Spellman®
High Voltage Electronics Corporation

Instruction Manual

XLG60P400/X2364

High Voltage Power Supply

MODEL :
SERIAL# :
DATE :

SPELLMAN
HIGH VOLTAGE ELECTRONICS CORPORATION
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IMPORTANT SAFETY PRECAUTIONS

SAFETY

THIS POWER SUPPLY GENERATES VOLTAGES THAT ARE DANGEROUS AND MAY BE FATAL. OBSERVE EXTREME CAUTION WHEN WORKING WITH THIS EQUIPMENT.

High voltage power supplies must always be grounded.

Do not touch connections unless the equipment is off and the Capacitance of both the load and power supply is discharged.

Allow five minutes for discharge of internal capacitance of the power supply.

Do not ground yourself or work under wet or damp conditions.

SERVICING SAFETY

Maintenance may require removing the instrument cover with the power on.

Servicing should be done by qualified personnel aware of the electrical hazards.

WARNING note in the text call attention to hazards in operation of these units that could lead to possible injury or death.

CAUTION notes in the text indicate procedures to be followed to avoid possible damage to equipment.

WICHTIGE SICHERHEITSHINWEISE

SICHERHEIT

DIESES HOCHSPANNUNGSNETZTEIL ERZEUGT LEBENSGEFÄHRLICHE HOCHSPANNUNG.
SEIN SIE SEHR VORSICHTIG BEI DER ARBEIT MIT DIESEM GERÄT.

Das Hochspannungsnetzteil muß immer geerdet sein.

Berühren Sie die Stecker des Netzteiles nur, wenn das Gerät ausgeschaltet ist und die elektrischen Kapazitäten des Netzteiles und der angeschlossenen Last entladen sind.

Die internen Kapazitäten des Hochspannungsnetzteiles benötigen ca. 5 Minuten, um sich zu entladen.

Erden Sie sich nicht, und arbeiten Sie nicht in feuchter oder nasser Umgebung.

SERVICESICHERHEIT

Notwendige Reparaturen können es erforderlich machen, den Gehäusedeckel während des Betriebes zu entfernen.

Reparaturen dürfen nur von qualifiziertem, eingewiesenem Personal ausgeführt werden.

“WARNING” im folgenden Text weist auf gefährliche Operationen hin, die zu Verletzungen oder zum Tod führen können.

“CAUTION” im folgenden Text weist auf Prozeduren hin, die genauestens befolgt werden müssen, um eventuelle Beschädigungen des Gerätes zu vermeiden.

PRECAUTIONS IMPORTANTES POUR VOTRE SECURITE

CONSIGNES DE SÉCURITÉ

CETTE ALIMENTATION GÉNÈRE DES TENSIONS QUI SONT DANGEUREUSES ET PEUVENT ÊTRE FATALES.
SOYEZ EXTRÊMENT VIGILANTS LORSQUE VOUS UTILISEZ CET ÉQUIPEMENT.

Les alimentations haute tension doivent toujours être mises à la masse.

Ne touchez pas les connectiques sans que l'équipement soit éteint et que la capacité à la fois de la charge et de l'alimentation soient déchargées.

Prévoyez 5 minutes pour la décharge de la capacité interne de l'alimentation.

Ne vous mettez pas à la masse, ou ne travaillez pas sous conditions mouillées ou humides.

CONSIGNES DE SÉCURITÉ EN CAS DE REPARATION

La maintenance peut nécessiter l'enlèvement du couvercle lorsque l'alimentation est encore allumée.

Les réparations doivent être effectuées par une personne qualifiée et connaissant les risques électriques.

Dans le manuel, les notes marquées « **WARNING** » attire l'attention sur les risques lors de la manipulation de ces équipements, qui peuvent entrainer de possibles blessures voire la mort.

Dans le manuel, les notes marquées « **CAUTION** » indiquent les procédures qui doivent être suivies afin d'éviter d'éventuels dommages sur l'équipement.

IMPORTANTI PRECAUZIONI DI SICUREZZA

SICUREZZA

QUESTO ALIMENTATORE GENERA TENSIONI CHE SONO PERICOLOSE E POTREBBERO ESSERE MORTALI.
PONI ESTREMA CAUTELA QUANDO OPERI CON QUESO APPARECCHIO.

Gli alimentatori ad alta tensione devono sempre essere collegati ad un impianto di terra.

Non toccare le connessioni a meno che l'apparecchio sia stato spento e la capacità interna del carico e dell'alimentatore stesso siano scariche.

Attendere cinque minuti per permettere la scarica della capacità interna dell'alimentatore ad alta tensione.

Non mettere a terra il proprio corpo oppure operare in ambienti bagnati o saturi d'umidità.

SICUREZZA NELLA MANUTENZIONE.

Manutenzione potrebbe essere richiesta, rimuovendo la copertura con apparecchio acceso.

La manutenzione deve essere svolta da personale qualificato, coscio dei rischi elettrici.

Attenzione alle **AVVERTENZE** contenute nel manuale, che richiamano all'attenzione ai rischi quando si opera con tali unità e che potrebbero causare possibili ferite o morte.

Le note di **CAUTELA** contenute nel manuale, indicano le procedure da seguire per evitare possibili danni all'apparecchio.

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Chapter 1

INTRODUCTION

1.1 Description of the X2364

The X2364 high voltage power supply represents an advanced approach to X-ray generator power requirements. This power supply provides all of the power, control, and support functions required for practically all X-ray applications. The X2364 provides high voltage, high current outputs with very low ripple. Extremely stable voltage and current outputs result in significant performance improvements over previously available technology. Low output ripple provides higher intensity levels, with no increase in tube loading.

These advancements are possible by Spellman's long history in X-ray power systems. This power supply utilizes extremely advanced resonant conversion techniques, along with sophisticated digital technology.

The X2364 is specifically designed for X-ray tube applications where the high voltage is a positive polarity, and the filament circuits are referenced to cathode ground potential, (grounded filament).

The X-ray tube voltage and tube emission current are all continuously adjustable via front panel and remotely via the built-in RS232 Interface.

The power supply operates from 187Vac to 264Vac mains.

1.2 X2364 Specifications

Specifications are customized to meet specific customer needs. See Appendix B for the detailed Specification Control Drawing.

1.3 Standard Features

The X2364 incorporates several standard features designed to optimize user satisfaction and safety.

KV AND MA/FILAMENT CURRENT RAMP CIRCUITS: This feature provides for a gradual rise for kV, mA and filament current. This feature is designed to limit voltage shock and filament shock to the X-ray tube. The kV ramp rate is approximately 6 seconds. The filament current is slowly increased until the desired mA level is achieved. This time is typically 5 seconds for full mA output. These ramp conditions are started at the initial HV ON control signal.

ARC DETECT / ARC QUENCH / ARC COUNT: These features allow the user to tailor the power supply to meet specific needs in dynamic load applications. If an arc occurs, the output is inhibited for approximately one second, then the output is ramped up to the preset level with the Slow-start circuitry. See Chapter 3 for operating details and information for user customization for these features.

INTERNAL FAULT PROTECTION: The X2364 continually monitors internal circuits critical to the proper operation of the power supply. In the event that one of these circuits does not function correctly, the fault detection circuit latches the appropriate fault on the front panel display and turns off the outputs and reverts the unit to the POWER DOWN mode.

INDICATOR LAMPS: HIGH VOLTAGE OFF and HIGH VOLTAGE ON indicators.

OUTPUT CABLE: A Spellman Delrin HV receptacle is designed to mate with an Anden P5 Series high voltage cable. The modified Alden P5 cable assembly, Spellman P/N 303217-002, is 42 inches long.

