at the toll-free service number on the front of this document for assistance in troubleshooting.

3.2 FLOAT/BOOST Voltage Control

Float and equalize controls are located inside the system front door. Two switches are provided, and operate as follows:

AUTO/TIMER SELECT SWITCH
This switch controls whether the charger's AUTOBOOST system is left to determine when to equalize the battery, or whether the front panel boost timer governs boost operation.

BOOST TIMER
This manually initiated timer places the charger in boost mode when turned past zero, provided that the AUTO/TIMER select switch is in the TIMER mode. The charger will stay in boost mode for the number of hours indicated on the timer dial. If the AUTO/TIMER select switch is in the AUTO mode turning on the timer will have no effect.

Explanation of FLOAT mode
This is the battery "maintenance" voltage. It is the normally fully charged voltage of the battery. This is the normal charging position for all batteries, and the recommended charging position at all times for maintenance-free batteries.

Explanation of BOOST mode
This voltage is slightly higher than the float setting, and is used to ensure that the cells of a battery are fully charged to the same voltage. Continued operation in boost is *not* recommended because the high charging voltage will cause battery electrolyte to boil away quickly. This is a particular problem with sealed batteries where there is no way to replenish lost electrolyte.

The float/boost control dial may indicate an AUTO position even though AUTOBOOST is not supplied. If AUTOBOOST is not supplied, the AUTO position will be locked out.

3.3 Explanation of AUTOBOOST

When in the AUTO mode the charger will automatically operate in the BOOST mode when output current exceeds 70% of the charger's rated current. The charger will revert to FLOAT mode when current drops below 50% of rated output.

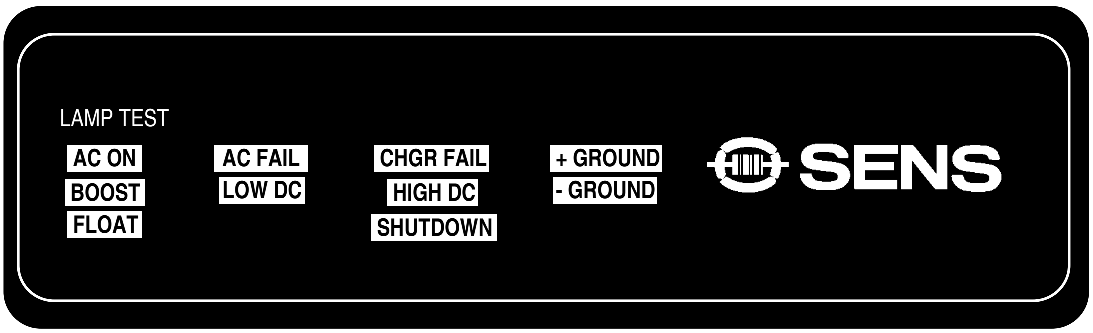
Please see the Appendix for a diagram of how the Autoboost system works. The AUTO setting eliminates the need to periodically equalize the cells of a battery as the charger does this automatically. *The AUTO position should not be selected when the continuous load on the charger is greater than about 50% of the charger's maximum rated current.*

3.4 This Section Intentionally Left Blank

3.5 Alarm Indications

NOTE: Chargers are equipped with a "dead-front" panel. Alarm LEDs are behind the dead front panel and will be visible when they illuminate due to an alarm condition, or when the TEST button is pressed. See Figure 3.5 for the location of LED indicators.

FIGURE 3.5
LED Indicators on Charger Front Panel



<u>AC ON</u>
Indicates that AC power is being supplied to the charger.

<u>BOOST</u>
The charger is operating in the BOOST mode.

<u>FLOAT</u>
The charger is operating in the FLOAT mode.

<u>AC FAIL</u>
Indicates that AC power is not available to the charger. The AC either failed, or the charger's input breaker is turned off or has been tripped.

<u>CHGR FAIL</u>
Indicates that the charger is failing to produce the output current required by the battery and load. When the battery and load demand no current the failure alarm will not activate.

In the event that the CHARGE FAIL and AC ON lights are illuminated simultaneously, then the charger has failed. The probable causes of an alarm, in descending order of likelihood are:

a) A failure of AC power
b) A tripped AC breaker
c) The charger has malfunctioned

<u>LOW DC</u>
Indicates that DC voltage has dropped to approximately 8.5% below nominal battery voltage (e.g. 220 volts for a 240 volt system). Probable causes:

a) The AC power has failed, and the battery has become discharged

b) The charger has malfunctioned and the battery has become discharged
c) The battery is defective

There is a time delay in the low voltage alarm which prevents the alarm from activating until approximately 30 seconds after the low voltage condition starts.

