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GENERAL ATOMICS
ELECTRONIC SYSTEMS

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CCS Power Supply
Operations & Maintenance
Manual

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This product is protected by U.S. Patent # 5,121,314.

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1 General Description and Specifications

General Atomics Electronic Systems (GA-ESI) CCS series is a high efficiency capacitor charging power supply line that utilizes a high frequency, series resonant inverter topology. The supply is packaged in an 8.75 inch tall, 19 inch rack mount chassis. The weight is approximately 65 pounds for oil-insulated supplies (≥10kV) and approximately 45 pounds for air-insulated supplies (<10kV). The power supply is specifically designed for constant current capacitor charging. The supply efficiency is greater than 85 percent, with a minimum power factor of 70 percent.

Fast over-voltage protection (OVP) is incorporated to prevent power supply damage in the event of an open-circuit load connection. Over-temperature protection is provided to prevent potential power supply failure in excessive ambient environments. Oil-insulated power supplies are forced air cooled by a single fan mounted on the rear panel, whereas air-insulated power supplies are forced air cooled by two fans mounted on the rear panel. Inrush current limit is also included to prevent surges on the user power grid during initial power supply turn-on.

Caution

The CCS power supplies are designed for capacitor charging applications; the power supply will not operate as a constant voltage source into a resistive type load.

TABLE 1-1
SPECIFICATIONS

Electrical Specifications

Regulation

- The regulation of the supply is load dependent. For most loads, the regulation will be maintained at about ±0.5% of full output voltage. For small load capacitors, the regulation is reduced, and the ripple voltage is increased. For additional information or assistance, please contact a Sales Engineer.

Charge Rate

- The charge rate is model dependent. The specified charge rate is measured at low input line voltage. The charge rate is line voltage dependent.

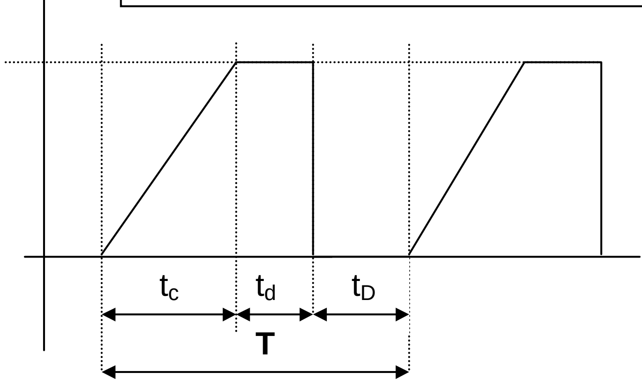
Output Voltage Stability

- ±0.2 percent typically over eight hours after 1.5 hour warm-up

TABLE 1-1
SPECIFICATIONS (cont'd)

Output Polarity	• Fixed, either positive or negative. It is set at the factory and cannot be reversed in the field.
Self-protection	• Over-current • Over-temperature • Over-voltage
Efficiency	• >85 percent
Power Factor	• ≥0.70 at beginning of charge cycle, increasing to >0.85 at the end of the charge cycle

Typical CCS Charging Profile and Definitions



T = period (sec)
t_c = charge time (sec);constant current
t_d = dwell time (sec)
t_D = dead time (sec, ≥DAD* = 100-200us)
$T = t_c + t_d + t_D$
f = rep-rate (Hz) — $E = (1/2)CV^2$
f = 1/T — $P = E/t_c$
C = capacitance (F) — V = chg voltage
P = supply output power (J/s)

*DAD: Delay after Discharge, set at the factory. This delay is built into the control circuit of the power supply. When the control circuit senses a discharge of the load, the supply will automatically inhibit itself for the duration of the DAD, typically 100-200µs. The purpose of this delay is to give the customer's high voltage switch (e.g. Thyratron) time to recover before charging resumes.

<u>Inputs</u>

Input voltage	• 208V, 400V, or 480V, 3∅, +/- 10%, 4 wire (L1, L2, L3 plus Ground) Delta or WYE service compatible, 50/60 Hz. 220VAC single phase and 300VDC inputs available, contact factory.

Input Current

- Per line:

$$I_{avg} = \frac{P_{out}}{\text{eff. x PF x Input Voltage x 1.732}} \quad (A / \varnothing)$$

where:
P_{out} - average rated output power (J/s)
PF - Power Factor ≥0.70
eff - efficiency > 0.85
Input voltage (Volts)

In applications where the charge time is several 60 Hz cycles long, the power line will begin to experience a peak current, which is twice the average current. This is due to the fact that the power supply starts out at the charge at essentially zero power (the output voltage is zero) and then ramps up to twice the average rated power, giving an average power of P_{out}.

Remote control

- HV ON/OFF, INHIBIT, VOLTAGE PROGRAM

<u>Outputs</u>

Monitor output signals

- End of Charge (EOC), HV ON indicator, Fault indicator, HV Inhibit indicator, AC ON indicator, INTERLOCK indicator

Remote power outputs

- +5.6V, +10V, +24V (unregulated)

<u>Mechanical Specifications</u>

Size

- 8.75 in. high (5U) x 20 in. deep, standard 19 in. rack mount

Weight

- 65 pounds (oil-insulated), 45 pounds (air-insulated)

Cooling

- Forced air with internal fan, minimum 3 inch spacing around rear and sides, 1 inch spacing on top of power supply chassis.

