

Temescal

CV-6SLX TECHNICAL MANUAL



Revision F, July 2008

Temescal, a part of Edwards Vacuum, Inc.
4569-C Las Positas Road, Livermore, CA 94551
Tel: 1-800-522-1215; Fax: 925-449-4096

Revision History

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Revision	Change Description	Reason/Application	Date	Approved
A	First preliminary version of manual	To support initial installation	March 2007	—
B	Second preliminary version of manual	Minor revisions to Sections 1 and 2. Added sections 3 and 4. Appended Pinout Table for rear panel diagnostic port J3 and Interconnect Diagram (0620-9502-0).	April 2007	—
C	Added Section 5. Minor changes to Sections 1-4.	Internal review only.	Dec. 2007	—
D	Added sections 4.2 and 5.3. Revised section 5.2. Minor corrections to Section 1-3.	Internal review only	May 2008	—
E	Minor corrections to all sections.	Pursuant to technical review of Rev. D.	June 2008	LW
F	Inserted new sections 2.2 and 2.4 plus Figures 2-6, 2-18, 4-2, and 4-4. Minor text revisions in Sections 1, 4, and 5.	Section 2 revisions made at request of Temescal Sales/Marketing. Section 4 changes made to improve technical accuracy.	July 2008	LW

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Attached Drawings

Pinout Table for Power Module Diagnostic Port (Rear Panel Connector J3)

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SUMMARY OF TERMS AND CONDITIONS OF SALE

MECHANICAL WARRANTY: For a period of twelve (12) months from the date of original shipment to Purchaser thereof, the apparatus and each part or component manufactured by Temescal, a part of Edwards Vacuum, Inc., hereinafter known as "Seller," is warranted to be free from functional defects in materials and workmanship. The foregoing warranty is subject to the condition that the apparatus, part, or component be properly operated under conditions of normal use, and that regular periodic maintenance and service be performed, or replacements made, in accordance with instructions provided by Seller. The foregoing warranty shall not apply to any apparatus, part, or component that has been repaired other than by Seller or an authorized representative of Seller, or in accordance with written instructions provided by Seller; that has been altered by anyone other than Seller; or that has been subject to improper installation or abuse, misuse, negligence, accident, or corrosion.

Purchaser's sole and exclusive remedy under the above warranty is limited to, at Seller's option, repair or replacement of defective parts or components, or return to Purchaser of the price of the apparatus. Any such obligation on Seller's part is subject to the following requirements: (x) the defect must be promptly reported to Seller; (y) if so advised by Seller, Purchaser must return the part or component with a statement of the observed deficiency not later than seven (7) days after the expiration date of the warranty to the address designated by Seller, during normal business hours, transportation charges prepaid; and (z) upon examination by Seller, the part or component must be found not to comply with the above warranty. Return trip transportation charges for the part or component shall be paid by Purchaser. In the event that Seller elects to refund the purchase price, the apparatus shall be the property of Seller and shall be promptly shipped to Seller at Seller's expense. This mechanical warranty shall be void and the apparatus shall be deemed to be purchased AS IS in the event that the entire purchase price has not been paid within thirty (30) days of original shipment of the apparatus.

THERE ARE NO EXPRESS OR IMPLIED WARRANTIES THAT EXTEND BEYOND THE WARRANTY HEREINABOVE SET FORTH. THERE IS NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE APPARATUS OR ANY PART OR COMPONENT THEREOF, AND NO WARRANTY SHALL BE IMPLIED BY LAW.

Items not of Seller's manufacture but resold by Seller are the products of other manufacturers and their warranty, if any, shall apply. THERE ARE NO WARRANTIES OF ANY KIND ON PRODUCTS OF OTHER MANUFACTURERS RESOLD BY TEMESCAL, EXCEPT THE WARRANTY OF TITLE, AND NO WARRANTIES SHALL BE IMPLIED BY LAW. THERE IS NO EXPRESS OR IMPLIED WARRANTY OF MERCHANTABILITY OR OF FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO PRODUCTS OF OTHER MANUFACTURERS.

PERFORMANCE WARRANTY: Seller warrants that the apparatus will comply with the specifications set forth in the purchase order. All specifications are subject to the corrections and tolerances allowed by the NEC. If the purchase order expressly provides for factory testing to verify compliance with the specifications, Purchaser shall be entitled to witness the testing and the results of the testing. Upon demonstration of compliance with the specifications by factory testing, Seller's liability for failure to comply with the specifications shall terminate. In the event that the purchase order does not describe a comprehensive test program for demonstration of compliance with the specifications, Seller's test program (which may incorporate extrapolation of data or test results based upon similarity of criteria established by Seller) shall be used for such purpose.

If the purchase order does not expressly provide for factory testing, compliance with the specifications shall be demonstrated by field testing which shall be conducted by Purchaser at Purchaser's expense. Seller shall have the right to: (a) witness the field testing and to verify the results of such field testing; (b) have free access to all data compiled by Purchaser in connection

with any field test; and (c) conduct its own field test at its own expense during any fourteen-day (14-day) consecutive period which may be mutually agreed upon by Seller and Purchaser; provided, however, that Seller shall have the right to field test within six (6) months of receipt from Purchaser of any notice of failure to comply with the specifications. If compliance with the specifications is to be demonstrated by field testing, Purchaser shall conduct and complete all field testing within sixty (60) days of the original shipment of the apparatus and shall promptly notify Seller of any failure to comply with the specifications. Seller shall not be liable for any failure to comply with the specifications demonstrated by field testing unless it receives notice thereof within sixty-seven (67) days of the date of original shipment of the apparatus.

In the event that factory testing or field testing does not demonstrate compliance with the specifications, Purchaser's sole and exclusive remedy under the above warranty is limited to, at Seller's option, repair or replacement of defective parts or components or return to Purchaser of the purchase price of the apparatus. In the event that Seller elects to refund the purchase price, the apparatus shall be the property of Seller.

Any obligations on Seller's part under this performance warranty are subject to the following requirements: (x) the nature of the failure of the apparatus to comply with the specifications must be promptly reported to Seller in writing; (y) if the apparatus has been delivered and field tested, Purchaser must return the apparatus or any part or component to Seller upon its request, not later than sixty-seven (67) days after initial shipment to Purchaser, to the address designated by Seller, during normal business hours, transportation charges prepaid; and (z) upon examination and testing by Seller, the apparatus must be found not to comply with the specifications. Return trip transportation charges for the apparatus or any part or component shall be paid by Purchaser. This performance warranty shall be void and the apparatus shall be deemed to be purchased AS IS in the event that the entire purchase price has not been paid within thirty (30) days of original shipment of the apparatus.

THERE ARE NO EXPRESS OR IMPLIED WARRANTIES THAT EXTEND BEYOND THE WARRANTY HEREINABOVE SET FORTH. THERE IS NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THE APPARATUS OR ANY PART OR COMPONENT THEREOF, AND NO WARRANTY SHALL BE IMPLIED BY LAW.

DISCLAIMER OF LIABILITY: IN NO EVENT SHALL SELLER BE LIABLE FOR DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES ARISING FROM ANY SOURCE such as, but not limited to, the manufacture, use, delivery (including late delivery), or transportation of any apparatus, part, or component sold to Purchaser, whether such damages are caused by Seller's negligence or otherwise. Without limiting the generality of the foregoing sentence, Seller shall not be liable for: the cost of capital; the cost of substitute apparatus, services, repairs, components, or parts; loss of profit or revenue; the cost of power, whether purchased or produced by the consumer thereof; loss of use of the apparatus or any part thereof, or of any other property owned by Purchaser; claims or costs of Purchaser's customers; injury to persons, or death; or damages to any property. In the event that any limited warranty or disclaimer of liability is found to be unlawful or inapplicable, or to have failed of its essential purpose, Seller's liability shall be limited to the amount paid by Purchaser for the apparatus.

SAFETY INSTRUCTIONS FOR OPERATING AND SERVICE PERSONNEL

Operators and service personnel should always wear safety glasses. Operators shall not enter areas intended for service access only. Only experienced service personnel should enter such areas, and only after taking the preliminary precautions described in paragraphs 1 through 6 below.

DANGER

Potentially lethal voltages may exist within this unit, even with the line power switched off. Service should only be attempted by qualified personnel. Failure to observe all safety precautions may result in personal injury.

This component is designed to operate as part of a system containing high-voltage equipment. Observe the precautions described below when servicing this system, especially when servicing components where high voltages may be present.

1. Before servicing or operating this equipment, read all the component manuals supplied with the system, paying special attention to safety instructions.
2. Post HIGH VOLTAGE WARNING signs in conspicuous locations within the service area.
3. Remove rings, watches, bracelets, and any other metal jewelry before working around high voltage.
4. DO NOT WORK ALONE!
5. Be sure that all equipment is connected to a power receptacle having the correct polarity and grounding, as prescribed by the local electrical codes. Refer to the power supply portion of the documentation to determine the proper electrical ground for high-voltage components.
6. Before servicing any high-voltage component, switch off the electrical power at the component's main power switch. This switch should have a lockout feature. Lock the power off and keep the key with you while you are working on the equipment.
7. Certain electrical parts (e.g., electrolytic capacitors) hold a lethal voltage even after the power is switched off. Before entering any service area, use a grounding hook to discharge such parts. Be sure that these parts are discharged before starting any repairs.
8. DO NOT touch high-voltage leads unless power is off and a grounding hook is connected to the parts to be serviced.
9. The high-voltage components of the system should be equipped with electrical interlocks to protect personnel from injury. DO NOT ATTEMPT TO DEFEAT, OVERRIDE, OR BYPASS THESE PROTECTIVE DEVICES!
10. Never leave loose ends on high-voltage connections.
11. Observe the following warning if the system employs Radio Frequency (RF) power.

DANGER

RF radiation—even at modest power levels—can cause serious injury. If any of the RF components (e.g., the RF power supply, the RF matching network, or the RF electrodes or shielding inside the product chamber) are moved or changed in any way, the RF energy may be radiated outside the equipment. Monitor the equipment to assure that external RF radiation is below the levels prescribed by any and all applicable safety codes.

Special Amendment for United Kingdom Users

All Electrical Power Sources: Safety Precautions

This component is designed to be used in an extra-high-voltage system. Only authorized personnel should be permitted to carry out work on this system.

Prior to any servicing, grounding hooks should be used to short out all high-voltage parts and conductors in both the vacuum system and the high-voltage power supply. Screens protecting extra-high-voltage conductors should be removed only if appropriate action has been taken to ensure that extra-high-voltage conductors are dead and cannot be reenergized inadvertently.

In addition, all personnel should be aware of:

1. The Electricity (Factories Act) Special Regulations (1908 and 1944), in particular, Regulations 18(d) and 28 of the 1980 Regulations, as amended; and
2. The employer's responsibility to set up suitable systems to safeguard the health and safety of employees, according to the Health & Safety at Work etc. Act (1974).

USER RESPONSIBILITY

This equipment will perform in accordance with the instructions and information contained in the user's manual and its referenced documents when such equipment is installed, operated, and maintained in compliance with such instructions. The equipment must be checked periodically. Defective equipment shall not be used. Parts that are broken, missing, plainly worn, distorted, or contaminated, shall be replaced immediately. Should such repair or replacement become necessary, a telephone or written request for service should be made to Temescal, Livermore, CA, a part of Edwards Vacuum, Inc.

The equipment, or any of its parts, shall not be altered without the prior written approval of Temescal. The user and/or purchaser of this equipment shall have the sole responsibility for any malfunction which results from improper use, faulty maintenance, damage, improper repair, or alteration by any party other than Temescal.

GUIDELINES AND GOOD PRACTICES

1. Follow applicable clean room procedures (smocks, masks, gloves, etc.).
2. Do not expose the vent and purge valves to excessive pressures. The nitrogen line regulator is factory set at 15 psi and must not be adjusted above 20 psi.
3. Prevent oil, grease, water, sweat, etc. from getting into the vacuum chamber.
4. Replace the source tray shield correctly to ensure that the ceramic parts or the high voltage feedthroughs are protected from being coated.
5. Clean all mechanical parts and seals with lint-free paper/cloth soaked with isopropyl alcohol (IPA). Dispose all IPA-exposed cleaning paper/cloth in a fireproof container, while ensuring proper safety precautions are being followed.
6. Polish scratched surfaces with Scotch-Brite, taking care not to produce any cross scratches.
7. Shaft seals are all ferromagnetic. No lubrication is required.
8. Check the chamber door's seal and sealing surfaces each time before closing it.
9. Check and clean with IPA the source tray seals and sealing surfaces each time before raising the source tray into place.
10. Train staff by competent personnel. DO NOT allow staff to operate or do maintenance and recovery work on the machine until they are trained by competent personnel.
11. Document all alarms, deviations, breakdowns, and servicings done on either a hardcopy or an electronic equipment-log system.

HEALTH HAZARD

The condensates deposited on the tank walls of a vacuum system are generally in the form of extremely fine particles. The nature, as well as the form, of the materials poses the following potential health hazards:

- a) Inhaling fine particles (powder) may cause damage to the lungs. To help prevent this, wear a protective respirator mask with fine filter that has been approved by the National Institute for Occupational Safety and Health (NIOSH) and the federal Mine Safety and Health Administration (MSHA).
- b) Some substances are toxic and inhaling them should be avoided. Take steps to ascertain whether or not the material being deposited is a known toxic substance. Refer to the Material Safety Data Sheet(s) covering the evaporant(s) in question.
- c) Certain powders (titanium, for instance) can cause flash fires when exposed to oxygen or other oxidizers. Therefore, when opening the chamber door after a deposition cycle, exercise extreme caution and allow time for the coating surface to oxidize. Breakage of some of the more reactive condensates may be hazardous, even when the above precautions are observed. In this situation, fire-protective clothing should be worn.
- d) Certain powders (platinum, for instance) are known to catalyze methyl alcohol vapors upon contact, generating heat in the process and possibly causing a fire to erupt. Therefore, never use methyl alcohol to wipe down or clean any internal tank surfaces of a vacuum system. Use isopropyl alcohol (IPA), instead. Dispose of all IPA-exposed lint-free paper/cloth into a fireproof container, while ensuring all proper safety procedures and precautions are being followed.

1 *PRODUCT DESCRIPTION AND SPECIFICATIONS*

1.1 Product Description

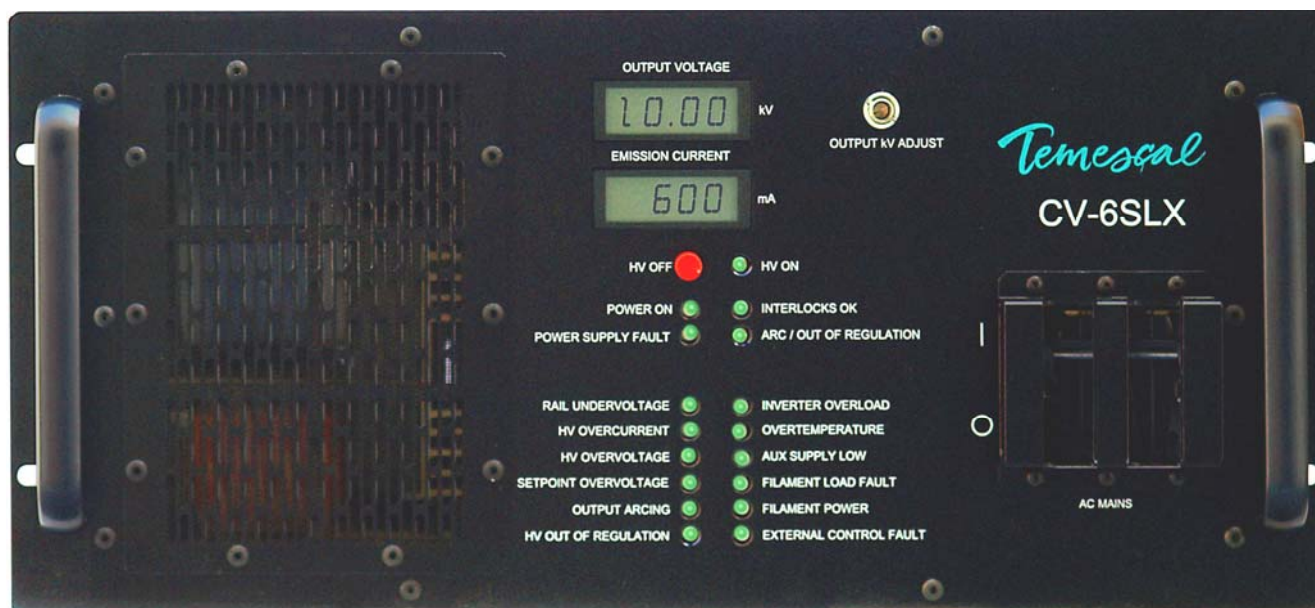
The Temescal Model CV-6SLX is a 6-kW, constant voltage, high-frequency, switching electron beam power supply. Designed to power and control a single electron beam source, the CV-6SLX is compatible with sources featuring either permanent-magnet or electromagnetic deflection. The power supply delivers up to 10 kV at 600 mA, making it possible to achieve substantial deposition rates in production environments. The CV-6SLX provides stable output at all voltage levels, rapid arc recovery, ease of integration, and safety and convenience for operating as well as service personnel.

The main components of the CV-6SLX power supply are the power module (see Fig. 1-1), the filament power supply (see Fig. 1-2), and the control and high-voltage cables required to connect them to each other and to the system control computer. Standard units also include a remote control unit (see Fig. 1-3). For a detailed list of the components and cables included with each power supply, see section 2.2. For complete installation instructions, see Section 2.

1.1.1 Power Module

Figure 1-1 shows the front panel of the CV-6SLX power module. For a detailed description of its control and display features, see section 3.2.

Figure 1-1: CV-6SLX Power Module Front Panel



Power Module Specifications

Dimensions

8.75 in. H × 19 in. W × 23 in. D

Weight: 61 lbs.

Input Power

208-V Model CV-6SLX

208 V ac +10% /–5%, 50/60 Hz, 27 A, 60 Hz

3-phase delta (4-wire)

400-V Model CV-6SLX

400 V ac +10% /–5%, 50/60 Hz, 15 A, 50 Hz

3-phase wye (5-wire, with neutral)

High Voltage Output

6 kW at 10 kV max.

Fully adjustable 0–10 kV

Regulated to within ±5%

Beam Current

Fully adjustable, 0–600 mA dc

Regulated to within ±5%

Environmental Requirements

Must be free of corrosive vapors

Ambient temperature: 104° F (40° C) maximum

Humidity: 10%–90%, noncondensing

1.1.2 Filament power supply

Figure 1-2 shows the filament power supply, a stand-alone assembly that must be installed near the vacuum chamber.

Figure 1-2: Filament Power Supply Front Panel



Filament Power Supply Specifications

Dimensions: 6.5 in. H × 6.5 in. W × 11 in. D

Weight: 14 lbs.

Input Power: 220 V ac ±10%, 6.25 A, 50-60 Hz, single-phase

Power Output: 10 V ac, 50 A, 40 kHz max.

1.1.3 Remote Control Unit

Figure 1-3 shows the half-rack remote control unit, whose dimensions are 5.24 in. high × 9.5 in. wide. For a detailed description of this unit's control and display features, see section 3.4.

Figure 1-3 Remote Control Unit



1.1.4 Interconnection Cables

The CV-6SLX is available in a GUI-driven-only version, which does not include a remote control unit. That version has a different cable set from the standard CV-6SLX power supply, which comes with a remote controller. For a detailed list of the components and cables included with each version of the power supply, see section 2.2.

2.1 Section Overview

This section describes the installation procedures required for proper operation of the CV-6SLX power supply. The topics covered are:

- Section 2.2 List of Components and Cables Supplied with the Unit
- Section 2.3 Rack Mounting the Power Module
- Section 2.4 Rack Mounting the Remote Control Unit
- Section 2.5 Mounting the Filament Power Supply
- Section 2.6 Grounding Requirements
- Section 2.7 Cable Installation on Standard Units
- Section 2.8 Cable Connections on Units Without a Remote Controller
- Section 2.9 Initial Power Up/Maintenance Power Up Procedure

To install a standard CV-6SLX unit (i.e., a unit equipped with the remote gun controller), follow the instructions in sections 2.3 through 2.7 plus those in section 2.9, skipping section 2.8. To install a CV-6SLX unit without a remote controller, follow the instructions in sections 2.3, 2.5, 2.6, 2.8 and 2.9, skipping sections 2.4 and 2.7.

CAUTION

Before beginning the installation procedure, make sure that the facility circuit breaker supplying power to the CV-6SLX is switched OFF and locked out with an appropriate lockout/tagout device. Also make sure that the FPS ON/OFF switch and the circuit breaker switch (labeled AC MAINS) on the power module front panel are both in the OFF position. The facility breaker must remain locked and tagged out during the entire installation procedure. Likewise, the power module's main circuit breaker switch and the FPS ON/OFF switch must both remain in the OFF position during the entire installation procedure. The Initial Power Up/Maintenance Power Up Procedure (see section 2.9) specifies the exact sequence in which the power is to applied to the unit.

2.2 List of Components and Cables Supplied with the Unit

2.2.1 Standard Units (With Remote Controller)

The components and cables listed below are supplied with standard units (i.e., units with a remote controller). These units will have the top-level PN 0620-9600-2 (for 208-volt units) or PN 0620-9600-3 (for 400-volt units).

- CV-6SLX power module, PN 6024-7110-0 (= 208-volt unit) or 6024-7120-0 (= 400-volt unit)
- Filament power supply, PN 0620-6604-0 or 0620-6604-2
- Remote control unit, PN 0620-9750-0
- Rack-mounting kit for remote control unit, PN 0411-6183-2
- FPS input power cable, PN 6622-0100-20
- Power module-FPS cable, PN 6338-2884-0
- HV control cable, PN 0620-9840-0
- Gun control cable, PN 0620-9730-0

- Gun Control-system I/O cable, PN 0620-9730-1
- HV coaxial cable, PN 6024-6112-1
- HV cable/conduit assembly, PN 0620-9654-0
- Bracket (PN 0040-9982-0) for securing HV conduit to source tray
- 16" grounding hook, PN 9900-4864-0
- 20' coil of 3"-wide copper strap, PN 5621-0032-3
- One copy of CV-6SLX Technical manual

2.2.2 Units Without a Remote Controller

The components and cables listed below are supplied with units without a remote controller. These units will have the top-level PN 0620-9600-0 (for 208-volt units) or PN 0620-9600-1 (for 400-volt units)

- CV-6SLX power module, PN 6024-7110-0 (= 208-volt unit) or 6024-7120-0 (= 400-volt unit)
- Filament power supply, PN 0620-6604-0 or 0620-6604-2
- FPS input power cable, PN 6622-0100-20
- Power module-system I/O cable (PN 6338-2886-0)
- Two 20' DB15M/DB15F cables (PN 6338-2884-0), one to serve as the power module-FPS cable, the other to serve as the FSP-system I/O cable
- HV coaxial cable, PN 6024-6112-1
- HV cable/conduit assembly, PN 0620-9654-0
- Bracket (PN 0040-9982-0) for securing HV conduit to source tray
- 16" grounding hook, PN 9900-4864-0
- 20' coil of 3"-wide copper strap, PN 5621-0032-3
- One copy of CV-6SLX Technical manual

2.3 Rack Mounting the Power Module

2.3.1 General Installation Guidelines

The CV-6SLX power module can be rack mounted in a standard 19" rack cabinet. It must be supported by two side shelf supports to hold the power supply weight. The rack vertical height required is 8-3/4 inches. The chassis depth is 23 inches. An additional 3" is required for clearance of terminals, plugs, and wiring. The panel should be secured to the rack cabinet by the four mounting holes provided.

DANGER: HIGH VOLTAGE

Removal of the power module top cover can expose personnel to dangerous or lethal voltages. Particular care should be taken regarding high voltage, which can arc over a considerable distance. It is not necessary to be in physical contact with a live terminal in order for an arc to send a lethal high-voltage discharge through a person's body.

The power module is designed to be installed in an indoor laboratory or clean room in which the immediate environment is controlled to maintain an ambient temperature of 40° C or lower and a noncondensing humidity level of 10%-90%. The screen covering the front panel air vent and the screen sandwiched between the exhaust fan and the rear panel provide IP40 ingress protection. These screens prevent solid foreign objects larger than 1 mm in diameter from penetrating the outside chassis but do not provide a barrier against liquids. Both screens must

be removed and cleaned whenever the fan airflow drops more than 15% from its original value or every two years, whichever comes first. The power module does not require any routine maintenance, aside from the cleaning of the screens.

2.3.2 Air Flow Requirements

The inverters have a temperature sensor that will shut down and latch out further operation if an overtemperature condition should occur. The customer must ensure a free flow of air is maintained through the cabinet and keep the ambient air temperature at the input to the power supply below 104° F (40° C). All air passages must be unobstructed. If air filters are used on the cabinet air input, they should be checked on a regular schedule for dirt and dust accumulation.

CAUTION

Cabinet doors and panels must not block air vents located on the unit's front and rear panels, providing at least 2" of clearance from these vents. A fan located on the rear panel pulls air in through the vents on the front panel, and exhausts warmer air through the rear vent.

2.4 Rack Mounting the Remote Control Unit

A mounting kit (PN 0411-6183-2) is provided with the unit to facilitate rack mounting the remote controller in a standard 19" electronics rack. First assemble the kit's mounting hardware inside the rack. Then secure the remote controller to the mounting hardware.

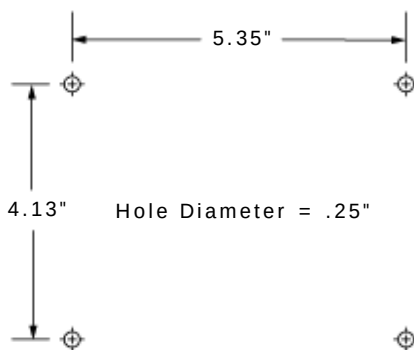
2.5 Mounting the Filament Power Supply

Install the FPS module in the vacuum cubicle, within 6 feet of the high-voltage feedthroughs that supply power to the e-beam gun. To do so, first drill four holes at the installation location, in the pattern shown in Figure 2-1. Then place the holes in the bottom of the FPS module over the drilled holes and secure the FPS in place with the hardware provided.

DANGER: HIGH VOLTAGE

Removal of any of the covers on the FPS module can expose personnel to dangerous or lethal voltages. Particular care should be taken regarding high voltage, which can arc over a considerable distance. It is not necessary to be in physical contact with a live terminal in order for an arc to send a lethal high-voltage discharge through a person's body.

Figure 2-1 Mounting Hole Pattern for FPS Module



2.6 Grounding Requirements

2.6.1 Facility Low-Impedance Grounding Requirements

Safe, dependable operation of the power supply cannot be ensured unless a good earth ground is provided for the system and the power supply. This ground must provide a low-impedance path for radio frequency (RF) as well as direct current (dc) electricity, and it must not be connected to that of any other system or equipment. Figure 2-2 shows two different methods of providing the required low-impedance ground on the facility side of the installation.

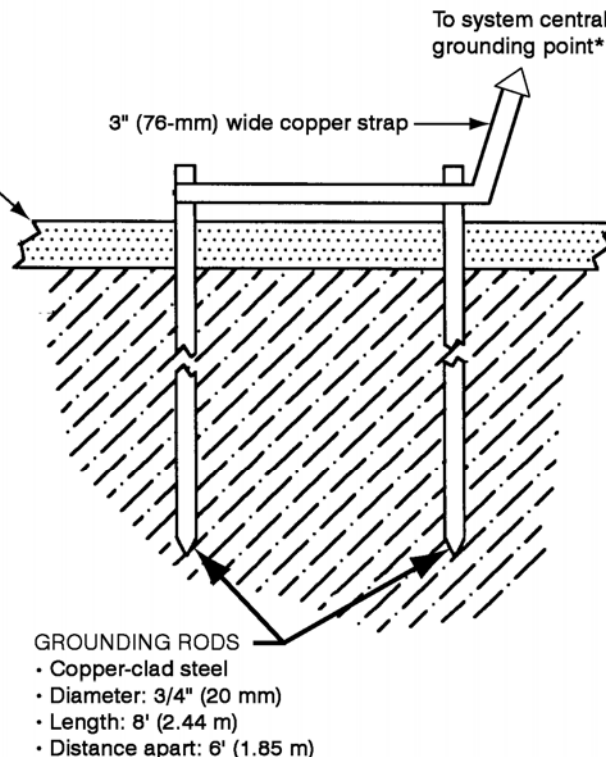
Figure 2-2 Facility Low Impedance Grounding Requirements

PREFERRED METHOD

1. As shown at right, sink two grounding rods through the floor of the building and into the earth, approximately six feet apart. The location chosen for these rods should be as close as possible to the vacuum cubicle. The rods must be copper-clad steel, 8 feet in length, and their top ends should extend approximately 6 inches above the surface of the floor.
2. Measure the resistance between the rods. If the resistance is greater than 3 ohms, try lowering it by pouring salt water or copper sulfate down the sides of the rods. If the resistance is still greater than 3 ohms, consult Temescal.
3. When you have verified that the resistance between the two grounding rods is 3 ohms or less, silver solder the copper strap connected to the system central grounding point to each of the rods.