HIGH DC
Indicates that the charger's output has exceeded a pre-set threshold level (approximately 20% above nominal battery voltage - e.g. 293 volts for a 240 volt system). If this alarm stays activated for any period of time, the charger should be shut down and serviced. The charger may have malfunctioned, or the alarm card may be misadjusted. The alarm actives immediately upon high voltage condition, but stays activated for approximately 30 seconds after the condition disappears.

HIGH DC SHUTDOWN
Indicates that the charger has been shut down by the high output voltage shutdown circuit. Probable causes of a high DC shutdown are as follows:

a) The float or boost voltages have been increased above the pre-set shutdown voltage
b) The high voltage shutdown set point has been changed from the factory setting.
c) The charger has malfunctioned, and is not regulating properly.

There is a delay of approximately 5 seconds after the onset of the high voltage condition until the unit shuts down. When a high volt shutdown occurs, the red HVS LED on the control board will illuminate, along with the SHUTDOWN LED on the front panel.

If the high DC shutdown activates the charger will stay off until the battery voltage drops to approximately nominal, at which point the circuit will reset and the charger will start. Manual reset of the shutdown is accomplished as follows:

1) Turn off the AC input breaker. (Note that while the SHUTDOWN LED will extinguish, the charger is still locked out. This is because the shutdown LED is driven by the control board's power supply, which is derived from the AC supply, rather than from battery).
2) Turn off the charger DC output breaker.
3) Wait for approximately one minute for capacitor voltage to decay through the capacitor bleeder resistor
4) Turn on the charger DC output breaker
5) Turn on the AC input breaker. If the charger is still in high DC shutdown, repeat steps 1 through 3, waiting longer before turning DC and AC breakers back on.

GROUND
This is a ground fault alarm. If either the charger's positive or negative is connected to ground, even through a high resistance path, this alarm will activate. LEDs indicate either positive or negative grounding. The Form C contact only indicates that a fault has occurred.

Some applications require that ground be referenced to either the positive or negative output. In this case, the activated ground fault alarm will be a nuisance. The alarm can be safely disabled by placing the ground fault jumper located on the alarm board (mounted on the charger's front door) in the "disabled" position. When pins 1 and 2 of J5 are connected together the ground fault alarm is enabled. When pins 2 and 3 are connected the ground fault alarm is disabled.

4 Adjustments

4.1 Output Voltage Adjustment

WARNING: Working inside the charger exposes you to dangerous AC and DC voltages. Do not touch circuit breakers, filter capacitors, heat sinks or any other exposed metal surfaces

NOTE: Do not tamper with factory adjustments unless sure adjustment is necessary. Temperature-compensated control circuitry automatically adjusts the output voltage depending on temperature. Adjust the output only (a) to correct a previous unauthorized adjustment, (b) to adjust the charger for a different type of battery (e.g. from lead-acid to nickel-cadmium) or (c) if your battery is consistently being over-charged or under-charged

NOTE: Unless authorized by SENS, any charger adjustment, including output voltage adjustment, voids the warranty.

Procedure

1. Use a precision external voltmeter connected directly to the battery circuit breaker.
2. Set the charger's front panel AUTO/TIMER control to TIMER. Insure that the timer is OFF (set to zero hours)
3. Open the system door and find the charger control card, which is located on the charger chassis. The control card uses a small PC board mounted transformer. The control card contains two potentiometers labelled "FLOAT" and "BOOST", both located near the center of the board.
4. Adjust the FLOAT pot until the desired voltage is achieved.

Adjustment of the BOOST voltage is similar to adjustment of FLOAT, except that you adjust the BOOST pot instead of the FLOAT pot. Be sure that the charger front panel mode switch is in TIMER, and that the timer is turned ON (past zero hours) when you make adjustments.

Please note that the BOOST adjustment controls the level above FLOAT voltage, not the absolute voltage. Therefore, whenever the FLOAT the voltage is changed, the BOOST voltage also changes.

4.2 Factory-Set Output and Alarm Voltages

NOTE: Output voltages are temperature compensated (vary with temperature). The factory settings below are at 20 degrees C. The compensation is -0.18% per degree C. The alarm voltage settings are NOT temperature compensated.