Operating Temp

- 0 to 40 ^{0}C inlet temperature

Humidity

- 10 to 90 percent. Non-condensing

<u>Option Specifications</u>

Several options are available for the CCS line of power supplies. Call the GA-ESI Sales Office at (858) 522-8400 for option pricing.

Option 01	Chassis slides – Mounted on sides of power supply	User installable
Option 02	Remote voltage sensing - <10kV models only	Factory installed
Option 04	Master-Slave interconnect cable – One per slave	User installable
Option 22	Delay after Discharge (DAD) custom configuration – Adjusted to ±5% of specified value (default 100-200µs)	Factory installed
Option 92	HV Enable Mode: Enable Active High	Factory installed
Option 99	Power Supply Test Log	

Model Number Nomenclature

CCS-UU-VVV-W-X-YYYY-Z

CCS: Capacitor Charging Power Supply
UU: Average power output (in kJ/s)
  02, 04, 06, 08, 10 and 12kJ/s are standard.
  12kJ/s is available for 400/480VAC inputs only for continuous operation.
  Higher power is available for limited duty cycle applications.
VVV: Maximum output voltage (in kV)
  2, 3, 5, 6 and 8kV are standard for air-insulated supplies
  10-50kV, in 5kV increments, are standard for oil-insulated supplies.
  Non-standard voltages up to 65kV are available.
W: Polarity
  P: Positive
  N: Negative
X: Instrumentation
  1: Instrumented with front panel controls
  2: Remote Controls only
YYYY: Modified Standard (Factory designated, 0000 is standard)
Z: Input Voltage
  C: 208VAC ± 10%, 3∅, 50-60Hz
  D: 400VAC ± 10%, 3∅, 50-60Hz
  H: 480VAC ± 10%, 3∅, 50-60Hz
  B: 220VAC ± 10%, 1∅, 50-60Hz (only available up to 4kJ/s)
  F: 300VDC ± 10%, (non-standard, contact the factory)

Example: CCS10030P10000C
Capacitor charging power supply, 10kJ/s, 30kV, Positive Polarity, Instrumented, Standard, 208VAC Input Voltage

2 Safety

2.1 PERSONNEL SAFETY

GA-ESI has made every effort to provide safety features to assure personnel safety in accordance with industry approved standards. The CCS power supplies are designed to meet UL 1950 and EN 60950 Safety Standards.

WARNING

The high voltage and AC power used in this power supply may be lethal. Before working with this equipment or components connected to the output of the power supply, turn OFF the control power and the main AC input power and securely ground all high voltage components.

CAUTION

A high voltage output capacitor must be connected to the high voltage output terminal of the power supply for the power supply to operate normally. Do not operate units without an output capacitor. Possible over-voltage damage could occur to the power supply's output rectifiers.

NOTE

External Interlock (TB2-1 & TB2-2) can be used in a system safety interlock scheme, but personnel should always securely ground all high voltage components before accessing any portion of the power supply.

The external interlock terminal strip, TB2-1 & TB2-2, can be used in a user's system interlock scheme to shut down the CCS power supply high voltage. The external interlock needs contact closure between TB1-1 & TB1-2, which enables the CCS +12Vdc control power. If the interlock contact is opened, the +12 V dc control power is removed, disabling the power supply. Interlock terminals of multiple power supply systems may NOT be chained together. To form a chain, isolated contacts must be used for the Interlock of each power supply.

DO NOT operate the unit without covers and panels or other mounting hardware as supplied and properly installed. All service should be performed by factory qualified personnel only.

2.2 EMERGENCY SHUTDOWN

In situations where the high voltage supply must be turned off due to an emergency situation involving personnel, facilities, or other equipment, the power supply should be inhibited using the HV INHIBIT, HV OFF, EXTERNAL INTERLOCK, and then the AC power removed. These means of stopping the output are listed in order of fastest response to the slowest.

WARNING

Under NO circumstances should the AC power be removed as the means of initially inhibiting the supply as this may not interrupt the HV output for several seconds.

2.3 EQUIPMENT SAFETY

The Power Supply is designed to operate with a 4 wire Delta or a WYE service. A neutral is not required for power supply operation.

CAUTION

A high voltage output capacitor must be connected to the high voltage output terminal of the power supply for the power supply to operate normally. Do not operate the power supply without an output capacitor. Possible over-voltage damage could occur to the power supply's output rectifiers.

CAUTION

The CCS power supply must be properly connected to the AC line with an appropriately rated Circuit Breaker, Fuse, Contactor, or Disconnect switch.

3 Connections

Please read Section 2, "Safety" carefully before proceeding.

WARNING

The high voltage and AC power used in this power supply may be lethal. Before working with this equipment or components connected to the output of the power supply, turn OFF the control power and the main AC input power and securely ground all high voltage components.

3.1 HV CONNECTION TO LOAD CAPACITOR

CAUTION

A high voltage output capacitor must be connected to the high voltage output terminal of the power supply for the power supply to operate normally. Do not operate units without an output capacitor. Possible over-voltage damage could occur to the power supply's output rectifiers.