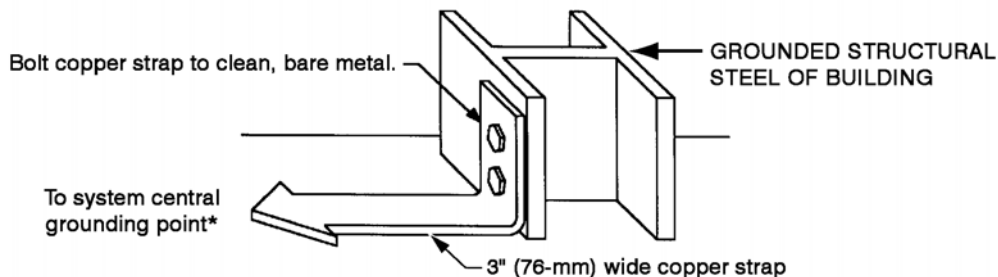
NOTE

Do NOT rely on mechanical connections between the copper strap and the grounding rods.



*Distance from system central grounding point to facility low-Z grounding point	Required size of connecting copper strap
0-60 ft. (0-18.3 m)	3 in. (76 mm) wide x .035-.050 (0.9-1.3 mm) thick
>60 ft.	Consult Temescal

ALTERNATIVE METHOD



The installation of twin rods of copper-clad steel is preferred. However, if the equipment is to be installed on the upper floors of a building, the system can be grounded by connecting the vacuum chamber to the steel structure of the building. Where copper straps are attached to frame members, the copper must be bolted to clean, bare patches of metal. The length of copper strap connected to the source tray must be securely bolted to a clean site on that part.

CAUTION

Do not use braided wire for any ground connections.

CAUTION

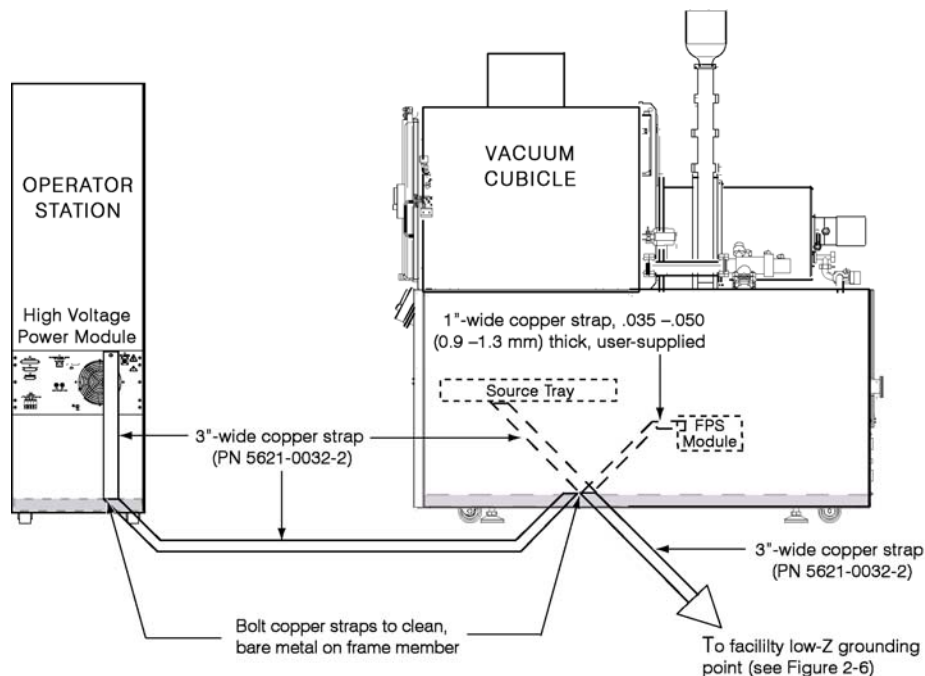
Do not rely on water pipes to establish the system ground connection. Multiple plumbing joints, each with tape and/or sealing compounds, make such a ground unreliable.

2.6.2 System Low-Impedance Grounding

Within the vacuum system, the low-impedance ground is provided by 3"- and 1"-wide copper straps. As Figure 2-3 shows, these straps must connect:

- the grounding stud labeled **RF GND** on the power module's rear panel (see Figure 2-4) to a grounding point on the frame of the operator station
- the operator station's grounding point to the vacuum cubicle's central grounding point
- the grounding stud labeled **RF GND** on the FPS front panel (see Figure 2-5) to the vacuum cubicle's main grounding point
- the source tray to the vacuum cubicle's main grounding point.

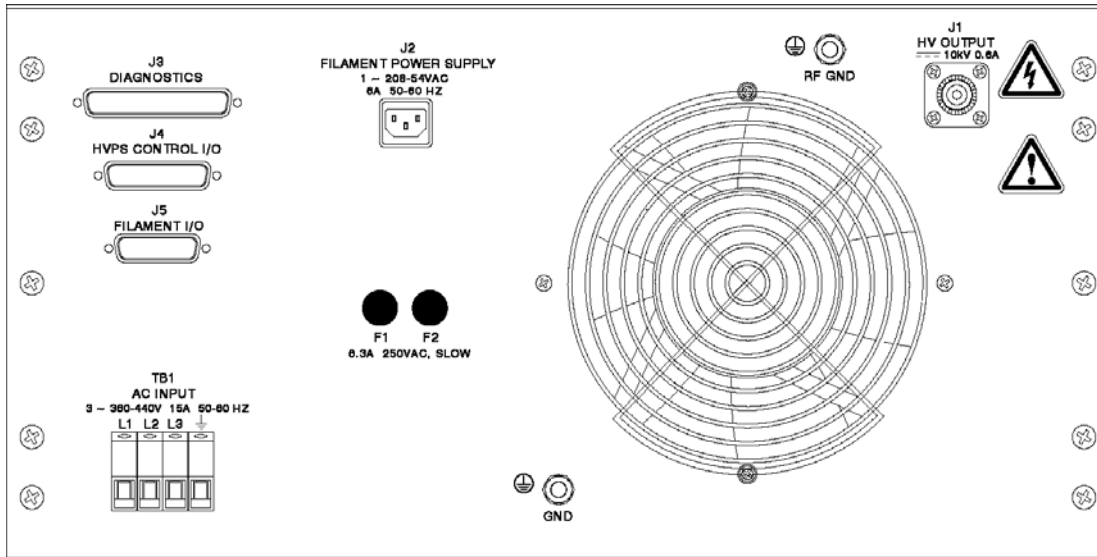
Figure 2-3 System Low Impedance Grounding Requirements



2.6.3 Power Module Grounding

Make connections to the power supply's grounding lugs as shown in attached drawing 620-9692, following the procedure described below.

- | Step | Action |
|------|---|
| 1 | A roll of 3"-wide copper strap (PN 5621-0032-3) is supplied with the unit. Cut off a length of this strap that will easily extend from the grounding lugs on the power module's rear panel to the operator station's frame. |
| 2 | Secure one end of this strap to the grounding stud labeled RF GND on the power module's rear panel (see Figure 2-4). |

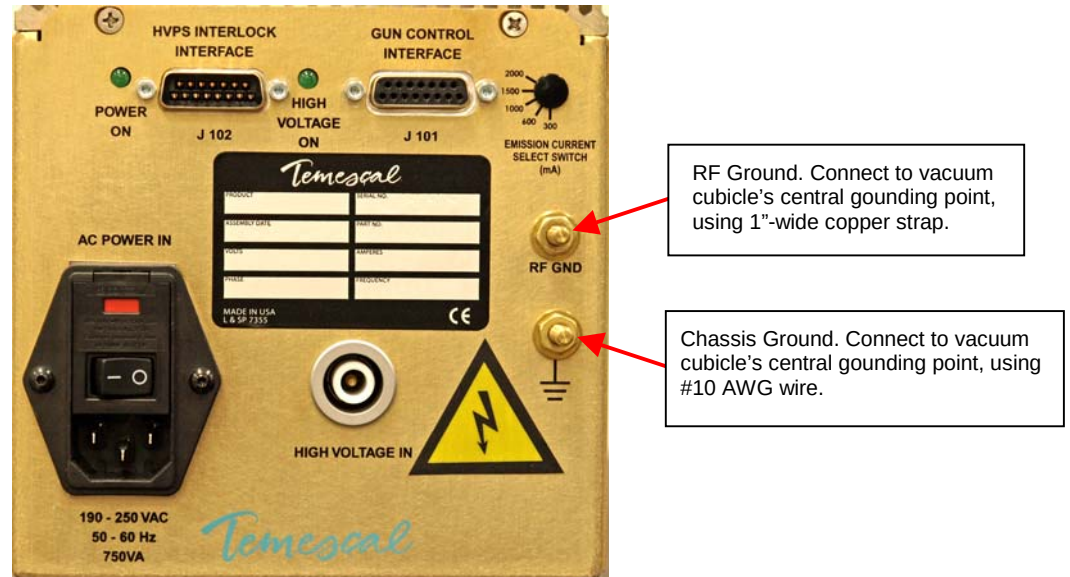
Figure 2-4 Power Module Rear Panel

- | | |
|---|---|
| 3 | Secure a length of #10 AWG wire to the grounding lug labeled GND on the power module rear panel. |
| 4 | Secure the loose end of the 3" copper strip and the loose end of the #10 AWG ground wire to a clear, bare patch of metal on the operator station's frame. The same fastener that secures the above copper strip to the frame should also secure one end of a length of 3" copper strap that connects to the vacuum cubicle's central grounding point, as shown in Figure 2-3. |

2.6.4 Filament Power Supply Grounding

Make connections to the grounding lugs on the FPS front panel as shown in attached drawing 620-9692, following the procedure described below.

- | Step | Action |
|------|---|
| 1 | Obtain a length of 1"-wide copper strap (user-supplied) that will easily extend from the filament power supply to the vacuum cubicle's central grounding point. |
| 2 | Secure one end of this strap to the grounding stud labeled RF GND on the FPS front panel (see Figure 2-5). |

Figure 2-5 Grounding Studs on FPS Front Panel

- 3 Secure a length of #10 AWG wire to the other grounding lug on the FPS front panel.
- 4 Secure the free ends of the 1" copper strip and the #10 AWG ground wire to the vacuum cubicle's central grounding point.

2.6.5 Electron Beam Source Ground

To ensure a good ground between the electron beam source and the vacuum cubicle, the following conditions must be met:

- The base of the source and the surface on which it is mounted (usually the upper surface of the source tray) must be clean and free of evaporated material.
- The mounting surface must be made of nonmagnetic material.
- The source must be securely bolted to the mounting surface.

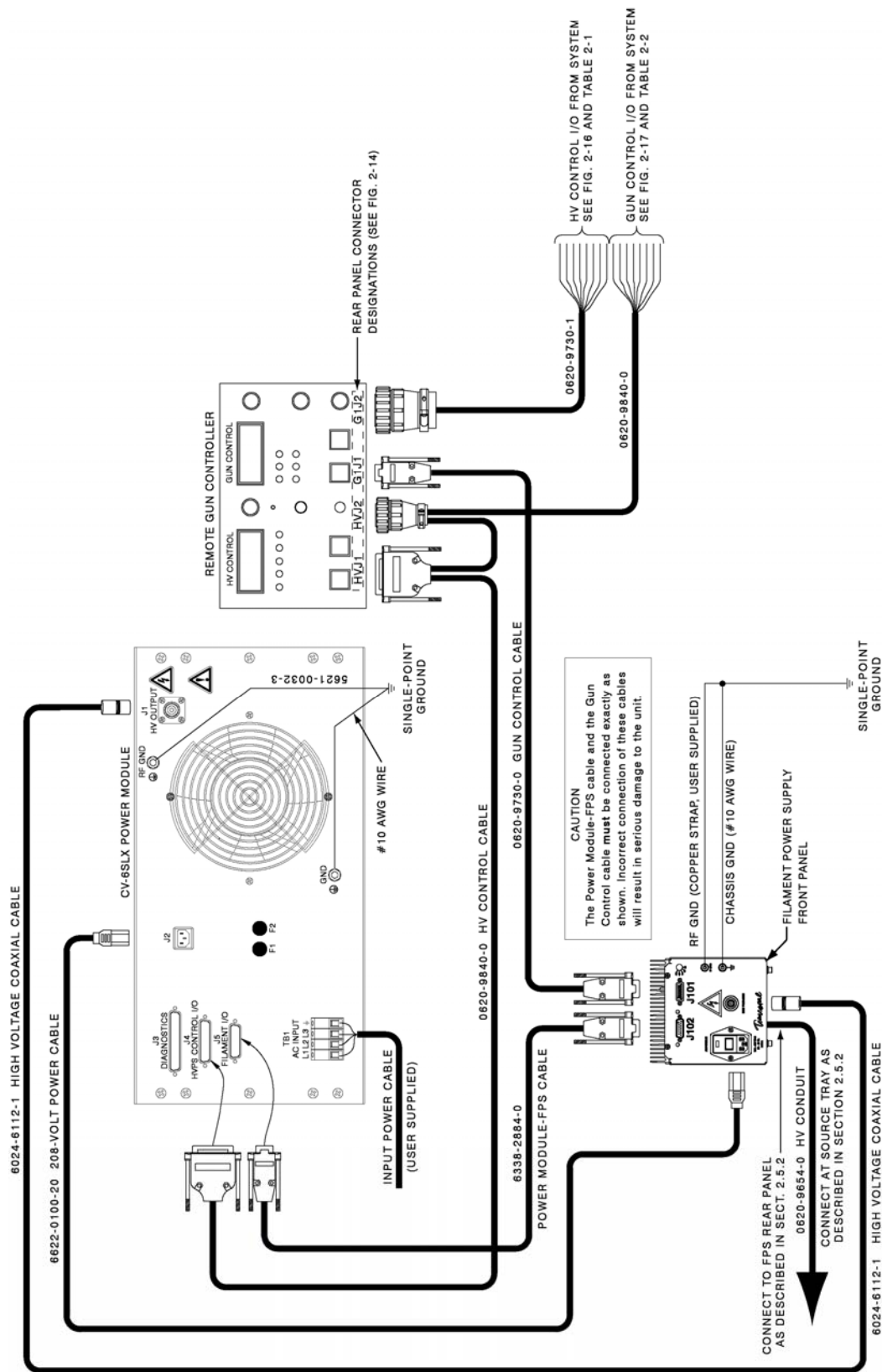
2.6.6 Mounting the Grounding Hook

If you are installing the CV-SLX unit in a system that does not already have a properly mounted grounding hook, install the grounding hook provided with the power supply in the vacuum cubicle, attaching its pigtail to the vacuum cubicle's central grounding point and the grounding hook's storage bracket at a convenient location nearby.

2.7 Cable Installation on Standard Units

On standard CV-6SLX units (i.e., units equipped with the remote gun control unit) connect cables as shown in Figure 2-4.

Figure 2-4 Cabling Diagram for Standard CV-6SLX



2.7.1 Connecting the Input Power Cables

Connecting the Power Module Input Power Cable

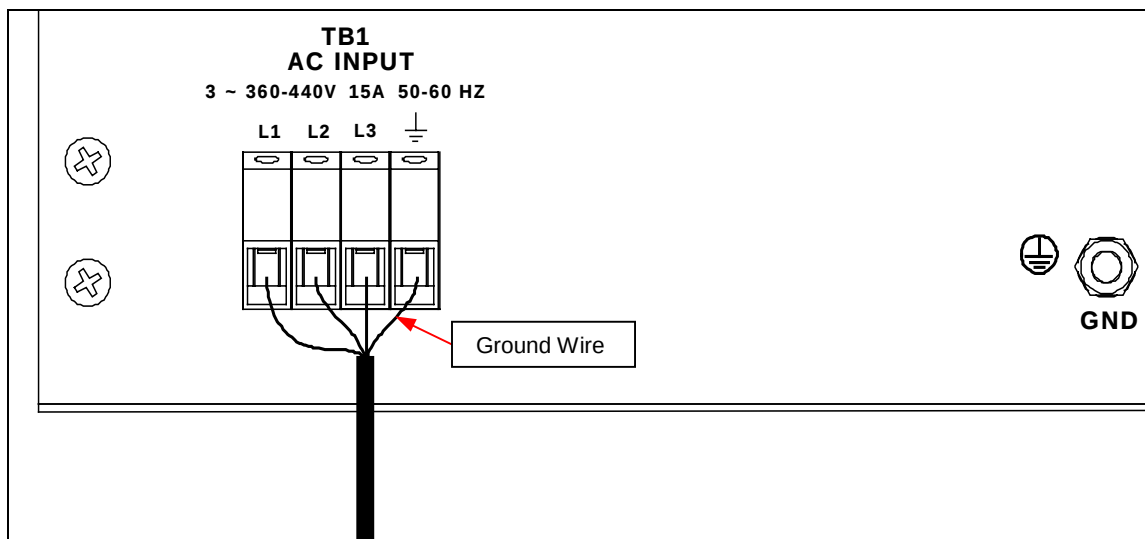
The CV-6SLX is available for the following input voltages:

- 208-V Model CV-6SLX (PN 6024-7110-0), 50/60 Hz, 3-Phase delta, 4-wire
Connect using AWG #10 stranded UL1015 wire
- 400-V Model CV-6SLX (PN 6024-7120-0), 50/60 Hz, 3-Phase wye, 5-Wire with neutral
Connect using AWG #12 stranded UL1015 wire

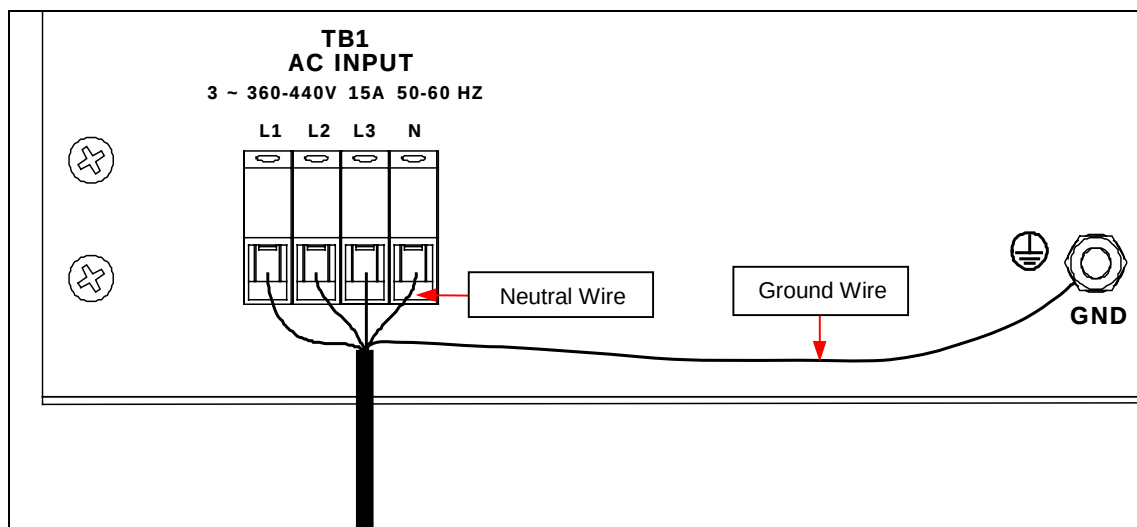
The input power cable is user supplied and must conform to the specifications listed above. Connect the power cable's conductors as shown in Figure 2-5.

Figure 2-5 Input Power Connections on Power Module Rear Panel

208-Volt CV-6SLX



400-Volt CV-6SLX



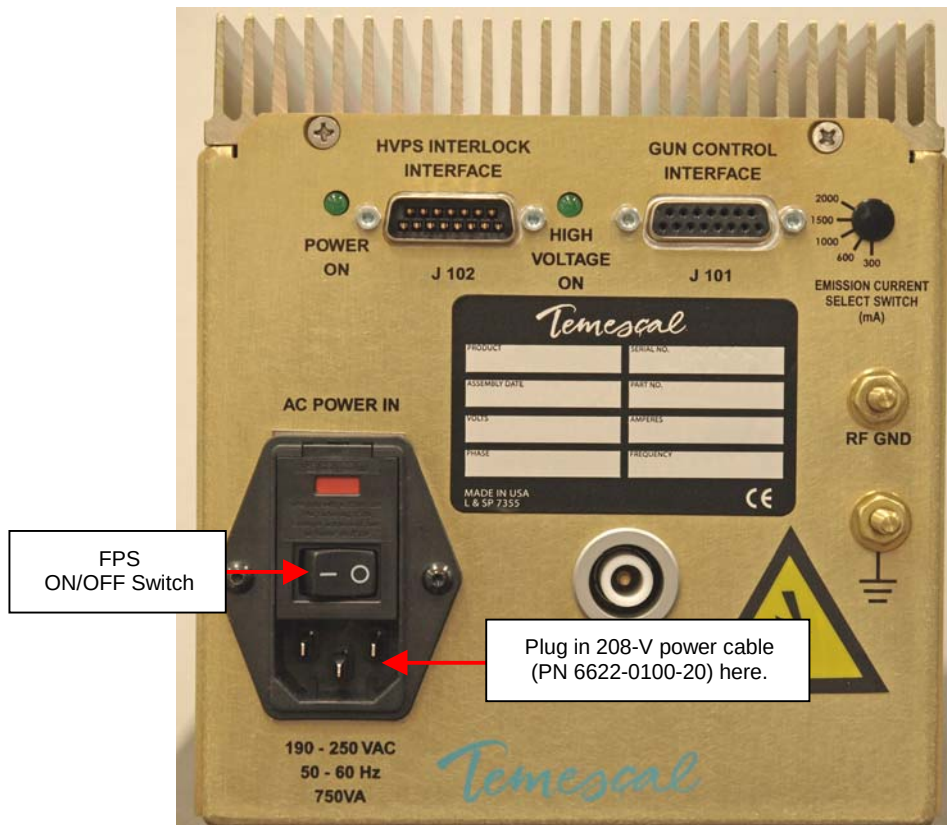
Connecting the FPS Input Power Cable (PN 6622-0100-20)

The FPS power cable (PN 6622-0100-20) is provided with the unit. Plug one end of this cable into rear panel connector J2 on the CV-6SLX power module (see Figure 2-4). Plug the other end into the power receptacle on the FPS front panel (see Figure 2-6).

CAUTION

Make sure that the ON/OFF switch on the FPS front panel (see Figure 2-6) remains in the OFF position until instructed otherwise in section 2.9.

Figure 2-6 Input Power Receptacle on FPS Front Panel



2.7.2 Connecting the HV Output Cables and Conduit (PN 0620-9654-0)

The cables that conduct the high voltage from the FPS to the source tray are contained in a length of flexible conduit. The part number of the HV cable/conduit assembly is 0620-9654-0. In connecting this assembly to the FPS and to the source tray, follow the instructions provided below.

Connecting the HV Output Cables and Conduit to the FPS

Connect the HV cable/conduit assembly to the FPS rear panel (see Figure 2-7), following the procedure described below.

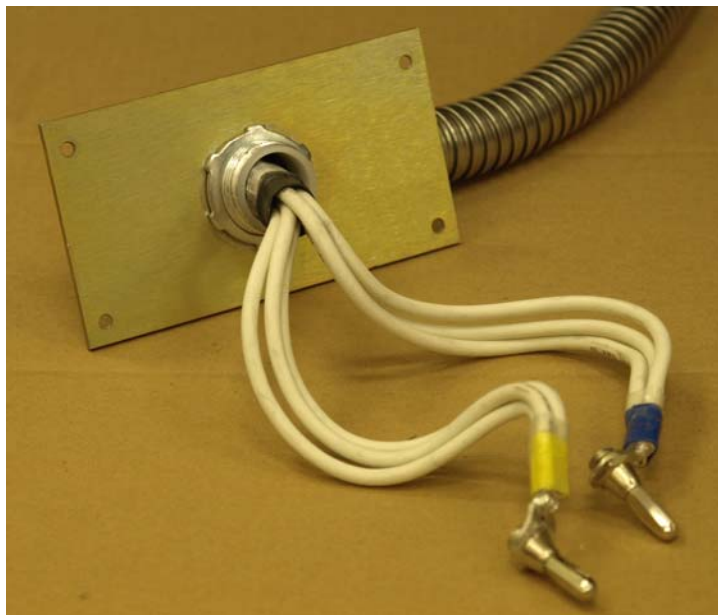
- | Step | Action |
|------|---|
| 1 | Remove four screws that secure the conduit panel to the FPS rear panel, as shown below. |

Figure 2-7 Removing the FPS Conduit Panel



- | | |
|---|---|
| 2 | Insert the threaded end of the conduit elbow into the hole in the conduit panel and secure the elbow with the nut provided, as shown in Figure 2-8. |
|---|---|

Figure 2-8 Conduit Properly Secured to FPS Conduit Panel



- | | |
|---|--|
| 3 | Figure 2-9 shows a portion of the FPS rear panel with the conduit panel removed. Plug the banana connectors on the ends of the HV cables into the receptacles shown in the illustration. |
|---|--|

Figure 2-9 FPS Receptacles for Banana Plugs on HV Output Cables

- 4 Replace the conduit panel, taking care to secure it in place with all four screws.

Connecting the HV Output Cables and Conduit at the Source Tray

Connect the other end of the HV output cables to the HV feedthroughs in the source tray, following the instructions provided below.

CAUTION

If the vacuum system has previously been in use with a high-voltage power supply, then before performing this procedure, touch the source tray and the terminals on both HV feedthroughs with a properly connected grounding hook.

- | Step | Action |
|-------------|---|
| 1 | Remove the nut that secures one of the feedthroughs to the underside of the source tray. |
| 2 | Install the HV conduit bracket (PN 0040-9982-0) supplied with the unit and secure it with the nut removed in Step 1, as shown in Figure 2-10. |

Figure 2-10 HV Conduit Bracket Properly Installed on HV Feedthrough

- 3 Using the nut supplied with the conduit, secure the conduit to the bracket as shown in Figure 2-11.

Figure 2-11 HV Conduit Properly Secured to Bracket

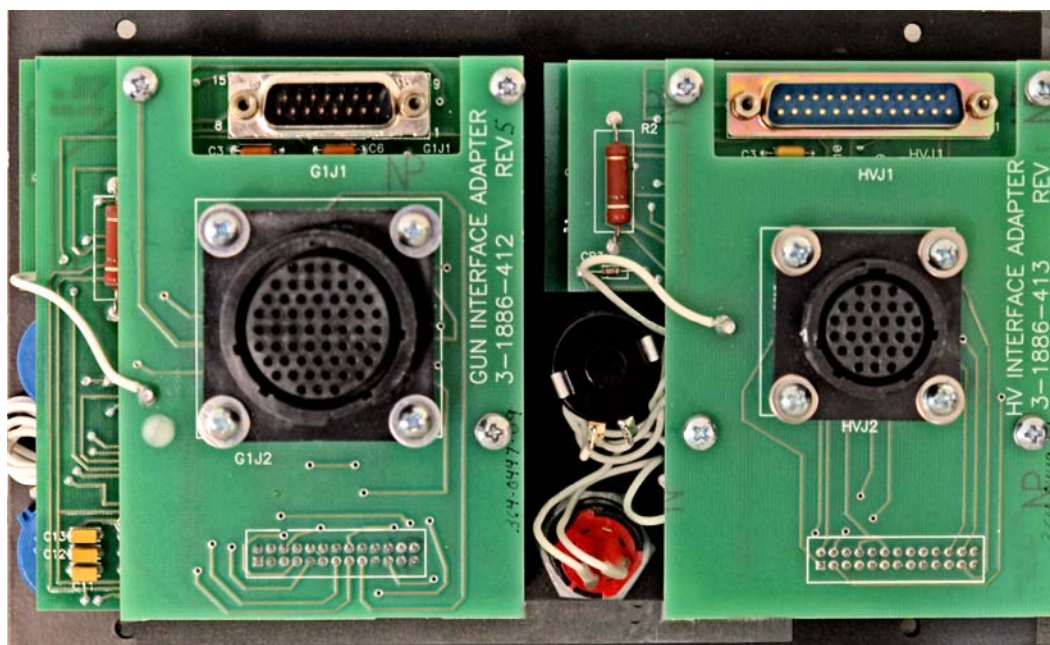
- 4 Secure the lugs on the ends of the HV cables to the feedthroughs, as shown in Figure 2-10. Either cable can be connected to either feedthrough, as polarity is not an issue.

2.7.3 Connecting the HV Coaxial Cable (PN 6024-6112-1)

The HV coaxial cable (PN 6024-6112-1) conducts the high voltage output of the power module to the FPS. Connect this cable to power module rear panel connector J1 and to the HIGH VOLTAGE IN connector on the FPS.