Chargers set for sealed maintenance-free lead-acid battery

		48 volt				
Float voltage		54.48				
Boost voltage		55.20				
Low DC alarm		44.00				
High DC alarm		58.44				
High DC shtdown		60.78				

Chart 4.2 shows the relationship between charger output voltage, alarms and high voltage shutdown Note that the output voltage is temperature compensated down to ten degrees C, below which the compensation ends.

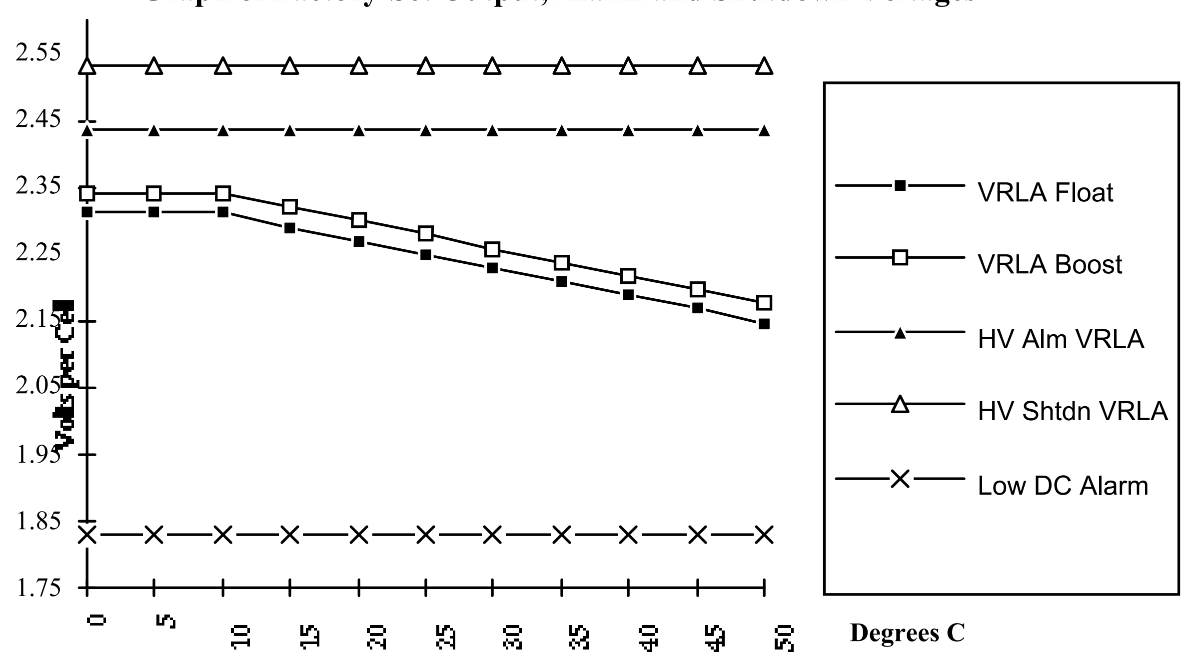
NOTE: Increasing the charger's output voltage does not increase the maximum voltage at low temperature. The maximum voltage is clamped to a fixed value. This prevents false high volt alarms and shutdowns during normal operation. If, however, the high volt alarm or shutdown are lowered from the factory settings, false alarms or shutdowns could occur at low temperatures.

To determine the charger's voltage at temperatures other than 20 deg. C., multiply the number of degrees Celsius difference between your ambient and twenty degrees times .0018. Multiply that product times the factory voltage setting (e.g. 54.48) and add it to the factory setting.

Example 1: Float voltage at 10 degrees C of a 24 volt charger set for 54.48 volts at 20 degrees C:
20-10 (.0018) (54.48) + 54.48 = **55.46** volts

Example 2: Float voltage at 50 degrees C of a 24 volt charger set for 54.48 volts at 20 degrees C:
20-50 (.0018) (54.48) + 54.48 = **51.54** volts

CHART 4.2
Graph of Factory-Set Output, Alarm and Shutdown Voltages



5 Trouble-shooting

5.1 Troubleshooting Table

If there is a problem and you suspect the charger is at fault, turn off the AC mains supply before proceeding. Ensure that the following are correct: AC input wiring, battery and/or load connections and PC card connectors. Ensure no foreign objects are in charger.