1.3.1 Remote Control via RS232 Interface

RS232 INTERFACE: An internal RS232 Interface provides all the remote functions to operate the X3145. Please see Chapter 8 for complete details.

EXTERNAL INTERLOCK: Interlock connections are provided on the terminal block on the rear of the chassis for connection to a safety switch. The unit will not operate unless the interlock circuit is closed. During high voltage operation, opening the interlock circuit will cause the High Voltage to shut off. This circuit should be used for safety interlock circuits.

1.3.2 System Status and Fault Diagnostic Display

"Dead Front" type indicators are provided to give the user complete indication of system operation and fault conditions. If a fault occurs the power supply will revert to the POWER DOWN mode. This is indicated by both the HV ON and HV OFF lamps turning off. To reset, depress the HV OFF switch.

VOLTAGE (CONTROL): Indicates the output voltage regulator circuit is maintaining voltage regulation.

CURRENT (CONTROL): Indicates the output current regulator circuit is maintaining current regulation.

INTLK CLSD: Indicates the EXTERNAL INTERLOCK connections are in the closed position. This also indicates closure of internal power supply interlocks.

INTLK OPEN: Indicates the EXTERNAL INTERLOCK connections are in the open position. This also indicates opening of internal power supply interlocks.

OVER VOLT: Indicates the overvoltage protection circuitry has caused the power supply to turn off. Overvoltage protection is internally set to 110% of rated output voltage.

OVER CURR: Indicates the output current has exceeded the preset limit. The overcurrent protection is internally set to 110% of the rated output current.

OVERPWR: Turns off the high voltage if the output power exceeds 412 Watts for more than 0.1 seconds.

ARC: Indicates that an arc has occurred or that the ARC COUNT/TRIP has shutdown the power supply.

RGLT ERR: Indicates a failure in the voltage, current or power regulation circuitry. This fault usually occurs when there is a lack of output power to maintain regulation.

CLG FLT: Indicates a temperature condition exceeding 60°C in the EG60 tube housing.

Chapter 2

Inspection and Installation

Initial inspection and preliminary checkout procedures are recommended. For safe operation, please follow the step-by-step procedures described in Chapter 3, Operating Instructions.

2.1 Initial Inspection

Inspect the package exterior for evidence of damage due to handling in transit. Notify the carrier and Spellman immediately if damage is evident. Do not destroy or remove any of the packing material used in a damaged shipment.

After unpacking, inspect the panel and chassis for visible damage.

Fill out and mail the Warranty Registration card accompanying the unit. Standard Spellman X2364 high voltage power supply and components are covered by warranty.

2.2 Mechanical Installation

The X2364 has front panel holes for standard EIA rack mounting. The rack must allow rear access for cable connections. Units are fully enclosed and are suitable for bench or tabletop operation. Standard unit dimensions are shown in Figure 2.1.

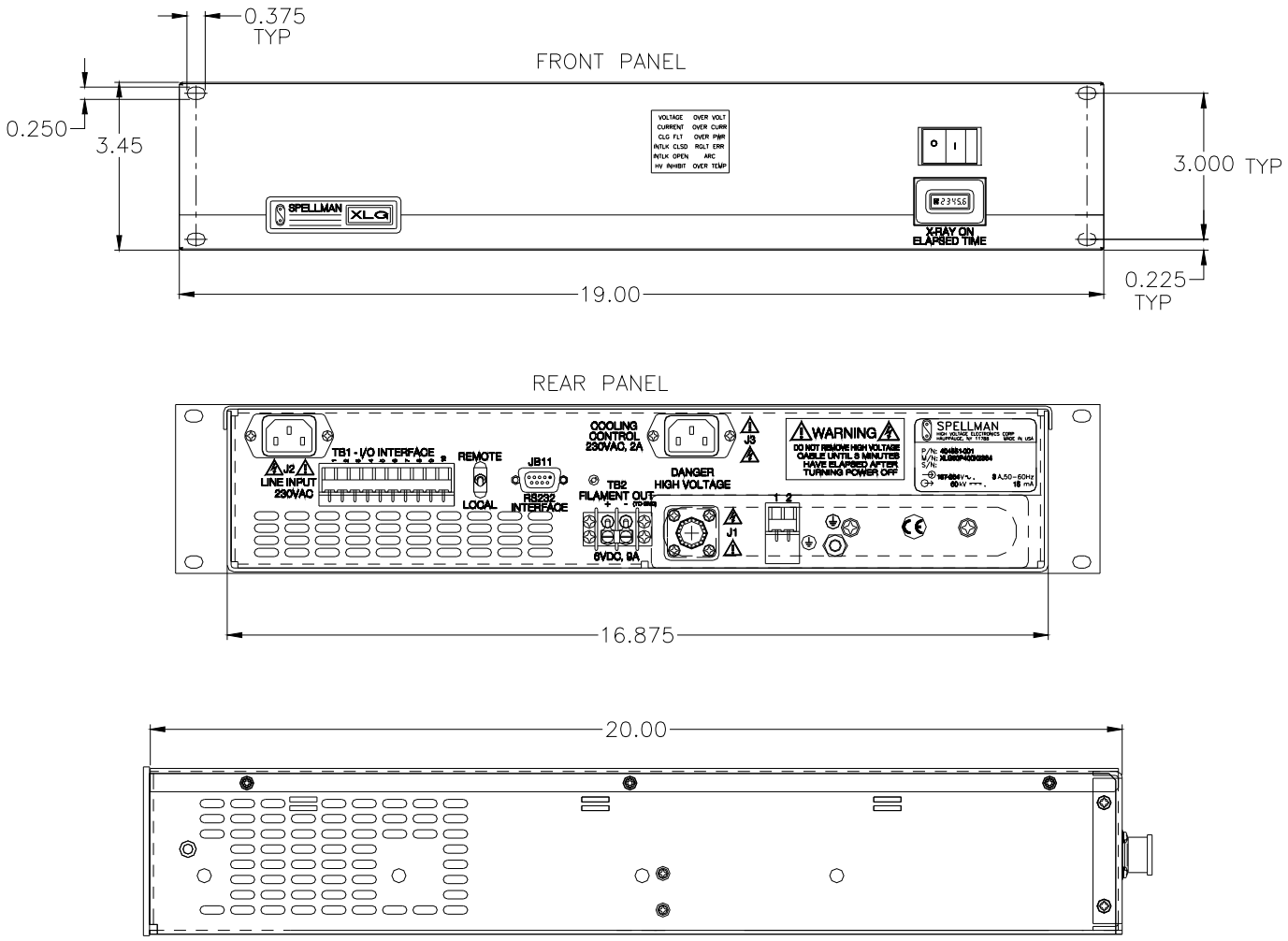

Figure 2.1 X2364 DIMENSIONS

Chapter 3

Operating Instructions

3.1 Operation

WARNING

THIS EQUIPMENT GENERATES DANGEROUS VOLTAGES THAT MAY BE FATAL.
PROPER GROUNDING OF ALL HIGH VOLTAGE EQUIPMENT IS ESSENTIAL.

WARNING:

Before connecting the power supply to the AC line, follow this step-by-step procedure.

Do not connect the power supply to the AC line until Step G is reached.

Failure to follow these procedures may void the warranty.

A) Insure that the Circuit Breaker is in the OFF position (0).

B) Check the input voltage rating on the nameplate of the supply and make certain that this is the rating of the available power source. Spellman X3145 operates from 187Vac to 264Vac, 50 to 60Hz, single phase.