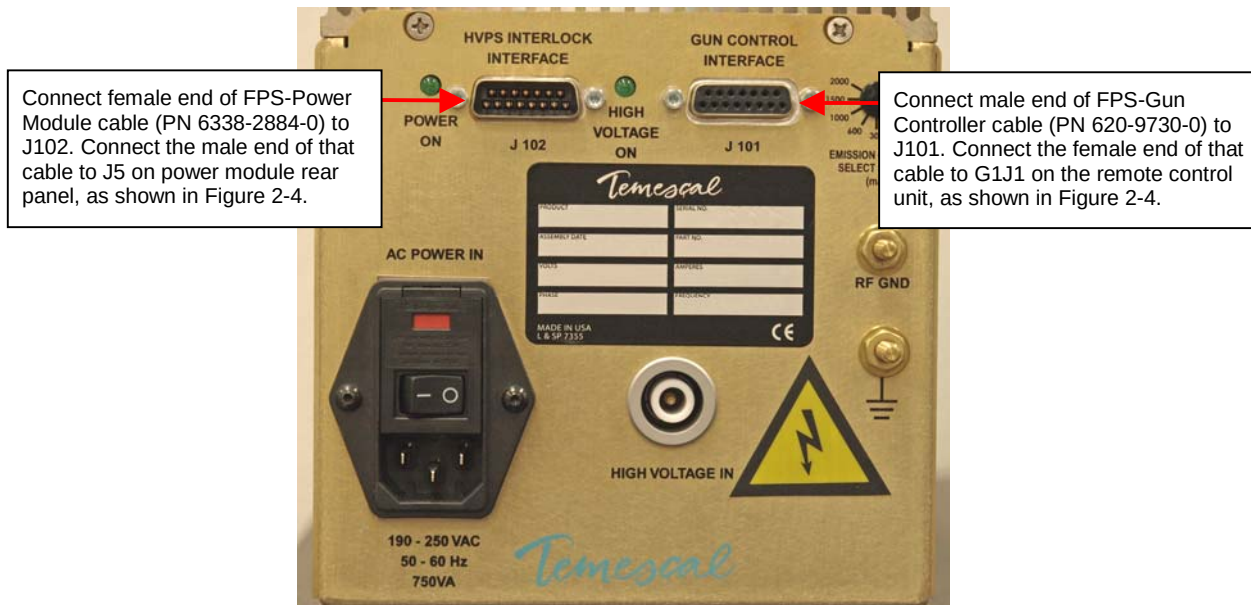
2.7.4 Connecting the Remaining Cables to the Remote Controller and FPS

Connect the remaining cables to the power module, the FPS, and remote controller, following the instructions provided below. Figure 2-12 shows the connectors on the remote controller's rear panel.

Figure 2-12 Remote Controller Rear Panel

- | Step | Action |
|------|--|
| 1 | Plug the power module-FPS cable into J5 on the power module rear panel and into FPS connector J102 (see Figure 2-13). |
| 2 | Plug the gun control cable (PN 0620-9730-0) into connector G1J1 on the remote controller and into J101 on the FPS (see Figure 2-13). |

Figure 2-13 FPS Cabling Detail on Standard Units



CAUTION

Connect the power module-FPS cable and the gun control cable exactly as described above. Incorrect connection of these cables will result in damage to the power supply.

- Plug the single male D connector on one end of the HV control cable (PN 0620-9840-0) into power module connector J4 (see Figure 2-4).
- Plug the female D connector on the other end of the HV control cable into HVJ2 on the remote controller (see Figure 2-12).
- The remaining connector on the end of the HV control cable is a 28-pin circular connector. Plug this connector into HVJ1 on the remote controller rear panel (see Figure 2-12).

2.7.5 Making I/O Connections to the Control System

The installer must make connections (1) between the control system and gun control-system I/O cable (PN 0620-9730-1) and (2) between the control system and the HV control-system I/O cable (PN 0620-9840-0). Control inputs and status outputs include both digital and analog signals. Digital inputs require a simple contact closure and carry 24 V dc at approximately 20 mA. All digital outputs are from contact closures rated at 2 A @ 220 V ac or at 2A @ 30 V dc.

Making Connections to the HV Control-System I/O Cable (PN 0620-9840-0)

System I/O-HV control connections are made via unterminated end of the HV control-system I/O cable. For detailed information about these I/Os, see Figure 2-14 and Table 2-1.

Figure 2-14 Signals Exchanged via the HV Control-System I/O Cable (PN 0620-9840-0)

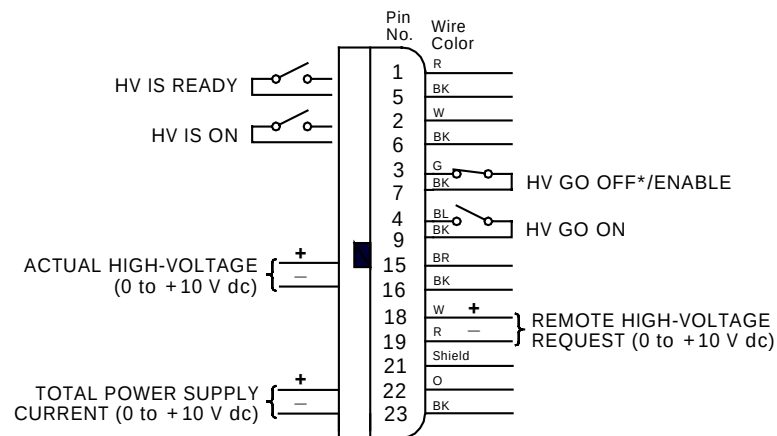


Table 2-1 Additional Information About Signals Exchanged via the HV Control-System I/O Cable

Digital Control Inputs			
Signal Name	HVJ2 Pins	Wire Colors	Function
HV GO OFF*/ENABLE	3 7	G BK	A momentary open pulse switches off the high voltage. If all HV control interlocks are made, contact closure of this line enables the HV to be switched on. NOTE: If these pins are not connected to a remote contact closure, they must be jumpered together, or the HV cannot be switched on.
HV GO ON	4 9	BL BK	If all HV control interlocks are made and the HV GO OFF*/ENABLE loop is closed, a momentary contact closure switches on the high voltage.
Analog Control Input			
Signal Name	HVJ2 Pins	Wire Colors	Function
REMOTE HV REQUEST	18 19	W(+) R(-)	If the HV control unit's VOLTAGE REQUEST REMote/RANGE switch is in the REMOTE position, this input linearly controls the high voltage. NOTE: This input must be 0 V dc to +10 V dc. The HV circuit cannot be controlled by a -10 V dc input.
Digital Outputs			
Signal Name	HVJ2 Pins	Wire Colors	Function
HV IS READY	1 5	R BK	Indicates that all HV control interlocks are made and that the HV GO OFF*/ENABLE loop is closed; the HV is ready to be switched on.
HV IS ON	2 6	W BK	Indicates that the high voltage is on.
Analog Outputs			
Signal Name	HVJ2 Pins	Wire Colors	Function
ACTUAL HIGH VOLTAGE	15 16	BR(+) BK(-)	Linearly represents the load (gun) voltage: 0 V = 0 Kv; 10 V = 10 kV
TOTAL POWER SUPPLY CURRENT	22 23	O(+) BK(-)	Linearly represents the total power supply's total current output: 0 V = 0 A; 10 V = 1 A.

Making Connections to the Gun Control-System I/O Cable (PN 0620-9730-1)

To make I/O connections between the control system and the remote controller's gun control panel, perform the procedure described below.

- | Step | Action |
|------|---|
| 1 | Plug the circular connector on end of the system I/O-gun control cable (PN 0620-9730-1) into remote controller rear panel connector G1J2 (see Figure 2-12). |
| 2 | Make the required I/O connections between the control system and the unterminated end of the system I/O-gun control cable. For detailed information about these I/O connections, see Figure 2-15 and Table 2-2. |

Figure 2-15 Signals Exchanged via the Gun Control-System I/O Cable (PN 0620-9730-1)

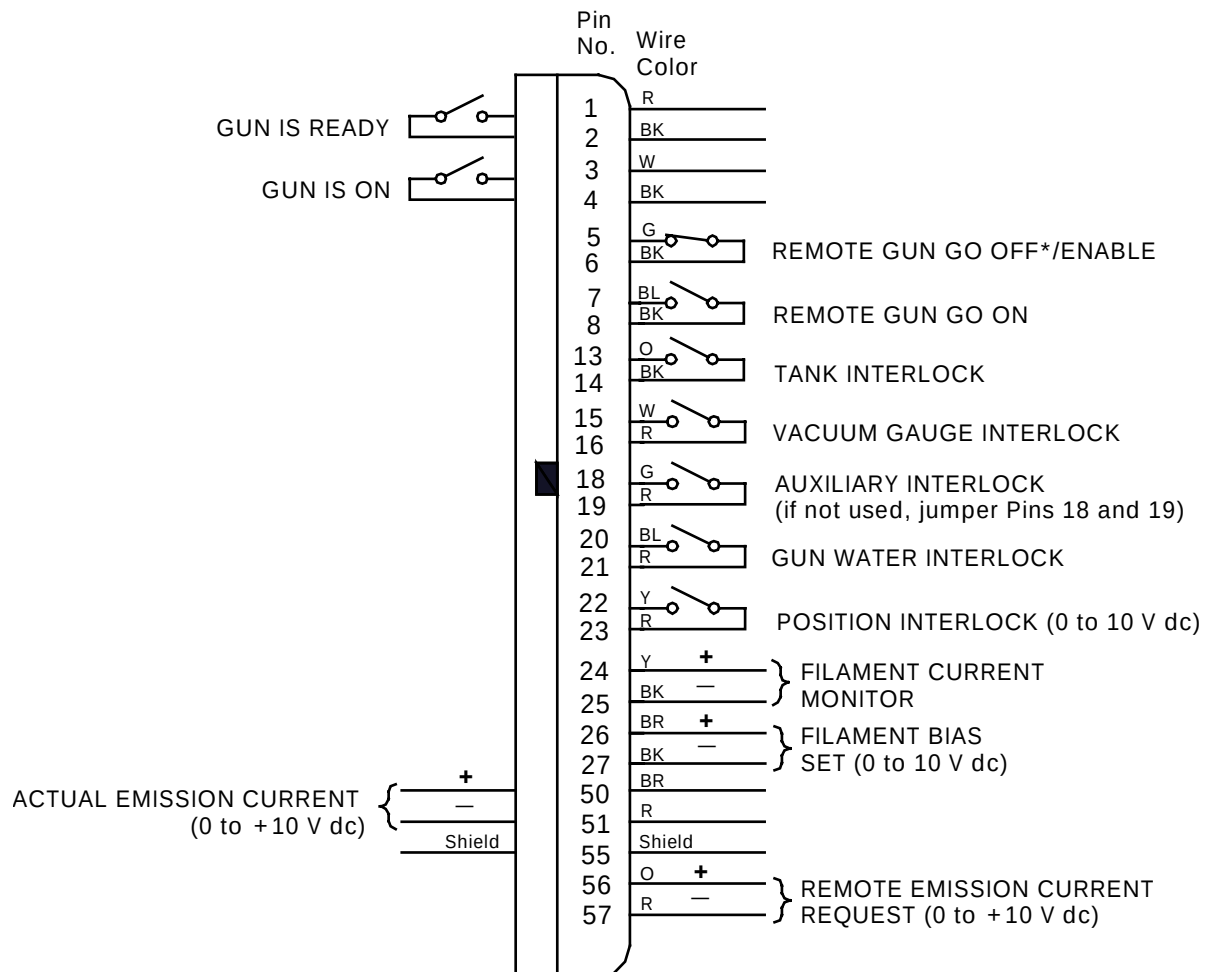


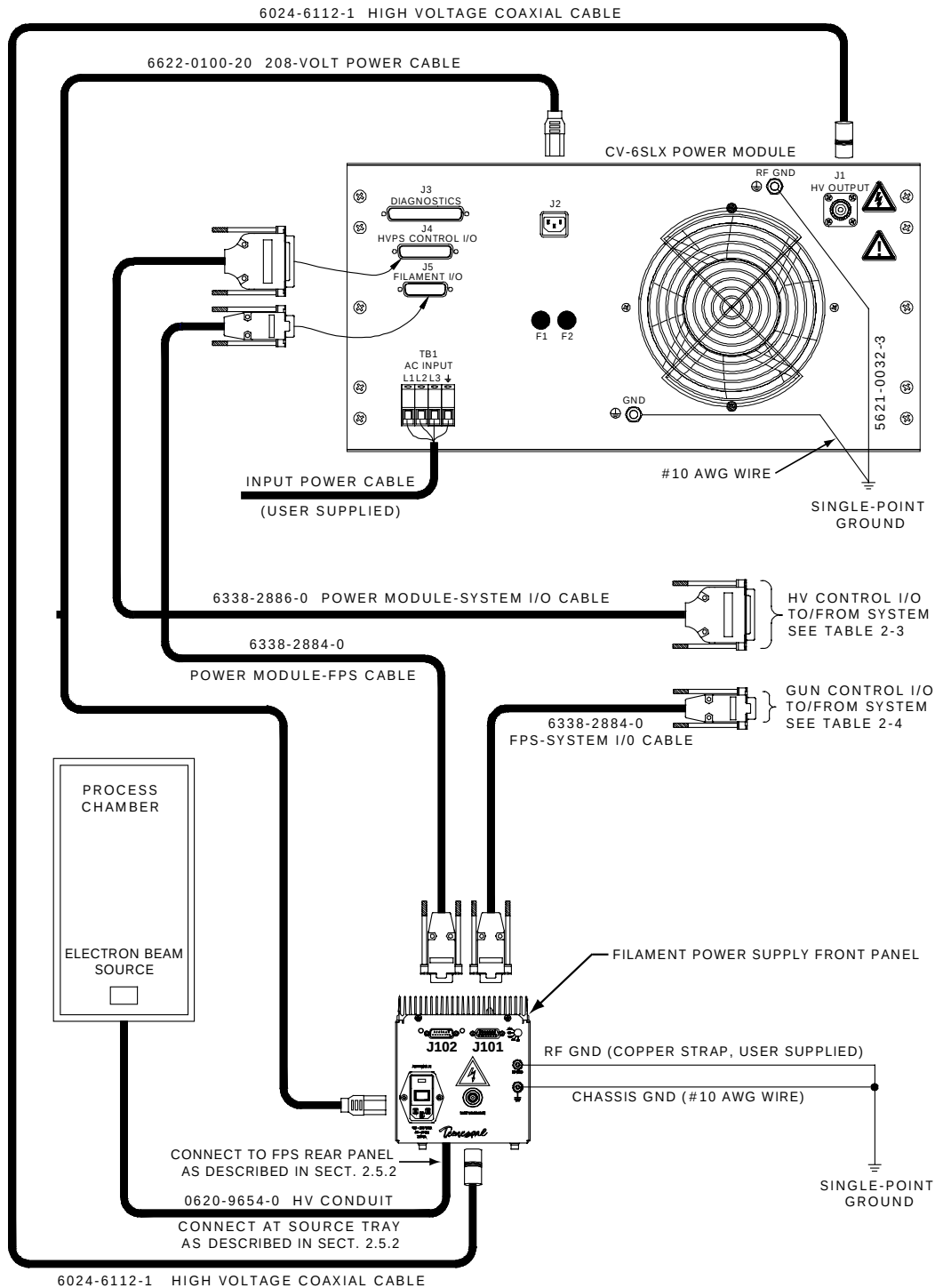
Table 2-2 Additional Details About Signals Exchanged via the Gun Control-System I/O Cable

Digital Interlock Inputs (Required)			
Signal Name	G1J2 Pins	Wire Colors	Function
TANK INTERLOCK	13 14	O BK	Prevents the gun from being switched on unless all vacuum system doors and covers are closed and locked.
VACUUM GAUGE INTERLOCK	15 16	W R	Ensures that product chamber ion gauge is on before gun is switched on.
AUXILIARY INTERLOCK	18 19	G R	Customer defined. Generally used with multipocket sources to ensure that the beam is OFF while the turret is rotating. If no external input is supplied, this input must be jumpered ON.
GUN WATER INTERLOCK	20 21	BL R	Prevents the gun from being switched on unless it is receiving sufficient cooling water. Signal to be supplied by a customer-installed flow switch.
POSITION INTERLOCK	22 23	Y R	If supplied by a beam sweep controller, this input switches off the gun if the beam travels beyond the sweeper's programmed position limits. If signal is not supplied by a sweep controller, these pins must be jumpered.
Analog Control Input			
Signal Name	G1J2 Pins	Wire Colors	Function
REMOTE EMISSION CURRENT REQUEST	56 57	O(+) R(-)	If the gun control unit's REMote/RANGE switch is in the REMOTE position, this input linearly controls emission current. 0 V = min. current; +10 V = full scale. On standard FPS units (i.e., PN 0620-6604-0), full scale = 600 mA. On units equipped with FPS PN 0620-6604-2, full scale = 1 A. NOTE: In both cases, the actual maximum emission current output is 600 mA.
Digital Control Inputs			
Signal Name	G1J2 Pins	Wire Colors	Function
REMOTE GUN GO OFF* /ENABLE	5 6	G BK	A momentary open pulse switches off the gun. If all gun control interlocks are made, the gun can be switched on again. NOTE: If these pins are not connected to a remote contact closure, they must be jumpered together, or the gun cannot be switched on.
REMOTE GUN GO ON	7 8	BL BK	If all gun control interlocks are made and the GUN GO OFF*/ENABLE loop is closed, a 2-sec. contact closure across these pins switches on the gun.
FILAMENT CURRENT MONITOR	24 25	Y BK	A 0 to 7.5 volt signal proportional to 0-75 amperes is available for driving a remote meter. The impedance should be 1 megohm or higher.
FILAMENT BIAS SET	26 27	BN BK	This input controls the filament bias current. Range: 0 V dc to +10 V dc. On all FPS units, 0 V dc = 0 A. On standard FPS units (i.e., PN 0620-6604-0), +10 V dc = 50 A. On units equipped with FPS PN 0620-6604-2, +10 V dc = 100 A.
Digital Outputs			
Signal Name	G1J2 Pins	Wire Colors	Function
GUN IS READY	1 2	R BK	Indicates that all gun control interlocks are made and that the GUN GO OFF*/ENABLE loop is closed, so the gun can be switched on.
GUN IS ON	3 4	W BK	Indicates that the gun is switched on.
Analog Output			
Signal Name	G1J2 Pins	Wire Colors	Function
ACTUAL EMISSION CURRENT	50 51	BR(+) R(-)	Linearly represents the actual emission current: 0 V = 0 A; 10 V = 600 mA.

2.8 Cable Connections on Units Without a Remote Controller

On CV-6SLX units not equipped with the remote gun control unit, connect the cables as shown in Figure 2-16.

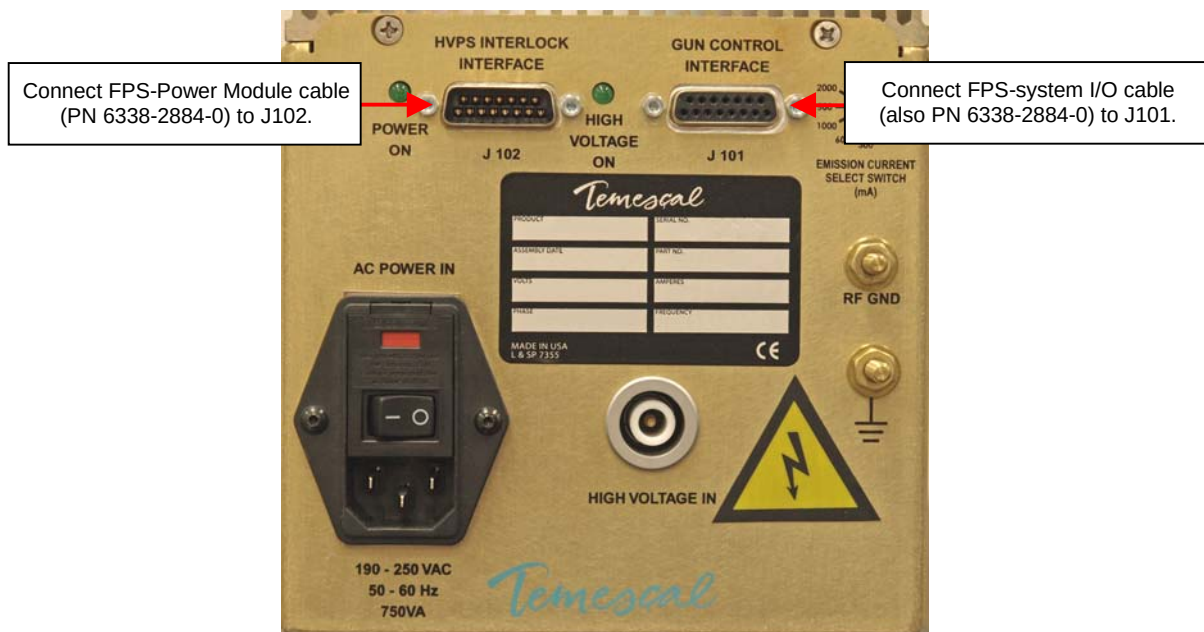
Figure 2-16 Cabling Diagram for CV-6SLX Units Without a Remote Controller



2.8.1 Connecting Cables on Units Without a Remote Controller

Step	Action
1	Connect the input power cables for the power module and the FPS as described in section 2.5.1.
2	Connect the HV coaxial cable as described in section 2.5.2.
3	Connect the HV output cables and conduit as described in section 2.5.3.
4	Plug the male end of the power module-system I/O cable (PN 6338-2886-0) into connector J4 on the power module rear panel (see Figure 2-4).
5	Plug the male end of the power module-FPS (PN 6338-2884-0) into connector J5 on the power module rear panel (see Figure 2-16).
6	Plug the female end of the power module-FPS cable into connector J102 on the FPS front panel (see Figure 2-17).
7	Plug the male end of the FPS-system I/O cable (also PN 6338-2884-0) into connector J101 on the FPS front panel (see Figure 2-17).
8	Make the I/O connections to the control system, as described in section 2.8.2.

Figure 2-17 FPS Cabling Detail on Units Without Remote Gun Controller(s)



2.8.2 Making I/O Connections to the Control System

The installer must make connections (1) between the control system and the power module–system I/O cable (PN 6338-2886-0) and (2) between the control system and the FPS–system

I/O cable (PN 6388-2884-0). If necessary, remove the female D connectors from the ends of these two cables. Control inputs and status outputs include both digital and analog signals. Digital inputs require a simple contact closure and carry 24 V dc at approximately 20 mA. All digital outputs are from contact closures rated at 2 A @ 220 V ac or at 2A @ 30 V dc.

Making Connections to the Power Module-System I/O Cable (PN 6388-2886-0)

The power module–system I/O cable plugs into connector J4 on the power module's rear-panel. Table 2-3 shows the pinout for control system end of that connector, cross-references signal names to wire colors, and provides additional information about most of the inputs and outputs.

Table 2-3 Signals Exchanged via the Power Module–System I/O Cable (PN 6388-2886-0)

CV-16SLX POWER MODULE		6388-2886-0	
(DB-25)	J4		
KV SET IN	1	1 WHT/GRN	1 KV SET IN, 0-10 VDC in for 0-10 kV
ANALOG COMMON	2	2 WHT/ORG	2 ANALOG COMMON
KV MONITOR OUT	3	3 WHT/RED	3 KV MONITOR OUT, 1-10 VDC for 0-10 kV
mA MONITOR OUT	4	4 ORG/WHT	4 mA MONITOR OUT, 0-10 VDC for 0-2.0 A
REM/LCL IN	5	5 WHT/BRN	5 REM/LCL IN, 10-24 V DC; high selects remote HV control
I/O SWITCHES POWER	6	6 BRN/WHT	6 I/O SWITCHES POWER
DIGITAL COMMON	7	7 RED/WHT	7 DIGITAL COMMON
HV ON IN +	8	8 WHT/BLK	8 HV ON IN +, 15-24 V DC input, maintained for HV ON
HV ON IN -	9	9 WHT/BLU	9 HV ON IN -, HV ON signal return (if externally sourced)
RESET +	10	10 BLU/WHT	10 RESET IN +, Momentary 15-24 V DC input to reset faults
RESET -	11	11 BLU	11 RESET IN -, RESET signal return (If ext. sourced)
HV ON IND OUT	12	12 BRN	12 HV ON IND OUT, 15-24 VDC = HV IS ON
FAULT IND OUT	13	13 VIO	13 FAULT IND OUT, 15-24 VDC = FAULT OCCURED
READY IND OUT	14	14 GRY	14 READY IND OUT, 15-24 VDC = HVPS READY
OUT OF REG IND OUT	15	15 BLK/WHT	15 OUT OF REG IND OUT, 15-24 VDC = HV OUT of REG
INTERLOCK OK IND OUT	16	16 GRN	16 INTERLOCK OK IND OUT, 15-24 VDC = Interlock OK
HV OFF IN +	17	17 WHT	
HV OFF IN -	18	18 RED	
SPARE	19	19 BLK	
SPARE	20	20 YEL	
SPARE	21	21 ORG	
SPARE	22	22 GRN/YEL	
SPARE	23	23 GRN/WHT	
REMOTE INTERLOCK +	24	24 PNK	24 External interlock string; user-supplied and defined.
REMOTE INTERLOCK -	25	25 TAN	25 Must be jumpered if no external interlocks are supplied.
		SHELL SHIELD	SHELL

NOTE

The interlocks are internally supplied with 24 V dc. Only contact closure need be supplied. The application of voltages to the interlock circuits will cause them serious damage. In addition, care must be taken not to allow voltages from other sources to affect these signals, as safety could thereby be compromised.

Making Connections via the FPS-System I/O Cable (PN 6388-2884-0)

The FPS–system I/O cable plugs into connector J101 on the FPS. Table 2-4 shows the pinout for that cable and cross-references signal names to wire colors.

Table 2-4 Signals Exchanged via the FPS–System I/O Cable (PN 6388-2884-0)**FILAMENT POWER SUPPLY**

(DB-15)	J101	6338-2884-0			
CONTROL PWR GND	1	1	BLU	1	To power ground
REQUEST SIGNALS COM	2	2	GRN	2	To analog ground
MONITOR SIGNALS COM	3	3	ORG	3	To analog ground
FIL OK + GUN IS ON	4	4	BRN	4	Outputs +24 V dc when filament is OK and gun is on
FIL BIAS SET SELECT	5	5	BRN/WHT	5	+24 V dc input activates Filament Bias Set input
GUN ENABLE	6	6	ORG/WHT	6	+24 V dc input enables FPS functions
GUN IS READY OUT	7	7	GRN/WHT	7	Outputs +24 V dc when gun is enabled
CONTROL DC PWR +24V	8	8	RED	8	Provides +24 V dc to external control circuits
EMISSION MONITOR OUT	9	9	RED/WHT	9	0-10 V dc output (= 0 to max. emission current readout)
EMISSION REQUEST IN	10	10	BLU/WHT	10	0-10 V dc input (= 0 to max. emission current request)
FILAMENT CURRENT MON	11	11	VIO	11	0-10 V dc output (=0-50 A on -0 and -1 model FPS units, 0-100 A on -2 FPS units)
FILAMENT BIAS SET IN	12	12	VIO/WHT	12	0-10 V dc input (=0-50 A on -0 and -1 model FPS units, 0-100 A on -2 FPS units)
AUTO-BIAS INDCR HI	13	13	BLK	13	+24 V dc output Auto Bias sequence is complete
GUN IS ON OUT	14	14	BLK/WHT	14	Outputs +24 V dc when gun is on
GUN GO ON IN	15	15	YELLOW	15	+24 V dc input switches on the gun
		SHELL	SHIELD	SHELL	

2.9 Initial Power Up/Maintenance Power Up Procedure

Follow the procedure described below when powering up the unit for the first time and whenever it has been powered down and lock/tagged out at the facility breaker (e.g., for maintenance).

Step	Action
1	Remove the lockout/tagout device from the facility circuit breaker supplying power to the CV-6SLX.
2	Set the facility breaker switch to the ON position.
3	Set the circuit breaker switch (labeled AC MAINS) on the power module front panel to the ON position.
4	Set the FPS ON/OFF switch (see Figure 2-6) to the ON position.

Follow the normal operating instructions to switch on and control the HV, the filament bias current, and the emission current. For operating instructions for standard units, see section 3.5. For operating instructions for units without a remote gun controller, see section 3.6.