Symptom	Possible Cause	Test	Corrective Action
No output / Fail alarm	Control board failure	Replace with known good board	Replace board,
	DC Fuse blown	Check fuse for continuity	Replace if open
	High DC Shutdown	Check HVS LED on control board	If lit, see "High Output Voltage" symptom below
	Power rectifier circuit failure	Test all power diodes with meter; test SCRs	Replace all shorted, open, or bad parts
AC breaker trips repeatedly	Power diode, SCR, or freewheeling diode short	Check all power devices for shorts	Replace shorted device(s)
DC fuse blows or DC breaker trips repeatedly	Control board failure	Replace with known good board	Replace board, send bad board to SENS for repair
	Freewheeling diode short	Check diode for short	Replace diode
Low output voltage / Low DC alarm	Control board failure	Replace with known good board	Replace board,
	Misadjusted float voltage	Adjust pot to see if output voltage is affected	Adjust float pot to correct output voltage
	Overloaded charger	Turn off DC breaker, check voltage on INSIDE breaker terminals	Check load for problems, and check battery condition
	Bad filter capacitor	Disconnect capacitors one at a time and check for change in output voltage	Replace capacitor that corrected output voltage when removed
High output voltage / High DC alarm	Line voltage less than charger's operating range	Measure AC line voltage	Use larger gauge AC wires or contact utility company
	Control board failure	Replace with known good board	Replace board
High ripple voltage	Misadjusted Float Voltage pot on control board	Adjust pot and see if output voltage is affected	Adjust float pot to correct output voltage
	Control board failure	Replace with known good board	Replace board,
	Power diode / SCR failure	Test power diodes; , perform SCR test on SCRs	Replace all open or bad parts
	AC line voltage too high	Check for AC line voltage over charger's specified operating range	Contact utility company
	Bad filter capacitor	Disconnect capacitors one at a time and check for change in output voltage	Replace capacitor that corrected output voltage when removed

Improperly functioning alarms or indicators	Alarm, display, or control board failure	Replace each board in turn with a known good board	Replace failed board(s)

5.2 Component Diagnostic Tests

Test #1: With transformer leads disconnected, energize the transformer with the normal AC supply voltage. Measure entire secondary voltage. It should be 1.5 to 2 times the nominal battery voltage.

Test #2: With one or both leads disconnected from the inductor, measure the resistance across the inductor terminals. If the resistance is near a short circuit condition, the inductor is OK.

Test #3: Using a digital multimeter set to the diode testing function, measure the junction voltage across the diode. A reading of between 0.4 volt and 0.8 volt in the forward polarity direction and infinity in the reverse polarity direction indicates a good diode.

Test #4: Refer to Figure 5.2. Disconnect all the leads to the SCR and its heat sink. Connect a voltmeter across the 1KΩ resistor to measure the voltage drop. With the battery connected as shown, V_{drop} should read approximately 2.3V (Vsource-0.7V). Remove the voltage source to the gate, but keep it connected to the 1KΩ resistor and cathode. V_{drop} should equal zero. Reconnect the gate and reverse the batteries polarity. V_{drop} should read zero volts. Readings other than these indicate a defective SCR.

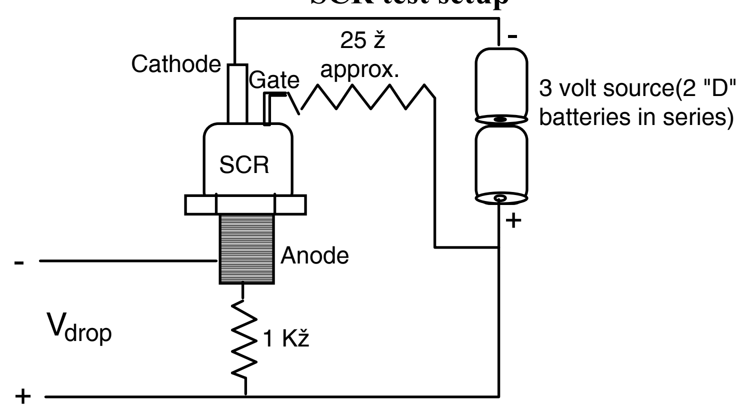
Test #5: Due to the modest cost of the control circuit, we recommend that the entire unit be replaced rather than attempting to repair it. If the trouble shooting guide has not revealed any defective components (tests #1-4), the control circuit should be replaced as a unit.

Test #6: Remove all wires from the current shunt. Place a milliohmmeter across the two terminals. The following formula should be used to determine the correct resistance:

Resistance in ohms should equal 0.5/Output current rating of the charger.