1. Install the supplied HV output cable to the power supply module rear panel HV connector. Be sure that the HV cable is fully seated into the connector.
2. Terminate and connect the other end of the HV coax cable to your capacitive load.

3.2 EXTERNAL INTERLOCK

The interlock (TB2-1 & TB2-2) must be satisfied (a contact closure applied between the two terminals) to "enable" the CCS power supply.

3.3 AC POWER

WARNING

The high voltage and AC power used in this power supply may be lethal. Before working with this equipment or components connected to the output of the power supply, turn OFF the control power and the main AC input power and securely ground all high voltage components.

Connect an AC power cable of appropriate wire gauge size to the power supply rear panel TB-1. Please follow the appropriate National Electric Codes for connection of ∅L1, L2, L3, and GND wiring. Connect the AC wires to an appropriately rated circuit breaker, fuse, or disconnect.

3.4 START UP AND SHUTDOWN

3.4.1 AC ON

Prepare the system for normal operation and carefully follow safe operating practices. When ready, remove the system interlock barriers and safety grounds to enable the system. Energize main AC via the facility main breaker and/or disconnect switch.

3.4.2 Controls

Carefully read Section 5.3, REMOTE CONTROL and Table 5-1 and follow the appropriate procedures.

3.4.3 Powering Down

First, inhibit the HV output. Then remove the AC POWER via the facility main breaker and/or disconnect switch.

4 Functional Description

The power supply module block diagram is shown in Figure 4-1. Each power supply module has four basic modular subassemblies: Input power, Inverter, High Voltage output and Control. The input power section includes a common / differential mode EMI filter, inrush surge limit circuit, and 3∅ line rectifier and filter capacitors. The power supplies include a Power Factor Correction (PFC) choke. The switching power inverter utilizes a series resonant “H” bridge topology, which drives the primary of a multi-secondary high frequency step-up transformer. Multiple, full-wave bridge, high voltage rectifier circuits produce the rectified high voltage output. The control circuit utilizes a high regulation scheme to drive the power converter depending on customer needs. All user controls are buffered and interface with the control circuit directly. The following is a detailed description of the functions of each element in the block diagram.

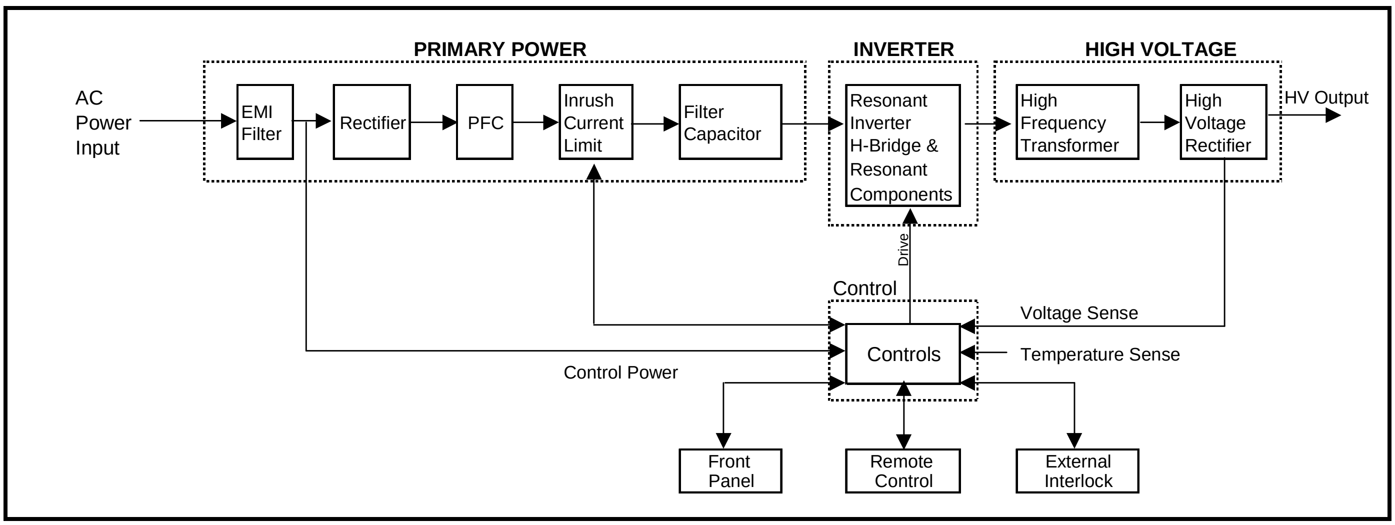


Figure 4-1. Power Supply Functional Block Diagram.

4.1 INPUT POWER

4.1.1 Input EMI Filter

The 3∅ input EMI filter attenuates both common mode (line-to-chassis) and differential mode (line-to-line) high frequency noise. This includes conducted EMI, RF noise generated internally by the power supply inverter circuit and externally generated noise which may enter the power supply on the power lines. The filter is composed of a 3∅ balanced inductor with "X" (line-to-line) and "Y" (line-to-ground) capacitors placed symmetrically on both sides of the inductor. The filter has a common mode attenuation of better than 40 dB at 1 MHz and above.