3 *Power Supply Operation*

3.1 Section Overview

This section covers the following topics:

Section 3.2: Power Module Controls and Indicators

Section 3.3 Switches and Indicators on Filament Power Supply Front Panel

Section 3.4 Control and Display Features on Remote Gun Controller

Section 3.5: Normal Power Supply Operation: Standard Units

Section 3.6: Normal Power Supply Operation: Units Without the Remote Gun Controller

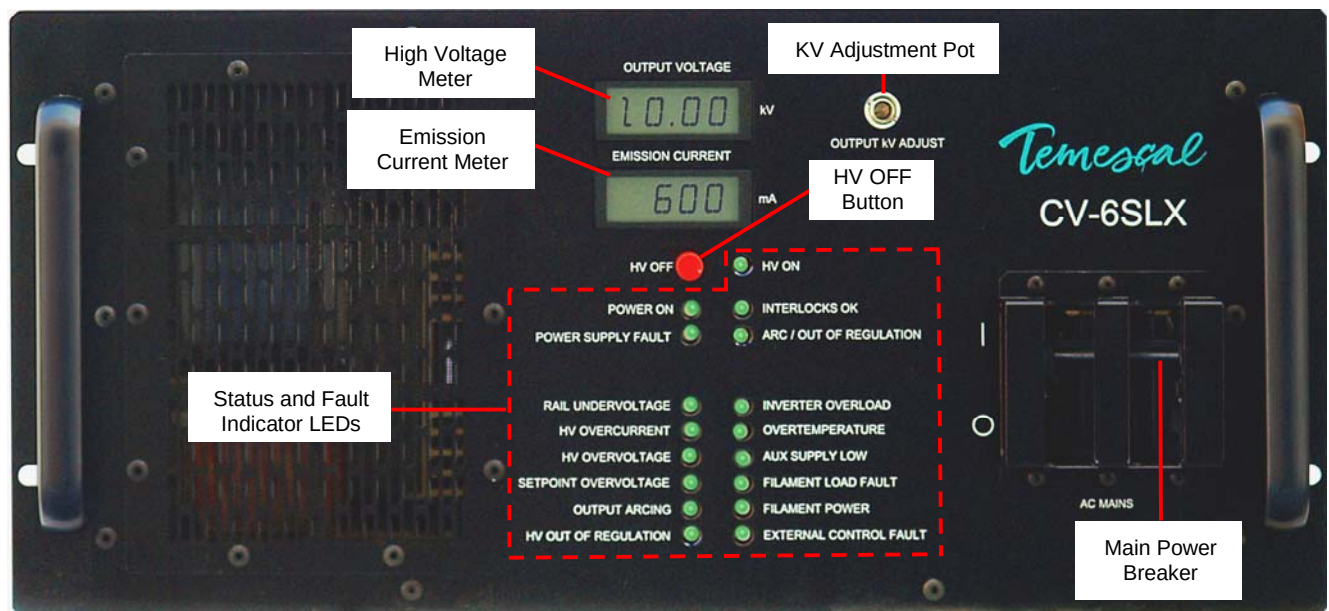
Section 3.7: Responding to Out Of Regulation Conditions and Power Supply Faults

Sections 3.2 through 3.5 and section 3.7 apply to standard CV-6SLX units. Sections 3.2, 3.3, 3.6, and 3.7 apply to units without a remote gun controller.

3.2 Power Module Controls and Indicators

Figure 3-1 shows the controls and indicators on the front panel of the CV-6SLX power module. Those features are described in detail below.

Figure 3-1: Power Module Front Panel



3.2.1 Front Panel Controls

Main Circuit Breaker Switch (Labeled **AC MAINS**)

High-Voltage Adjustment Pot (labeled **Output kV Adjust**)

HV OFF Button

3.2.2 Front Panel Indicators

Display Meters

- **Output Voltage** meter (0–10 kV)
- **Emission Current** meter (0–600 mA)

Status LEDs

- **Power ON** LED
- **HV ON** LED
- **Interlocks OK** LED. External interlocks (including power supply covers) are satisfied.
- **Power Supply Fault** LED. Turns red when one or more of the following latching faults has occurred:
 - Rail Undervoltage
 - HV Overcurrent
 - HV Overvoltage
 - Setpoint Overvoltage
 - Output Arcing
 - Inverter Overload
 - Overtemperature
 - Aux Supply Low
 - External Control Fault
- **Arc/Out of Regulation** LED. Flashes yellow when arcs occur and when the HV is momentarily out of regulation for any other reason.
- **Filament Power** LED. Filament power supply is powered up.

Fault Indicator LEDs

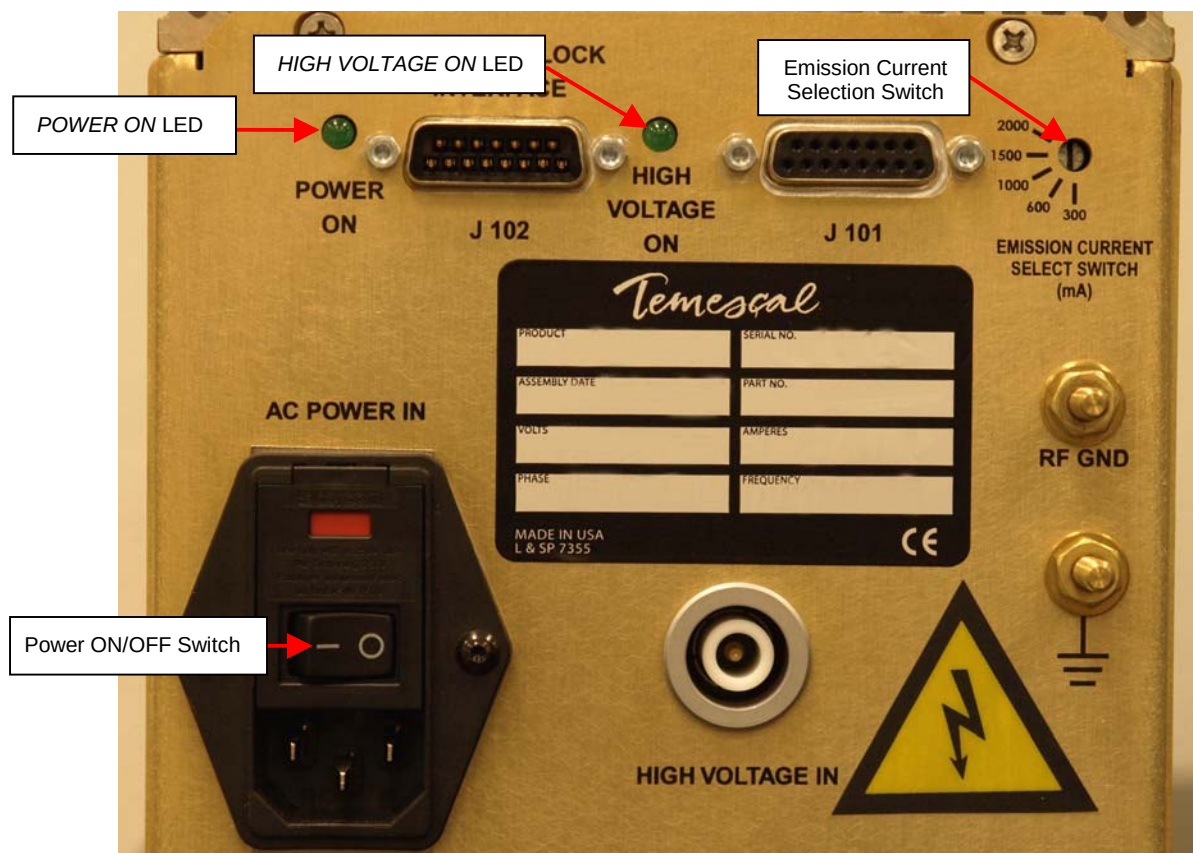
The following LEDs indicate latching faults, which necessitate the application of the Reset signal before the power supply can be restarted. Unless otherwise noted, all of these LEDs turn red when the fault condition in question occurs.

- **Rail Undervoltage** LED. Inverter rail voltage is below 80% of nominal (range = 540 V to 565 V).
- **HV Overcurrent** LED. HV output current is more than 105% of its maximum (= 600 mA).
- **HV Overvoltage** LED. HV output voltage is more than 105% of its maximum (= 10 kV).
- **Setpoint Overvoltage** LED. HV output voltage is more than 105% of its setpoint value.
- **Output Arcing** LED. Arc rate exceeds 200 arcs/sec., or continuous arcing persists for more than 120 sec.
- **HV Out of Regulation** LED. HV circuit out of regulation for more than 2 seconds.
- **Inverter Overload** LED. Inverter current exceeds maximum allowable (= 100 A).
- **Overtemperature** LED. Inverter temperature above 67° C, or cooling fan failure.
- **Aux Supply Low** LED. Nominal ± 24 V dc control voltage is below 19.5 V dc.
- **Filament Load Fault** LED. Open circuit in filament load (= filament broken or burnt out).
- **External Control Fault** LED. Short circuit in 24 V dc supplied by filament power supply for external interlock string.

3.3 Switches and Indicators on Filament Power Supply Front Panel

Figure 3-2 shows the switches and LED indicators on the FPS front panel.

Figure 3-2 Filament Power Supply Front Panel



The switches and indicators on the FPS front panel are:

- Power ON/Off switch: Must be switched ON in order for unit to operate.
- **POWER ON LED**: When lit, indicates that unit is being supplied with input power.
- **HIGH VOLTAGE ON LED**: When lit, both the power module and the FPS indicate that the HV is on. For further details, see Table 5-13.
- Emission current selection switch: A black plastic cap normally covers this switch, which is factory set for the power supply with which it is supplied and should require no further attention. Figure 3-2 shows the switch set to the 300-mA position. For a standard CV-6SLX power supply (i.e., with the remote control unit), it should always be set to the 600 mA position. For CV-6SLX without the remote control unit, it should be set to 1000 mA.

3.4 Control and Display Features on Remote Gun Controller

Figure 3-3 shows the remote HV/gun control unit. Control/display features on the HV Control panel are described in detail below the illustration.

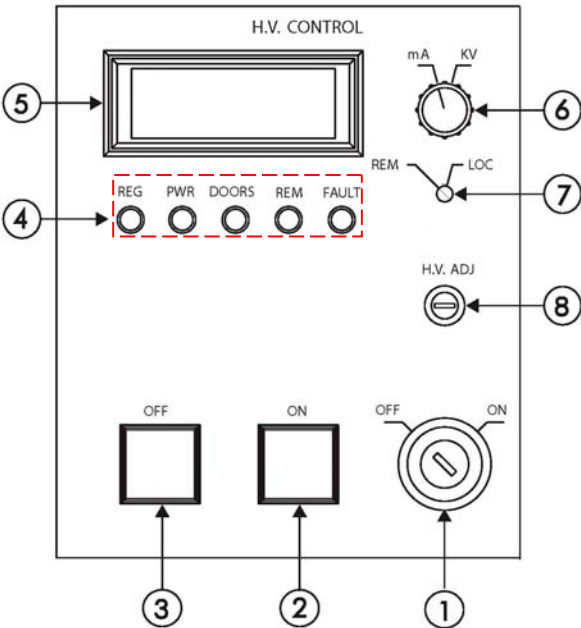
Figure 3-3 Remote Control Unit



Control/Display Features on HV Control Panel

Figure 3-4 shows the following control/display features on the front panel of the HV Control portion of the single gun control unit's front panel. The control/display features on this panel are described below.

Figure 3-4 Control/Display Features on HV Control Panel

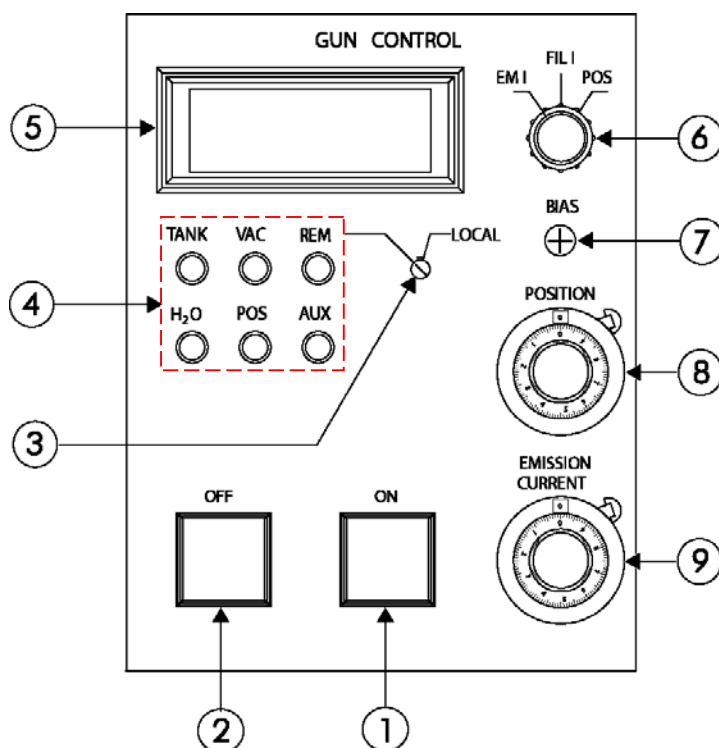


1. Key switch: Must be turned to the ON position in order to enable the HV. When key switch is in the OFF position, the HV is disabled.
2. High voltage ON button and HV ON indicator light: When the HV Ready light inside the High Voltage OFF is illuminated, pressing this button switches on the high voltage. When the high voltage is on, the HV ON indicator light inside this button is illuminated.
3. HV OFF/HV Reset button and HV Ready indicator light: When the HV is ON, pressing this button switches off and resets the high voltage. When the HV is off and the HV interlock chain is made, the HV Ready light inside this button is illuminated. Pressing this button when both conditions are true switches the high voltage ON.
4. LED Indicators:
 - **REG LED**: Illuminated when HV circuit is out of regulation for more than 2 seconds; mimics the **HV Out of Regulation** LED on the power module's front panel.
 - **POWER LED**: Illuminated when all dc power supplies are operating correctly; mimics the operation of the **Aux Supply Low** LED on the power module's front panel.
 - **DOORS LED**: Illuminated when the interlocks for power module and FPS covers and any customer-defined and supplied external interlocks are all made.
 - **FAULT LED**: Illuminated when any latching power module (i.e., HV-related) fault occurs; mimics the operation of the **Power Supply Fault** LED on the power module's front panel.
 - **REM LED**: Illuminated when REM-LOC switch is set to REM.
5. Meter: This 3.5-digit LCD meter displays either of two readouts:
 - Power supply total current (0-600 mA)
 - High voltage (0-10.0 kV)
6. Meter select switch: This switch enables the user to select either high voltage and power supply total current for display on the adjacent meter.
7. REMote-LOCal switch: When this switch is in the LOCAl position, the user can adjust the HV manually from the HV control panel. When this switch is in the REMote position, the HV request is controlled either by a remote input, usually from a control system, or via the OUTPUT kV ADJUST pot on the power module front panel. The HV ON and HVOFF buttons are always active, regardless of the position of the REM-LOCAL switch.
8. HV ADJ pot: When the REM-LOC switch is set to LOC, this 3-turn pot enables the user to set the high voltage level. It is normally set to 10 kV.

Control/Display Features on Gun Control Panel

Figure 3-5 shows the following control/display features on the front panel of the Gun Control panel. The control/display features on that panel are described below.

Figure 3-5 Control/Display Features on Gun Control Panel



1. Gun ON button and Gun ON indicator light: When the Gun Ready indicator light inside the Gun Control panel's OFF button is illuminated, pressing the Gun ON button switches on the gun. The Gun ON indicator light inside the Gun ON button is illuminated when the gun is on.
2. Gun OFF button and Gun Ready indicator light: When the gun is on, pressing this button switches it off. When the gun is off and the TANK, VAC, AUX, and H₂O interlock LEDs are lit, the Gun Ready indicator light inside this button is also lit.
3. REMote-LOCAL selector switch: When this switch is in the LOCAL position, the user can set the emission current request and bias current request manual via the Gun Control panel. When the REM-LOCAL switch is set to REM, these functions are controlled by remote inputs, normally from a host computer. The GUN ON and GUN OFF buttons are always active, regardless of the position of the REM-LOCAL switch.
4. Indicator LEDs:
 - **TANK LED**: Illuminated when the customer-supplied input for the TANK interlock is closed. If the Tank interlock is open, none of the other interlock LEDs will be lit, as Tank is the first in the interlock series.
 - **VAC LED**: Illuminated when the customer-supplied input for the Vacuum interlock is closed. If this interlock is open, the LEDs for the H₂O, POS (if used), and AUX (if used) interlocks will not be lit.
 - **REM LED**: Illuminated when the REM-LOCAL switch is in the REM position.

- **H₂O LED:** Illuminated when the customer-supplied input for the H₂O interlock is closed, indicating that cooling water is flowing to the e-beam source. If this interlock is open, neither the POS nor the AUX interlock LED will be lit.
 - **POS LED:** A contact closure designed to be supplied by a beam sweep controller. The position interlock should be closed when the position of the beam is within the limits preset on the optional beam sweep controller.
 - **AUX LED:** The auxiliary interlock is a customer-supplied contact closure. If the contact is open, none of the interlock LEDs that follow will be illuminated.
5. **Meter:** Displays either emission current (0-600 mA) or filament current (0-75 A), depending on the position of the adjacent EMI I/FIL I/POS switch.
 6. **EMI I/FIL I/POS switch:** Position of this switch determines whether the Gun Control panel's meter displays emission current or filament current.

NOTE

The Gun Control meter displays nothing when the EMI I/FIL I/POS switch is in the POS position, as position control is not implemented on the CV-6SLX.

7. **BIAS control:** If the Gun Control panel's LOC-REM switch is set to LOCAL, adjusting this pot varies the filament bias current (0-50 A on units with FPS PN 0620-6604-0; 0-100A on units with FPS PN 0620-6604-2).
8. **POSITION dial:** Not implemented
9. **EMISSION CURRENT dial:** When the gun and the high voltage are both ON and when this panel's LOCAL-REMOTE switch is set to LOCAL, this dial enables the user to adjust the emission current. When the high voltage is on, the impedance of the load is determined by the filament temperature.

3.5 Routine Power Supply Operation on Standard Units

3.5.1 Switching Main Power On/Off

To switch on three-phase input power to the power module, set the front panel's main power breaker (labeled AC MAINS) to the ON position (i.e., all the way up). To switch off main input power, set that breaker to the OFF position (i.e., all the way down).

NOTE

The main power breaker on the power module front panel also controls power to the filament power supply (FPS) module.

3.5.2 High Voltage Control

Switching on the High Voltage

If the power module's main breaker switch is in the ON position, and if, immediately previously, you have *not* switched off the high voltage by pressing the HV OFF button on the power module front panel, you can switch on the high voltage by performing these steps:

Step	Action
1	If the keyswitch on the HV control panel (see Figure 3-4) is not in the ON position, turn it to that position. The HV Ready light inside the HV control panel's OFF button should then light.
2	If the HV Ready light is lit, press the HV control panel's ON button to switch on the high voltage.

Switching off the high voltage by pressing HV OFF button on the power module front panel triggers a latching Power Supply fault. In that event, or if a latching Power Supply fault has occurred for any other reason, you must perform the following procedure to switch on the HV.

Step	Action
1	Press the HV OFF button on the power module front panel again. When the HV is off, pressing that button asserts the RESET signal.
2	If the keyswitch on the HV control panel (see Figure 3-4) is not in the ON position, turn it to that position. The HV Ready light inside the HV control panel's OFF button should then light.
3	If the HV Ready light is lit, press the HV control panel's ON button to switch on the high voltage.

Adjusting the High Voltage

The high voltage can be adjusted in either of two ways, depending on whether the REM/LOC switch on the HV control panel is in the REMote or the LOCAl position:

1. Switch in LOCAl position: Using a flat-bladed screwdriver, turn the H.V. ADJ pot.
2. Switch in REMote position: Vary the REMOTE HV REQUEST signal, which is supplied via G1J2 Pins 18 and 19 on the remote gun controller's rear panel (see Figure 2-15).

Switching Off the High Voltage

The high voltage is automatically switched off if:

- any internal or external interlock is no longer made
- the power supply goes into an latched HV Out Of Regulation state
- a latching Power Supply Fault occurs.

The high voltage can be intentionally switched off in any of the following ways:

1. The control system can assert the HV GO OFF signal, which is supplied via at HVJ2 Pins 3 and 7 on the remote gun controller's rear panel (see Figure 2-15).
2. The operator can press the HV OFF button on the power module front panel.
3. The operator can press the OFF button on the HV control panel (see Figure 3-4).
4. The operator can turn the HV control panel's key switch to the OFF position.

3.5.3 Switching the Filament Current On/Off

NOTE

In order for the filament current to be switched on, the FPS module's power cable must be properly connected to a source of 220-V ac power, and the module's ON/OFF switch must be in the ON position.

Switching On the Filament Current

The operator can switch on the filament current by pressing the ON button on the Gun Control panel (see Figure 3-5) and holding it down for 2 seconds. Alternatively, the control system can switch on the filament current by asserting the REMOTE GUN GO ON signal for 2 seconds. The REMOTE GUN GO ON signal is supplied via G1J2 Pins 7 and 8 on the remote gun controller's rear panel (see Figure 2-16).

NOTE

Once the HV and the gun are both switched on, the emission current will ramp up to requested level after a 10–15 second delay.

Switching Off the Filament Current

The operator can switch off the filament current by simply pressing the OFF button on the gun control panel (see Figure 3-5). The control system can also switch off the filament current by momentarily de-asserting the REMOTE GUN GO OFF*/ENABLE signal, which is supplied via G1J2 Pins 5 and 6 (see Figure 2-16).

3.5.4 Adjusting the Filament Bias Current and the Emission Current

Adjusting the Filament Bias Current

The filament bias current can be adjusted in either of two ways:

1. The operator can adjust the BIAS pot on the gun control unit's front panel (see Figure 3-5), or
2. The externally supplied FILAMENT BIAS SET signal can be varied. That signal is supplied via Pins 26 and 27 on remote gun controller rear-panel connector G1J2 (see Figure 2-16).

Adjusting the Emission Current

The emission current can also be adjusted in either of two ways:

1. The operator can adjust the EMISSION CURRENT dial on the gun control unit's front panel (see Figure 3-5), or
2. The externally supplied REMOTE EMISSION REQUEST signal can be varied. That signal is supplied via G1J2 Pins 26 and 27 on the remote gun controller's rear panel (see Figure 2-16).

3.6 Routine Power Supply Operation on Units Without a Remote Gun Controller

3.6.1 Switching Main Power On/Off

To switch on three-phase input power to the power module, set the front-panel's main power breaker to the ON position (i.e., all the way up). To switch off main input power, set the main power breaker to the OFF position (i.e., all the way down).

NOTE

The main power breaker on the power module front panel controls power to the filament power supply (FPS) module. Switching the HV On/OFF and Adjusting the HV Level

3.6.2 High Voltage Control

Switching On the High Voltage Under Normal Operating Conditions

The control system can switch on the high voltage by asserting the HV GO ON signal (15–24 V dc) for two seconds at Pin 8 of power module rear panel connector J4 (see Table 2-3).

Switching On the High Voltage Following a Latching Fault Condition

Switching off the HV by pressing the HV OFF button on the power module front panel triggers a latching Power Supply Fault. In that event, or when any other latching fault has occurred, the following signals must be supplied, in the order given below, to switch the HV back on.

NOTE

If a Power Supply fault has occurred because of a latching fault condition—and not because the user has pressed the power module's HV OFF button—the underlying fault that triggered the latching fault must be corrected before the HV can be reset. For detailed troubleshooting instructions, see Section 5.2.

1. The RESET signal must be supplied. This can be accomplished in either of two ways. Either the operator can press the HV OFF button, or the control system can assert the RESET signal at Pins 8-9 of power module rear panel connector J4 (see Table 2-3). If the RESET attempt is successful, all status and interlock LEDs on the power module should be green, except for HV ON.
2. If the reset attempt has been successful, the control system must assert the HV GO ON signal at Pin 8 of power module rear panel connector J4.

If this sequence of operations fails to restart the HV, further troubleshooting will be required to clear the underlying fault condition.

Adjusting the High Voltage Level

The HV level is adjusted by varying the external kV SET IN signal (0–10 V dc = 0–10 kV), which is supplied via Pin 1 of power module rear panel connector J4 (see Table 2-3).

Switching Off the High Voltage

The high voltage is automatically switched off if:

- any internal or external interlock is no longer made
- the power supply goes into an HV Out Of Regulation state
- a latching Power Supply Fault occurs

The high voltage can be switched off by the control system in either of two ways:

3. The control system can momentarily de-assert the HV GO ON signal supplied via Pins 8-9 of power module rear panel connector J4 (see Table 2-3).
4. The control system can assert the HV GO OFF signal supplied via Pins 17-18 of power module rear panel connector J4.

3.6.3 Switching the Filament Current On/Off

NOTE

In order for the filament current to be switched on, the FPS module's power cable must be properly connected to a source of 220-V ac power, and the module's ON/OFF switch must be in the ON position.

Switching On the Filament Current

The gun (i.e., filament current) can be switched on only by an externally supplied GUN GO ON signal, which must be applied via Pin 15 of FPS front panel connector J101 (see Table 2-4).

NOTE

Once HV and gun are both switched on, emission current will ramp up to requested level after a 10–15 second delay.

Switching Off the Filament Current

The filament current can be switched off only by de-asserting the GUN GO ON IN signal, which is supplied via Pin 15 of FPS front panel connector J101 (see Table 2-4).

3.6.4 Adjusting the Filament Bias Current and the Emission Current

Adjusting the Filament Bias Current

On units without a remote gun controller, the bias current can be adjusted only by varying the FILAMENT BIAS SET IN signal, which is supplied Pin 12 on the FPS front panel connector J101 (see Table 2-4).

NOTE

When the FIL BIAS SET SELECT signal (supplied via J101 Pin 5) is low, the Autobias circuit of the FPS controls the bias current. When the FIL BIAS SET SELECT signal is high, the operator can control the bias current from the control system's user interface.

Adjusting the Emission Current

On units without a remote gun controller, the emission current can be adjusted only by varying the EMISSION REQUEST IN signal, which is supplied via Pin 10 FPS rear panel connector J101 (see Table 2-4).

3.7 Responding to Out of Regulation Conditions and Power Supply Faults

During normal operation, the Out of Regulation LED on the power module front panel will flash intermittently as arcs occur. The flashing will increase in frequency as arcs increase in frequency. If arcs become too frequent or persist at too high a rate for too long, the internal OUT OF REGULATION is asserted, latching off the HV and triggering a Power Supply fault. The Out of Regulation LED will then glow steadily.

To switch the HV back on when a the power supply is in an Out Of Regulation state, or when a latching Power Supply fault has been triggered by any other condition, the RESET signal and the HV ON signal must be asserted, in that order. On standard units, the operator can simply press the HV OFF button (which supplies the RESET signal when the HV is off) and then press the ON button on the HV control unit's front panel (see Figure 3-4). On units without a remote gun controller, the following signals must be supplied in order for the HV to be switched on when a latching Power Supply fault has occurred:

- the RESET signal, supplied via Pins 10 and 11 on power module rear panel connector J4
- the HV ON signal, supplied via Pins 8 and 9 on the same connector.

If the Out of Regulation condition occurred because of intermittent arcing, the HV should come back on. The same applies to Power Supply faults that occur because the operator has switched off the high voltage by pressing the HV OFF button on the power module front panel. In the case of an Out Of Regulation state triggered from a dead short, it will be necessary to identify and eliminate the source of the short, which may be due to a flake in the vacuum chamber or to a defect or fault in the HV circuit. Power Supply faults triggered by latching faults other than Out Of Regulation will also require troubleshooting. For troubleshooting instructions covering these cases, see Section 5.

4 *Theory of Operation*

4.1 Section Overview

This section provides separate theories of operations for the major modules of the CV-6SLX power supply. Section 4.2 contains a theory of operation for the power module, and section 4.3 covers the FPS in detail.

4.2 Power Module Theory of Operations

4.2.1 Top Level Theory

Several physical and functional assemblies form the HVPS. Referring to the top-level schematic (Figure 6.1 above), AC line power is connected to the HVPS through terminal block TB1. Line filter LF1 then creates high frequency filtering to minimize conductive emissions from the unit, as well as provides immunity to common levels of AC line transients. The load side of the line filter then feeds three-phase circuit breaker CB1, as well as auxiliary filtered IEC outlet J2. This AC connector is fused at 6.3A by F1 and F2, which are accessible on the rear panel through panel-mounted fuse holders. The IEC outlet is sourced differently, depending on the unit's line voltage range: the 208VAC unit connects the IEC outlet between phases, while the 400VAC unit connects it between a phase and neutral. This is intended to maintain the IEC outlet voltage between 187VAC and 254VAC, considering the $\pm 10\%$ tolerance of voltages applied to TB1.

Grounding to the unit is provided through two external fasteners. One threaded stud in the lower center of the rear panel must be connected to an earth ground for safety. Another threaded stud on the rear panel, near HV output connector J1 and labeled "RF GND", provides a ground return for the HV output. Internally, ground wires are connected together with a ground "block", mounted to the bottom panel.

