

# Instruction Manual

## CCM SERIES

### High Voltage Power Supply

MODEL :  
SERIAL# :  
DATE :

**SPELLMAN  
HIGH VOLTAGE ELECTRONICS  
CORPORATION**

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- **COMPACT & LIGHTWEIGHT PACKAGE**
- **POWER FACTOR CORRECTED INPUT**
- **LOW COST MODULAR OEM PLATFORM**
- **RUGGED IGBT INVERTER DESIGN**
- **AUXILIARY +24VDC @ 2.2 AMP OUTPUT PROVIDED**

[www.spellmanhv.com/manuals/CCM](http://www.spellmanhv.com/manuals/CCM)

Spellman's CCM capacitor charging module is designed to provide 3100 joules per second at an output voltage up to 4000 Volts. With a power density of 6.6 watts per cubic inch, the CCM packs more than 30% more power into the same volume when compared to other commercially available units. The power factor corrected AC input, small package size and comprehensive analog interface simplifies integrating the CCM into your OEM system design. Available in either positive or negative polarity, the CCM is fully arc, open and short circuit protected.

### TYPICAL APPLICATIONS

UV light sources for curing and sterilization  
Industrial and medical laser applications  
ICP-MS applications

### SPECIFICATIONS

#### Input Voltage:

180-264 Vac, 47-63 Hertz, power factor corrected input  
≥0.98, fused via externally accessible fuses

#### Efficiency:

>85%

#### Output Power:

3100 Joules per second, average

#### Output Voltage:

4000 Volts, maximum

#### Output Polarity:

Positive or negative, specify at time of order

#### Pulse to Pulse Repeatability:

±0.6% up to 120 Hertz

#### Temperature Coefficient:

≤100ppm per degree C

#### Fault Diagnostic System:

Over Temperature, Over Voltage and Open Load sensing

#### Environmental:

Temperature Range:

Operating: 0°C to 40°C

Storage: -40°C to 85°C

Humidity:

10% to 90% RH, non-condensing

#### Cooling:

Forced air

#### Ground Stud:

M6 X10mm, M6 nut supplied

#### Input Line Connector:

2 position Phoenix HDFK4 connector

#### HV Output Connector:

Kings KV-79-15, Bulkhead mounted

#### +24Vdc Output Connector:

AMP #1-350942-0

#### Dimensions:

5.81" H X 5.8" W X 14" D (148mm x 147mm x 356mm)

#### Weight:

14.5lb. (6.6kgs)

#### Regulatory Approvals:

Compliant to 2004/108/EC, The EMC Directive and  
2006/95/EC, The Low Voltage Directive.



## 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.

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# 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 EXTRÊMEMENT 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 entraîner 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 QUESTO 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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# 1 INTRODUCTION

## 1.1 DESCRIPTION OF THE CCM SERIES

This series of high voltage power supplies represents an advanced approach to capacitor charging power requirements. These power supplies incorporate a resonant output circuit topology, and a power factor correction input circuit to achieve a fast charging rate and high efficiency power conversion while generating minimal line voltage harmonics.

These achievements are made possible only by Spellman's long history in high power conversion systems. This series of power supplies utilizes a unique power factor control topology that eliminates the rectifier that is usually required on the AC input. As a result, the power factor of the supply is maintained at approximately 0.99, thus reducing the AC mains current requirement for maximum rectifier circuit efficiency and minimum parts count.

The High Voltage power conversion circuit is a high power inverter utilizing IGBT devices in a half bridge topology to drive a step up transformer and output bridge rectifier circuit. The transformer is specially designed to provide a predetermined leakage inductance; eliminating the need for a discrete inductor to act in series resonance with the output circuit reflected capacitance. Innovations such as this allow the power supply to be configured with a high degree of physical efficiency, resulting in a relatively small package size.

In addition to the main high voltage output, the CCM supply provides a 24vdc auxiliary output capable of supplying 3 amperes continuous current to a ground referenced load.