4.1.2 Inrush Current Limit

The inrush current limit circuit prevents high inrush surge currents during the charging of the input capacitors when the AC power is initially energized. The input capacitors are initially charged through a resistor, which limits the inrush charging current to less than the average operating current. After approximately 1.5 seconds a relay is actuated to bypass the inrush limiting resistor, thus connecting the input capacitors directly to the input rectifier.

4.1.3 Rectifier and Filter

The 3∅ AC line is rectified and filtered to provide the power supply with a stable internal DC bus voltage.

4.2 INVERTER

The power converter utilized in the CCS power supply is a series resonant "H" bridge topology operating in the 30 to 60 kHz range. This particular converter topology is ideal for high power, capacitor-charging applications since it reflects a high source impedance to the output; consequently, this topology is inherently short circuit proof. The output characteristics of the inverter topology combined with the CCS control topology result in a constant current (linear) charging profile.

The H-bridge switch elements are comprised of insulated gate bipolar transistors (IGBT's). The characteristics of these devices provide reliable high voltage, high current capability. When used as switches in a series resonant configuration in PRM (normal regulation) mode, the devices switch at zero current because of the sine wave property of the current in the LC circuit. As a consequence, the switching transistors have near-zero switching losses as compared to conventional pulse width modulated, quasi-square wave converter topologies.

4.3 HIGH VOLTAGE OUTPUT CIRCUITRY

A multiple secondary high voltage transformer is used to step up the inverter voltage to the required output voltage. Multiple high voltage secondary windings are used to reduce the effects of parasitic resonance caused by secondary inductance and self-capacitance and to simplify the diode assemblies. Each winding is full-wave rectified by a high voltage diode bridge configuration. The rectifier circuits are then connected in series to sum the rectified voltage levels to the final output level.

The high voltage power transformer and high voltage output section have been specially designed for this application. Each of the components were optimized based on the output voltage and current to ensure that no component is over-stressed. Additionally, particular attention has been paid to spacing requirements to ensure adequate voltage stand off.

4.4 CONTROL CIRCUITRY

The inverter operates in the full resonant mode during charging. Once the desired output voltage has been reached, the controller will deliver individual pulses of current ("charge buckets") to the load as needed to maintain the set voltage. Refer to Table 1-1 for complete regulation specifications.

A fast over-voltage protection (OVP) circuit is also provided in the event of an accidental output open circuit. The circuit latches the fault and must be reset to resume normal operation.

CAUTION

The user should NOT allow the power supply to operate into an open circuit.

CAUTION

The CCS power supplies are designed for capacitor charging applications, and the power supply will not operate as a constant voltage source into a resistive type load.

5 Operating Instructions

The system is capable of being operated either from the front panel or the remote control input. When operating from the front panel, the remote program voltage input must be open circuited in order to achieve the programmed voltage from the front panel. The user interface consists of a single 25 pin DB-25 female connector located on the back of the instrumented supply. The pin-out is described in Table 5-1.

5.1 EXTERNAL INTERLOCK

An external safety interlock is provided by TB2-1 and TB2-2 on the rear panel of each power supply. The Interlock can be utilized as a safety switch to disable the power supply HV output in the event of an external fault condition. An open circuit between TB2-1 and TB2-2 on any power supply will stop operation of the power supply system, and latch the fault condition. In order to resume power supply operation, the interlock must be made and the power supply reset by cycling the HV OFF and then ON again.

5.2 LOCAL CONTROL

There are two 3-position switches on the front panel of the instrumented power supply. These switches are for HV ON/OFF Control and Remote/Local selection of the programmed voltage setpoint, Vprog.

The HV ON/OFF Control switch will override the HV command from the Remote Control when placed in the up (ON) or down (OFF) position. When this switch is placed in the up (ON) position, the high voltage is commanded ON, and the output will go to the program setpoint determined by the Remote/Local Vprog selection switch and the appropriate Remote or Local Vprog input.

The Remote/Local Vprog selection switch allows three methods of voltage program control. The user may force the Vprog to be determined by the front panel potentiometer (down or Local Vprog position), by the remote control input (up or Remote Vprog position), or allow the Remote Control to select either the Vprog setpoint by proper toggling of pin 8 on the Remote Control input cable.

Selecting the front panel switch for Local voltage programming will force the Master unit to ignore the programming commands received from the remote connection (note, in this mode, the remote Vprog input should be an open circuit to prevent this input from affecting the accuracy of the programmed voltage). Once Local voltage programming has been selected, the front panel potentiometer is used to set the desired high voltage output. The “View Set” button on the front panel may be depressed to determine the high voltage program setpoint before actually energizing the output.

Figure 5-1. CCS High Voltage Power Supply Front Panel – Instrumented.

5.3 REMOTE CONTROL

The user controls and monitor interfaces for the power supply are available through the remote control DB25 (female) connector on the rear panel of the instrumented power supply module. Multiple modules are operated using the interface connector on the rear panel of the power supplies (J902 “NEXT” connected to J901 “IN” of the next supply in the chain). Any number of slave units may be chained in this fashion. A summary of the remote interface is shown in Table 5-1. A detailed description of each function follows.

Attention should be given to the length, routing and shielding of the remote control cable. Recommended length is $\leq$20 feet. 22 gauge (AWG) wire cable, shielded, is the minimum recommended wire size. For lengths greater than 20 feet, it will be necessary to use larger conductors to avoid adverse effects from the wire resistance. Routing of the wire near the HV output cable can induce currents/voltages on the control lines which can result in erratic power supply operation or even remote control input damage.