Mounted to the front panel and shielded from inadvertent operation by a "kick" guard, circuit breaker CB1 provides over-current protection of the three AC line phases. The load side of the circuit breaker feeds Inverter board A1, whose functions are discussed in a section below. Several other components and assemblies connect to the Inverter.

Two AC line phases from the Inverter feed the primary of step-down transformer T2 (wired with jumpers for a 1:1 ratio in the 208VAC unit and 2:1 ratio in the 400VAC unit), which in turn powers the AC input of +24VDC auxiliary power supply PS1. The +24VDC output of PS1 connects back to the Inverter, and provides low voltage power to the other board assemblies in the HVPS.

Temperature inputs come from two separate devices connected to the Inverter, thermostat S2 and IC sensor U1. S2 opens when the Inverter heat sink rises above a preset temperature, while U1 generates an analog voltage scaled to the temperature of the heat sink near the Inverter IGBTs. Both sensors feed the over-temperature fault circuitry. Cooling of internal components is provided by +24VDC fan B1 mounted on the rear panel, which draws airflow in through the front panel grille, and exhausts at the rear. An integrated jammed rotor sensor in the fan senses when the blades have stopped spinning, and will trip an over-temperature fault.

After the circuit breaker, the three AC line phases are fed to the Inverter for conversion from 50/60Hz AC power into high frequency power. Part of the conversion process involves rectifying the AC input voltage through a three-phase bridge rectifier and current smoothing with “DC link” choke L1. This inductor improves the power factor of the HVPS as seen by the AC power grid. High speed IGBTs in the Inverter switch the rectified bus voltage through HV Transformer T1 at 25kHz, thereby converting the intermediate DC power once again into AC power. HV Rectifier board A2 then converts the high frequency, high voltage output of the HV Transformer into DC high voltage power. In addition, the HV Rectifier scales the output voltage and current for feedback to the Regulator control circuits. DC output voltage is delivered from this board to the external load through custom high voltage “cablewell” connector J1. The mating connector and cable for J1 is provided with each HVPS.

Virtually all logic, control, and analog processing functions are managed on Regulator board A3. To provide visual indications on the front panel, Display and Control board A4 is connected and sandwiched between the front panel and the Regulator. In addition, the Display and Control board provides an HV OFF pushbutton, output voltage adjustment potentiometer, and voltage and current LCD displays for the user. The Regulator links with the customer's remote interface through the three D-subminiature connectors on Interface board A5, which is mounted to the upper left corner of the rear panel. The most critical function of the Regulator is to compare the output feedback to the provided references and then feed the Inverter IGBT gate drives to properly actuate them.

4.2.2 Module Level Theory

A1 Inverter

Two versions of the Inverter board (P/N 9150035-014 and 9150035-012) are used in the 208VAC and 400VAC units, respectively, however they are virtually identical. The three AC line phases are fed to the Inverter board through three pins of J32, which is a Molex Mini-Fit Sr. series connector. Two phases of the AC are distributed to the primary of the step-down transformer through slow-blow AC fuses F1 and F2, which protect the transformer from over-current (1A for the 208VAC unit, and ½A for the 400VAC). J24 connects the fuses to the transformer.

Rail Capacitor Charging

To limit AC inrush current during charging of the rail capacitors, thermistors R97 and R129 act as a series resistance between the AC line and the bridge rectifier. At high line, the peak inrush current is approximately 16A for both AC input voltage units. The rail capacitors are charged to 97% of their final voltage level through these thermistors and two phases of the three-phase bridge rectifier formed by CR17, 23, and 28 before the +24VDC auxiliary power supply starts delivering its output. Once the +24VDC supply has energized and the rail voltage exceeds its minimum value (as determined on the Regulator board: 220VDC and 430VDC for the 208VAC and 400VAC units, respectively), three-phase relay K1 is activated through J31 (and a connecting cable to J3) by signal AC_RLY_ON from the Regulator.

With the contacts of relay K1 closed, all three phase currents are rectified by CR17, 23, and 28 and somewhat filtered for high frequency noise by C64 and C61. The resulting DC-biased current passes through high-speed fuse F3, which protects downstream components from over-current (40A for the 208VAC unit, and 20A for the 400VAC). AC power factor is passively improved with the DC link choke (1.2mH for the 208VAC unit, and 4.8mH for the 400VAC), which connects to the Inverter through J25. Two extra pins on J25 are used for the additional current in the 208VAC unit. The last constituent of the Inverter rail is formed by bulk electrolytic capacitors C46-57 (arranged in a series-parallel matrix). The series capacitor banks are voltage-balanced by R65, 67, 68, and 71, which also serve as discharge resistors when power is removed from the unit. It is important to note that circuit nodes on the schematic connected to the symbol used for the negative side of the Inverter, “ground” with a ‘C’ attached to it ($\text{---}\text{C}$), are floating at a high voltage with respect to ground, and should never be connected to anything earth/ground referenced. Schematic symbol ($\text{---}\text{B}$) is also connected to this floating node, and should never be connected to earth/ground as well.

Full Bridge IGBT Inverter

IGBTs Q6, 7, 10, and 11 form the “heart” of the Inverter, switching on-and-off at 25kHz to drive current through the primary of the HV Transformer. The IGBTs are arranged in a full-bridge configuration, and are controlled in a phase-shifted scheme, whereby Q7 and Q11 are always in an opposite conducting state from each other (i.e. one is on while the other is off), as are Q6 and Q10 always in an opposite state. By shifting the phase between these two pairs of IGBTs, the effective current-on time delivered to the HV Transformer can be varied precisely. The IGBT switching sequence generated by the phase-shift modulated (PSM) controller chip on the Regulator is connected through J11 (which contains other control signals as well) to the Inverter. Driver chips U7 and U8 transmit those signals to the gates of the IGBTs through DC coupling capacitors C35 and C36, and gate drive transformers T1 and T2 (which have a 1:1:1 transfer ratio). Separate turn-on and turn-off gate resistor pairs are employed (to limit EMI and turn-off losses, respectively), as well as high frequency series ferrite beads to limit ringing on the gates. Each IGBT possesses an “RCD” (resistor, capacitor, and diode) snubber circuit between its collector and emitter leads (e.g. R41, C43, and CR6). This snubber circuit limits the collector voltage overshoot during turn-off and protects the IGBT from damage.

High frequency current from the rail capacitors passes through the input terminals of Hall-effect current sensor U15, through the half-bridge IGBTs, through resonant capacitor C2, and out to

the HV Transformer primary through J8. Capacitor C2 and the leakage inductance of the HV Transformer form part of a resonant tank that allows zero current switching (ZCS) of the IGBTs under most conditions. ZCS reduces power dissipation in the IGBTs, and lowers EMI from the Inverter. The output and supply terminals of current sensor U15 link back to the Inverter through a connecting cable to J1, and are electrically isolated from the input terminals and the IGBT current. U15 has a 75:1 current-to-voltage transfer ratio on its output terminal, which is buffered by op amp gate U3:C. This buffered representative signal of the IGBT current is sent directly to the Regulator on J11, and is also compared to +1.24V by U9 after going through an RC low pass filter with a gain of approximately 0.8 at 25kHz. When the signal exceeds +1.24V (approximately 116A peak), U9 pulls the SET pin of U10:B to ground, thereby latching its output high. This signal, RAIL_FAULT, gets passed to the Regulator on J11, and triggers an Inverter Overload indicator.

Temperature Sensing

Two temperature measuring devices are connected to the Inverter, a thermostat switch (connected to J2) and an active temperature sensor (connected to J6). The thermostat switch contacts remain closed as long as the temperature of the Inverter heat sink where it is mounted stays below 77°C, but open when that trip point is exceeded. When the contacts are open the SET pin of U10:C falls to ground, thereby latching its output high. This signal, THERMO_FAULT, gets passed to the Regulator on J11, and triggers an Overtemperature indicator. All latches on the Inverter board are reset by the Regulator through signal RESET* on J11. The active temperature sensor is also mounted to the Inverter heat sink, but is closer to the IGBTs and produces a linearly scaled output voltage relative to its temperature (10mV/°C). This analog temperature signal, TEMP_OUT, is passed directly to the Regulator for processing.

Auxiliary Power and Rail Voltage Monitor

Auxiliary +24VDC power is fed to the Inverter board on J5 as power signal AUX_24, which (along with being passed directly to the Regulator) then powers two items, the +24V bus through CR2 and the DC fan through low-pass filter L1 and C20 to J4. If the rotor of the fan becomes jammed, its alarm output on J4 is sent to the Regulator and triggers an Overtemperature indicator. The +24V bus is connected back to the Regulator on J11, and also powers +24V-to-±15V DC-DC converter U1. This isolated ±15V supply powers the rail voltage sense circuitry. Since the Inverter rail is not ground referenced, and floats several hundred volts from it, some form of isolation barrier is needed to scale and convert the rail voltage magnitude to the ground referenced Regulator. R157-165, R176, and C96 form a filtered 89:1 voltage divider network across the rail, which feeds an analog isolation circuit. This circuit, powered by the ±15V from U1, employs a filtered control amplifier (U4) that drives a high linearity optocoupler (U2) configured to compensate for temperature and age-related optocoupler drift. The isolated output of the optocoupler is amplified by U3 and scaled by potentiometer R2 for a final 100:1 ratio of rail voltage to signal output, which is routed to the Regulator on J11. Several of the signals on J11 are not connected on these versions of the Inverter board, and have no functionality despite their node names: pins 11, 12, 13, 14, 16, 18, and 22.

A2 HV Output

Secondary Tuning

High frequency AC voltage driven on the primary of the HV Transformer by the Inverter is transformed by a fixed ratio (15:225), and connected to the input of the HV Output board (P/N 9170079-012) at J1 and J2. Since the AC high voltage magnitude on J1 will be at least two times as large as that on J2 (with reference to ground), and the “finish” winding lead of the HV Transformer has more spacing to ground than the “start” lead, J1 must always be connected to the “finish” lead. Between J1 and J2, effectively across the HV Transformer secondary, is the “secondary tuning” capacitance. This capacitor bank, formed by C31-35 and C41-45, creates a series-parallel resonant circuit with the primary leakage inductance of the HV Transformer. The resonant circuit both smoothes HV Transformer primary current wave shapes and enables zero current switching in the Inverter IGBTs, which reduces EMI and switching losses, respectively.

HV Rectification

A full-wave voltage “doubler” is employed on the HV Output board to produce a rectified output voltage that is double the peak-to-peak voltage across the HV Transformer secondary winding. Two series strings of high-speed diodes, CR1-13 and CR14-26, as well as C28 and C29, form this doubler circuit. Capacitors C1-26 are used to evenly distribute the reverse AC voltage across the diodes. Each diode is subjected to less than 62% of its rated reverse voltage. High voltage film capacitor C27 is used as a storage element, reducing the output ripple voltage. High power wire-wound resistors R9-14 carry all of the output current, and are used to limit the current delivered from output capacitors C27-29 in the event of a single load arc or time-limited continuous arcing. The Regulator will actively terminate the HV output before these resistors overheat from their arc-limiting duty. The final output is connected to the rear panel HV cable well through J3.

Voltage and Current Feedback

Scaled voltage and current feedback are supplied to the Regulator through connector J5. R1, C36, and C38 form a frequency compensated voltage feedback network to the Regulator, which coupled with a low side resistance of approximately $96\text{k}\Omega$ on the Regulator, produces an equal DC and AC voltage division ratio of roughly 200:1. Resistor R6 protects the voltage feedback capacitors from damage induced during HV output arcing by inherently limiting the arc current to 0.33A peak. Spark gap E2 protects the Regulator input from over-voltage in the event of a feedback network component failure. Parallel resistors R2 and R3, along with noise filtering components R4, R5, and C37, create a voltage signal relative to the current delivered by the HV Output board to the load. This ratio, 3.75V:1A, provides a voltage signal to the Regulator for processing. Similarly to E2, E1 protects the Regulator input from over-voltage should a current feedback component fail.

Chassis ground is solidly connected to the HV Output board through a conductive standoff attached to the bottom side of the board, which helps reduce noise and “ground bounce” in the control circuits. Terminal J4 is also connected to this ground “plane”. Pin 6 of J5 is not connected on this version of the HV Output board, and has no functionality despite its node name.

A3 Regulator

kV Feedback and Control

Output voltage control of the HVPS is the primary function of the Regulator, and starts with the user programming the desired voltage setpoint. This is accomplished either locally or remotely, via the front panel OUTPUT kV ADJUST potentiometer or a pin on the rear panel J4 HVPS CONTROL I/O connector (referred to as the User Interface), respectively. These two signals are brought onto the Regulator through connectors J13 and J1 as signals KV_REF_LCL and KV_REF_REM, respectively. These reference control signals, scaled for +10VDC = –10kVDC, are calibrated with potentiometers R114 and R108, and fed to analog switches U35:B and U35:C, respectively. Only one signal is routed through the analog switches to the reference inverter amplifier, as determined by the signal LOCAL (where High = +5VDC = Local Mode), which comes from the User Interface through an isolating optocoupler (U17:A). The now single calibrated voltage reference signal, KV_REF_CAL, is filtered, scaled, and inverted via op amp U33:E. The voltage output of U33:E produces a fixed current flow through R194, 207, and 211, which is fed away from the inverting terminal of voltage error amplifier U30:C, discussed later. “Shunt” jumper J14 is used during the test process to check the over-voltage fault circuit.

To control the output voltage in a closed loop, the reference signal must be compared to the feedback signal. The partially divided output voltage signal is brought in from the HV Output board through pin 4 of J12, and further divided and filtered for noise with R118, R142, R149, C76, C83, C88, and C89. Potentiometer R118 is also used during test to match the feedback waveform shape to the actual output waveform shape. Potentiometer R90 and R134 are used to compensate for the effect of the voltage drop across the arc limiting resistors on the HV Output board, which add a load current dependent voltage offset. The negative feedback signal is inverted by op amp U30:B, before being fed to the voltage error amplifier as signal KV_CAL. This signal creates a current flow through R146 and R156 that is proportional to the HV output voltage. Error amplifier U30:C varies the Inverter IGBT duty cycle so that its inverting terminal stays at zero volts, which is the condition when the current flow through R146 and R156 is equal but opposite to the current flow through R194, 207, and 211. This is how the Regulator maintains the HV output voltage at the requested setpoint. Components R143, R154, R155, C90, C96, and C101 form a two-pole and two-zero frequency compensation network, which ensures that the closed voltage control loop is quick to respond, but is always stable as well.

mA Feedback and Control

The current setpoint, feedback, and error amplifier work in similar ways to their voltage counterparts. Current setpoint programming is only “received” internally, created by +10VDC reference chip U22 in conjunction with filtering, inverting, and scaling buffer op amp U33:D. The reference current fed away from the inverting terminal of current error amplifier U30:D through R79, 81, and 204 is calibrated by potentiometer R81 to maintain a fixed 0.6ADC HV output current when the HVPS is in current control mode. Differential amplifier U32:B takes the current feedback signal from the HV Output board connected across pins 1 and 3 of J12, through some RC filtering, and scales it with R174 and R132. The scaling equation for the output pin of U32:B is equal to $1 + \{50500/(R174 + R132)\}$, which allows potentiometer R132 to calibrate the output pin to 6VDC when the HV output current is 0.6ADC. This voltage then creates a current in R192 and R193 that is equal but opposite to the flow in R79, 81, and 204,

when current error amplifier U30:D is closing the control loop. Components R180, R193, R203, C105, C112, and C123 form a two-pole and two-zero frequency compensation network, which is optimized for output current control.

CR34, CR39, and R160 are configured so that the lower magnitude output between the voltage and current error amplifiers is connected to the error amplifier bus, signal ERR_AMP, and enables the HVPS to switch to constant 0.6ADC current control mode only when the voltage error amplifier can no longer maintain the requested HV output voltage. Test jumper J10 is used to switch between open and closed loop control modes, which is only utilized during troubleshooting. Normally the unit is in closed loop mode with the jumper across pins 2 and 3, but with the jumper across pins 1 and 2 the output voltage is manually controlled with potentiometer R98.

Phase Shift Modulator

R135 and C73 form a low pass filter on the error amplifier bus to minimize switching noise. A voltage limiter is created by R125, R133, and U23, which limits the error amplifier bus to approximately 4.9VDC and protects the input pin of phase shift modulator (PSM) chip, U26. This chip is also damaged by negative voltages on its pins, so CR26 is used to clamp negative spikes. The PSM chip creates the correctly timed gate waveforms for the Inverter IGBTs relative to the level of the error amplifier bus (i.e. increasing bus creates increasing phase shift). The internal error amplifier in the PSM chip is effectively bypassed by being configured as a voltage follower, and slightly filtered by C84. Potentiometer R121, R163, and C99 set the PSM chip's internal oscillator frequency, which is double the IGBT switching frequency by definition. R121 is calibrated so that the switching frequency is set for 25kHz. Potentiometer R45, R162, and C98 together set the slope of the comparator voltage ramp, which permits adjusting the maximum phase shift or effective duty cycle. Currently R45 is set at test for 100% duty cycle. R137 and R159 set the delays between the C/D and A/B gate drive outputs, respectively, which not only assures no IGBT cross conduction current, but also enables zero voltage switching (ZVS) of the IGBTs under certain conditions. The four gate output signals (GATEA, GATEB, GATEC, and GATED) connect to the Inverter board on J8 through series protection resistors R128-130. Since the pulse currents on the gate drive outputs can sometimes be large, the PSM chip employs separate power and ground connections to isolate the drive circuitry from the sensitive control pins. Drive-related pins VC and PGND are therefore also isolated on the board layout through R157 and R164, and a separate copper ground plane for PGND, shown symbolically as .

Analog Monitors

Several analog monitors scale and buffer feedback from other boards and sensors in the unit, delivering them to the interface connectors and front panel displays. The already buffered HV output voltage feedback signal is calibrated by R61, buffered by U33:B, current-limited by resistor R182, fed to the interface connector through J1, and the front panel display through J13. The HV output current feedback is similarly processed by R72, U33:C, and R183, and fed out through J1 and J13. The output of the analog Inverter temperature sensor, mounted on the heat sink near the "warmest" IGBT, is routed in through J8, and then filtered, scaled, and buffered by U14:B. IGBT_TEMP is linearly scaled from 0 to +10VDC to represent 0 to 160°C.

This signal is then connected out to the Diagnostics connector through J1, and also fed to “comparator” U20.

+24VDC control power connected directly to the Auxiliary supply through the Inverter on J8 is scaled (+10VDC = +24VDC), filtered, and buffered by U16:E, and fed to the Diagnostics connector (via J1) through current-limiting resistor R77. A square wave signal representing the effective duty cycle of the PSM chip gate outputs is created by U27:B, which is then averaged, scaled, and buffered by U16:C to create a signal where +10VDC = 100% effective duty cycle. This signal is routed to the Diagnostics connector through current-limiting resistor R83 and out on J1. The isolated and scaled rail voltage signal on J8 from the Inverter is slightly filtered and buffered by U16:D (so that +10VDC = +1000VDC) to feed to the Diagnostics connector through current-limiting resistor R93 and out on J1.

Arc Monitoring and Management

High voltage output arcs are detected by comparator U8:B by comparing the buffered output voltage feedback signal KV_CAL (through jumper J11) to ground. R16 and R27 create a small positive DC reference (approximately +0.12VDC), which is briefly driven below ground (through C6) by the steep negative slope of KV_CAL during an output arc. This triggers U8:B to pull its output low, which pulls the “Arc Bus” low through ORing diode CR10. The “Arc Bus” is also pulled low by comparator U8:C through CR11 if the Inverter current signal coming through J13 (RAIL_CURR) exceeds the calibrated value set by R20. Sometimes HV arcs reveal themselves by high currents in the Inverter. When the “Arc Bus” goes low, this triggers the input of one-shot U18:B, creating a retriggerable 2.21ms long output pulse. The active low-output ($\overline{Q}$) pulse creates signal SHUTDOWN*, its inverse SHUTDOWN (through inverter U13:E), and a –14VDC pulse, SHTDN_NEG, created by U14:C configured as a bipolar output inverter. Signal SHUTDOWN* turns MOSFET Q14 off, which allows the voltage divider created by R126 and R136 to apply +3.33VDC to the CS+ (Current Sense) pin of the PSM chip. Since the CS+ pin is greater than +2.5VDC, the PSM chip immediately disables its gate output pins until the CS+ is pulled once again to 0VDC by Q14 when SHUTDOWN* goes high after 2.21ms. During this 2.21ms the Inverter IGBTs stop switching and providing power to the HV Rectifier, which allows the HV arc that started this sequence to clear before the Inverter is reactivated. SHUTDOWN turns MOSFET Q15 on, which pulls the error amplifier signal to the PSM chip to ground, thereby initiating another method of Inverter shutdown. SHTDN_NEG activates yet another shutdown method by turning both Q18 and Q19 on, which short the current and voltage references to ground, respectively. By requesting no current and no voltage, the Inverter switching is effectively shut down here too. However, Q18 and Q19 have a secondary function as “soft starts” since the reference signals will “slowly” charge using R79/C129 and R194/C124, respectively, over roughly 100 μ s.

The 2.21ms long active high output (Q) pulse from U18:B (ARC), created by an HV arc, is fed into the input of frequency-to-voltage converter U1 (an LM2907). (ARC also briefly flashes the ARC/OUT OF REGULATION LED yellow on the front panel via OR gate U37:E and J13.) U1 uses a charge pump to create a voltage output (on pins 5 and 10) which is linearly related to the frequency of the square wave on its input. The values of R2, C1, and C2 have been chosen to create a frequency-to-voltage equation of $V = 0.0199 \times f$, where V is in VDC and f is in Hz. This signal is scaled and filtered by R19, R59, and C19, and then buffered by U14:D. The buffered

output can be selected by jumper J3 to be fed to the Diagnostics connector, but this is not currently the default jumper setting. Prior to the U14:D buffer, the scaled (100:104) and filtered signal is compared by U8:D to +1.92VDC, created by the divider formed from R40 and R49, which pulls its output low when the arcing frequency exceeds approximately 100Hz (see frequency-to-voltage equation above). This turns MOSFET Q16 off, which allows C91 and C92 to start charging to +5VDC through R144 and R147. The charging voltage on these two capacitors is scaled and buffered by U14:E so that ARC_DUR is equal to +10VDC after 120s, which assumes the arcing frequency has exceeded 100Hz during all 120s. If the arcing frequency drops below 100Hz, the capacitors are discharged to ground by Q16, and will start the charge sequence from 0VDC the next time the frequency exceeds 100Hz. ARC_DUR is fed to the Diagnostics connector through current-limiting resistor R97 via J3 and J1.

Another outcome of the “Arc Bus” going low is the creation of a retriggerable two-second output pulse produced by one-shot U39:B. This two-second signal is fed to the Diagnostic connector via Q28 and J1.

“Out of Regulation” Monitoring

Since there are separate voltage and current error amplifiers, these can be used to determine if the HVPS is able to regulate its output to the requested voltage setpoint. When the HV output voltage has not reached (or cannot reach) its given setpoint, the voltage error amplifier will go to its positive “rail” to try and force the Inverter to its maximum duty cycle. During this condition, if the Inverter and HV Rectifier can achieve 600mA of output current, the current error amplifier will be some fixed value, much lower than its positive rail and the “railed” voltage error amplifier. This will create current through R104 and the emitter diode of U19:A, thereby turning on the optocoupler’s output transistor and switching OOR high. OOR going high briefly flashes the ARC/OUT OF REGULATION LED yellow on the front panel via OR gate U37:E and J13, and it briefly flips its status pin on the Filament Interface connector via Q22 and J1. If this OOR transition occurs when HV is on, one-shot U21:B will create a retriggerable two second long output pulse. The active high-output (Q) pulse (OUT_OF_REG) feeds several circuits. Via J13 it flashes the HV OUT OF REGULATION LED yellow for two seconds to give a visual indication of the condition. It controls a status pin on the Diagnostics connector via Q10 and J1, and on the User Interface connector via jumper J17, Q21, and J1.

Power-Up and Manual Resets

When the HVPS is first powered up from the AC line connection, the +15VDC auxiliary supply line will slowly rise from 0VDC to its final value. Two RC “timers”, formed by R39, R43, R44, C18, and C27, are compared by U7:E to create a reliable active low reset signal approximately 120ms after the +15VDC supply starts rising. This ensures that all latches, one-shots, and flip-flops (from PUP_RST* and RESET*, via Q11 and Q12) are reset properly before they fully power up. Latches that must be cleared, either manually or automatically, during normal HVPS operation receive that reset via RESET*. This signal is created from either of two sources. A manual reset is brought in from the User Interface connector via J1 as two pins (RESET IN+ and RESET IN–) which require momentary shorting to initiate the reset. When these two pins are shorted, current flows through the emitter diode of optocoupler U10:B, which turns on its output transistor and causes the input of one-shot U21:C (through OR gate U5:C) to transition high.

This creates a retriggerable 100- μ s long output pulse which briefly drives RESET* low, and clears all the latches. This “reset” one-shot is also triggered by an HV Off command, routed through jumper J16 (which can be moved so that the one-shot triggers from an HV Enable command) and OR gate U5:C.

HV Enable, On, and Off Commands

Functioning as an HV Enable command, two pins on the User Interface connector (HV ON IN+ and HV ON IN–) are brought in via J1 and require momentary shorting to initiate the enable. Just like the reset, when these two pins are shorted, current flows through the emitter diode of optocoupler U10:A, which turns on its output transistor and causes HV_EN_IN to transition high, originating an HV Enable command. Similarly, for the HV Off command, two pins on the User Interface connector (HV OFF IN+ and HV OFF IN–) are brought in via J1 and require momentary opening to initiate the off request. When these two pins are opened, current stops flowing through the emitter diode of optocoupler U19:B, which turns off its output transistor and causes HV_OFF_IN* to transition low (HV_OFF_IN transitions high due to inverter gate U13:B), originating an HV Off command. The HV Off command can also be initiated locally using the front panel HV OFF pushbutton switch routed onto the Regulator through J13, which momentarily shorts the input of one-shot U18:C high, activating a retriggerable 470 μ s long output pulse. This output pulse turns Q24 on, shorting the anode of optocoupler U19:B to ground, shunting current away from it and turning its output transistor off momentarily.

The HV Enable command is used to activate the HV On command when several conditions are met. To begin with, the reset (R) pin of flip-flop U24:B must be low, which requires that the HV Off command pins on the User Interface connector be shorted (HV_OFF_IN is low) and the Sum Fault bus signal (SUM_FLT) be low. These two conditions allow the output of OR gate U37:C to be low. Then, a momentary closure of the User Interface HV ON IN pins creates a rising-edge trigger on the clock pin of U24:B (HV_EN_IN), latching the high state of HV_OFF_IN* (inverse of HV_OFF_IN by definition) onto the flip-flop's Q output pin. Since HV_OFF_IN* is high, and if SUM_FLT* is high (indicating no faults in the HVPS), HV_ON will also go high since the inputs of AND gates U27:C and U12:C are all high. With HV_ON high, the output of AND gate U27:D (SHUTDOWN*) will go high and the PSM chip will allow its gate outputs to start switching (as discussed in the Arc Monitoring and Management section above). If the Sum Fault bus signal (SUM_FLT) transitions high, indicating there is a serious fault somewhere in the HVPS, HV_ON will go low as a result of the input to AND gate U12:C going low (which receives the inverse of SUM_FLT from inverter gate U13:F). This will immediately terminate the PSM chip's gate outputs. In addition, when SUM_FLT transitions high, one-shot U39:C will produce a 100 μ s wide output pulse, which resets the flip-flop output to low through OR gate U37:C. Assuming that either a Reset or HV Off command has been issued to clear the Sum Fault bus, another HV Enable command is then required to cycle the flip-flop output high again. The HV Off command will also reset the flip-flop output to low, setting ***HV_ON*** low.

The READY signal is high when the SUM_FLT* bus is high (fed through jumper J18 and into one input of AND gate U12:B, indicating no faults), when the User Interface HV OFF IN pins are shorted (i.e. HV_OFF_IN* is high, fed into one input of AND gate U27:E), and when HV_EN* is high (fed into the other input of AND gate U27:E, indicating a User Interface HV Enable command has not been requested). To prevent the customer's system from tripping itself off

prematurely during the duration of an HV Enable command, the HV_EN* signal is OR-ed with the HV_EN_IN signal by gate U37:B, whose output only goes low after the HV Enable command has been latched and the User Interface HV ON IN pins have opened again. Status indicators for READY, HV_ON, and SUM_FLT are created by Q29, Q1/Q30, Q25, Q26, Q27, and Q23, and sent to the User Interface, Diagnostics, and Filament connectors through J1. HV_ON also turns the HV ON LED green on the front panel through J13.