If the resistance is more than 20% too low, the current shunt should be replaced.

FIGURE 5.2
SCR test setup



6 Theory of Operation-Control Circuit

6.1 Introduction

This section provides information on operation of the SENS single phase battery charger control circuit. Schematics are included in the back of the manual to assist in understanding the circuits as they are discussed.

6.2 Power Train Format - General

The charger utilizes a single phase, full wave half controlled bridge rectifier with two power diodes, two power SCRs (silicon controlled rectifiers) and a freewheeling diode.**6.3 Control Circuits - General**

Electronic loop control circuits are utilized for output voltage and current control. A quasi loop control circuit is used to cross couple the voltage and current control loops to maintain close tracking for fast control transfer from one control mode to another.

6.4 Alarm and Special Function Circuits - General

A soft start circuit is allows the charger output to rise slowly when power is turned on.

Battery temperature compensation is standard. Temperature sensing is either local (sensing element located on charger control board), or remote, depending on whether the remote sensor is connected to the control board. The remote sensor is optional.

A load share circuit allows multiple chargers to share output current equally when operated in parallel.

A charge fail alarm is activated when there is both a loss of current and a low control bus which then activates an LED on the display board.

The high voltage shutdown circuit operates when battery voltage is too high. An alarm light on the control board is illuminated, and the charger firing circuits are shut down.

6.5 Board Power Supplies and SCR Firing - Detail

<u>Control Circuit Operating Supplies - Detail</u>
Operational amplifiers and other circuits require positive and negative 12 volts DC. Negative 2.5 and 5.5 volt reference voltages are used for the current and voltage loop controls. Circuitry for each phase requires a control transformer or separate winding on the power transformer phase winding to provide supply voltages, synchronization and timing for SCR firing. A 36 volt center tapped winding is used.

<u>12 Volt Supplies - Detail</u>
Center tapped control windings from the transformer are rectified through a bridge. The positive and negative bus peak charges the capacitors to a +/- 20 VDC. Regulators VR1 and VR2 regulate the voltages to positive and negative 12VDC. Tantalum capacitors are used to filter high frequency noise. These positive and negative lines supply operating power for all PC board electronic circuits.

<u>Negative 2.5 and 5.5 Volt Buses - Detail</u>
A resistor drops the -12 volts to -5.5 VDC and -2.5 VDC through a temperature sensor zener(LM335) and a band gap zener(LM285). The bandgap zener provides a very stable - 2.5 VDC reference which is used to derive the reference voltage for the output voltage control and the current limit circuitry. The temperature sensor zener(LM335) is used to create a -5.5 VDC temperature compensated reference voltage.

<u>Ramp and Ramp Reset Circuits - Detail</u>
The control winding voltage is rectified to a full wave pulsating waveform. The signal is fed to an op-amp negative input where it is compared to a DC level of 450 mV (millivolts). When the rectified voltage drops below this level, the output goes high to turn on a transistor. The collector drops to near ground, discharging the capacitor across collector to emitter. As the rectified waveform rises above 450 mV, the capacitor charges up thus creating a ramp that is synchronized with the phase voltage.

<u>Firing Pulse - Detail</u>
At a comparison amplifier, the ramp signal is compared to the DC control bus voltage. When the ramp signal rises above the DC control bus level, the output of the op-amp goes high. This turns on an npn transistor which turns on the SCR firing circuit.

<u>SCR Firing - Detail</u>

During the half cycle when SCR anode is positive, a firing pulse will be generated and applied to a MOS-FET. If the MOS-FET gate is positive biased, the positive anode voltage will flow through the MOS-FET and out to the SCR gate, thus turning on the SCR. Each circuit has a blocking diode to avoid current flow through the MOS-FET during the negative half cycle of the AC waveform.

6.6 Voltage and Current Control Loops - Detail

The loop control circuits consist of the voltage control circuit and the current control circuit. The DC output must be carefully controlled and adjusted automatically for battery temperature variations to prevent overcharging or undercharging the battery. Output current must be limited to prevent excessive charge rate which can shorten battery life, as well as to protect the charger from overload conditions.

NOTE: Refer to the "Special Function and Alarm Circuits", later in this discussion, as they are an integral part of the operation of the control loops.

Voltage Control - Detail
The voltage control amplifier compares the scaled down output voltage to a precision temperature compensated reference voltage. When the output is higher than the reference level, the control amplifier generates a DC control signal which is coupled to the control bus and in turn is fed to the firing circuits to determine SCR firing angle. An increasing control bus voltage causes a delay in firing and reduced output. As output is reduced to the correct voltage, the control bus voltage and firing angle stabilize, and output remains constant.