Figure 5-2. Typical CCS High Voltage Power Supply Rear Panel.

5.3.1 High Voltage Inhibit

A +4 to +24V INHIBIT input is provided on pin 7 to rapidly disable the inverter when the HV ON is in the activated state. The INHIBIT allows for a fast termination of a charging cycle or external logic controlled charging periods. The INHIBIT input pin is referenced to GROUND. Upon release of the INHIBIT, a HV command is necessary in order to resume power supply charging. The power supply typically can shut down in $\leq$33 us. The control for the INHIBIT is set at the factory as Inhibit Active High.

5.3.2 End-of-Charge (EOC)

An open collector output is provided on pin 13 that is in a Logic "1" state, i.e., the output transistor collector is low when the supply is in the charging mode. The collector goes high when the preset charge voltage is reached and the supply switches to the "keep alive" mode. This signals the EOC and tells the remote user the load capacitor is charged to the programmed voltage and is awaiting discharge into the load. The collector will remain in the high state as long as the load capacitor voltage is at the programmed voltage level. This output is referenced to GROUND and can sink up to 25mA. Pins 11 and 15 of the remote control connector (J901), are available for use as the control signal grounds.

CAUTION

The maximum voltage to be applied to any open collector output through a pull-up resistor is +24 V DC. The pull-up resistor should limit the current to less than 25mA.

5.3.3 Voltage Monitor

A 0 to +10 V output signal located on pin 5 of the remote control connector (J901) provides a linear analog monitor of the power supply output voltage corresponding to 0-100% full scale output. This output signal is referenced to ground, pins 11 and 15.

5.3.4 Current Monitor

An analog current monitor of the power supply's output current is located on pin 6 of the remote control connector (J901). The current monitor voltage output is calibrated depending on the average output current of the power supply. For output currents ≤ 600mA, the current is represented as 1V/100mA. For output currents > 600mA, the current is represented as 1V/1A. This output signal is referenced to ground, pins 11 and 15.

5.3.5 AC ON Monitor

An open collector output on pin 18 of the remote control connector (J901) is used for the AC Power On monitor. The open collector is in the conducting state only when the AC power in the power supply is on. This output is referenced to control signal ground and can sink up to 25mA of current.

5.3.6 HV ON Monitor / HV Inhibit Monitor

An open collector output on pin 14 of the remote control connector (J901) is used for the HV ON / HV Inhibit monitor. The open collector is in the conducting state only when the HV is ON, and in the high impedance state when the power supply is inhibited. This output is referenced to control signal ground and can sink up to 25mA of current.

5.3.7 Interlock Monitor

Pin 2 of the remote control connector (J901) is used for the Interlock monitor. +12V is present on this pin only when the interlock of the power supply is closed (i.e. contact closure on TB2-1 & TB2-2) and the AC power is on. The output impedance of this pin is 10kΩ. This output is referenced to control signal ground.

5.3.8 HV On Control

Pin 4 of the remote control connector (J901) is used for HV On/Off control. A +4 to +24V signal applied to this pin will turn on the power supply HV, provided there are no faults and no inhibit signal is present. The HV will stay on as long as the power supply HV control is present and no fault or inhibit signal occurs. The HV can be toggled Off & On by removing and reapplying the HV On control signal. This input signal is referenced to control signal ground, pins 11 and 15.

5.3.9 HV On Monitor

An open collector output on pin 17 of the remote control connector (J901) is used for the HV On monitor. The open collector is in the conducting state only when the HV ON is present and the power supply set is putting out power. This is referenced to control signal ground and can sink up to 25mA of current.

5.3.10 Fault Monitor

An open collector output on pin 9 of the remote connector (J901) is used for the Fault monitor. The open collector is in the conducting state when no fault is present. A fault is latched and will not clear until the HV ON input is cycled from ON to OFF and back to ON. This may be accomplished either from the Remote Control or the front panel HV control switch. Internal power supply fault conditions are: open interlock, over-temperature, or over-voltage. This output is referenced to control signal ground, pins 11 and 15, and can sink up to 25mA of current.

5.3.11 HV Set Point

A 0 to +10Vdc input signal on pin 12 of the remote control connector (J901) will set the power supply output voltage level. 0 to +10Vdc input linearly corresponds to 0 to 100% output voltage. This input signal is referenced to control signal ground, pins 11 and 15.

5.3.12 +24Vdc Power

Pin 3 of the remote control connector (J901) is supplied with +24Vdc to be used for driving the user interface. This dc power can supply maximum of ~20mA for interface drive current. The current is limited by an internal 1k Ohm resistor. This signal is referenced to control signal ground, pins 11 and 15.

5.3.13 +10V Reference

Pin 10 of the remote control connector (J901) is supplied with a +10V reference to be used with an external potentiometer to set the voltage programming. It is recommended that the external potentiometer be at least 10k Ohms in value. This signal is referenced to control signal ground, pins 11 and 15.