Faults

Numerous fault circuits are used to determine if there is a malfunction in the HVPS serious enough to shut down the HV output. In several of these circuits a compensated shunt voltage regulator (TL431) with a +2.5VDC reference is used as a 3-pin 2.5V comparator. If the voltage applied to the reference pin exceeds +2.5VDC, the cathode of the TL431 is pulled to ground where the anode is connected. This creates a very simple over-limit comparator. All fault signals are diode “OR-ed” onto the SUM_FLT bus by CR43, 44, and 46-48, which creates a single high signal indicating at least one HVPS fault is present, and turns the front panel POWER SUPPLY FAULT LED red through J13.

The buffered kV feedback signal KV_CAL is divided and filtered by R4, R6, R8, and C3, and fed into the input of TL431 “comparator” U3. R4 is calibrated so that U3 trips latch U11:C when the output voltage exceeds –10.5kVDC. The latch’s output turns the front panel HV OVERVOLTAGE LED red through J13 and (via Q7 and J1) pulls the open-collector over-voltage status pin low on the Diagnostics connector. Feedback signal KV_CAL is also used to trip the reference over-voltage fault. Calibrated voltage reference signal KV_REF_CAL is compared to KV_CAL (divided by R7 and R14) by U7:C, using R7 to calibrate the circuit to trip when the actual output voltage exceeds the reference setpoint by 5%. R9, 13, and 214 are used to add an offset voltage to KV_REF_CAL so that U7:C is not forced to compare two +0VDC signals, which would result in an undefined output. When comparator U7:C trips, latch U11:D sets its output high, turns the front panel SETPOINT OVERVOLTAGE LED red through J13, and (via Q8 and J1) also pulls the open-collector over-voltage status pin low on the Diagnostics connector.

Like the over-voltage circuit, the buffered mA feedback signal MA_CAL is divided and filtered by R34, R37, R38, and C14, and fed into the input of “comparator” U9. R37 is calibrated so that U9 trips latch U11:E when the output current exceeds 636mADC. The latch’s output turns the front panel HV OVERCURRENT LED red through J13 and (via Q6 and J1) pulls the open-collector over-current status pin low on the Diagnostics connector.

Two arc-related faults can be tripped on the Regulator. The output of frequency-to-voltage converter U1, which linearly converts the repetition frequency of the output arcing to a DC voltage according to the formula $V = 0.0199 \times f$, is divided and filtered by R3, R15, and C137 before feeding the input of “comparator” U4. R15 is calibrated so that U4 trips when the arcing rate exceeds 200Hz, setting the output of latch U25:D high and flipping ARC_FLT high through OR gate U5:B. ARC_FLT is also tripped high when ARC_DUR reaches +10VDC, indicating an output arcing event with a rate greater than 100 Hz has exceeded 120s in duration. This determination is made by divider and filter R100, R225, and C138, and “comparator” U29. The output of latch U25:E is set high when U29 toggles, making ARC_FLT go high through the other input of OR gate U5:B, and turning front panel OUTPUT ARCING LED red through J13.

Three sensor inputs from the Inverter are brought in over J8 and used to trip the over-temperature fault. If the IGBT temperature sensor signal (IGBT_TEMP) exceeds 67°C, U20 (a TL431 “comparator”) pulls the input “SET” pin of S-R latch U25:B to ground, thereby latching its output high, and tripping an over-temperature fault (TEMP_FLT = high) through OR gate U37:D. TEMP_FLT turns the OVERTEMPERATURE LED red on the front panel through J13 and (via Q17 and J1) pulls the open-collector status pin low on the Diagnostics connector. TEMP_FLT is similarly “tripped”, through OR gate U37:D, by HTSNK_FLT, which is latched high on the Inverter when the heat sink thermostat temperature exceeds 77°C. Finally, the fan's failed rotation detector output signal (FAN_ALARM) maintains MOSFET Q13 in the off state when it is shorted to ground during normal fan rotation. If the fan blades stop spinning, FAN_ALARM opens (with respect to ground), Q13 turns on, and U25:B latches TEMP_FLT high. Jumper J9 is used during test to prevent an over-temperature fault if the fan is not connected.

Comparator U7:D transitions when the +24VDC auxiliary supply bus drops below +19.5VDC, indicating the auxiliary supply is either failing or is being loaded down. This sets the output of latch U25:C (AUX_FLT) high, turning front panel AUX SUPPLY LOW LED red through J13. Similarly, comparator U8:E switches when the fused +24VDC interface supply bus (+24V_FUS) drops below +20VDC, indicating the current draw on the User Interface +24VDC supply pin has exceeded 0.2ADC and self-resetting PTC fuse F1 has opened. This sets the output of latch U2:C (CNT_PWR_FLT) high, turning front panel EXTERNAL CONTROL FAULT LED red through J13. Typically this reveals that the User Interface +24VDC supply pin is inadvertently shorted to ground or another interface pin.

Two interlock pins on the User Interface connector, two interlock pins on the Filament connector, and the top cover interlock switch all must be shorted/closed to prevent the interlock fault from activating. If this interlock loop opens in any location, the emitter diode of optocoupler U17:B stops conducting, thereby turning off its output transistor. (Note: Self-resetting PTC fuse F2 is used to prevent pulling down the +24VDC supply bus if any of the external interlock pins are unintentionally shorted to ground.) When the optocoupler turns off, the output of latch U2:B is set high, creating an interlock fault. This turns the front panel INTERLOCKS OK LED red through inverter gate U13:G and J13, (via Q2 and J1) pulls the open-collector interlock status pin low on the Diagnostics connector, and (via Q20 and J1) deactivates the interlock “OK” status pin on the User Interface connector.

The scaled and filtered rail voltage signal feeding buffer U16:D also feeds comparator U7:B. R1 is calibrated so that when the Inverter rail voltage rises above +220VDC for 208VAC unit (+427VDC for 400VAC unit), the output of U7:B goes high. This sets AC_RLY_ON high as well, which is sent to the Inverter on J8 to activate the three-phase AC relay and permit power operation in the Inverter. If the rail voltage falls below +220VDC for 208VAC unit (+427VDC for 400VAC unit), the output of U7:B goes low, setting the output of latch U11:B high and turning front panel RAIL UNDERVOLTAGE LED red through J13. Jumper J7 is used during test to defeat the rail under-voltage fault during low voltage rail testing.

Finally, the high output of the Inverter rail current fault latch connected through J8 (RAIL_FAULT on the Inverter, RAIL_CURR_FLT on the Regulator) turns front panel INVERTER OVERLOAD LED red through J13.

Power Supplies, References, and Grounds

+24VDC from auxiliary power supply PS1 is brought in through the Inverter on J8 (referenced to the $\equiv$ ground), and then further filtered, regulated, and converted on the Regulator. A –15VDC supply bus (referenced to the “analog” $\equiv_A$ ground) is created from the +24VDC bus by DC-DC converter U36, which powers circuits on the Regulator, as well as on the Inverter (through noise filtering inductor L2 and J8). The +24VDC bus is filtered by L3 and C71 before being regulated down to a +5VDC supply by U31 and a +15VDC supply by U28. The +5VDC supply bus (referenced to the $\equiv_D$ ground) powers circuits on the Regulator, as well as on the Display and Control board through J13. The +15VDC supply bus (referenced to the “analog” $\equiv_A$ ground) powers circuits on the Regulator, as well as on the Inverter (through noise filtering inductor L1 and J8) and on the Display and Control board through J13.

The output of precision +10VDC reference U22 (+10V_REF) feeds op amp U16:B configured as a voltage follower. This provides a slightly less precise +10VDC reference (+10), but with much more current capability than the U22 reference. The +10 reference is used on the Regulator and the Display and Control board through J13.

Jumper J15 can be used to change the voltage level of status signals fed to the active driver on the Interface board, which is set to +24VDC by default. Two sources of +24VDC power are supplied to the Interface board through J1. The +24VDC supply bus is directly connected through pin 56, while a current-limited version is provided through self-resetting 0.2ADC fuse F1 through pin 22. To select between which grounds are connected to the Diagnostics and Filament connectors, jumpers J5 and J6, respectively, can be changed. The default positions for the jumpers are for the $\equiv_D$ ground.

Miscellaneous

Two active high (+15VDC to +24VDC) signals from the Filament connector indicate whether the customer’s Filament module power and load are “OK”. The Regulator buffers those signals with Q5 and Q4, respectively, so that the FILAMENT POWER and FILAMENT LOAD FAULT LEDs on the front panel are illuminated red when a “not OK” condition is present.

Low leakage diodes are used to protect sensitive signal lines that are connected to circuits off the Regulator. These center-tapped diodes, CR27-29, 31, 33, 37, 38, 41, and 49, clamp each signal line to the +15VDC or –15VDC supplies when an arc or ground bounce induces an excessive voltage onto that line.

Pins on J1 unused by the Regulator are connected to open pad holes, and referenced with a “W” designator (e.g. W2, W8, etc.). These are used to support prototyping changes that require tying previously unconnected signals to the Regulator. Finally, op amp U30:E and its adjacent components are not used on the current version of the HVPS, but can be activated in the future through jumper J11.

A4 Display and Control Board

LEDs and LCD Displays

Seventeen LEDs, which protrude through the front panel, provide visual status indications of various circuits within the HVPS. The underlying function and appropriate illumination color are discussed in the preceding Regulator theory section, as well as in Section 7 of this manual. The actual circuit method for illuminating all but one of the LEDs is discussed here, using the Sum Fault LED as an example. The logic-level SUM_FLT status signal comes in through J1 and connects to the input of inverter U5:B. This creates the condition where NPN arrays U1:B and U1:C receive inverse signals from each other, thereby conversely illuminating the dual-color LED CR2. If the input to U1:B is high, its output is pulled to ground by its internal transistor, consequently shunting current away from (turning off) the green LED element. Conversely, U1:C then receives a low input, deactivating its output transistor and allowing current to flow in (turning on) the red LED element. Fifteen other bicolored LEDs are driven in the same manner, however the Power On LED is illuminated differently. The green LED element of CR1 is illuminated as soon as the +24VDC supply bus comes up, indicating that AC power has been applied to the HVPS and the auxiliary power supply is functioning properly.

Two LCD displays are used to show the magnitude of the output voltage and current. M1 displays the actual HV output voltage in kV (e.g. 10.00 = –10kVDC output) and M2 displays the actual output emission current in mA (e.g. 600 = 600mA output). Fed by the kV and mA monitor signals from the Regulator, and filtered with C7 and C5, potentiometers R24 and R13 calibrate the voltage and current displays, respectively.

Controls

An access hole in the front panel allows a chassis-mounted potentiometer (connected through J2) to adjust the output voltage setpoint in local mode. The potentiometer uses the +10VDC reference from the Regulator to produce a +0VDC to +10VDC reference voltage. Finally, as a safety feature, momentary pushbutton switch S1 is used to initiate an HV Off command on the Regulator, regardless of whether the unit is in local or remote mode.

A5 Interface Board

Mounted to the rear panel so its three D-subminiature connectors protrude enough to allow external attachment, the Interface board provides interconnection between the user's control system and the Regulator. J1 (J5 on rear panel, 15-pin D-sub) connects to the user's Filament module, J2 (J3 on rear panel, 37-pin D-sub) provides diagnostic signals to the user, and J3 (J4 on rear panel, 25-pin D-sub) serves as the active control interface with the user (User Interface connector). J4 simply routes all signals on the Interface board to the Regulator. Since the location of the unit's top cover interlock switch (which opens its contacts when the top cover has been removed) is adjacent to the Interface board, J5 provides the shortest path for the switch's contacts to the interlock circuitry on the Regulator.

The Interface board also contains one active IC (U1), a +24VDC driver array. The driver's gates buffer certain output status signals to the Filament and User Interface connectors, providing a

+0VDC or +24VDC output signal depending on the polarity of the gate's input. Power for U1 comes from one of three sources, selected by the combination of jumpers J6 and J7. Jumper J6 selects between an internal or external source of +24VDC for the driver chip (default is internal), while jumper J7 selects between the fused or unfused internal +24VDC supplies (default is unfused). If J6 is positioned for the external supply, the position of J7 is irrelevant.

4.3 FPS Theory of Operation

4.3.1 Overview of FPS Operation

The filament power supply module (see Figure 4-1) provides emission current control and measurement, filament power and control, and high-voltage switching. The filament circuit utilizes high-frequency switch mode technology similar to that of the high-voltage circuit. The filament circuit requires single-phase power of approximately 208–230 V.

Figure 4-1 Filament Power Supply (FPS) Module



Figures 4-2 and 4-4 show the locations of the major components in the standard FPS unit (i.e., with PN 0620-6604-0) and for FPS units with PN 0620-6604-2. Figures 4-3 and 4-5 are top-level block diagrams for the same units. Primary power enters the FPS via J302 and is routed to the Filament Supply PCB. The FPS consists of two major functional sections, the Filament Supply PCB and the Filament Output section. The Filament Supply Board supplies and controls the filament power. The filament output section combines the filament power with the negative HV from the power module and routes the combination to the filament. As Figure 4-3 shows, the Filament Output section on standard FPS units consists of an HV vacuum relay and a filament transformer. On FPS units with PN 0620-6604-2, the Filament Output section consists only of the filament transformer (see Figure 4-5). Section 4.3.3 describes the Filament output section in greater detail.

Figure 4-2 Component Location in Standard FPS Units (PN 0620-6604-0)

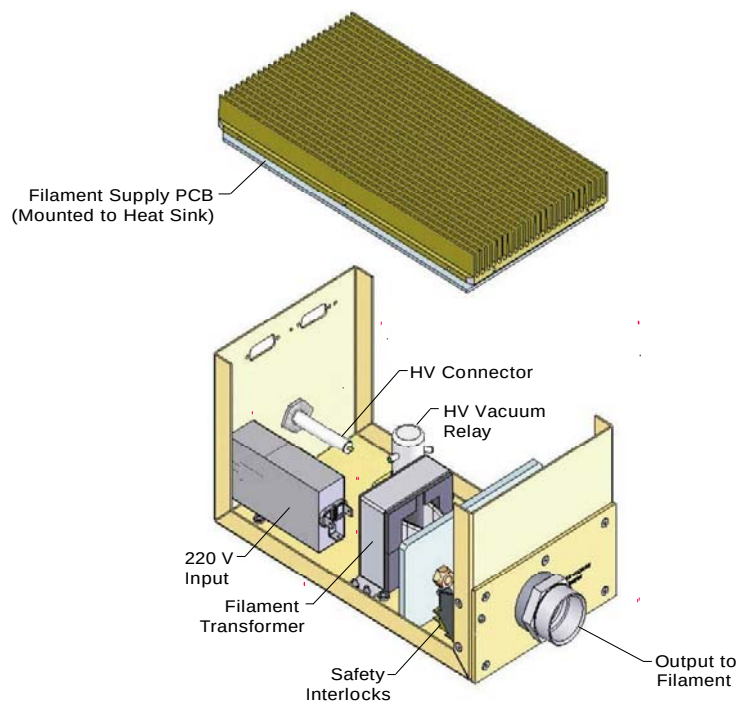


Figure 4-3 Top Level Block Diagram for Standard FPS Units (PN 0620-6604-0)

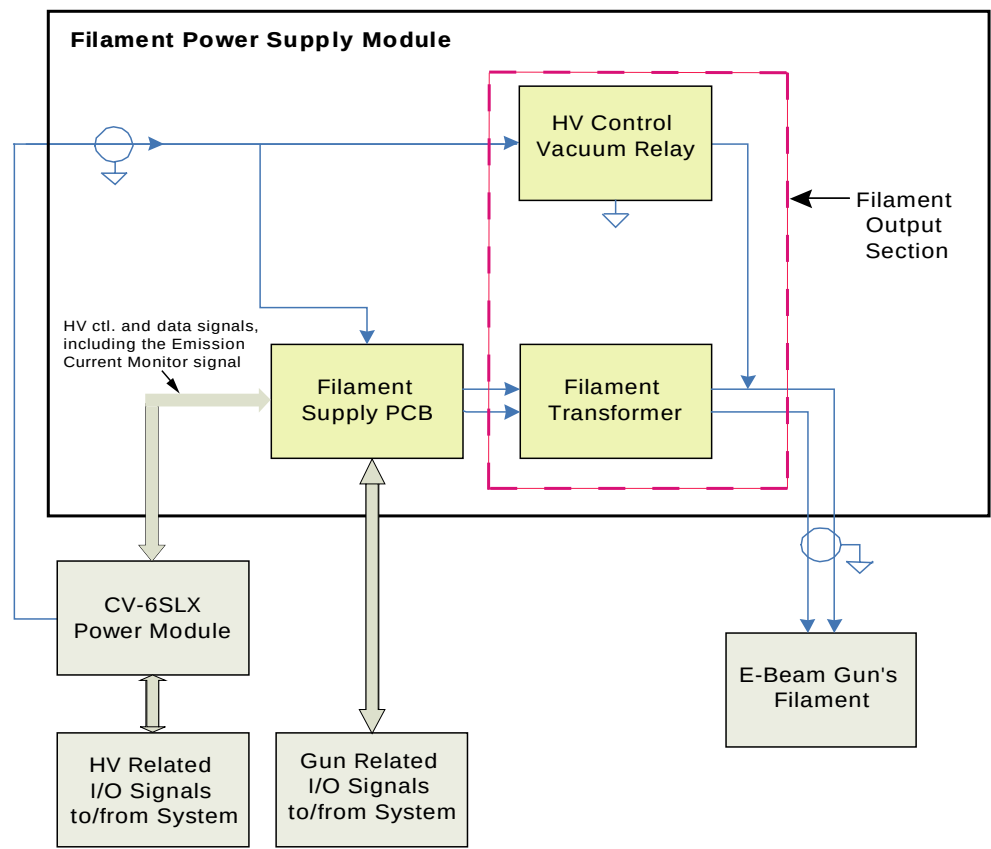


Figure 4-4 Component Location in Standard FPS Units (PN 0620-6604-2)

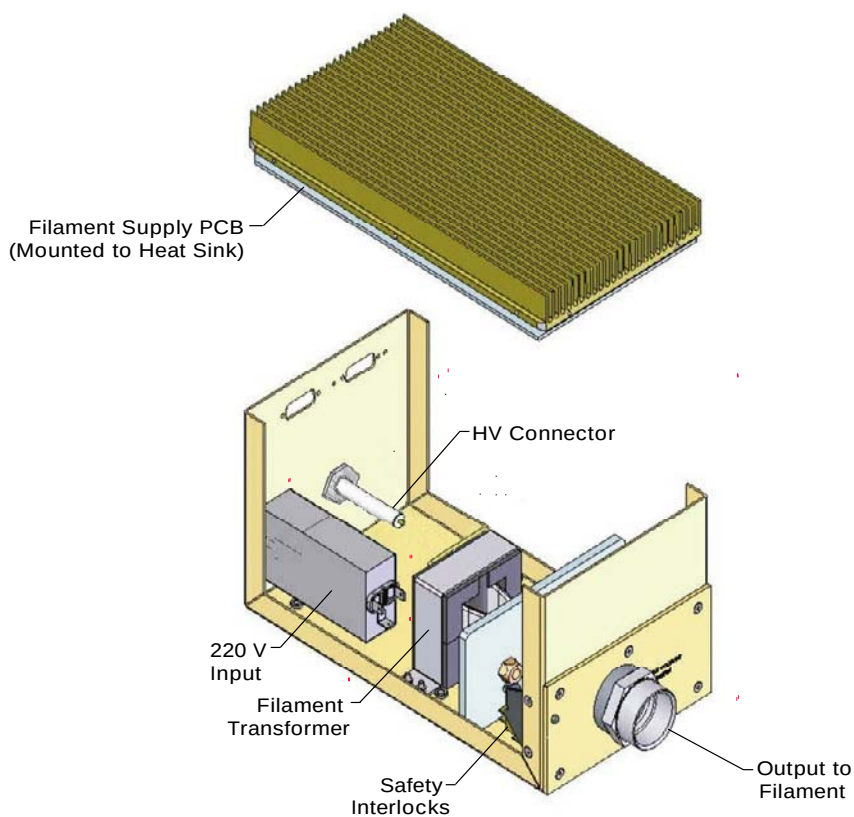
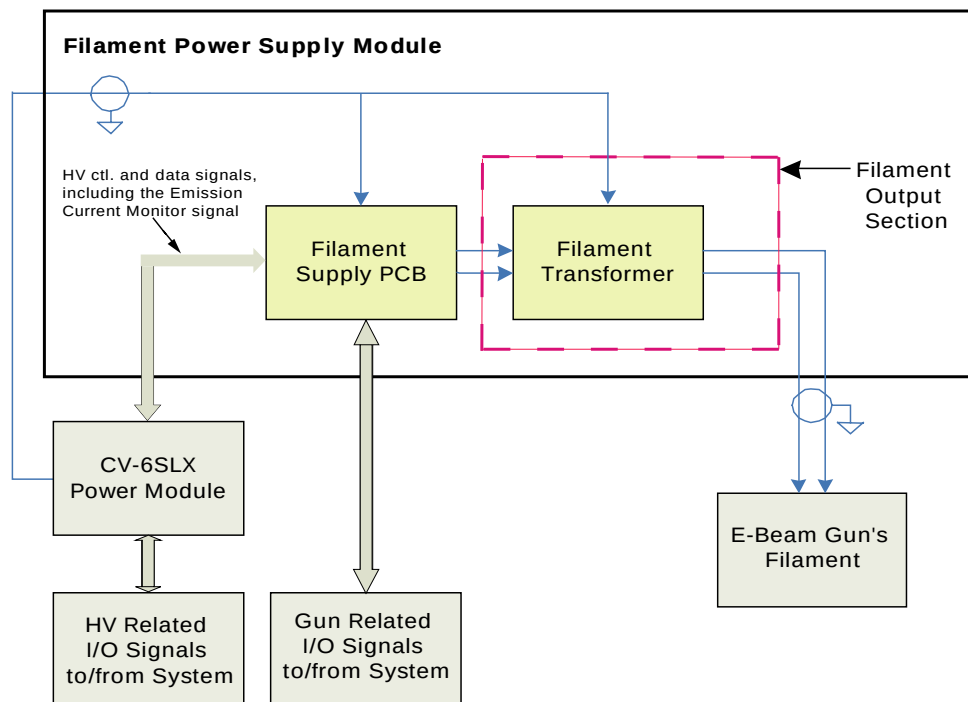


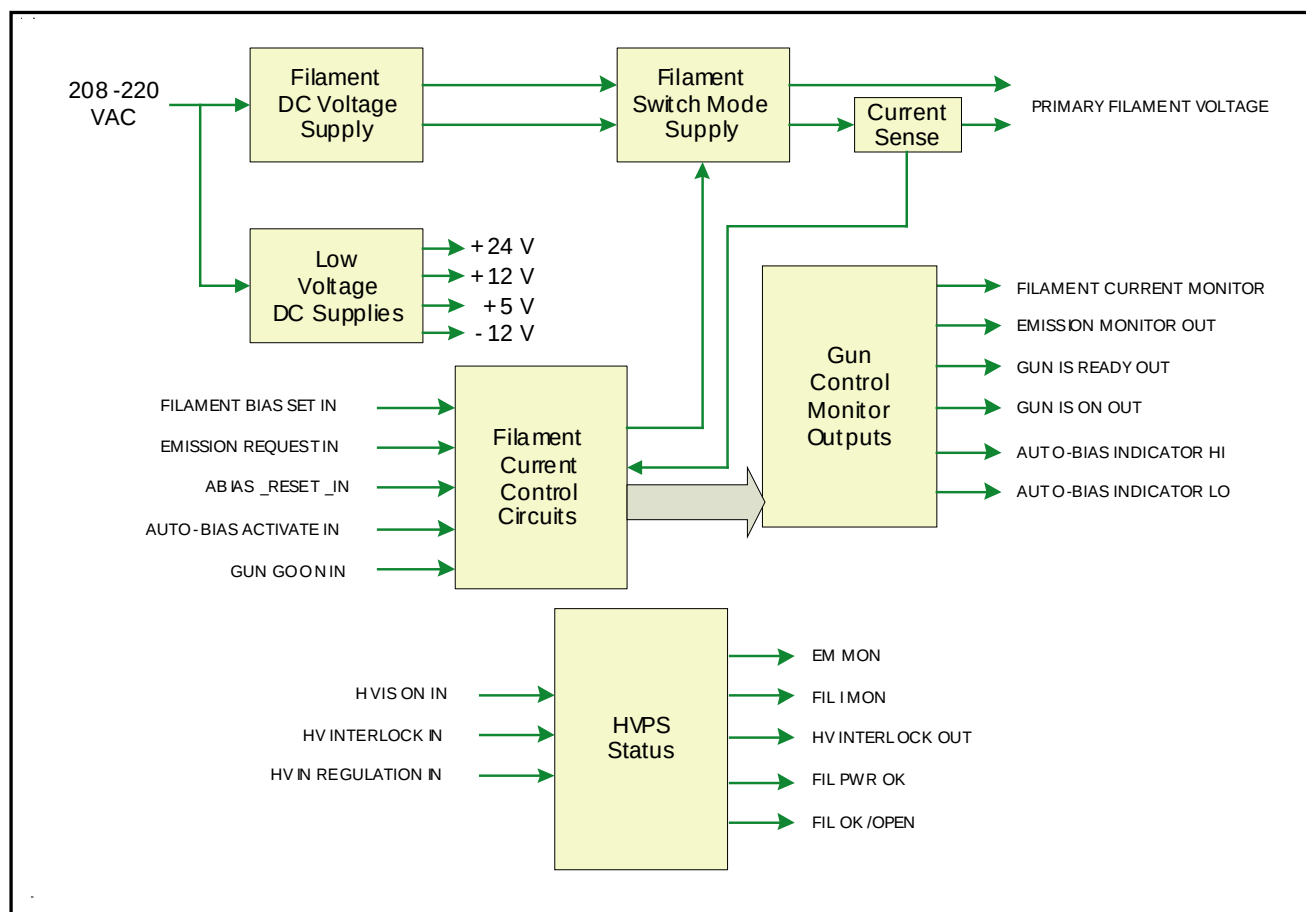
Figure 4-5 Top Level Block Diagram for FPS Units with PN 0620-6604-2



4.3.2 Filament Supply PCB

Figure 4-6 is a top-level block diagram for the Filament Supply PCB, whose circuits are described in detail below.

Figure 4-6 Filament Supply PCB Overview Block Diagram



Filament DC Voltage Supply for Switch Mode Converter

A single-phase bridge rectifier circuit provides the raw dc power for the high-frequency switches. The DC voltage is filtered and a + (positive) rail voltage and a - (negative) rail voltage is established. The single-phase 220-V power for the filament and positions circuits enters on J104 Pin 1 and 4. The circuit is protected by fuses F-1 and F-2. The ac power is rectified by DB-10 and filtered by inductors L-10 and L-11 in combination with rail capacitors C-11 and C-12.

Low-Voltage DC Supplies

Low DC voltages of +24 V, +12 V, +5 V and -12V are supplied by T-102 via bridge rectifiers DB-14 and DB-15. +12 V and +5V are down regulated from +24 V by VR-101 and VR-103. -12 V is down-regulated from -24 V by VR-102. These supplies provide power for the logic and control circuits on the board.

Filament Switch Mode Supply

The filament supply uses IGBT switches and operates at a frequency of approximately 28.5 kHz. The filament transformer steps down the voltage with a ratio of 10:1 to provide approximately 10 V rms at the filament. There are no rectifiers on the output of the transformer as the filament input is high frequency AC. The filament circuit is current-regulated. There are two modes of filament operation: One with HV OFF and one with HV ON.

A. HV OFF

Filament Reference: Filament Bias Set

Filament Feedback: Filament Primary Current

B. HV ON

Filament Reference: Autobias (if active)/Emission Current Set

Filament Feedback: High Voltage Current

The filament switch mode supply IGBT switches Q-10 and Q-11 switch the primary of the filament transformer between the voltage rails at a frequency of approximately 34 kHz. The filament transformer connects to the center point of the rail capacitors. Thus, half of the rail voltage is impressed alternately on the transformer by the IGBT inverters. Gate driver ICs U-10A and U-10B, in conjunction with transformer T-101, provide the gate drive for the IGBT switches. Inductor T-103 has a dual function of adding impedance in the primary and a sensing circuit for fault currents. Capacitors C-20 through C-24 are tuning capacitors for the output circuit.