C) **PROPER GROUNDING TECHNIQUE:** The chassis of high voltage power supplies must be grounded, preferably to a water system ground using copper pipe or other earth ground using the connection terminal at the rear of the unit. See Figure 3.1 for a typical operating setup.

The return line from the load should be connected to the terminal on the rear of the power supply. Using a separate external ground at the load is not recommended.

The units are provided with a three-conductor line cord.

D) Attach the output cable to the load.

E) Plug the high-voltage output cable into the rear of the supply and hand-tighten the knurled collar.

F) For initial turn-on, rotate the KILOVOLT control fully counter-clockwise to the zero voltage position.

G) The input power cable may now be connected to the AC power line.

H) Switch the front panel circuit breaker to the ON position (1). (If the supply is to be turned off for an extended period of time the line cord should be disconnected). The unit is now in the HIGH VOLTAGE OFF mode. The HIGH VOLTAGE OFF light should be lit.

I) Depress and hold the HIGH VOLTAGE OFF switch. The front panel meters will now read the preset value of the KILOVOLT control dial and the MILLAMPERES control dial. To preset the desired level of the current and voltage during operation, hold the HIGH VOLTAGE OFF switch and rotate the appropriate control dial while noting its corresponding meter reading. Release the HIGH VOLTAGE OFF switch.

NOTE: No actual output is being produced at this stage.

J) Depress the HIGH VOLTAGE ON switch. The light inside the switch should light up and the output will slow start to the preset level output voltage and/or output current.

Note: The X2364 is equipped with a slow start circuit that ramps the output up to its maximum setting in approximately 6 seconds after the HIGH VOLTAGE ON switch is depressed.

K) To terminate the generation of output power, depress the HIGH VOLTAGE OFF switch. In the HIGH VOLTAGE OFF mode the power supply's fault and interface circuits are still active.

L) To turn off the power supply, turn the circuit breaker to the off position (0).

WARNING

AFTER TURNOFF, DO NOT HANDLE THE LOAD UNTIL THE CAPACITANCE HAS BEEN DISCHARGED!
LOAD CAPACITANCE MAY BE DISCHARGED BY SHORTING TO GROUND.

WARNING

THE VOLTMETER ON THE POWER SUPPLY FRONT PANEL DOES NOT READ THE OUTPUT VOLTAGE WHEN THE POWER IS TURNED OFF, EVEN IF A CHARGE STILL EXISTS ON THE LOAD.

CAUTION

ALWAYS OPERATE THE UNIT WITH THE COVER ON.

A fan maintains safe operating temperature in the X2364 power supply by drawing air over the circuit components. The cover must be on in order to direct the airflow over the areas that need cooling. In operation, the unit must be places so that the air intake and the fan exhaust are clear of any obstructions that might impede the flow of air.

3.2 Standard Features

A note on remote signal grounding. Whenever applicable, electrical isolation should be provided when interfacing with any high voltage power supply. For power control signals such as EXTERNAL INTERLOCK, COOLING FAULT and Fail Safe Lamp isolated relay contacts or switches should be used. Spellman application engineers are available to assist in interface circuitry design. All interface cables should be properly shielded.

REMOTE CONTROL via RS232 Interface: Please refer to the RS232 Interface Manual incorporated herein.

EXTERNAL INTERLOCKS: Interlock connections are provided on the terminal on the rear of the chassis for connection to a safety switch. The unit will not operate unless the interlock circuit is closed. If the interlock is not being used, the jumper installed on the terminals. If there is an open between the interlock terminals the unit's high voltage inverter will be disabled. During high voltage operation, opening the interlock circuit will cause the unit to revert to the HIGH VOLTAGE OFF mode. Subsequent closing of the interlock circuit will NOT return the unit to HIGH VOLTAGE ON mode, this must be accomplished by depressing the HIGH VOLTAGE ON switch. See Figure 3.2 for the recommended interface circuit.

ARC DETECT / ARC QUENCH ARC COUNT: The ARC DETECT circuit senses dynamic arcing or discharge conditions present at the output load. If an arc occurs, the output is inhibited for one second. After the one-second period, the output is ramped up to the previous set level. This ramp is based on the standard six-second slow start feature. The ARC DETECT ramp circuit may be disabled by removing CR35 on the Control/Power PWB. Caution should be observed if this feature is disabled. Discharge rates of greater than 1 Hz may cause excessive power dissipation in the power supply's output limiting resistors.

The ARC COUNT feature will allow the user to program the ARC fault parameters. The ARC indicator on the front panel will illuminate for approximately one second after each arc has occurred. The power supply can be programmed to trip to the POWER DOWN mode if an arc occurs. The standard feature is programmed to trip the power supply if 8 arcs occur within a twenty second period. **FAIL SAFE LAMP INDICATOR:** A Fail Safe Lamp indicator for remote indication of HV ON mode. The lamp is ON when HV is ON. If the lamp becomes defective or is not connected, the HV is disabled and the INTLK OPEN on the front panel is lit. The lamp rating must be 12V, 120mA. See Figure 3.3 for recommended interface.