Loop controls require a feedback signal from the function being controlled. Since the positive DC output is the system ground or circuit common point, feedback is taken from the negative output. The output is scaled down to approximately -5.5 VDC. Control loop stability is maintained by a type I compensation loop.

Float/Boost /Autoboost - Detail
Chargers are equipped with two charging modes, float and boost. AUTOBOOST automatic equalize operation is an option. Float mode charges the batteries up to their normal charged voltage, while boost mode will charge the batteries over their normally charged voltage. The purpose is so that the individual cells in the battery will equalize, thus improving battery performance. However, extended time in boost mode can result in battery damage due to overcharging and consequent electrolyte loss.

The float/boost/autoboost function is controlled either by a manual rotary switch or a timer. When the timer is on, the charger is in boost mode. When time runs out the charger reverts back to float mode. By changing the -5.5 VDC reference voltage different output voltages can be obtained. This is done by switching in resistance, thus changing the gain of the reference voltage op-amp.

When the charger is in AUTOBOOST, the current signal is monitored by an op-amp. When output current rises above 70% of the charger's rating, the charger switches to boost mode where until output demand drops below 50% of rated current. Hysteresis reduces the chance of the charger oscillating between float and boost modes. The float/boost switching is controlled by the output of the op-amp and an analog switch.

NOTE: The AUTOBOOST switch position should not be selected when the continuous load on the charger is greater than about 50% of the charger's maximum rated current.

Current Control - Detail
The current control circuit monitors the charger output current via the current shunt in the power train. The millivolt shunt signal is amplified by an instrumentation amplifier which also removes common mode voltage. The gain is adjusted by a trimpot for a -2.25 volt level at the amplifier output at full output current. The output is coupled to the input of loop control amplifier where it is compared to the current limit setpoint. The output is fed to the control bus via a steering diode. The loop control amplifier is stabilized with a type I compensation scheme.

Control Loop Tracking - Detail
A control loop tracking system is employed to keep the voltage and current control amplifiers within 0.6 volts of each other. Without this system, the non controlling amplifier will drive its output to the negative rail. With the integrator capacitors charged to this level, considerable recovery time is required to discharge them when a control transition occurs. The result is momentary loss of control

leading to excessive output voltage or current.

The control bus signal is coupled to the negative input of each amplifier. The positive input of the current tracking amplifier is coupled to the output of the current control amplifier which wants to swing negative when not in control of the control bus. The difference is amplified and coupled back to the negative input of the current amplifier. This forces its output to remain within 0.6 volts of the control bus rather than driving to the negative rail.

6.7 Special Function and Alarm Circuits - Detail

Soft Start - Detail
When the charger is energized, it is desirable to let the DC output rise slowly to prevent voltage and current surge which can be damaging to equipment. The soft start circuit accomplishes this by holding the control bus high to cut off SCR firing initially and then lowering it slowly.

When the circuit becomes energized a 6.8 VDC zener diode charges up a capacitor that is coupled to the positive input of an op-amp follower. This causes the output to go high thus taking control of the bus. This charges up slowly thus gradually giving back control of the bus to the control loops. If there is an AC failure or a high voltage shutdown, the capacitor is discharged so the soft start circuit will be ready for the restart of the circuit.

Temperature Compensation System - Detail
The reference voltage is automatically temperature compensated at a rate of -0.18% per degree Celsius. This causes the output voltage to be reduced 0.18% if battery temperature increases one degree or to be increased if temperature decreases. Two temperature probes may be provided: a remote one located at the battery and a local one mounted on the PC board for use when the remote probe is absent or broken. If the remote probe is removed, the circuit senses its absence and automatically switches to on board temperature sense.

The LM335 solid state sensors are similar to a temperature variable zener diode with a positive temperature coefficient of 10 mV per degree C. This temperature coefficient needs to be inverted to a -.18%. This is done by comparing the temperature compensated -5.5 VDC with an uncompensated -5.5 VDC through a seesaw op-amp. This circuit creates the correct temperature compensated reference voltage.