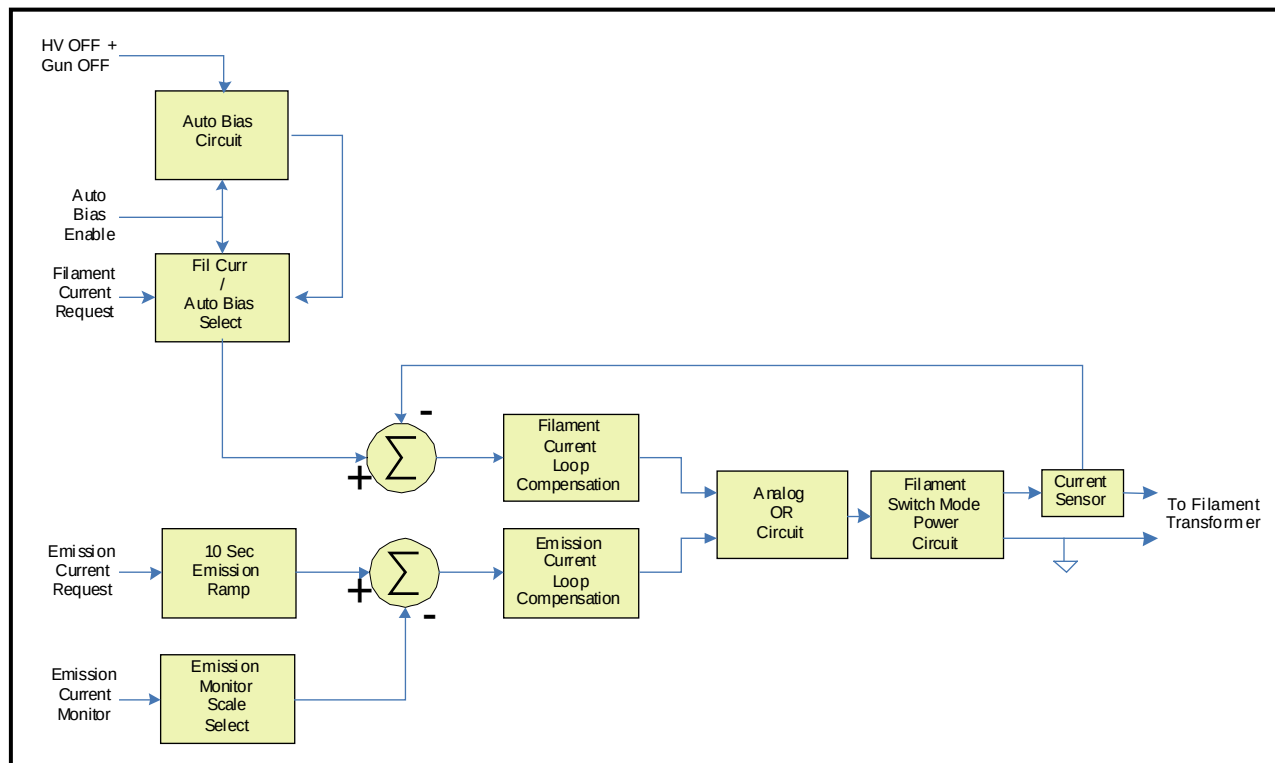
The IGBT switches are driven from the PWM modulator chip U-101. This IC has two outputs. One output drives IGBT switch Q-10 and the other drives IGBT switch Q-11. The PWM is controlled by the filament current control circuits. The filament current feedback circuit utilizes transformer CT-10 to measure the filament transformer primary current. The signal is rectified by DB-11 and scaled by A-102. The feedback signal scaling is $5.0 \text{ V} = 50 \text{ A}$.

Filament Current Control Circuits

Filament Current Control Loop

Figure 4-7 shows a block diagram of the control and power circuits. As that diagram shows, the filament current is regulated by filament current feedback or emission current feedback. The analog OR circuit (U-106B along with D-13A and D-13B) selects emission-current regulation or filament-current regulation, depending on which request signal is greatest.

Assume that Filament Current Request (FCR) is asserted and Emission Current Request (ECR) is zero and that Auto Bias Enable is not asserted. The scaling for FCR is 0 to 5.0 volts = 0 to 50.0 amperes. FCR is buffered by A-103 and fed via analog switch A-104B and buffer inverter U-205B to the summing junction at the input to the filament current loop compensation amplifier U106A. The output of U106A feeds the PWM U101 via buffer U106B to drive the switch mode power inverter. The filament feedback signal from buffer A102 is fed to the summing junction at the input to the filament current loop compensation amplifier (U106A). Ideally, the FCR level will be just below the point where emission current takes place, therefore when zero emission current is called for FCR will dominate. An alternative to FCR to drive the filament current loop is auto bias. Analog switches A104A and U104B form an SPDT switch that selects either FCR or the Auto Bias signal as the input to the filament current summing junction. The Auto Bias circuit is described in greater detail below.

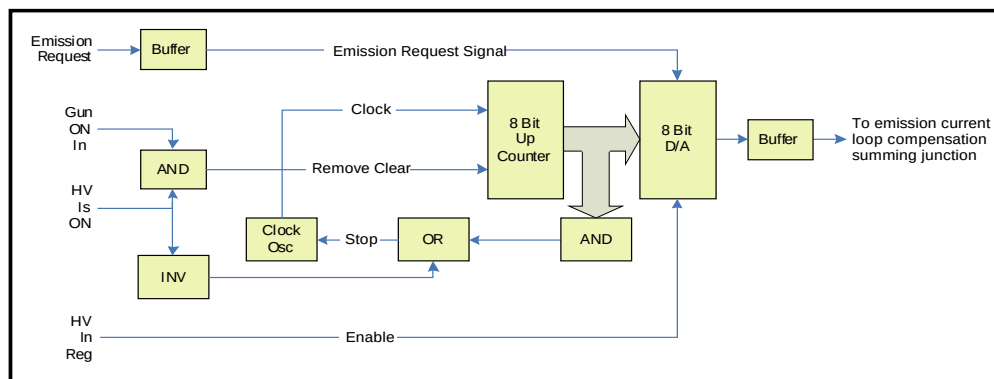
Figure 4-7 Block Diagram of Filament Supply PCB Control and Power Circuits**Emission Current Control Loop**

When emission current (ECR) is called for the emission current loop control comes into play and the filament current control loop is ignored. ECR is first buffered by A105 and then fed to the 10-sec ramp circuit to gradually increase the emission current to the desired level. The output of the ramp circuit U103-2 is fed to inverting buffer U205A to the summing junction of the emission current loop compensation circuit of U106A via R55. The emission current feedback signal, Emission Monitor (EM) comes from the HV current transducer in the Filament Output Section of the FPS and is scaled by a rotary switch selection of gain values for buffer A101. The output of A101 is also fed to the summing junction of the emission current loop compensation circuit of U106A via R52. As above, the output of U106A feeds the PWM U101-2 via buffer U106B to drive the switch mode power inverter.

Emission Current Request Ramp

Figure 4-8 is a block diagram for the emission current ramp circuit, which allows the graceful assertion of emission current in 255 steps. With the following conditions, Emission Request, Gun On, HV On, and HV In Reg signals asserted, the clock U104 begins clocking the 8-bit counter U11 from its cleared state. When the counter reaches 255 the AND of its outputs stops the clock oscillator. The eight outputs of the counter drive the 8-bit digital to analog converter U103. The output of the D/A is the count times the Emission Current Request Signal divided by 256.

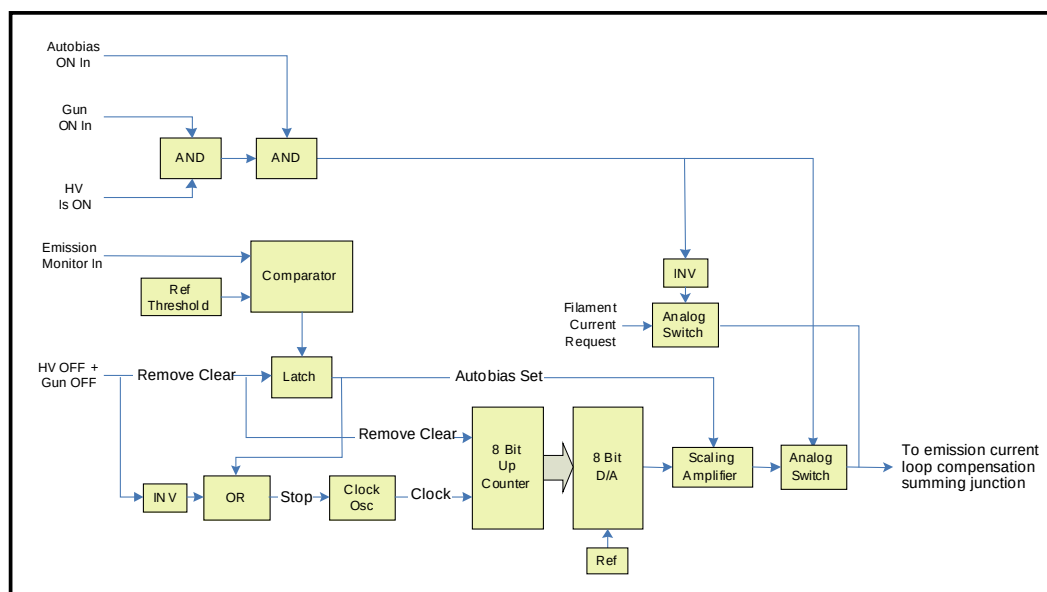
Figure 4-8 Emission Current Ramp Circuit



Auto Bias Circuit

Figure 4-9 shows the Auto Bias circuit, which is designed to maintain the filament current at a level just below the zero emission current point. To do so, the Auto Bias circuit gradually increases the filament until emission current begins to flow. When this is detected, the emission current is scaled back to a point just below emission threshold. The process begins with Gun ON and HV ON asserted and with Auto Bias invoked. As noted above, switches A104A and A104B form an SBDT switch that selects either the filament current request or the Auto Bias signal as the input to the filament current loop compensation summing point. Selection by this SBDT switch of the Auto Bias signal also removes the clear from counter U101 and clears the stop from clock oscillator U203, allowing it to clock the counter. The counter outputs drive the 8-bit D/A converter U202. The D/A output is Ref times the count divided by 256 volts. This count-up process continues until Emission Current is above the threshold, as determined by comparator U102C. The comparator output sets the latch U16B Auto Bias Set. The latch output stops clock U203 and slightly reduces the gain of scaling amplifier U105B via analog switch A104C, setting the autobias level just below the emission point.

Figure 4-9 Autobias Circuit Block Diagram



4.3.3 Filament Output Section

The filament output section of the FPS connects the filament power with the negative HV and connects the combination with the filament via a two-conductor cable. The high voltage (0–10 kV) from the HV Power Supply enters the FPS via J301. On standard FPS units (PN 0620-6604-0), the high voltage is routed to the vacuum relay (K101). On such units, K101 either connects the negative HV to the secondary of the filament transformer or applies a ground to the secondary of the filament transformer. The relay is driven from the Filament Supply PCB via J103 pins 5 and 6.

FPS units with PN 0620-6604-0 omit the vacuum relay. On those units, the high voltage is connected to the secondary of the filament transformer T1, which has a 10:1 ratio. The filament transformer connects the high voltage, low current output of the FPS to the filament with low voltage, high-current filament current, superimposing the negative DC HV on the AC filament current.

4.3.4 Safety Interlocks

The safety interlocks insure that circuits are safely connected and that the box is closed before operation can continue. Safety interlocks are provided by switches S101 and S102 in the filament output section of the FPS. These interlocks are routed to the Filament Supply PCB via J103 pins 3 and 4 and are connected in series with the cover interlocks on the CV-6SLX power module. Therefore, in order for FPS operation to take place, the FPS covers and the power module covers must be in place, closing the interlock switches, and the FPS cover interlock switches must be connected to the Filament Supply PCB.

5

Troubleshooting

5.1 Section Overview

This section covers the following topics:

5.2 Troubleshooting Procedures

5.3 Filament Power Supply Fuse Replacement Procedure

5.4 Suggested Spare Parts

DANGER: HIGH VOLTAGE

Removal of either the power module top cover or the FPS top cover can expose personnel to dangerous or lethal voltages. Particular care should be taken regarding high voltage, which can arc over a considerable distance. It is not necessary to be in physical contact with a live terminal in order for an arc to send a lethal high-voltage discharge through a person's body.

5.2 Troubleshooting Procedures

This section consists of a series of tables that describe troubleshooting procedures for the CV-6SLX. Each table is organized around an LED state or a operational symptom that should be easily identifiable to the operator. For a detailed explanation of power module front panel LEDs, see section 3.2.2 (p. 3-2). The titles of the troubleshooting tables are:

Table 1: No input power indicated

Table 2: Fan not rotating

Table 3: One or more power supply interlocks not made

Table 4: Power supply fails to achieve HV Ready state

Table 5: Power supply fails to achieve Gun Ready state

Table 6: HV does not switch on

Table 7: Gun does not switch on

Table 8: No filament current after GUN ON state achieved

Table 9: No beam emitted after filament current is switched on

Table 10: HV output unstable

Table 11: Gun out of regulation

Table 12: Power supply out of regulation

Table 13: **FILAMENT POWER** LED does not light

Table 14: LED(s) indicate an out-of-regulation condition

Table 15: **RAIL UNDERVOLTAGE** LED lights red

Table 16: **HV OVERCURRENT** LED lights red

Table 17: **HV OVERVOLTAGE** LED lights red

Table 18:	SETPOINT OVERVOLTAGE LED lights red
Table 19:	OUTPUT ARCING LED lights red
Table 20:	OUT OF REGULATION LED lights yellow
Table 21:	ARC/OUT OF REGULATION LED lights yellow
Table 22:	INVERTER OVERLOAD LED lights red
Table 23:	OVERTEMPERATURE LED lights red
Table 24:	AUXILIARY SUPPLY LOW LED lights red
Table 25:	EXTERNAL CONTROL FAULT LED lights red
Table 26:	FILAMENT LOAD FAULT LED lights red
Table 27:	FILAMENT POWER FAULT LED lights red
Table 28:	POWER ON LED on FPS front panel does not light
Table 29:	HIGH VOLTAGE ON LED on FPS front panel does not light

Required Pre-Troubleshooting Procedure for Power Module

The following procedure must be performed prior to any troubleshooting procedure that requires removal of the power module's top cover.

Step	Action
1	Switch off the circuit breaker (labeled AC MAINS) on the power module front panel.
2	Open the vacuum cubicle doors and touch the source tray and both high-voltage feedthroughs with a properly connected grounding hook.
3	Disconnect the HV coaxial cable from connector J1 on the power module rear panel.
4	Wait at least 10 minutes before proceeding to Step 5.
5	Remove the power module's top cover and lay it across the rear of the unit, so that it covers approximately 25% of its rear area.
6	Switch on the power module's main circuit breaker.

Required Pre-Troubleshooting Procedure for Filament Power Supply

The following procedure must be performed prior to any troubleshooting procedure involving removal of the FPS top cover.

Step	Action
1	Perform Steps 1-3 of the procedure described in section 5.2.1.
2	Wait at least 10 minutes before performing Step 3 of this procedure.
3	Remove the FPS top cover.
4	Remove the FPS left-side cover.
5	If you are troubleshooting a standard FPS unit, (i.e., with PN 0620-6604-0), touch a properly connected grounding hook to the HV vacuum relay inside the FPS. If you are troubleshooting an FPS unit with PN 0620-6604-2, touch a properly connected grounding hook to the connection for either of the two HV output leads.

Figures 5-1 and 5-2 show the front panel controls and indicators on the CV-6SLX power module and the remote control unit. Figure 5-3 shows the major power module components that are referred to in the troubleshooting tables.

Figure 5-1 Control/Display Features on CV-6SLX Power Module Front Panel

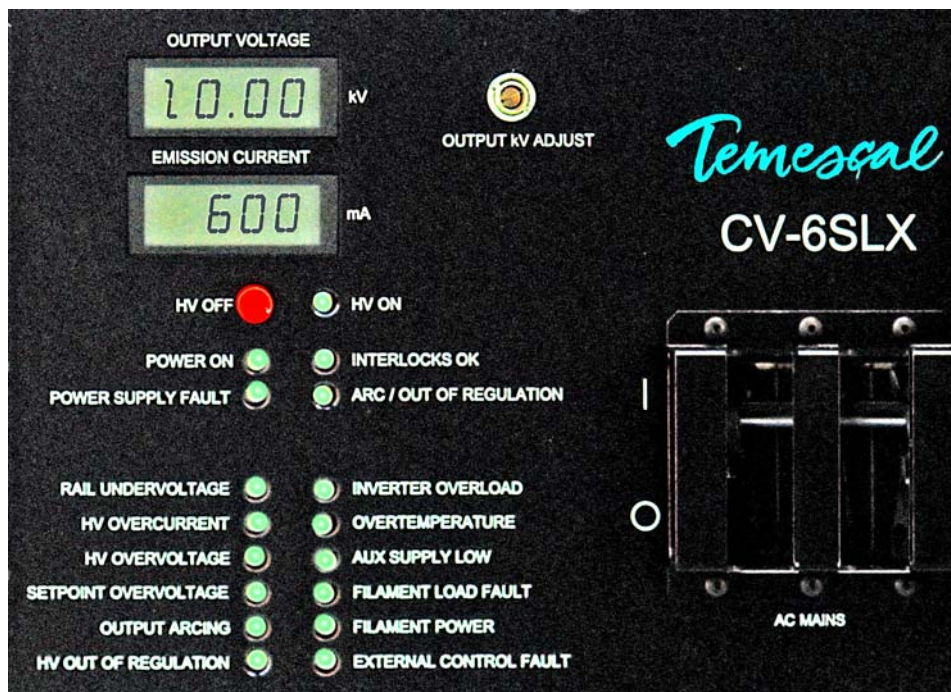
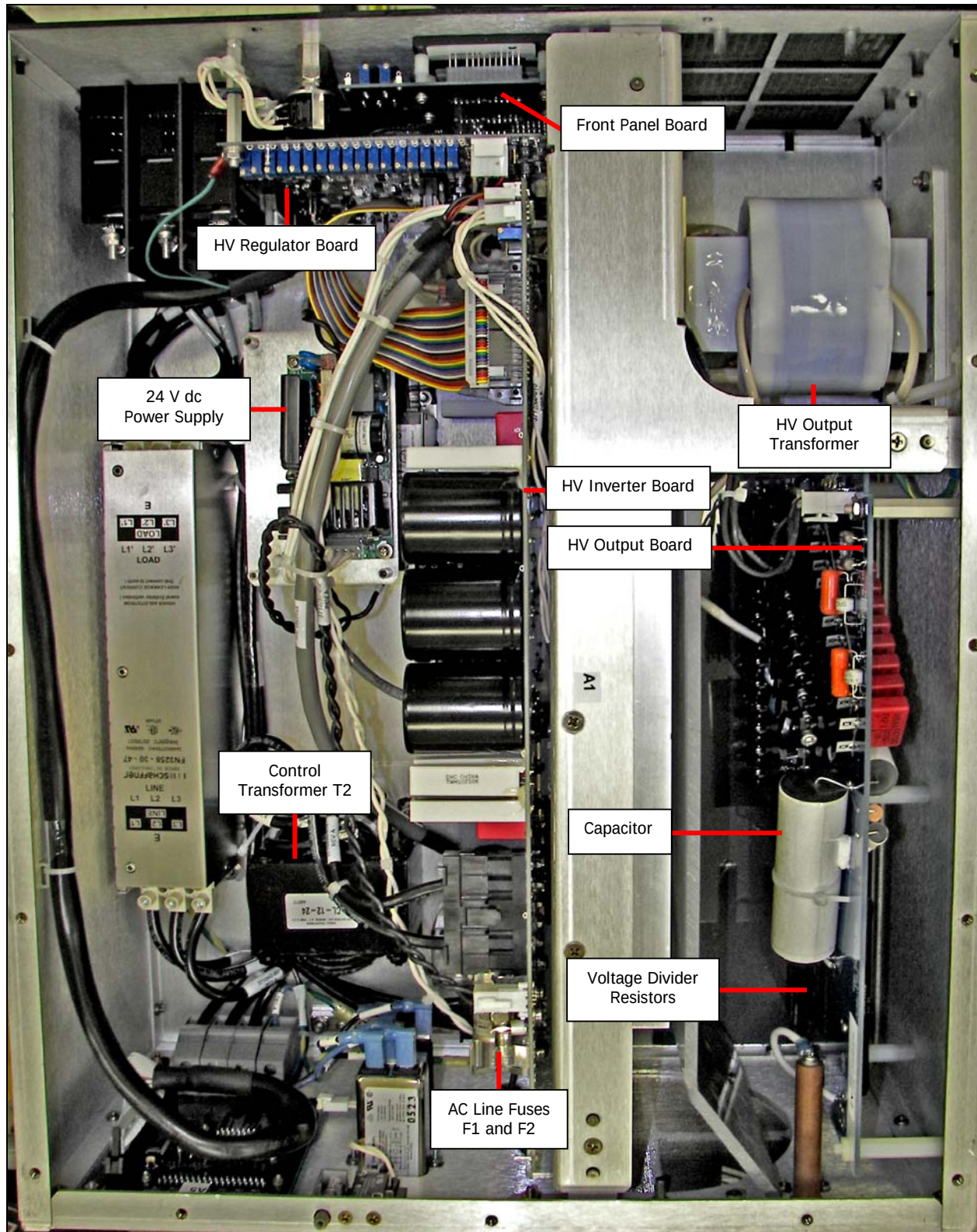


Figure 5-2 Front Panel of Remote Control Unit



Figure 5-3 Major Components Inside CV-6SLX Power Module



Abbreviations

TCS = Temescal Control Software
HVRB = High Voltage Regulator Board
FPSB = Filament Power Supply Board
FPB = Front Panel Board
FPS = Filament Power Supply

Table 1. General Condition: No input power indicated

Symptoms:

TCS: PSU1_RDY_ALM - Power Supply Control Not Ready Timeout Alarm

Remote Control: PWR LED fails to Light; displays are dark.

Power Module: POWER ON LED Fails to Light; displays are dark.

Possible Causes	Procedure
1. Loss of main line power.	1. Check circuit protection devices (i.e., either circuit breakers or fuses) for input power to ensure they are not tripped or blown.
2. Power supply's front breakers are tripped.	2. Reset front breakers and proceed with normal power up of unit. If breakers trip again, further troubleshooting is required.
3. Loose or faulty line power connection.	3. Check for secure connections on main three-phase line power connector on rear of unit.
4. Connections, components, or boards have come loose.	4. Verify that all boards, and connectors are securely mounted or connected.
5. Unit's internal line filters or connections are faulty.	5. Turn off line power at wall main. Remove top cover of power module and check connections from incoming line voltage line filter.
6. Power On indicator lamp is blown.	6. Check for correct bulb operation.
7. Fuse on HVRB blown	7. Check fuse F1 (0.2 A) on HVRB
8. Fuses on Inverter board blown	8. Check fuses F1, F2 and F3 on Inverter board
9. AC Control transformer faulty	9. Check input to control transformer H1 and H4 for 480 V ac and output at X1 and X4 for 240 V ac
10. 24 V DC power supply faulty	10. Check 24 V DC power supply input at pins 1 and 3 for 240 V ac and output at pins 3 and 4 for 24 V dc.

Table 2. General Condition: Fan not rotating

Symptom: Fan Does Not rotate when PS powers up

Possible Causes	Procedure
1. Fan is defective.	1. Check fan for mechanical operation
2. Fan is mechanically stuck	2. Check to see whether fan is clogged with dust or dirt. Excessive dust build-up around edges of fan will prevent it from moving. Clean and blow out dust. Restart.
3. Fuses on Inverter board blown	3. Check fuses F1, F2 and F3 on Inverter board
4. AC Control transformer faulty	4. Check input to control transformer H1 and H4 for 480 V AC and output at X1 and X4 for 240 V ac
5. 24 V DC power supply faulty	5. Check 24 V DC power supply input at pins 1 and 3 for 240 V ac and output at pins 3 and 4 for 24 V dc.
6. Fuse on HVRB blown	6. Check fuse F1 (0.2 A) on HVRB
7. Fan's electrical are faulty.	7. Check both wires leading out from inverter board at pins J4-1 and J4-2 for +24 V dc.

Table 3: General Condition: One or more PS interlocks not made**Symptoms:****TCS: PSU1_RDY_ALM - Power Supply Control Not Ready Timeout Alarm****Remote Control: One or More Interlock Indicator LEDs Fail to Light****Power Module: Interlocks OK LED lights RED**

Possible Causes	Procedure
1. Interlock indicated by the unlit LED farthest to the left is not made.	1. Check to see whether that interlock is made. If not, make appropriate corrections until it is made.
2. Interlock Voltage (+24 V DC) not present	2. On HVRB, measure TP10 for +24 V DC. If voltage is not present, proceed to next step of this procedure.
3. Fuse on HVRB blown	3. Check fuse F2 (0.2 A) on HVRB
4. +24 V DC interlock signal interrupted external to power supply.	4. Check interlocks (Doors, Tank, Vacuum, Water, Position, Auxiliary and FPS cover switch). On HVRB check pins J1-58 and J1-60 to ensure all external interlocks have been made.
5. FPS interlock (top cover switch) failed	5. On HVRB, check pins J1-11 and J1-13. If return signal is not present, confirm switch operation. Replace top cover switch and/or harness and/or connector.

Table 4. General Condition: PS fails to achieve HV Ready state**Symptoms:****TCS: PSU1_RDY_ALM – Power Supply Control Not Ready Timeout Alarm****Remote Control: HV Ready LED Fails to glow Yellow**

Possible Causes	Procedure
1. Confirm that the Power ON, HV and Gun Interlocks are made.	1. Refer to Table 3.
2. Faulty or loose cable connections.	2. Make sure that all power module and FPS cable connections are correctly and securely made.
3. HV Ready Signal output incorrect	3. On HVRB check TP2 for +15 V DC HV ready signal.
4. Confirm control voltages (+/- 15 V DC, +10 V DC and +5 V DC)	4. On HVRB check pins J13-2 for +15 V DC, J13-14 for -15 V DC, J13-10 for +10 V DC and J13-6 for +5 V DC. Replace HVRB if any of the control voltages are missing.
5. One or more faults still active	5. On HVRB check TP33 for clear SUM_FLT signal. If TP33 is high, repeat Step 1 of this procedure and/or replace HVRB.

Table 5. General Condition: PS fails to achieve Gun Ready state**Symptoms:****TCS: SRC1_GON_ALM – Source 1 Gun Control GO ON Timeout Alarm****Remote Control: Gun Ready LED Fails to glow Yellow**

Possible Causes	Procedure
1. Confirm Power ON, HV and Gun Interlocks.	1. Refer to Table 3.
2. Faulty or loose cable connections.	2. Make sure that all power module and FPS cable connections are correctly and securely made.
3. Gun Ready signal disrupted on FPSB	3. Perform the procedures described in Tables 28 and 29.

Table 6. General Condition: HV does not switch on**Symptoms:****TCS: PSU1_GON_ALM - Power Supply Control Go On Timeout Alarm****Remote Control: HV Enable/Go On LED Fails to glow Green****Power Module: HV ON LED Fails to glow Green**

Possible Causes	Procedure
1. Confirm Power ON, HV and Gun Interlocks.	1. Refer to Table 3.
2. Faulty or loose cable connections.	2. Make sure that all power module and FPS cable connections are correctly and securely made.
3. HV Ready signal not present	3. Refer to Table 4.
4. HV Enable signal from Interface not present	4. On HVRB, check pins J1-26 and J1-28 for HV Enable signal. If signal is missing check interface connections and/or troubleshoot HV/Gun remote controller.
5. HV Enable signal on HVRB disrupted	5. On HVRB, check TP26 for HV Enable signal. If signal is missing replace HVRB, else hard reset power supply.

If the preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the HV path and emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J101, switch the power supply back on, and proceed with the troubleshooting steps described below.

6. HV Resistor damaged or defective.	6. Remove power from power module. Remove top cover and visually inspect HV Output section. Check resistors R6 and R7 for short or open circuit.
--------------------------------------	--

Table 7. General Condition: Gun does not switch on**Symptoms:****TCS: SRC1_GON_ALM – Source 1 Control Go On Timeout Alarm****Remote Control: Gun Enable/Go On LED Fails to glow Green**

Possible Causes	Procedure
1. Faulty or loose cable connections.	1. Make sure that all power module and FPS cable connections are correctly and securely made.
2. Confirm Gun Ready signal	2. Refer to Table 5.
3. Emitter damaged	3. Follow instructions in gun manual to troubleshoot emitter issues.
4. No HV relay control voltage	4. On FPSB check pins J103-6 for +24 V DC. If signal is present replace HV relay else replace FPSB
5. Defective HV relay in FPS.	5. Check for presence of high voltage at output of FPS. <i>WARNING: Perform this step only with suitable test equipment (DMM with 10 Megohm input resistance and Fluke 80-K-40 test probes or the equivalent) and a with safety assistant present.</i>
6. Gun Enable/Go On signal not present	6. On FPSB check J101 Pin 15 for +24 V DC. If signal is present, replace FPSB
7. Confirm GUN IS ON signal	7. On FPSB check J101 Pin 14 for +24 V dc. If signal is present, replace FPSB.

If the preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the HV path and emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J101, switch the power supply back on, and proceed with the troubleshooting steps described below.