## 1.2 STANDARD FEATURES

The CCM series incorporates several standard features designed to optimize user control and safety.

**INRUSH CONTROL:** This feature limits the AC input current required to charge the rail capacitors when power is applied to avoid blowing line fuses or tripping external circuit breakers. This feature is designed to limit AC mains inrush current to less than 30 amps peak for one half cycle of the AC line power.

**INVERTER DELAY:** The high voltage inverter circuit is inhibited for approximately one second following the inrush control cycle to allow the power factor control pre-regulator to stabilize the rail power before high voltage is generated. Internal housekeeping supplies are also allowed to turn on and stabilize during this time so that reference voltages, etc. reach their correct operating levels.

**OPEN CIRCUIT FAULT SENSING:** The CCM series monitors High Voltage output and compares it to the input program signal. If this circuit detects an output level 20% greater than the program level, a latching fault is generated, which inhibits the HV inverter circuit so that no HV output is present. A condition of output 20% greater than the program will occur if the external load capacitor is removed, thus resulting in an OPEN CIRCUIT latched fault. If the program voltage is set above 8vdc, and the external load capacitor is removed, a HV OVERVOLTAGE latching fault will occur, since the overvoltage condition will be reached before the OPEN CIRCUIT condition. In either case, the HV output will be inhibited. Removing AC power for approximately 30 seconds resets the fault latch.

**OVERVOLTAGE FAULT SENSING:** The CCM series monitors High Voltage output and compares it to an internal reference. If this circuit detects an output level greater than the reference level, a latching fault is generated, which inhibits the HV inverter circuit so that no HV output is present. The internal reference is set to produce a fault condition if output voltage exceeds 4.0KVDC. Removing AC power for approximately 30 seconds resets the fault latch.

**OVERTEMP FAULT SENSING:** A thermostat switch attached to the CCM unit heat sink will cause the HV Inverter circuit to be inhibited if the heat sink temperature exceeds 80 deg C. When the heat sink cools down, the inverter inhibit will automatically be removed, and normal operation will resume.

**INHIBIT:** The high voltage inverter is inhibited by +5v on the inhibit pin of the I/O connector. A 0V signal or ground will enable the HV inverter. If the inhibit input is not connected (open circuit), the inverter will be inhibited. The inhibit signal only affects the inverter circuit, and does not affect the power factor control. DC rails are maintained at 405vdc as long as AC power is applied to the unit.

### 1.2.1 SYSTEM STATUS AND FAULT DIAGNOSTIC DISPLAY

LED indicators are provided to give the user indication of system operation and fault conditions. These can be viewed through access holes on the front panel of the unit. If a fault occurs, the power supply inverter will shut down. OPEN CIRCUIT and OVERVOLTAGE faults are latched. Removing AC power for approximately 30 seconds resets the fault latch. The OVERTEMP fault will cause the inverter to shut down until the heat sink temperature cools sufficiently, and normal operation will then resume automatically.

**POWER ON:** Indicates the 24vdc power supply is operating.

**HV ON:** Indicates the INHIBIT input is in the HV ENABLE mode.

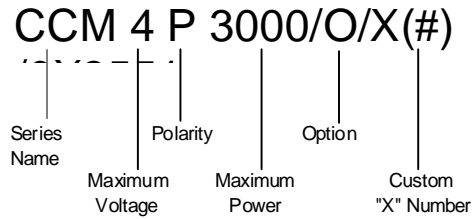
**GEN FAULT:** Indicates the OPEN CIRCUIT, OVERVOLTAGE, or OVERTEMP protection circuitry has caused the power supply to turn off.

### 1.3 OPTIONS:

The options available are listed in Table 1.1. See Section 5 for more information on these options along with operating and set-up instructions. With few exceptions, these options can be retrofitted to your power supply at the factory in a short time. For price and retrofit arrangements, contact the Spellman Sales Department.