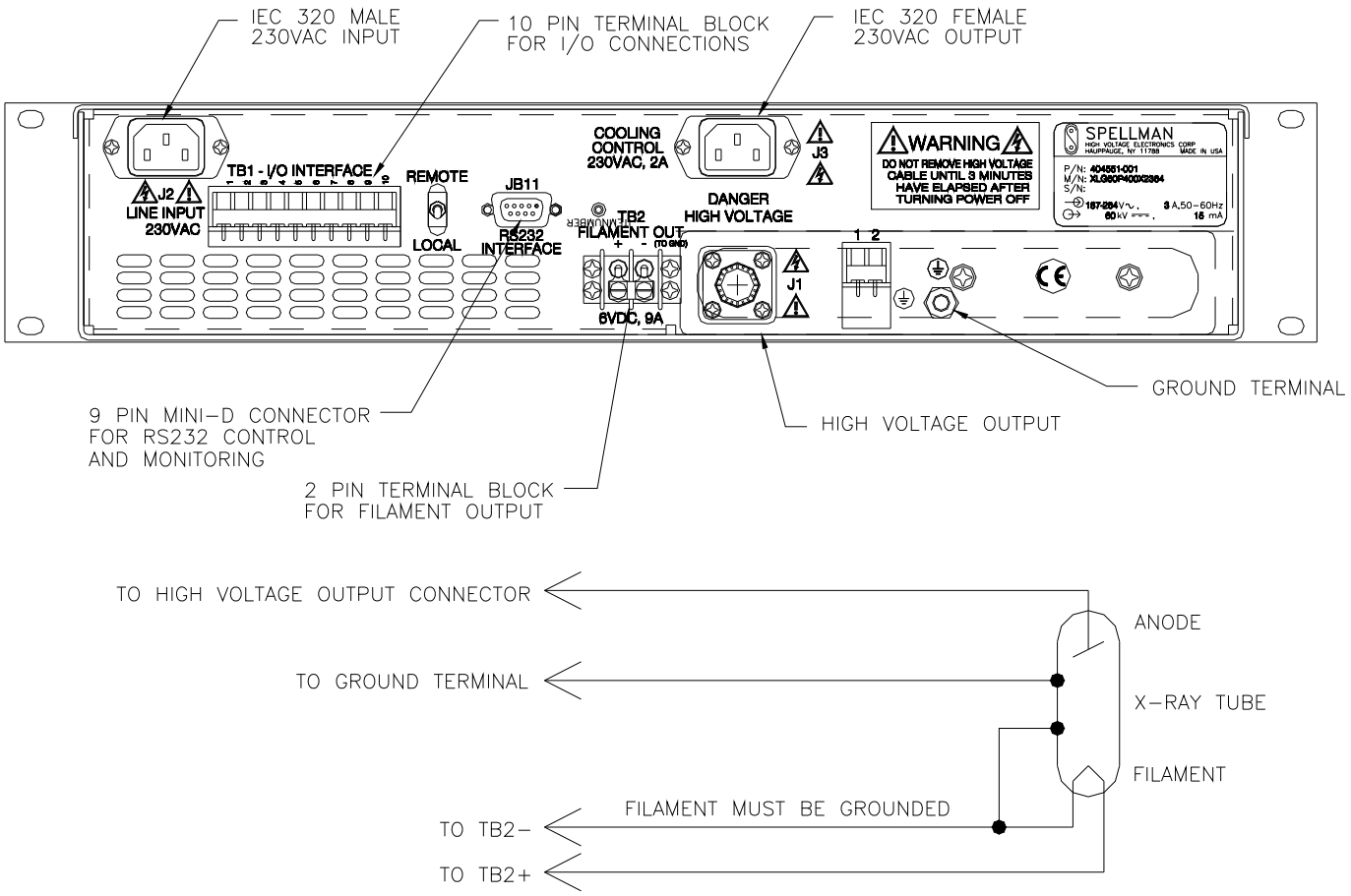

Figure 3.1 Typical Operating Setup X2364
Rear Panel

It is recommended to use isolated contacts / switches or relays for both interlocks.
They should be located as close as possible to the power supply
Signals are ~ 15Vdc, 25mA max and are only to be used for contact closure.

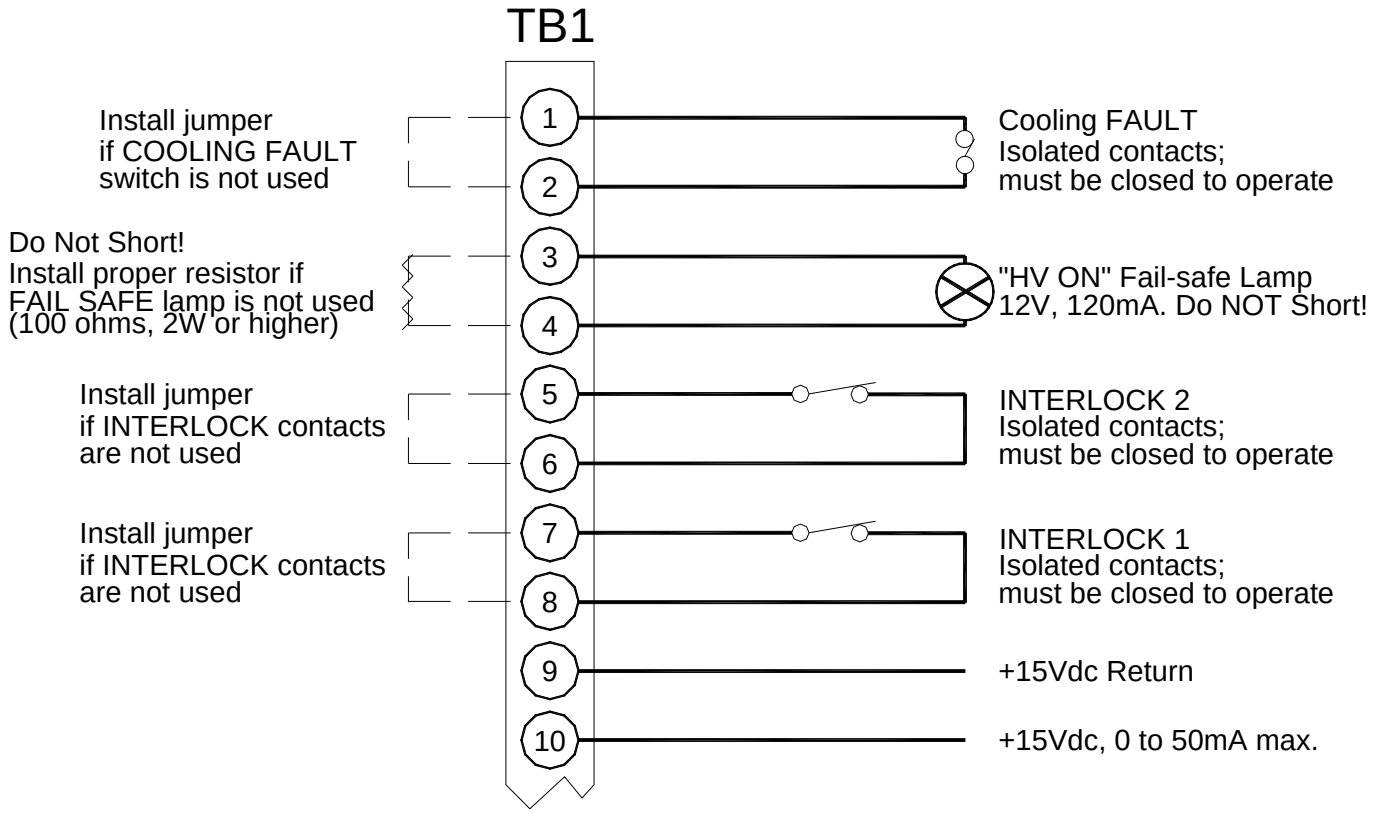

Figure 3.2 Rear Panel I/O Interface

Chapter 4

PRINCIPLES OF OPERATION

The X2364 high voltage power supply utilizes sophisticated power conversion technology. A variety of analog, digital and power conversion techniques are used throughout. The intention of the Principles of Operation is to introduce the basic function blocks that comprise the X2364 power supply. For details on a specific circuit, consult Spellman's Engineering Department.

See Table 4.1 for a list of the main assemblies found in the X2364 power supply.

The X2364 power supply is basically an AC to DC converter. Within the power supply, conversions of AC to DC, then high frequency AC, then to high voltage DC take place. By reviewing further the sub-assemblies, a basic understanding of the process can be gained.

4.1 Chassis

The X2364 is a compact, high efficiency, high voltage power supply. The power supply can supply up to 400 watts of DC power. Output voltages of up to 60kV can be generated.

WARNING

The energy levels used and generated by the power supply can be lethal! Do not attempt to operate the power supply unless the user has a sufficient knowledge of the dangers and hazards of working with high voltage. Do not attempt to approach or touch any internal or external circuits or components that are connected or have been connected to the power supply. Be certain to discharge any stored energy that may be present before and after the power supply is used. Consult IEEE recommended practices for safety in high voltage testing #510-1983.

4.2 Line Rectification and Filtering

Basic single-phase rectification provides the DC voltage for the high frequency inverter. The line input voltage can vary from 187 up to 264 volts within the X2364.

Circuit protection is provided by CB1 (SYSTEM BLOCK DIAGRAM). CB1 is a fast acting magnetic trip type circuit breaker. The line input is connected directly to the line side of CB1. The load side of CB1 is connected to the CONTROL/POWER PWB. The load side of CB1 is also connected to T1 and, via. the HV ON/OFF relay to the Remote Cooling Control socket. T1 is a step-down type line transformer. T1 provides voltage for housekeeping and control circuit power.

WARNING

LINE VOLTAGE IS PRESENT WHENEVER THE POWER SUPPLY IS CONNECTED TO EXTERNAL LINE VOLTAGES. BE SURE TO DISCONNECT THE LINE CORD BEFORE OPENING THE UNIT. ALLOW 5 MINUTES FOR INTERNAL CAPACITANCE TO DISCHARGE BEFORE REMOVING ANY COVER.