TABLE 5-1. 25 PIN REMOTE CONTROL INTERFACE

PIN #	DESCRIPTION
1	No Connect: This signal pin is used as an interface between the Master and Slave units. Do not connect anything to this pin.
2	Interlock Indicator: • +12V present when interlock contacts are closed • Z_{out} = 10kΩ
3	+24Vdc Unregulated: • 20mA maximum
4	High Voltage ON/OFF: Turns High Voltage On and Off if external interlock and remote control enable conditions are met. • Logic state "1" (+4 to +24V dc) = High Voltage ON • Logic state "0" (0 to +1V dc) or open circuit =High Voltage OFF • Z_{in} = 10 kΩ
5	Voltage Monitor: Filtered and buffered representation of the HV output. • 0 to 10V dc =0 to 100% of the power supply's rated output voltage • Z_{out} = 100Ω
6	Current Monitor: Average current output of the Master power supply. • CCS ≤ 600mA rated output current; 1V=100mA • CCS > 600mA rated output current; 1V=1A • Z_{out} =1kΩ
7	Inhibit (responds in ≤33 us): Inhibits power supply in a single switching cycle, removing HV output. • Inhibit active high • Logic "0" (0 to +1V dc) = power supply is free to run • Logic "1" (+4 to +24V dc) = power supply is inhibited • Z_{in} = 100 kΩ If Option 92 is installed (Enable Active High), the logic is reversed. Note that with Option 92 installed, this pin has to be pulled high to make the power supply run, even if the supply is to be controlled from the front panel in local mode.

TABLE 5-1. 25 PIN REMOTE CONTROL INTERFACE (cont.)

PIN #	DESCRIPTION
8	Remote/Local Control: Used to determine if the power supply is controlled from the front panel (Local) or the Remote Control inputs. See section 5.2 for front panel switch settings to make proper use of this pin. • Pin grounded; power supply in remote control mode • Logic state “1” (+4 to +24V dc) or open circuit; power supply in local control mode
9	Fault: • Internal power supply fault conditions are: open interlock, over-temperature, or over-voltage • Open collector output • High impedance state represents an internal power supply fault condition • Low impedance state = 100Ω • I_{sink} =25mA max
10	+10V Reference: For use with an external potentiometer to set Vprogram. • 2mA maximum
11,15	GROUND for Control Signals: • 225mA maximum • Digital & Analog Grounds connected together
12	Remote Voltage Programming: • With the supply in the remote mode (remote enabled), this is a 0 to 10V input for 0 to 100% output voltage • Z_{in} =10 kΩ Note: This input must be an open circuit when in the Local Vprogram mode to prevent interference with the front panel potentiometer setpoint.
13	End of Charge (EOC): Indicates the power supply has reached the programmed voltage setpoint. • Open collector output; High impedance state represents EOC • Low impedance = 100Ω • I_{sink} =25mA max
14	HV ON / Inhibit Monitor: Indicates the power supply is inhibited. • Open collector output • Low impedance state represents HV ON • High impedance state represents HV output inhibited • Low impedance = 100Ω • I_{sink} = 25mA max

TABLE 5-1. 25 PIN REMOTE CONTROL INTERFACE (cont.)

PIN #	DESCRIPTION
16	No Connect: This signal pin is used as an interface between the Master and Slave units. Do not connect anything to this pin.
17	High Voltage ON Monitor: Indicates HV ON. • Open collector output • Low impedance state represents High Voltage On • Low impedance state = 100Ω • I_{sink} =25mA max
18	AC ON Monitor: Indicates AC power is ON. • Open collector output • Low impedance state represents AC power ON • Low impedance state = 100Ω • I_{sink} = 25mA max
19-25	No Connection: These pins are not to be connected by the user.

5.3 AC INPUT CONNECTIONS

The AC power connections are made to TB1 located on the rear panel as shown in Figure 5-3. The ground wire must be connected to the chassis ground (GND) screw terminal located next to TB1.

NOTE

The chassis ground connection MUST be made to assure personnel safety.

The 3∅ input cable should be sized to handle the maximum input current stated in the electrical specifications section of this manual.

Figure 5-3. AC Power Connections.

6 High Voltage Output Connection

The high voltage output is accessed through the rear panel with a coax cable assembly. A short (~8 ‘) cable for connection of the high voltage from the power supply to the load has been included. See Figure 6-1 for the location of the HV Output connector.

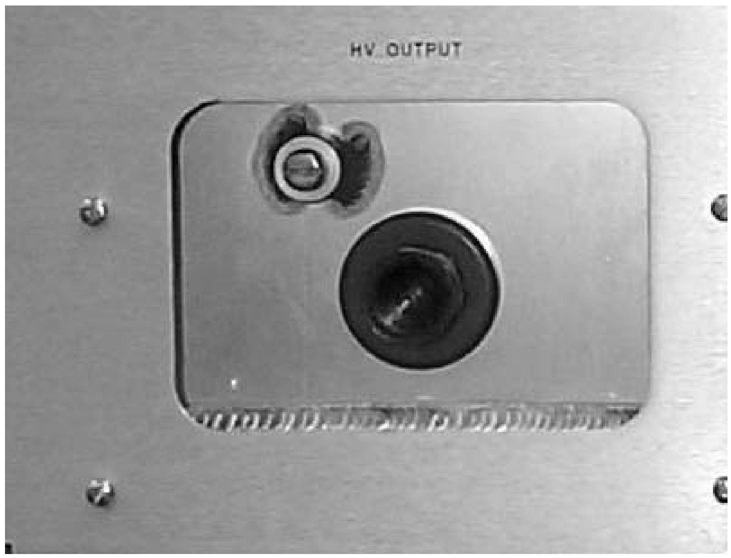


Figure 6-1. Typical HV Output Connector.