### 1.4 INTERPRETING THE MODEL NUMBER

The model number of the power supply describes its capabilities. After the series name is:



OPTION CODE	OPTION
	THERE ARE NO OPTIONS AVAILABLE FOR THE CCM
	SERIES AT THIS TIME.

Table 1.1

## 2 INSPECTION & 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 CCM High voltage power supplies and components are covered by warranty. Custom and special order models (with an X suffix in the model number) are also covered by warranty.

### 2.2 MECHANICAL INSTALLATION

Units in the CCM series have flanges on each side for mounting. Allow access on front side for cable connections and allow at least 2 inches at front and rear of unit for cooling air intake and venting. Units are fully enclosed and are suitable for bench or tabletop operation. Standard unit dimensions are shown in Figure 2.1.

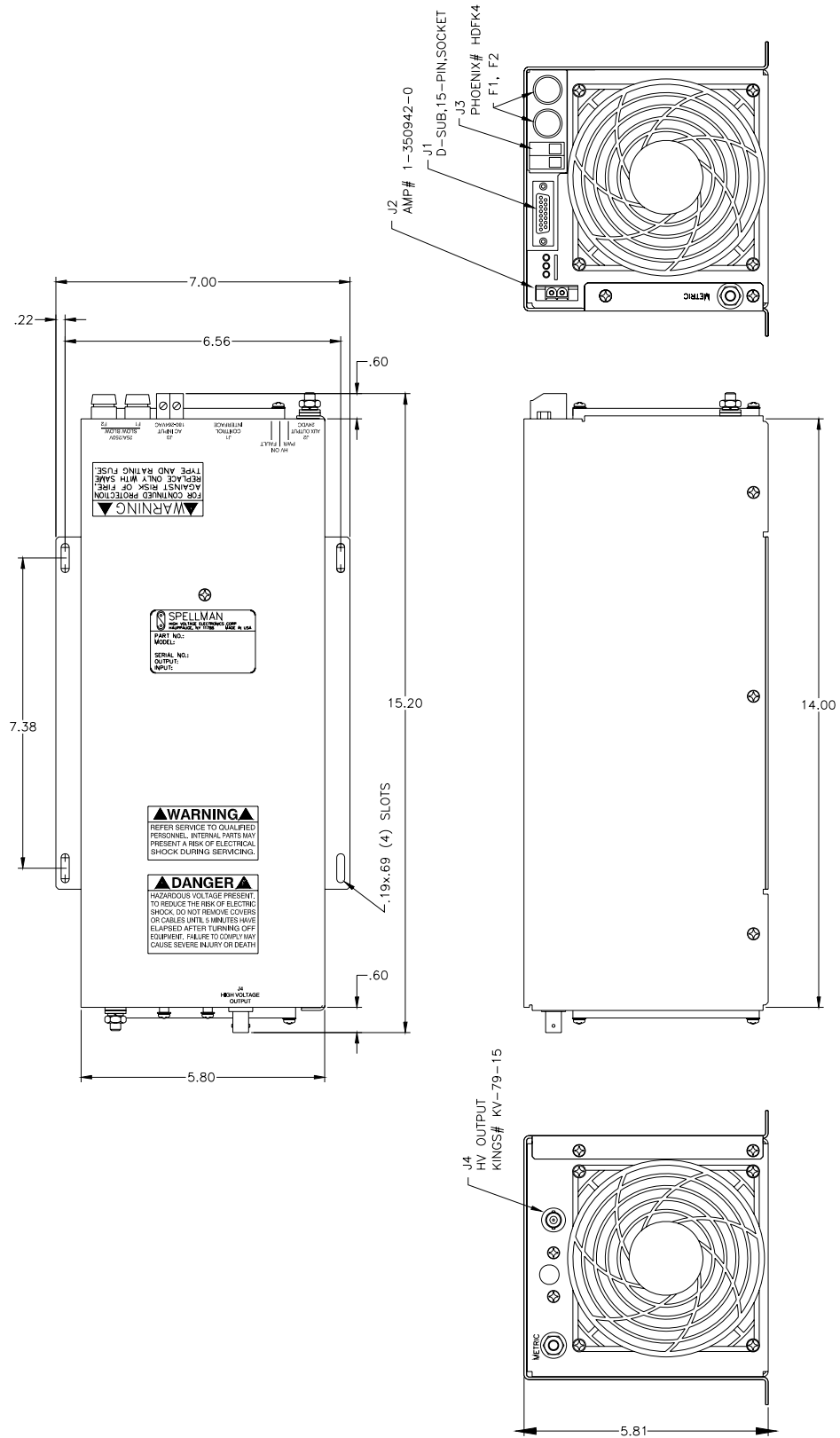


Figure 2.1 Unit Dimensions

# 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.**

### IMPORTANT:

**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 E is reached.**

**Failure to follow these procedures may void the warranty.**

A) Check the input voltage rating on the nameplate of the supply and make certain that this is the rating of the power source to be connected. Units operate on 180 - 264VAC single phase, unless ordered with a different input voltage.

B) Proper Grounding Technique: The chassis of the high voltage power supply must be grounded to the local earth ground.

C) Connect the HV cable to the output load capacitor, and to HV connector J4 on the CCM supply. If the HV output is not terminated into a capacitor of at least 0.5uf, an OPEN CIRCUIT error fault may occur.

D) For initial turn on, set the program control voltage to the zero position.

E) The input power cable may now be connected to the AC power source.

F) Depending on input voltage requirement, the line current requirements will vary. Typically, a 50Amp service is advised. If unsure of service requirements, consult Spellman's Engineering Department.