When CB1 is ON, voltage is applied to CR10. CR10 is an isolated diode rectifier bridge that contains the rectifier diodes used for line voltage rectification. The output of CR10 is connected to a capacitor filter (C11 through C14). Capacitors are initially charged through resistive inrush limiters.

Approximately 1 second after CB1 is turned on, a relay is energized to short the resistor limiters. This relay is K1. This DC voltage is supplied to the high frequency inverter.

The DC rails are connected to the high frequency rail capacitors. These capacitors are high frequency, low loss type. Capacitors C21 and C22 provide the energy storage for the high frequency inverter.

	X2364
ASSEMBLY TITLE	ASSEMBLY NO.
System Interconnect Top Assy	404551-001
Power/Cont Bd	404560-001
Multiplier Assy	403932-062
Filament Board	404241-004
Front Panel Bd	403895-005

Table 4.1 List of Main Assemblies

4.3 Inverter

The inverter is a series resonant, series/parallel loaded topology. A proprietary control scheme is used for regulating the power generated from the inverter. Q3 is a module of two high speed IGBT's. This device provides high frequency switching to control the resonant current flow. The typical resonant operating period is approximately 10uSeconds. The gate control for the switching devices is provided by T2 on the CONTROL/POWER PWB. U4 and U5 are the gates high current drivers. T2 provides line voltage isolation

4.4 High Voltage Transformer

The output of the High Frequency Resonant Inverter is connected to the primary of the High Voltage Transformer. The High Voltage Transformer is a step-up type. Typically secondary voltage is approximately 5kV peak at full output.

4.5 High Voltage Assembly

The High Voltage consists of a full wave, full bridge multiplier. It utilizes various parallel/series arrangements of a full wave voltage doubler.

Output filtering is typically provided by the capacitors of the multiplier. Voltage feedback for regulation and monitoring is provided by a high bandwidth resistive/capacitive divider. Current feedback for regulation and monitoring is provided by a sense resistor connected at the low voltage end of the High Voltage Rectifier/Multiplier Circuit.

4.6 Control/Power PWB

The majority of control circuits for power supply controls are located on the CONTROL/POWER PWB.

+15VDC, -15VDC, and +10VDC is generated on the CONTROL/POWER PWB. High Voltage On/Off control is accomplished by K3, and its associated circuitry. Interlock control is provided by K4.

Voltage feedback from the high voltage divider is sent to U9. Gain adjust is provided on the FILAMENT PWB. The KV feedback signal is sent to the front panel DVM and to the RS232 REMOTE INTERFACE PWB for remote monitoring. K2 provides switching between feedback and program signal for the front panel DVM's. This allows the user to preset the desired output before energizing high voltage.

Program voltages are typically ramped up to set level by the slow start circuits of U10.

Arc sense circuits U15 and U18 provide sensing, quench and indication of arc conditions.

Current feedback from the high voltage rectifier is sent to sense resistors located on the FILAMENT PWB. Calibrated feedback is then sent to U6.

An overvoltage protection circuit provides protection in the unlikely event of a main control loop failure. R74 and R75 provide the threshold for the overvoltage protection (OVP) control.

U13 and U19 circuits provide visual indication of the control mode, which is in operation. These signals are sent to the FRONT PANEL ASSEMBLY for front panel status indication.

The resonant control circuitry consists of a voltage to frequency and voltage to pulse width converter. U22 generates all frequency and pulse width control signals. U21 provides specific control functions for the resonant control.

System Fault Control and Indication is provided by U23 U24, and U25 and associated circuitry. Diagnostic signals are latched and then sent to the FRONT PANEL ASSEMBLY for status indication.

4.7 Front Panel Assembly

Front Panel control meters, and status indications are connected to the FRONT PANEL PWB. The FRONT PANEL PWB interfaces directly to the CONTROL/POWER PWB.

4.8 Filament Supply PWB

The power for the X-ray tube is provided by the filament inverter. The filament inverter is a high frequency, series resonant inverter. The inverter provides regulated current to the primary of the filament transformer. The filament isolation transformer output is then rectified by CR8 and CR9, filtered by C6 through C11, and then connected to the output block terminal TB1.

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Chapter 5

MAINTENANCE

This section describes periodic servicing and performance testing procedures.

WARNING

THIS POWER SUPPLY GENERATES VOLTAGES THAT ARE DANGEROUS AND MAY BE FATAL. OBSERVE EXTREME CAUTION WHEN WORKING WITH HIGH VOLTAGE.

5.1 Periodic Servicing

Approximately once a year (more often in high dust environments), disconnect the power to the unit and remove the top cover.

5.2 Performance Test

WARNING

HIGH VOLTAGE IS DANGEROUS.

ONLY QUALIFIED PERSONNEL SHOULD PERFORM THESE TESTS.

High voltage test procedures are described in Bulletin STP-783, Standard Test Procedures for High Voltage Power Supplies. Copies can be obtained from the Spellman Customer Service Department. Test equipment, including an oscilloscope, a high impedance voltmeter, and a high voltage divider such as the Spellman HVD-100 or HVD-200, is needed for performance tests. All test components must be rated for operating voltage.

5.3 High Voltage Dividers

High voltage dividers for precise measurements of output voltage with an accuracy up to 0.1% are available from Spellman. The HVD-100 is used for voltages up to 100KV. The HVD-200 measures up to 200KV. The Spellman divider is designed for use with differential voltmeters or high impedance digital voltmeters. The high input impedance is ideal for measuring high voltage low current sources, which would be overloaded by traditional lower impedance dividers.

Chapter 6

REPLACEMENT PARTS

6.1 Replacement Parts

Cotact the Spellman Customer Service Department for parts lists for specific models.

Spellman provides parts and subassemblies for its high voltage power supplies but recommends that only qualified personnel perform the repair. High voltage is dangerous; even minor mistakes in repairs can have serious consequences.

When requesting parts please give the model number and serial number of the power supply

6.2 Correspondence And Ordering Spare Parts

Each Spellman power supply has an identification label on the rear of the chassis that bears its model and serial number.

When requesting engineering or applications information, please state the model and serial number of the power supply. If specific components or circuit sections are involved in the inquiry, it is helpful to indicate the component symbol number(s) shown on the applicable printed circuit board..

When ordering spare parts, please specify the part's description, the part's reference designation or part number, and the model and serial number of the unit.

Chapter 7

FACTORY SERVICE

7.1 Warranty Repairs

During the Warranty period, Spellman will repair all units free of charge. The Warranty is void if the unit is worked on by other than Spellman personnel. See the Warranty in the rear of this manual for more information. Follow the return procedures described in Section 7.2. The customer shall pay for shipping to and from Spellman.

7.2 Factory Service Procedures

Spellman has a well-equipped factory repair department. If a unit is returned to the factory for calibration or repair, a detailed description of the specific problem should be attached.

For all units returned for repair, please obtain an authorization to ship from the Customer Service Department, either by phone or mail prior to shipping. When you call, please state the model and serial numbers, which are on the plate on the rear of the power supply, and the purchase order number for the repair. A Return Material Authorization Code Number (RMA Number) is needed for all returns. This RMA Number should be marked clearly on the outside of the shipping container. Packages received without an RMA Number will be returned to the customer. The Customer shall pay for shipping to and from Spellman.