7 Voltage Reversal Protection

7.1 INTRODUCTION

This section describes a Voltage Reversal Protection or Fault Protection circuit for use with GA-ESI line of CCS capacitor charging power supplies. It is designed to assist users with the issue of protecting the power supplies from transient voltage reversals that are present in many applications, either continuously or under fault conditions.

Energy storage capacitor voltage can reverse in polarity as it discharges. As a result, the CCS power supply output rectifiers can experience significant surge currents if the output is connected directly to the energy storage capacitor (or the "load capacitor" as shown in Figure 7-1) during the discharge. The magnitude and duration of the surge currents are dependent on the characteristics and parameters of the discharge circuit.

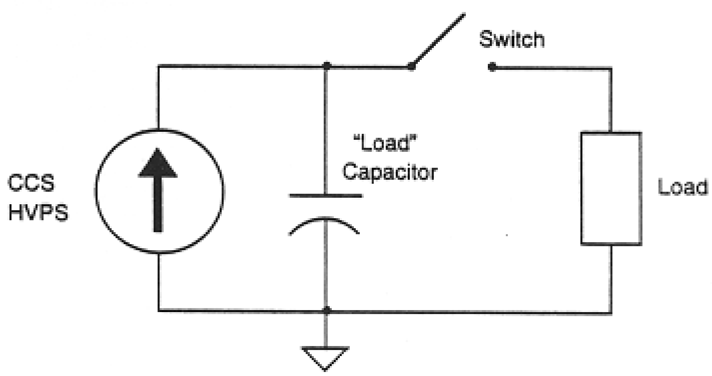


Figure 7-1. Typical Application Of CCS Capacitor Charging Power Supply

If this surge current (together with the normal power supply current) exceeds the peak current rating, or the integrated average current rating of the rectifiers, irreversible damage to the power supply may occur.

Table 7-1 lists the CCS power supplies by voltage and power, identifying the high voltage rectifier ratings of peak repetitive surge current for an 8.3ms pulse, peak non-repetitive surge current for an 8.3ms pulse, and average current rating of the rectifier. Ambient temperature is assumed to be the temperature of the oil in the high voltage tank, not the temperature that the supply is operated in.

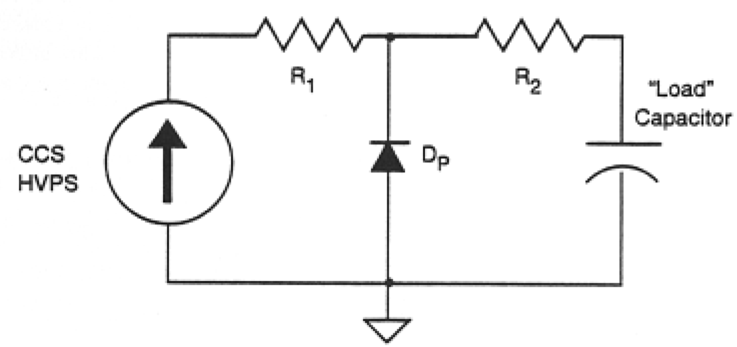
Voltage kV	Power kJ/s	Peak Repetitive Surge Current, A 8.3ms, 25°C Ambient	Peak Non-Repetitive Surge Current, A 8.3ms, 25°C Ambient	Average Current Rating, A 100°C Ambient
2-8	2-12	16	100	8
10	2-5	10	60	1
10	6-8	20	120	2
10	10-12	50	200	3*
15-20	2-5	8	40	0.5
15-20	6-8	16	80	1
15-20	10-12	35	150	2.2*
25-50	2-5	5	25	0.25
25-50	5-8	10	50	0.5
25-50	10-12	25	100	1.5*

*At 55°C ambient temperature

Table 7-1. Current Ratings for Output Rectifiers.

7.2 HIGH VOLTAGE PROTECTION CIRCUITRY

If the application can result in surge currents exceeding any of the ratings listed in Section 7-1, then the CCS power supply must be protected externally. External voltage reversal protection, such as a freewheeling diode assembly with series resistors, as shown in Figure 7-2, is recommended.



Notes:

- R_1 limits the surge current through the power supply output rectifiers
- D_P selected by maximum voltage of circuit and load surge current
- R_2 limits surge current through D_P, select based on D_P surge current ratings

Figure 7-2. Suggested Voltage Reversal Protection Circuit Schematic

In Figure 7-2 above, resistor R_2 limits the peak current through the diode stack, D_p. Choosing the value of R2 begins with a trade-off of two parameters, the peak surge current through the diode stack D_p, and the power dissipated in R_2 during normal operation. If R_2 is chosen as a large resistance value, the current ratings of the diode stack D_p are reduced, but the power dissipation in R_2 during the normal charging process increases. Also, to ensure voltage accuracy and repeatability, the voltage drop across R_2 during charging must be small compared with the capacitor charging voltage desired.