8. Power module and/or FPS defective.	8. Return power module and FPS to Temescal
---------------------------------------	--

Table 8. General Condition: No filament current after GUN ON state achieved**Symptom: Gun Switches On But Has No Filament Current**

Possible Causes	Procedure
1. Faulty or loose cable connections.	1. Make sure that all power module and FPS cable connections are correctly and securely made.
2. Emitter damaged	2. Follow instructions in gun manual to troubleshoot emitter issues.
3. Incorrect filament bias current	3. Adjust filament bias current
4. Filament Power Supply Module fault	4. Refer to Tables 28 and 29.

Table 9. General Condition: No beam emitted after filament current is switched on

Symptom: HV, Gun and Filament Current Switch On, But No Beam Is Emitted

Possible Causes	Procedure
1. Faulty or loose connections.	1. Make sure that all HV and FPS connections are correctly and securely made.
2. Confirm HV Ready signal	2. Refer to Table 4.
3. Confirm Gun Ready signal	3. Refer to Table 5.
4. Emitter damaged	4. Follow instructions in gun manual to troubleshoot emitter issues.
5. Confirm HV IS ON signal	5. Refer to Table 6.
6. Confirm GUN IS ON signal	6. Refer to Table 7.
7. Confirm Emission request	7. On FPSB, check TP3 for emission request (1.2 V = 1.2 A).
8. Confirm HV request	8. On HVRB check TP30 (in remote mode) and TP36 (in local mode) for 1V=1KV.
9. No HV relay control voltage	9. On FPSB check pins J103-6 for +24 V DC. If signal is present, replace HV relay; else replace FPSB
10. Defective HV relay in FPS.	10. Check for presence of high voltage at output of FPS. <i>WARNING: Perform this step only with suitable test equipment (DMM with 10 Megohm input resistance and Fluke 80-K-40 test probes or the equivalent) and a with safety assistant present.</i>
11. Emission Power Control Voltage not OK	11. On FPSB, check pins J103-9 for +24 V DC
12. Faulty Emission feedback	12. On FPSB, check pins J103-8 for scaled DC voltage (0-5V = 0-2A).
13. Defective FPSB	13. Replace FPSB.

Table 10. General Condition: HV output unstable**Symptom: HV Fluctuates or Sags From Requested Level**

Possible Causes	Procedure
1. Incorrect or fluctuating line voltage	1. Confirm input line voltage
2. Faulty or loose cable connections.	2. Make sure that all power module and FPS cable connections are correctly and securely made.
3. Emitter damaged	3. Follow instructions in gun manual to troubleshoot emitter issues.
4. No HV relay control voltage	4. On FPSB check pins J103-6 for +24 V DC. If signal is present replace HV relay else replace FPSB
5. Defective HV relay in FPS.	5. Check for presence of high voltage at output of FPS. <i>WARNING: Perform this step only with suitable test equipment (DMM with 10 Megohm input resistance and Fluke 80-K-40 test probes or the equivalent) and a with safety assistant present.</i>
6. System improperly grounded for HV.	6. Follow grounding instructions provided in e-gun manual.

If the preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the HV path and emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J101, switch the power supply back on, and proceed with the troubleshooting steps described below.

7. HV Resistor/Capacitor damaged or defective.	7. Remove power from power module. Remove top cover and visually inspect HV Output section. Check resistors R6 and R7 and capacitors C36 and C38.
8. HV Voltage divider resistors faulty.	8. Check voltage divider circuit resistors R1 and R6.

Table 11. General Condition: Gun out of regulation

Symptom: When Gun And HV Are Switched On, Filament Current Ramps Up and Goes Out of Regulation

Possible Causes	Procedure
1. Faulty or loose connections.	1. Make sure that all HV and FPS connections are correctly and securely made.
2. Short in HV path	2. Check emitter, feethroughs and cables for signs of shorts.
3. Emitter damaged	3. Follow instructions in gun manual to troubleshoot emitter issues.
4. No HV relay control voltage	4. On FPSB check pins J103-6 for +24 V DC. If signal is present replace HV relay else replace FPSB
5. Defective HV relay in FPS.	5. Check for presence of high voltage at output of FPS. <i>WARNING: Perform this step only with suitable test equipment (DMM with 10 Megohm input resistance and Fluke 80-K-40 test probes or the equivalent) and a with safety assistant present.</i>

If the preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the HV path and emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J101, switch the power supply back on, and proceed with the troubleshooting steps described below.

6. FPS defective	6. Replace FPS
------------------	----------------

Table 12. General Condition: Power Supply out of regulation**Symptoms:****TCS: PSU1_FAIL_ALM - Power Supply Control Is On Failure Alarm****Remote Control: REG LED Lights Up****Power Module: OOR LED Lights Up**

Possible Cause	Procedure
1. System improperly grounded for HV.	1. Follow grounding instructions provided in e-gun manual.
2. Incorrect line voltage.	2. Confirm line voltage as per manual.
3. Incorrect line phase.	3. Confirm line phase as per specifications.

If preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable from J104.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J104, switch the power supply back on, and proceed with the troubleshooting steps described below.

Possible Cause	Procedure
4. Faulty or loose cable connections.	4. Make sure that all power module and FPS cable connections are correctly and securely made.
5. Short in HV path	5. Check emitter, feedthroughs and cables for signs of shorts.
6. Emitter damaged	6. Follow instructions in gun manual to troubleshoot emitter issues.

Table 13. FILAMENT POWER LED does not light

Possible Cause	Procedure
1. Loss of main line AC power from power module.	1. (a) Check 220V AC voltage at connector J104
	1. (b) Check AC line fuses F1 and F2
2. No control voltage	2. Check Filament control power 24 V DC at pin J101-8
3. Control Voltage power supply fault	3. On FPSB check TP11 for +24 V DC, TP10 for +15 V DC, TP9 for -15 V DC, and TP14 for +5 V DC. If anyone of the voltages is not present, replace FPS.

Table 14. General Condition: LED(s) indicate out of regulation condition**Symptom: FPS High Voltage LED does not Light**

Possible Cause	Procedure
1. FPS not powered up.	1. Refer to Table 28.
2. High Voltage IS ON signal not present	2. High voltage is not switched ON
3. Confirm HV ON signal	3. On FPSB, check pins J3-8 and J3-9 for HV ON signal.
4. High Voltage IS ON signal on FPSB not present.	4. On FPSB, check pins J5-1 for +24 V DC. If signal is not present replace FPSB

Table 15. RAIL UNDER VOLTAGE LED Lights Red**Symptom: Rail Voltage under 430 V DC**

Possible Cause	Procedure
1. System improperly grounded for HV.	1. Follow grounding instructions provided in e-gun manual.
2. Incorrect line voltage.	2. Confirm line voltage as per manual.
3. Incorrect line phase.	3. Confirm line phase as per specifications.
4. Faulty or loose cable connections.	4. Make sure that all power module and FPS cable connections are correctly and securely made.

If preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable from J104.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J104, switch the power supply back on, and proceed with the troubleshooting steps described below.

Possible Cause	Procedure
5. Rail Voltage Below 430 V DC	5. Confirm rail voltage on HVRB TP22. If voltage is greater than 4.3 V DC proceed to next step else skip to step 7.
6. Rail voltage set point tampered/ changed	6. Adjust R1 to the set point indicated on the test data sheet provided with this unit.
7. Rail resistors damaged	7. On Inverter board confirm low rail voltage on TP38. Turn the power off, measure series resistors R159 through R165 for a total resistance of 1.743KOhm.
8. Inverter capacitors faulty	8. Replace Inverter board

Table 16. HV OVERCURRENT LED Lights Red**Symptom: HV Output current is above 636 mA**

Possible Cause	Procedure
1. Incorrect or fluctuating line voltage	1. Confirm input line voltage
2. Faulty or loose cable connections.	2. Make sure that all power module and FPS cable connections are correctly and securely made.
3. Emitter damaged	3. Follow instructions in gun manual to troubleshoot emitter issues.
4. No HV relay control voltage	4. On FPSB check pins J103-6 for +24 V DC. If signal is present replace HV relay else replace FPSB
5. Defective HV relay in FPS.	5. Check for presence of high voltage at output of FPS. <i>WARNING: Perform this step only with suitable test equipment (DMM with 10 Megohm input resistance and Fluke 80-K-40 test probes or the equivalent) and a with safety assistant present.</i>
6. System improperly grounded for HV.	6. Follow grounding instructions provided in e-gun manual.

If preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable from J104.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J104, switch the power supply back on, and proceed with the troubleshooting steps described below.

Possible Cause	Procedure
7. HV Current over maximum value of 636mA.	7. Confirm HV current on HVRB at TP17. If voltage is greater than 6.36 V DC proceed to next step else skip to step 9.
8. HV current set point tampered/changed	8. Adjust R37 to the set point indicated on the test data sheet provided with this unit.
9. HV Current sense resistors damaged.	9. On HV Output board confirm high HV current on pins J5-1 and J5-3. Turn the power off, measure resistors R2 through R5.
10. HV Output circuit faulty	10. Replace HV Output Board

Table 17. HV OVERVOLTAGE LED Lights Red**Symptom: HV Output voltage is above 105% of setpoint**

Possible Cause	Procedure
1. Incorrect or fluctuating line voltage	1. Confirm input line voltage
2. Faulty or loose cable connections.	2. Make sure that all power module and FPS cable connections are correctly and securely made.
3. Emitter damaged	3. Follow instructions in gun manual to troubleshoot emitter issues.
4. No HV relay control voltage	4. On FPSB check pins J103-6 for +24 V DC. If signal is present replace HV relay else replace FPSB
5. Defective HV relay in FPS.	5. Check for presence of high voltage at output of FPS. <i>WARNING: Perform this step only with suitable test equipment (DMM with 10 Megohm input resistance and Fluke 80-K-40 test probes or the equivalent) and a with safety assistant present.</i>
6. System improperly grounded for HV.	6. Follow grounding instructions provided in e-gun manual.

If preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable from J104.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J104, switch the power supply back on, and proceed with the troubleshooting steps described below.

Possible Cause	Procedure
7. HV Voltage over maximum value (105% of set point).	7. Confirm HV voltage on HVRB at TP12 for 1V = 1KV. If voltage is less than 105% of setpoint proceed to next step else skip to step 9.
8. HV voltage set point tampered/changed	8. Adjust R7 to the set point indicated on the test data sheet provided with this unit. Monitor TP1 to while adjusting R7.
9. HV Voltage sense resistors damaged	9. On HV Output board confirm high HV overvoltage on pins J5-4 and J5-6. Turn the power off, measure resistors R8.
10. HV Output circuit faulty	10. Replace HV Output Board

Table 18. SETPOINT OVERVOLTAGE LED Lights Red**Symptom: HV Output voltage setpoint is above 10.5KV**

Possible Cause	Procedure
1. HV set point is above 10.5KV	1. Using the potentiometer on the front panel of the power module or HV/Gun Remote controller, adjust kV below 10.5KV.
2. Faulty reference voltage	2. In Local mode, on HVRB measure TP36 or in remote mode measure TP30 by 1V=1KV. Correct appropriate reference inputs.
3. Faulty HVRB	3. Replace HVRB

Table 19. OUTPUT ARCING LED Lights Red**Symptom: One or more output arcing faults are active. Arc duration > 120ms or Arc Rate > 200Hz**

Possible Cause	Procedure
1. Faulty or loose connections.	1. Make sure that all HV and FPS connections are correctly and securely made.
2. Emitter damaged	2. Follow instructions in gun manual to troubleshoot emitter issues.
3. Defective HV relay in FPS.	3. Check for presence of high voltage at output of FPS. <i>WARNING: Perform this step only with suitable test equipment (DMM with 10 Megohm input resistance and Fluke 80-K-40 test probes or the equivalent) and a with safety assistant present.</i>
4. System improperly grounded for HV.	4. Follow grounding instructions provided in e-gun manual.
5. Chamber Pressure too high	5. Chamber pressure should be less than 1×10^{-5} mtorr.
6. HV feedthrough shorted	6. Check copper bus bars and HV feedthroughs for shorts, coatings, cracks or arc marks

Table 20. HV OUT OF REGULATION LED Lights Yellow**Symptom: HV Output voltage is not regulating to setpoint**

Possible Cause	Procedure
1. Incorrect or fluctuating line voltage	1. Confirm input line voltage
2. Faulty or loose cable connections.	2. Make sure that all power module and FPS cable connections are correctly and securely made.
3. Emitter damaged	3. Follow instructions in gun manual to troubleshoot emitter issues.
4. No HV relay control voltage	4. On FPSB, check pins J103-6 for +24 V DC. If signal is present replace HV relay else replace FPSB
5. Defective HV relay in FPS.	5. Check for presence of high voltage at output of FPS. <i>WARNING: Perform this step only with suitable test equipment (DMM with 10 Megohm input resistance and Fluke 80-K-40 test probes or the equivalent) and a with safety assistant present.</i>
6. System improperly grounded for HV.	6. Follow grounding instructions provided in e-gun manual.
7. Chamber Pressure too high	7. Chamber pressure should be less than 1×10^{-5} mtorr.
8. HV feedthrough shorted	8. Check copper bus bars and HV feedthroughs for shorts, coatings, cracks or arc marks

If preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable from J104.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J104, switch the power supply back on, and proceed with the troubleshooting steps described below.

Possible Cause	Procedure
9. HV Overcurrent state or HV Overvoltage state.	9. On HVRB check TP59 for Overvoltage and TP69 for Overcurrent. Refer to Tables 16 and 17.

Table 21. ARC/OUT OF REGULATION LED Lights Yellow**Symptom: Output is arcing or is not regulating to setpoint**

Possible Cause	Procedure
1. Incorrect or fluctuating line voltage	1. Confirm input line voltage
2. Faulty or loose connections.	2. Make sure that all HV and FPS connections are correctly and securely made.
3. Emitter damaged	3. Follow instructions in gun manual to troubleshoot emitter issues.
4. No HV relay control voltage	4. On FPSB check pins J103-6 for +24 V DC. If signal is present replace HV relay else replace FPSB
5. Defective HV relay in FPS.	5. Check for presence of high voltage at output of FPS. <i>WARNING: Perform this step only with suitable test equipment (DMM with 10 Megohm input resistance and Fluke 80-K-40 test probes or the equivalent) and a with safety assistant present.</i>
6. System improperly grounded for HV.	6. Follow grounding instructions provided in e-gun manual.
7. Chamber Pressure too high	7. Chamber pressure should be less than 1×10^{-5} mtorr.
8. HV feedthrough shorted	8. Check copper bus bars and HV feedthroughs for shorts, coatings, cracks or arc marks

If preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable from J104.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J104, switch the power supply back on, and proceed with the troubleshooting steps described below.

Possible Cause	Procedure
9. HV Overcurrent state, HV Overvoltage state, or Arc state	9. Perform the procedures described in Tables 15-20, in that order.

Table 22. INVERTER OVERLOAD LED Lights Red

Symptom: Inverter current > 150Apk

Possible Cause	Procedure
1. Incorrect or fluctuating line voltage	1. Confirm input line voltage
2. Faulty or loose connections.	2. Make sure that all HV and FPS connections are correctly and securely made.

If preceding steps have failed to correct the fault, perform the following procedure:

1. Switch off the power supply.
2. Disconnect HV output cable from J104.
3. Switch on the power supply and the HV and leave them switched on for no more than 9 seconds, observing whether the symptom persists during that interval.

CAUTION

DO NOT leave the high voltage on for more than 9 seconds with the HV cable disconnected. Doing so will result in the emitter's filament burning out.

4. If the symptom is not in evidence during Step 3, troubleshoot the emitter assembly, following the instructions in the e-gun manual. If the symptom persists during Step 3, reconnect the HV output cable to J104, switch the power supply back on, and proceed with the troubleshooting steps described below.

Possible Cause	Procedure
3. Rail voltage incorrect	3. Perform the procedure described in Table 15.
4. Rail sensor is defective	4. Replace rail sensor HAS-300-S on Inverter board
5. Inverter Board defective	5. Replace Inverter Board
6. HVRB defective	6. Replace HVRB

Table 23. OVERTEMPERATURE LED Lights Red

Symptoms: One or more temperature faults are present. IGBT Temp > 67° C or Heatsink Temp >77° C or Fan Stopped

Possible Cause	Procedure
1. Incorrect or fluctuating line voltage	1. Confirm input line voltage
2. Faulty or loose connections.	2. Make sure that all HV and FPS connections are correctly and securely made.
3. Inverter temperature fault	3. On HVRB check TP16 for a maximum of 10V = 60°. If TP16 > 10 V DC proceed to next step, else skip to step 5.
4. Temperature sensor above maximum value or defective	4. Replace temperature sensor or provide adequate cooling. Clean any dirt collected near the sensor.
5. Heat sink temperature fault	5. On HVRB check TP65 for 15 V DC to confirm heat sink fault. If TP65 ~ 15 V DC proceed to next step else skip to step 7.
6. Heat sink overheated or thermostat faulty	6. Provide adequate cooling for heat sink. Clean any dirt collected on or near the heat sink. Replace thermostat if necessary.
7. Cooling fan fault	7. Visually verify operation of fan. Clean any dirt or clog near the fan.
8. Cooling fan fault alarm	8. On HVRB check pin J8-6 for 24 V DC to confirm fan fault.
9. Fan drive voltage not present	9. See Table 2.

Table 24. AUXILIARY SUPPLY LOW LED Lights Red**Symptom: Control Supply voltage is below minimum value**

Possible Cause	Procedure
1. Confirm low auxiliary power	1. On HVRB check pin J8-27 for +24 V DC.
2. Inverter Auxiliary power fault	2. On Inverter board check pins J5-3 or J5-4 for 24 V DC.
3. Fuses on Inverter board blown	3. Check fuses F1, F2 and F3 on Inverter board.
4. AC Control transformer faulty	4. Check input to control transformer H1 and H4 for 480 V AC and output at X1 and X4 for 240 V AC
5. 24 V DC power supply faulty	5. Check 24 V DC power supply input at pins 1 and 3 for 240 V AC and output at pins 3 and 4 for 24 V DC.

Table 25. EXTERNAL CONTROL FAULT LED Lights Red**Symptom: External Control voltage is below minimum value (< 20 V DC)**

Possible Cause	Procedure
1. Control voltage not present	1. On HVRB, check TP10 for +24 V DC
2. Control voltage fuse blown	2. Check fuse F1 on HVRB
3. Control supply voltage not present	3. On HVRB, check pins J8-26 for +24 V DC
4. Fuses on Inverter board blown	4. Check fuses F1, F2 and F3
5. AC Control transformer faulty	5. Check input to control transformer H1 and H4 for 480 V AC and output at X1 and X4 for 240 V AC
6. 24 V DC power supply faulty	6. Check 24 V DC power supply input at pins 1 and 3 for 240 V AC and output at pins 3 and 4 for 24 V DC.

Table 26. FILAMENT LOAD FAULT LED Lights Red**Symptom: Minimum filament load not present**

Possible Cause	Procedure
1. Control voltage not present	1. On HVRB check TP10 for +24 V DC
2. Control voltage fuse blown	2. Check fuse F1 on HVRB
3. Control supply voltage not present	3. On HVRB check pins J8-26 for +24 V DC
4. Fuses on Inverter board blown	4. Check fuses F1, F2 and F3
5. AC Control transformer faulty	5. Check input to control transformer H1 and H4 for 480 V AC and output at X1 and X4 for 240 V AC
6. 24 V DC power supply faulty	6. Check 24 V DC power supply input at pins 1 and 3 for 240 V AC and output at pins 3 and 4 for 24 V DC.

Table 27. FILAMENT POWER FAULT LED Lights Red**Symptom: Filament Power supply module power not present**

Possible Cause	Procedure
1. Control voltage not present	1. On HVRB check TP10 for +24 V DC
2. Control voltage fuse blown	2. Check fuse F1 on HVRB
3. Control supply voltage not present	3. On HVRB check pins J8-26 for +24 V DC
4. Fuses on Inverter board blown	4. Check fuses F1, F2 and F3
5. AC Control transformer faulty	5. Check input to control transformer H1 and H4 for 480 V AC and output at X1 and X4 for 240 V AC
6. 24 V DC power supply faulty	6. Check 24 V DC power supply input at pins 1 and 3 for 240 V AC and output at pins 3 and 4 for 24 V DC.

Table 28: POWER ON LED on FPS front panel does not light

Possible Cause	Procedure
1. No input AC power	1. Verify that the unit's power switch (see Figure 5-4) is in the ON position. If O.K., make sure that the FPS input power cable is securely plugged in at both ends. If O.K., make sure that power module main breaker is switched on. If O.K., check and replace fuse(s), as described in section 5.3. If O.K., then try replacing input power cable. If FPS cannot be powered up, return it to Temescal
2. No control voltage	2. Check filament control power 24 V DC at pin J101-8.
3. Control voltage power supply fault	3. On the FPSB, check the following test points for the voltages listed below: • TP11 for +24 V DC • TP10 for +15 V DC • TP9 for -15 V DC • TP14 for +5 V DC If any of these voltages is not present at the test point indicated, replace the FPS.

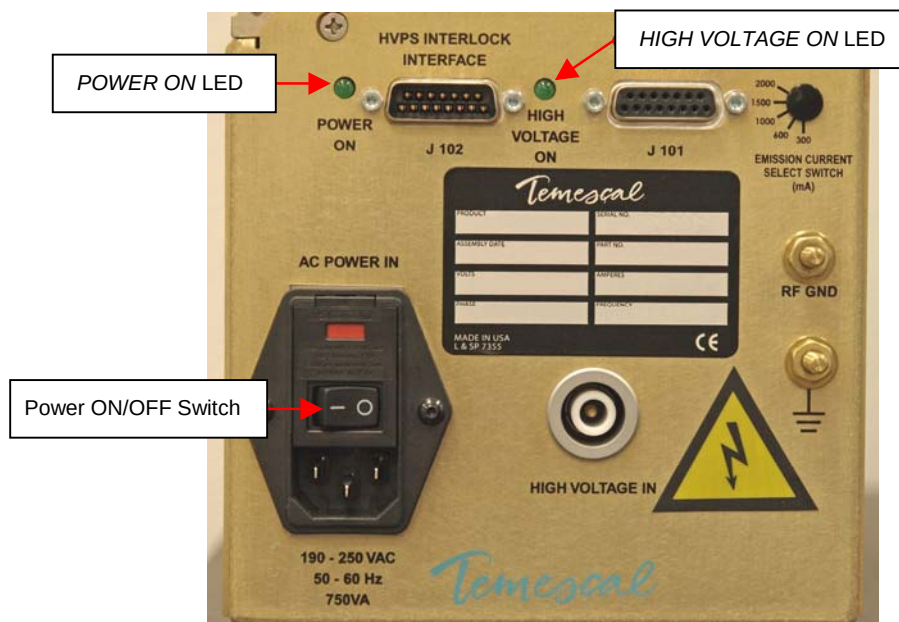
Figure 5-4 ON/OFF Switch and Indicators on FPS Front Panel

Table 29: FPS front panel *HIGH VOLTAGE ON* LED does not light

Possible Cause	Procedure
1. FPS is not powered up.	1. Refer to Table 12.
2. HIGH VOLTAGE IS ON signal not asserted.	2. High voltage is not switched ON at power module.
3. On FPSB, HV ON signal not present.	3. On FPSB, check pins J3-8 and J3-9 for HV ON signal.
4. On FPSB, HIGH VOLTAGE IS ON signal not present.	4. On FPSB check pins J5-1 for +24 V DC. If signal is not present, replace FPSB.

5.3 FPS Fuse Replacement Procedure

To check the fuses input power fuses and replace them as necessary, follow the instructions provided below.

- | Step | Action |
|------|--|
| 1 | Set the FPS ON/OFF switch to the OFF position. |
| 2 | Switch off the facility breaker providing AC power to the FPS. |
| 3 | Unplug the input power cable from its receptacle on the FPS front panel. |
| 4 | Using a flat-bladed screwdriver, pry open the fuse block's cover as shown in Figure 5-5. |

Figure 5-5 Prying Open the Fuse Block's Cover

- | | |
|---|--|
| 5 | Using the same screwdriver, pry the fuse block out of its holder, as shown in Figure 5-6. Figure 5-7 shows the fuse block extracted from its holder. |
|---|--|

Figure 5-6 Extracting the Fuse Block from the FPS**Figure 5-7 Fuse Block Removed from FPS**

- 6 Check the fuses and replace them as necessary.
- 7 Push the fuse block all the way into its holder and snap its cover back into place.
- 8 Reconnect the FPS input power cable.
- 9 Switch on the facility breaker that supplies power to the FPS.
- 10 Set the FPS ON/OFF switch to the ON position.

5.4 Suggested Spare Parts

5.4.1 Suggested Spare Parts for 208-Volt Units

Component/Assembly	Part Number
Fuse 6.3 A, 250 V ac	6024-7324-0
Fuse, 40 A, 700 V dc Semi	6024-7354-0
Diode 1600 V, 56 A	6024-7364-0
Power Entry Module	6024-7312-0
Power Supply, 24 V dc, 2.7 A	6024-7352-0
IGBT	6024-7330-0
Aux Transformer, 480 VCT In/240 VCT Out	6024-7319-0
Choke, 1.2 mH/4.8 mH	6024-7307-0
Circuit breaker 30 A, 600 V ac, 3-Pole	6024-7384-0
Fan, 24 V dc, 325 cfm	6024-7379-0
Line Filter	6024-7310-0
HV Transformer	6024-7355-0
Display and Controls PCB	6024-7345-0
Interface PCB	6024-7346-0
HV PCB	6024-7390-0
Regulator PCB	6024-7344-0
Inverter PCB	6024-7335-0

5.4.2 Suggested Spare Parts 400-Volt Units

Component/Assembly	Part Number
Fuse 6.3 A, 250 V ac	6024-7324-0
Fuse, 20 A, 700 V dc Semi	6024-7351-0
Diode 1600 V, 56 A	6024-7364-0
Power Entry Module	6024-7312-0
Power Supply, 24 V dc, 2.7 A	6024-7352-0
IGBT	6024-7330-0
Aux Transformer, 480 VCT In/240 VCT Out	6024-7319-0
Choke, 1.2 mH/4.8 mH	6024-7307-0
Circuit breaker 15 A, 600 V ac, 3-Pole	6024-7383-0
Fan, 24 V dc, 325 cfm	6024-7379-0
Line Filter	6024-7310-0
HV Transformer	6024-7355-0
Display and Controls PCB	6024-7345-0
Interface PCB	6024-7346-0
HV PCB	6024-7390-0
Regulator PCB	6024-7344-0
Inverter PCB	6024-7350-0

REAR PANEL DIAGNOSTICS (DB37)				
	Pin	Range	Proportion	Description
Cable Shield	1	N/A	N/A	
Analog Controls (0-10 VDC)				
HV Output Voltage	2	0-10 VDC	0-10 KVDC	Fault at above 10.5 KVDC
HV Output Current	3	0-10 VDC	0-1,000 maDC	Fault at above 630 maDC
HV Inverter IGBT Temperature	4	0-10 VDC	0-160C	Fault at above 67C?
HV Inverter Rail Voltage	5	0-10 VDC	0-1,000 VDC	Fault at below 430 VDC
Arc Counter Integrator	6	0-10 VDC	0-480S	Fault at above 120S continuous arcing at above allowable rate
HV Inverter PWM Duty Cycle	7	0-5 VDC	0-100%	
EG Filament Current	8	0-10 VDC	0-50 AAC	
EG Emission Current	9	0-10 VDC	0-2,000 maDC	
Analog Common	22	N/A		
Digital Controls (0 / 24 VDC)				
24VDC Control Power	10	0-10 VDC	0-24 VDC	Fault at below 19.5 VDC
Over Temp Trip	11	0 / 24 VDC	0 VDC = Fault	Inverter temperature overload (above 67C) or cooling fan failure.
External Interlocks	12	0 / 24 VDC	0 VDC = Fault	
HV Enable (ready)	13	0 / 24 VDC	0 VDC = Fault	
HV Go ON	14	0 / 24 VDC	0 VDC = OFF	
Over-Current Trip	15	0 / 24 VDC	0 VDC = Fault	HV output current above 105% of nominal (nominal = 600 MA).
Over-Voltage Trip	16	0 / 24 VDC	0 VDC = Fault	HV output voltage above 105% of maximum (maximum = 10 KV).
Arc Counter Active	17	0 / 24 VDC	0 VDC = Fault	Arc rate or duration exceeds maximum programmed limits (200/second or continuous arcing for more than 120 seconds).
Out of Regulation	18	0 / 24 VDC	0 VDC = Fault	HV output voltage out of "voltage regulation" mode for over 2 seconds duration.
EG Filament Status	19	0 / 24 VDC	0 VDC = Fault	Fault = Open filament
EG Filament Power Status	20	0 / 24 VDC	0 VDC = Fault	Fault = Filament Power Supply OFF
Digital Common	23	N/A	N/A	