A preliminary estimate for repairs will be given by phone by Customer Service. A purchase order for this amount is requested upon issuance of the RMA Number. A more detailed estimate will be made when the power supply is received at the Spellman Repair Center. In the event that repair work is extensive, Spellman will call to seek additional authorization from your company before completing the repairs.

7.3 Shipping Instructions

All power supplies returned to Spellman must be sent shipping prepaid. Pack the units carefully and securely in a suitable container, preferably in the original container, if available. The power supply should be surrounded by at least four inches of shock absorbing material. Please return all associated materials, i.e. high voltage output cables, interconnection cables, etc., so that we can examine and test the entire system.

All correspondence and phone calls should be directed to:

Spellman High Voltage Electronics Corp.
475 Wireless Boulevard
Hauppauge, New York 11788
TEL: (631) 630-3000 FAX: (631) 435-1620
E-Mail: sales@Spellmanhv.com
http://www.spellmanhv.com

Chapter 8

RS232 INTERFACE MANUAL

This document describes the specific implementation of the Spellman – Customer RS-232C Serial Data Interface. This interface is an add-on to the Spellman XLG Power Supply. Its purpose is to provide remote monitoring and control capability of certain analog and digital functions. The interface is microcontroller-based and is built on a module that interfaces with the power supply control assembly. Since the data link between the Customer computer and the Spellman Power Supply is fully dedicated and hardwired (there are no intermediate devices such as modems), none of the RS-232C handshaking signals are required.

The interface uses ASCII encoded character strings for data transmission. Transmission error checking is implemented using modulo 256 checksums. The transmission format is 9600 baud, no parity and one stop bit.

The interface within the power supply acts strictly as a slave device. It will not transmit any messages over the data link unless it is first commanded to by the Customer master computer.

The design is based on the 87C552 microcontroller. This unit has a built-in eight channel analog multiplexer and 10-bit A/D Converter. To perform D/A conversions, we are using external 12-bit D/A Converters. To meet our resolution requirements of 0.1%, 10 bits is the maximum number of bits that can be used.

8.1 RS232 Overview

RS-232C is used with single-ended transmission over relatively short lines. The standard defines the electrical characteristics for the interfacing of Data Terminal Equipment (DTE) and Data Communications Equipment (DCE). **In our case, the Customer Computer is the DTE and the Spellman Power Supply equipment is the DCE.**

RS-232C recommends the use of DB-25 female connector jacks mounted of the DCE (the power supply) equipment. However, since none of the RD-232C handshaking lines will be used, a DB-9 female connector will be used to save space.

The DB-9 connector will be configured to work with a "standard" 9 pin IBM PC-AT compatible communications port as defined below. If the power supply is connected to a "standard" 25 pin communications port the interconnect cable must reverse pins 2 and 3 as shown in Table 8.1.

The required signal connections at the power supply's DB-9 connector are:

Pin 2 – RxD – Receive Data
(computer receive line / power supply transmit line)

Pin 3 – TxD – Transmit Data
(computer receive line / power supply receive line)

Pin 5 – GND – Ground Signal

Pin 1, 4 and 6 of the power supply's BD-9 connector are shorted together at the connector.

Pin 7 and 8 of the power supply's BD-9 connector are shorted together at the connector.

Pin 9 of the power supply's BD-9 connector is not used.

The ASCII codes that are used by the data interface are shown in Table 8.2.

SIGNAL NAME	DB-9 PINOUT	DB-25 EQUIV	COMMENTS (pins refer to DB-9)
Data Carrier Detect (DCD)	1	8	Shorted to pins 4 & 6
Receive Data (RxD)	2	3	Power supply transmit line
Transmit Data (TxD)	3	2	Power supply receive line
Data Terminal Ready (DTR)	4	20	Shorted to pins 1 & 6
Signal Ground (GND)	5	7	Signal ground
Data Set Ready (DSR)	6	6	Shorted to pins 1 & 4
Request to Send (RTS)	7	4	Shorted to pin 8
Clear To Send (CTS)	8	5	Shorted to pin 7
Ring Indicator (RI)	9	22	Not used

TABLE 8.1 DB-9 I/O PIN-OUT

CHARACTER SENT	ASCII CODE	COMMENTS
SOH	01	Start of Header
<CR>	0D	Carriage Return
0	30	
1	31	
2	32	
3	33	
4	34	
5	35	
6	36	
7	37	
8	38	
9	39	
A	41	USE CAPITAL LETTERS
B	42	
C	43	
D	44	
E	45	
F	46	
Q	51	
R	52	
S	53	
V	56	

TABLE 8.2 Relevant ASCII Codes

8.1.1 Signal Summary

The data interface receives and transmits digital data packets between the Customer computer and the Spellman power supply that represent the analog and digital signals defined below:

Analog Control Signals sent from Customer Computer to Spellman Power Supply:

1. Voltage Control (0 – FFF hex represents 0-60 kilovolts output)
2. Current Control (0 – FFF hex represents 0-15 milliamperes output)

Internal to the power supply interface, the D/A converters have an analog output range of 0 to +10 volts DC, where FFF hex represents full scale.

Digital Control Signals sent from Customer Computer to Spellman Power Supply:

1. X-ray On (0 = off, 1 = on)
2. X-ray Off (0 = on, 1 = off)

(This function also provides reset)

Programming a digital control bit to a "1" will generate an internal 250 millisecond pulse that will assert the desired function.

Analog Monitor Signals sent from Spellman Power Supply to Customer Computer:

3. Voltage Monitor (0 – 3FF hex represents 0-60 kilovolts output)
4. Current Monitor (0 – 3FF hex represents 0-15 milliamperes output)

Internal to the power supply interface, the A/D converters have an analog input range of 0 to +5 volts DC, where 3FF hex represents full scale.

Digital Monitor Signals sent from Spellman Power Supply to Customer Computer:

1. Cooling Fault (1 = fault)
2. Overcurrent Fault (1 = fault)
3. Overpower Fault (1 = fault)
4. Overvoltage Fault (1 = fault)
5. Arc Fault (1 = fault)
6. Regulation Error Fault (1 = fault)
7. Interlock Status (0 = closed, 1 = open)
8. Local/Remote Control Mode Indicator (0 = local, 1 = remote)

8.2 Command Structure

The general operation of the data link is described in this section.

The Customer computer can send three possible commands to the Spellman power supply:

SET POWER SUPPLY (S) command

QUERY POWER SUPPLY (Q) command

SOFTWARE VERSION LEVEL REQUEST (V) command.

The **SET** command contains a total of 18 bytes and instructs the power supply to change any or all of its control signals. The power supply may execute the Set command and respond with a simple 2 byte ACKNOWLEDGE (A) packet, or, if errors are detected, the power supply will not execute the Set command but will return a 5 byte ERROR (E) packet.

A **Query** command contains a total of 5 bytes, and is used to request that the power supply return an information packet containing analog and digital information that it monitors. The power supply responds by sending back a 16 byte RESPONSE (R) packet.

In response to a 5 byte Version Request command, the power supply will return a 6 byte **SOFTWARE VERSION LEVEL RESPONSE PACKET (B)** packet to the computer.

For all three commands, if communication errors or illegal conditions are detected by the power supply, the command will not be executed and the appropriate 5 byte **ERROR (E)** packet will be sent back to the computer.

8.2.1 Set Command ("S") and Acknowledge ("A") Response

Prior to sending a Set Command that performs any function other than a Power Supply Reset, the computer should ensure that no fault conditions are existing within the power supply. This is done by first sending a Query Command and examining the returned Response Packet.