As an added safety feature, the -0.18% temperature compensation slope automatically adjusts to zero slope at approximately 10 degrees C. This clamps the output voltage at the appropriate temperature compensated level to avoid excessive output voltage. This is accomplished by coupling an op-amp tracking circuit to the float/boost reference voltage. The tracking circuit takes a -5.5V non temperature-compensated voltage and creates a clamping voltage through gain resistors and a perfect diode op-amp output . When the float/boost reference voltage drops below this level the circuit clamps the reference voltage, thus clamping output voltage.

Load Share - Detail
When multiple chargers are connected to a common battery for redundancy or additional capacity, it is often desirable to force the chargers to share the load equally. The load share circuit is simple to set up, requiring only a single wire connection between chargers and charger output leads of identical length and gauge. Any number of chargers may be accommodated.

The wire connection may be thought of as a floating "averaging bus" to which each charger may be connected if conditions are right. Each charger contributes information to the bus from its current amplifier. When the parallel circuits are being utilized there will be one lead charger with the remaining being followers. The lead charger is the one having the highest current output at the time of parallel activation.

For charger followers, the averaging bus is compared to the current output of the charger. In this situation the current output will be lower than the averaging bus, thus producing a low output on the op-amp and lowering the control bus to produce a higher output.

For the lead charger, the comparison between the averaging bus and the current output produces a high output of the op-amp. This means it can not lower the control bus and the output remains the same.

Charge Fail Alarm Circuit - Detail
For the Charge Fail Alarm to activate two conditions must be met. First, there must be a low current condition. The current signal from the output of U8 is compared to a set voltage of approximately negative 20 mV at U1 pins 9 and 10. If output current falls below approximately 1% of the charger's rated current output, the current signal will rise above negative 20 mV and make U1 pin 8 go low. Second, there must be a low control bus condition . The control bus is compared to a set voltage of approximately 500 mV at U5 pins 2 and 3. If the control bus falls below this level meaning there should be a high current output, U5 pin 1 goes low. When both these conditions are met, a low signal from U1 pin 7 is sent to the alarm board producing a charge fail alarm.

High Voltage Shutdown Circuit - Detail
A circuit is provided to shut down the charger in the event that its output voltage exceeds a pre-set, adjustable level. When DC voltage rises higher than this level the circuit shuts down the control bus, thus disabling SCR firing and the charger's output. The circuit contains hysteresis so that reset will not occur until battery voltage falls below an acceptable level. Upon activation a relay with two sets of Form C contacts is energized and an on-board LED is lit. The signal is also sent to the alarm board to activate the display LED.

7 Theory of Operation- Alarm/ Display

7.1 Introduction

The alarm/display circuit monitors battery voltage and charger performance. The alarm circuitry consists of up to eight separate circuits: AC Fail, Charge Fail, High DC, Low DC, Low Voltage Load Disconnect, Ground Fault, Option, and Summary. Note that some of the alarm relays utilize time delays of approximately 25 seconds. This is deliberate, and is intended to eliminate the incidence of spurious alarm indications.

AC Fail, Charge Fail, High DC, Low DC and Summary alarms are included on all alarms cards. The Ground Fault, Low Voltage Load Disconnect and Option alarms are optional, and may or may not be included on the alarm. Each alarm circuit , with the exception of the summary alarm, has its own display LED, and all the alarms have relays with Form C contacts. The alarm/display board is also equipped with additional circuitry to monitor the float/boost status of the charger as well as voltmeter and ammeter calibration adjustments.

7.2 Printed Circuit Assembly Operating Supplies

The alarm/display circuitry operates on +12 V and ground with the ground being battery -. This voltage is obtained from the battery to assure operation at all times. The battery voltage is fed into a 12 V zener diode through a dropping resistor mounted off the board. This voltage is then filtered through a 10 μF capacitor, C1. This voltage supplies all op-amps and most display circuits.

A +2.5 V reference voltage is created for comparison applications. The +12V supply is fed into a band-gap zener diode (D2) through a 10K resistor. This voltage is buffered and sent out to the circuits.

7.3 Battery Voltage Sense

Because the alarm circuitry operates with a +12 V supply, the battery voltage must be sensed at a lower voltage. This is done through dropping resistors R8-R11. By adjusting potentiometer R22, a +5.5 V reference is obtained at the rated output voltage of the charger. This reference voltage rises and falls proportionally with the battery voltage.

7.4 Low DC Alarm

The Low DC alarm will activate when the battery voltage drops below the specified Low DC voltage.