The design of the diode stack D_p is dictated by the peak surge current resulting from the selection of R_2 and the power supply output voltage. CKE[1] supplies high voltage diode stacks for use as freewheeling diodes, and can assist in choosing the proper diode stack.

Resistor R_1 is selected to limit the peak surge current through the power supply output high voltage rectifiers due to the forward voltage drop across D_p. To limit the power dissipation and to maintain charging accuracy, R1 should be as small as possible. For practical purposes. R_1 and R_2 are often chosen to have the same value. Both R_1 and R_2 must be capable of handling the DC current (and power) as well as any instantaneous transient or surge. Typically, a non-inductive ceramic type of resistor is recommended, such as the Kanthal Globar[2] line of type-AS resistors.

1 CKE; www.hvca.com
2 Kanthal Globar; www.globar.com

8 Mounting

The power supply is contained in a standard 19 in. wide by 8.75 in. (5U) tall rack mount chassis. The chassis depth is approximately 20.5 in. When mounting the power supply in a rack mount cabinet, allow a minimum of 3 in. of space at the rear and on each side of the supply for proper cooling airflow. Use a bend radius of ≥2 in. for the output cable. When mounting the supply in a rack mount cabinet, the power supply must be supported by chassis slides provided in order to avoid excessive stress in the front panel.

CAUTION

The power supply is designed to be mounted by the chassis slides provided. Mounting the supply by the front panel ONLY can result in damage to the unit.

NOTE

When mounting chassis slides, do not insert screws more than 1/4 in. into chassis.

9 Application Notes and Comments

9.1 CHARGING LARGE CAPACITOR BANKS

For applications involving large capacitances which take longer than several 60 Hz cycles to charge, the user supplied external circuit breaker that feeds the AC to the power supply may begin to "see" the peak current rather than the average current. For such situations, the breaker may have to be sized for the peak current rating. The peak current rating needed to supply the CCS power supply is typically twice the average current rating.

9.2 OVERVOLTAGE/NO LOAD CONDITION

The CCS power supply is designed to self inhibit in case of an open load. The OVP circuitry will protect the power supply in the event of an accidental open circuit output connection or no load condition. The user should make every effort to prevent this condition from occurring.

CAUTION

Do not operate unit without an output capacitor. Possible over-voltage damage could occur to the power supply's output rectifiers.

9.3 VOLTAGE REVERSAL PROTECTION

Please read Section 7 for information on dealing with voltage reversal protection for the CCS power supply.

9.4 SPECIAL APPLICATIONS

For special applications not outlined in this manual, please consult a GA-ESI applications engineer at (858) 522-8400 for information and/or specific details regarding your needs.

10 Service

All servicing must be conducted or supervised by GA-ESI service engineers. The power supply is modular and the modular sections can be removed for servicing or exchanged under the direction or supervision of GA-ESI service engineers. It is therefore recommended that the product be returned to GA-ESI for servicing, for both warranty and after warranty repair. Prior to shipping a power supply for service, call the GA-ESI Sales Office at (858) 522-8400 to obtain a "Returned Goods" number.

WARNING

If AC power is connected to the AC input of the power supply, AC power will be present in the power supply. This voltage may be lethal. Before working within this equipment, disconnect the main 3∅ AC input power at the source, and wait a minimum of five minutes for the energy stored in the AC filter capacitors to dissipate. Upon opening the unit, discharge the input capacitors through a resistor (appropriately rated to safely discharge up to 1000 V) and then securely ground the filter capacitors.

CAUTION

The making of adjustments to a module in the power supply must be done by GA-ESI or its properly trained representatives. Severe damage may occur due to improper adjustment. Any warranty service must be performed by or under the direct supervision of factory qualified personnel only.

11 Troubleshooting Guide

Problem	Possible Cause
Power supply does not turn ON when AC POWER applied.	AC power source is not energized. Internal fuse for control logic may be opened.
Remote High Voltage ON cannot be activated	External rear panel interlock connection not made properly on TB201, see Section 5.1. Improper wiring and/or shorted pins remote interface.
High Voltage ON activated, but no voltage is produced.	High voltage output is shorted at load.
	Voltage adjust control is set to zero.
	High voltage output rectifiers may be damaged.
	Option 92 may be installed. Check the remote control setup.
External Circuit Breaker or Contactor trips during Power Supply AC power turn-on.	Circuit breaker may be under-rated.
Power supply output voltage comes up, then fault indication occurs.	Open circuit on the output of the power supply.

For problems not covered in the troubleshooting guide, contact the GA-ESI Sales Office at (858) 522-8400 to speak with an applications engineer.

Appendix A- Schematic Diagrams

13214	Schematic Diagram, Input Board, 400/480VAC
13397	Schematic Diagram, Input Board, 208VAC
13465	Schematic Diagram, Inverter, 400/480VAC
14025	Schematic Diagram, Inverter, 208VAC
13208	Schematic Diagram, Inverter Driver
96026	Schematic Diagram, High Voltage Output, Oil
13636	Schematic Diagram, High Voltage Output, Air
12482	Schematic Diagram, Remote Control Interface

Appendix B: Material Safety Data Sheets

Shell DIALA-AX Oil MSDS