BYTE #	DESCRIPTION
1	Start of message character ("SOH" character; hex 01)
2	Command Identifier Character (S character, hex 53)
3-5	Voltage Command (0-60kV corresponds to 0-FFF hex)
6-8	Current Command (0-15mA corresponds to 0-FFF hex)
9-11	000 hex
12-14	000 hex
15	Digital control data (X-ray ON, X-ray OFF Power Supply Reset)
16-17	Modula 256 Checksum of all previous bytes except start Character
18	End of message character (carriage return, hex OD)

TABLE 8.3 SET Command Byte Contents

Note that it is legal to send a SET command that does not assert either of the digital controls (X-ray On or X-ray Off). For example, if X-rays were in and it was desired to change one or more of the two analog controls, a command packet could be sent containing the new values for the analog controls but with the digital control bits set to 0. In this case, the analog values will be changed and X-rays will remain on.

If one or more of the six digital fault monitor signals (signals 1 through 6 listed under "Digital Monitor Signals…" of section 8.1.1) are active, the Set command packet must include a Power Supply Reset assertion.

The **Set** Command is only valid when the power supply is set to the Remote Mode.

The protocol for the **Set** Command is as follows:

The power supply receives the "S" command and performs a checksum comparison and other error checking. If a communication or other error is detected, the power supply will not execute the command but will send an error message back to the computer. If the checksum compares properly and no errors exist, the power supply will execute the Set command and return a simple 2 byte Acknowledgement message. The computer should then Query the power supply to be sure that the power supply parameters are set as desired.

The data will be ASCII encoded, where scaling is done in the Customer computer. The resolution for the two analog controls is 12 bits, so full scale will be represented by FFF hex. The first byte, "SOH", can be entered at the keyboard by the "CONTROL-A" key combination ("CTL-A").

All alphabetical entries should use **CAPITAL** letters only. Use of lower case letters will result in errors.

The byte definitions of the command message are shown in Table 8.3. Note that high order bytes are sent first.

An example will illustrate the ASCII data protocol is used. Assume that the Customer computer sends a command to the power supply that sets the analog power parameters to 33kV, 3.75 milliamperes current, and asserts the digital X-ray On control.

The following 18 byte packet will be sent:

Byte 1 will contain the ASCII character SOH, which will be sent as 01 hex = 0000 0001 binary (enter Ctrl-A at the computer keyboard).

Byte 2 is the Set Power Supply command identifier character S. In ASCII, this is 53 hex = 0101 0011 binary (enter capital S at the computer keyboard).

Byte 3 through 5 represents the voltage. 33,000 volts is 55% of full scale. Full scale (60,000 volts) with 12 bit resolution is FFF-hex. 33,000 volts is therefore represented as 8CC hex (within an error of 1 lsb). Bytes 3-5 will be sent containing the ASCII representation of 8CC (enter 8CC at the computer keyboard):

Byte 3: 38 hex = 0011 1000 binary
Byte 4: 43 hex = 0100 0011 binary
Byte 5: 43 hex = 0100 0011 binary

Byte 6 through 8 represents the current. 3.75 milliamperes is 25% of full scale. Full scale (15mA) with 12 bit resolution is FFF hex. 3.75mA is therefore represented as 3FF hex (within an error of 1 lsb). Bytes 6-8 will be sent containing the ASCII representation of 3FF hex (enter 3FF at the computer keyboard).

Byte 6: 33 hex = 0011 1011 binary
Byte 7: 46 hex = 0100 0110 binary
Byte 8: 46 hex = 0100 0110 binary

Byte 9 through 11 are required to fill in the control string. 000 hex should be entered. Bytes 9-11 will be sent containing the ASCII representation of 000 hex (enter 000 at the computer keyboard).

Byte 9: 30 hex = 0011 0000 binary
Byte 10: 30 hex = 0011 0000 binary
Byte 11: 30 hex = 0011 0000 binary

Byte 12 through 14 are required to fill in the control string. 000 hex should be entered. Bytes 12-14 will be sent containing the ASCII representation of 000 hex (enter 000 at the computer keyboard).

Byte 12: 30 hex = 0011 0000 binary
Byte 13: 30 hex = 0011 0000 binary
Byte 14: 30 hex = 0011 0000 binary

Byte 15 represents the digital control data. The digital control byte is assigned as follows (only the least significant four bits are encoded into the ASCII byte):

Bit 0 X-ray on (On = 1)

Bit 1 0

Bit 2 X-ray Off and reset (Off and reset = 1)

Bit 3 unused

The digital control nibble will therefore contain 0001 binary = 01 hex. The ASCII representation is (enter number 1 at the computer keyboard):

Byte 15: 31 hex = 0011 0001 binary

The checksum is calculated on all bytes before it excepts the SOH character. Bytes 16 and 17 will therefore contain the remainder of a modulo 256 addition of bytes 2 through 15. In hex, these bytes are:

53 + 38 + 43 + 43 + 33 + 46 + 46 + 30 + 30 + 30 + 30 + 30 + 30 + 31hex = 321 hex

Since modulo 256 decimal is modulo 100 hex, we can divide 321 hex by 100 hex. The remainder is 21 hex. Therefore 21 hex will be sent in bytes 16 and 17 in ASCII representation as 32 hex and 31 hex. Note that the actual implementation of the checksum by the data interface is very simple and requires no actual division. The data bytes are simply added up in an eight bit counter whose carry overflow is ignored. The result stored in the counter will be the checksum remainder (if entering the checksum directly from the computer keyboard, enter the numbers 2 and 1):

Byte 16: 32 hex = 0011 0010 binary
Byte 17: 31 hex = 0011 0001 binary

The last byte is the carriage return (press the "Enter" key on the computer keyboard), represented is ASCII as:

Byte 18: 0D hex = 0000 1101 binary.

To summarize, the entire 18 ASCII character packet will be sent as follows, where the start character, SOH = Ctrl-A = 01 hex is the first byte sent and the carriage return = 0D hex is the last byte sent:

Byte Number:

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Enter at the keyboard:

Ctrl-A S 6 C C 3 F F 0 0 0 0 0 0 1 2 1 Enter

Sent in ASCII coded hexadecimal:

01 53 38 43 43 33 46 46 30
30 30 30 30 30 31 32 31 0D

(Note that the spaces between bytes are shown for clarity only and are not actually sent).

The actual data is sent in serial binary format. Each 8-bit byte is framed with 1 start and 1 stop bit. No parity bits are being sent or received. Therefore this data packet is 180 bits long.

The data interface will receive this command and place it in a temporary memory area. Before executing the command, several checks are made. If an illegal condition is detected the command will not be executed and an error message will be sent back to the computer. The conditions that are checked are described in Section 8.4 (Errors) of this document.

If no errors are detected, the data interface will execute the command, and then send a 2 byte Acknowledge Packet back to the computer.

The format of the Acknowledge Packet is:

A <CR> where <CR> indicates the carriage return.

In ASCII coded hexadecimal: 41 0D

8.2.2 Query Command

The 5 byte command to request power supply status is the Query ("Q") command. The Query command is valid in both Local and Remote modes.

The protocol for the Query command will be as follows:

The power supply will receive a Q command requesting information. If the command is properly received with no errors detected, the power supply will return with the Response Packet back to the computer. If errors are detected in the command, the power supply will return an appropriate error message.

The format of the command is:

SOH Q Check 1 Check 2 <CR>

Entered at the keyboard:

Ctrl- A Q 51 Enter

Sent in ASCII coded hexadecimal:

01 51 35 31 0D

where the checksum, which does not include the SOH character, will always be hex 51, transmitted in two ASCII bytes representing 5 and 1.