This is done by comparing the battery reference voltage and +2.5 V. The trip point of this alarm is set by potentiometer R37. Upon activation of this alarm, pin 1 of U7 drops low thus lighting LED DN5. After approximately 25 seconds of time delay, relay K4 is de-energized by FET Q3. This alarm is fail safe, meaning that if the +12 V supply were disrupted for any reason the relay would automatically drop to the fail position.

7.5 High DC Alarm

The High DC alarm will activate when the battery voltage rises above the specified High DC voltage. This is done by comparing the battery reference voltage and +2.5 V. The trip point of this alarm is set by potentiometer R43. Upon activation of this alarm, pin 7 of U7 drops low thus lighting LED DN8. After approximately 25 seconds of time delay, relay K5 is energized by FET Q6 through op-amp U4 pin 1. This alarm is not fail safe, therefore the second stage op-amp is needed to activate the relay.

7.6 & 7.7 These Section sIntentionally Left Blank7.8 AC Fail Alarm

An AC Fail alarm is detected when the +12 V supply from the control board is not present. Because the control board is grounded off the shunt "-" which is a positive ground, an opto-isolator is used on the alarm board. Both signals are fed into U2 through R4. When there is no current to the diode of the opto-isolator the output transistor is turned off. This puts +12 V to pin 9 of U3. This is compared to the +2.5 V reference, which makes pin 8 of U3 go low turning on DN4 and de-energizing K2 through FET Q1. This alarm is fail safe, meaning that if the +12 V supply were disrupted for any reason the relay would automatically drop to the fail position.

7.9 Charge Fail Alarm

Just like the AC Fail alarm, the control board sends a +12 V signal to the alarm board when there is a failure of output The signal is fed into opto-isolator U1 through R1. When there is no current to the diode of the opto-isolator the output transistor is turned off. This puts +12 V to pin 13 of U3. This is compared to the +2.5 V reference, which makes pin 14 of U3 go low turning on DN7 and de-energizing K3 through Fet Q4. This alarm is fail safe, meaning that if the +12 V supply were disrupted for any reason the relay would automatically drop to the fail position. The charge fail logic circuitry is located on the control board.

7.10 High Voltage Shutdown Alarm

When the charger is in a high voltage shutdown condition, the control board sends a +12 V signal to the alarm board. This voltage sends a current through opto-isolator U6, thus turning on the output transistor and turning on transistor Q13. This lights LED DN9 to display the high voltage shutdown. The remote alarm contact for this alarm is located on the control board and activation of this alarm will not activate the summary alarm.

7.11 Ground Fault Alarm

The ground fault alarm activates when there is leakage current to the chassis caused by the presence of battery + or - on the chassis. By using a dual opto-isolator U5, this current can be detected. If battery "-" is on the chassis, current is sent through the opto-isolator by resistor R13 and zener diode D3. This activates the ground "-" output transistor turning off Q9 and turning on Q10. This lights DN11 and sends a high signal to U3 pin 3. This is compared with +2.5 V producing a high output energizing K1 through Q2. If battery "+" is on the chassis, current is sent through the opto-isolator by resistor R14 and zener diode D4. This activates the ground "+" output transistor turning off Q11 and turning on Q12. This lights DN10 and sends a high signal to pin 3 of U3. Once again K1 is energized. This alarm is not fail safe. The sensitivity of this alarm is typically 100 micro amps of ground current.

7.12 Summary Alarm

Whenever a failure occurs, that alarm will send a high signal to pin 6 of U4. This is then compared with +2.5 V producing a low output on pin 7 of U4 and de-energizing K8 through Q7. This alarm is fail safe, meaning that if the +12 V supply were disrupted for any reason the relay would automatically drop to the fail position.

7.13 AC On, Float and Boost LED's

The AC On LED will light whenever +12 V is sent from the control board through J2 pin 3. Current is sent through R46 thus lighting DN1.

The float and boost indicators are controlled by a signal sent from the control board. When this signal is at +12 V, the charger is in float. When it is at control board ground the charger is in boost. This signal is fed into Q15. When it is high Q15 is turned on and float LED DN3 is lit. If the signal is low , Q15 is turned off and Q14 is turned on, thus lighting boost LED DN2.

7.14 Lamp Test

By pressing the lamp test button (2 pole, 2 position momentary switch) on the front of the PCA all LEDs should light unless the AC has failed on the control board in which case the AC on, float, and boost LED's will not light. When this switch is pressed all alarm LED's are connected to ground through a steering diode. Each alarm has its own steering diode to prevent their relay from activating during the test. AC On, float and boost circuits are connected to control board +12 V thus turning on their LED's