8.2.3 Response Packet (R)

The 16 byte Response packet will be returned to the computer in response to a valid Query command. It will contain status information in the following order:

BYTE#	DESCRIPTION
1	Response identifier character "R"
2-4	Voltage Monitored (0-60kV corresponds to 0-3FF hex)
5-7	Current Monitored (0-5mA corresponds to 0-3FF hex)
8-10	Not used by the system (0-3FF hex)
11-13	Digital Monitors (9 bits encoded in three ASCII bytes)
14-15	Modulo 256 checksum of bytes 2-13

TABLE 8.4 – Response Packet Byte Contents

Note that the analog monitors have 10 bit resolution, therefore, full scale is represented in hexadecimal as 3FF. **The checksum is calculated of bytes 2 through 13.**

The eight digital monitor status bits are sent as ASCII characters. The bit assignments are:

Byte 11:

Bit 0	Arc Fault (1 = fault)
Bit 1	Regulation Error Fault (1 = fault)
Bit 2	Over Temperature (1 = fault)
Bit 3	Interlock Status Indicator (0 = closed)

Byte 12:

Bit 0	Cooling Fault (1 = fault)
Bit 1	Overcurrent Fault (1 = fault)
Bit 2	Unused
Bit 3	Overvoltage Fault (1 = fault)

Byte 13:

Bit 0	Local/Remote Mode Indicator Fault (1 = fault)
Bit 1	Unused
Bit 2	Unused
Bit 3	Unused

For example, a monitored voltage of 60kV will correspond to 3FF hex, sent with ASCII encoding as follows:

Byte 2: 33 hex
Byte 3: 46 hex
Byte 4 46 hex

If X-rays were On, there was an Overvoltage fault and we were in Remote Mode, the digital status bytes will be:

Byte 11: 33 hex (0000 binary = 0 hex)
Byte 12: 38 hex (1000 binary = 8 hex)
Byte 13 31 hex (0001 binary = 1 hex)

8.2.4 Software Version Request ("V") command and Response ("B")

The 5 byte command to request the software revision level of the power supply's data interface is the "V" command. **The Version command is valid in both Local and Remote modes.**

The protocol for the V command will be as follows:

The power supply will receive a V command requesting information. If the command is properly received with no errors detected, the power supply will return the 6 byte Version Response (B) packet back to the computer. If errors are detected in the V command, the power supply will return an appropriate error message.

The format of the V command is:

SOH V Check 1 Check 2 <CR>

Entered at the keyboard:

Ctrl- A V 6 Enter

Sent in ASCII coded hexadecimal:

01 56 35 36 0D

where the checksum, which does not include the SOH character, will be hex 56, transmitted in two ASCII bytes representing 5 and 6.

The format of the 6 byte Respense Packet (B) will be:

B 2 byte revision level 2 byte checksum <CR>

For example, if a V command was properly received by a data interface with software revision level 25, the following packet will be returned kto the computer:

B 2 2 byte Checksum <CR>

Sent in ASCII coded hexadecimal:

42 32 35 36 37 0D

Since the checksum of 32 hex + 35 hex is 67 hex which is transmitted on ASCII as two bytes containing 36 and 37 hex.

8.3 Local / Remote Communication Mode

A rear panel switch of the power supply will determine whether the power supply will be controlled locally (from the power supply's front panel) or remotely (from the Customer computer via the data link).

In Local Mode, the power supply will be controlled only via its own front panel. If the Customer computer attempts to change any of the controlled parameters using a Set command the data interface will ignore the command and return an error message (Error 1) back to the computer.

In **Local** Mode, the data interface will, however, respond to either a Query (Q) or Version (V) request command by returning the requested information in a Query Response (R) or a Version Response (B) status packet.

In **Remote** Mode, the power supply will respond to S and Q or V commands. In this mode, controlled parameters can be changed only via the S command from the computer. The front panel pots will be inoperative, although the front panel indicators and switches will continue to function.

8.4 Error Responses (E) and Illegal Conditions

Error responses are messages sent back to the computer in response to a communication error detected on receipt of an S, Q or V command or an illegal setting in an S command. The 5 byte error response packet takes the following form:

E 1 byte error code 2 byte checksum <CR>.

The checksum is only calculated on the 1 byte error code. For example, for error 6, the error byte will be transmitted as 36 hex. The checksum of 36 hex is 36 hex which is transmitted in ASCII as two bytes containing 33 and 36 to represent the 3 digit and 6 digit, respectively.

Error codes are:

1. Local Mode Error – a Set command was attempted while the power supply was set to Local Mode. A **Set** command will only be executed when the Power Supply is set to the Remote Mode. The error packet that will be returned to the computer will be:

Characters sent:

E 1 3 1 <CR>

Sent in ASCII coded hexadecimal:

45 31 33 31 0D

Since the checksum of 31 hex is 31 hex which is transmitted in ASCII as two bytes containing 33 and 31.

2. Undefined Command Code – the command character received was not an S, Q or V. The power supply will send back this error message if the second character of the received command packet is not an S, Q or V. The error packet that will be returned to the computer will be:

Characters sent:

E 2 3 2 <CR>

Sent in ASCII coded hexadecimal:

45 33 33 32 0D

3. Checksum Error – the transmitted checksum received in the command packet did not match the checksum calculated on the received bytes. The error packet that will be returned to the computer will be:

Characters sent:

E 3 3 3 <CR>

Sent in ASCII coded hexadecimal:

45 33 33 33 0D

4. Extra Byte(s) Received – a byte other than the carriage return character was received in the last expected byte position of the command. The error packet that will be returned to the computer will be:

Characters sent:

E 4 3 4 <CR>

Sent in ASCII coded hexadecimal:

45 34 33 34 0D

5. Illegal Digital Control Byte in Set Command – only one of the following two conditions can be set in the digital control byte of the Set command at any one time:

X-ray On
X-ray Off and Reset

If the computer requests that the power supply set more than one of the above conditions simultaneously, error 5 will be generated. The error packet that will be returned to the computer will be:

Characters sent:

E 5 3 5 <CR>

Sent in ASCII coded hexadecimal:

45 35 33 35 0D

6. Illegal Set Command Received While a Fault is Active – if a fault is active at the time a **Set** command is received, the command muse assert the X-ray Off / Reset command. If the computer attempts to turn X-rays On, or to change only the analog control signals while the fault is active, the command will be rejected and error 6 will be generated. The error packet that will be returned to the computer will be:

Characters sent:

E 6 3 6 <CR>

Sent in ASCII coded hexadecimal:

45 36 33 36 0D

The fault signals that are checked are:

Cooling Fault

Overcurrent Fault

Overpower Fault

Overvoltage Fault

Arc Fault

Regulation Error Fault

Interlock Status
(open is interpreted as a fault)

8.5 Command Summary

Commands sent from the computer to the power supply start with the "SOH" character followed by a command identifier letter. The defined commands from the computer to the power supply are:

S - Set Power Supply (contains desired power supply settings) – 18 bytes.

Q - Query Power Supply (requests that the power supply returns to the computer a Response Packet) – 5 bytes.

V - Request Power Supply Software Version Level – 5 bytes.

Responses from the power supply back to the computer start with an A, R, E or B character:

A – Acknowledge Response Packet – 2 bytes

R – Data Response Packet – 16 bytes

E – Error Response Packet – 5 bytes

B – Software Version Level Response Packet – 6 bytes

All command and response packets end with a carriage return character <CR>.

To obtain information on Spellman's product warranty please visit our website at:

http://www.spellmanhv.com/en/About/Warranty.aspx