G) AC power can now remain in the ON position and HV can be turned ON and OFF via the INHIBIT signal on the I/O connector. With AC power applied, the "24v POWER" led at the front panel should be illuminated. If the HV inhibit signal is +5v (or open circuit), the HV ON led (center led) will be OFF, and the HV inverter will be disabled.

If the HV INHIBIT signal is 0v, the HV ON led will illuminate, indicating that the HV inverter is enabled.

H) The magnitude of HV output is controlled by the application of program voltage input. Program voltage of 0 to +10vdc will result in HV output from 0 to +4.0kvdc. The program voltage should be set for desired HV output before enabling output by applying 0v to the INHIBIT input.

I) HV output can be turned OFF by applying +5v to the INHIBIT input (or by opening the circuit to the inhibit input).

J) OPEN CIRCUIT fault will occur if the HV output of the CCM supply is not terminated into a suitable capacitor (0.5uf or greater). This is a latching type fault, and is reset by removing AC power from the unit for approximately 30 seconds.

K) OVERVOLTAGE fault will occur if the output voltage is increased above +4kvdc. This is a latching type fault, and is reset by removing AC power from the unit for approximately 30 seconds.

L) OVERTEMP fault will occur if the internal heat sink temperature exceeds 80 degrees centigrade. This is a non-latching type fault, and normal operation will resume after the heat sink temperature returns below approximately 60 degrees centigrade.

### WARNING

AFTER TURN OFF, DO NOT UNPLUG THE OUTPUT CABLE UNTIL THE INTERNAL CAPACITANCE IS DISCHARGED (APPROXIMATELY 10 SECONDS).

### WARNING

THE OUTPUT MONITORING SIGNALS AT THE POWER SUPPLY I/O CONNECTOR DO NOT READ THE OUTPUT VOLTAGE WHEN THE AC POWER IS TURNED OFF, EVEN IF A CHARGE STILL EXISTS ON THE LOAD.

## 3.2 STANDARD FEATURES:

### 3.2.1 PROGRAMMING:

Table 3-1 lists all connections available at the user I/O connector. The programming signal allows remote adjustment of the output voltage via external voltage source. Input impedance is 1 megohm. For remote program, a positive voltage source from 0 to 10V = 0-100%, is applied to the appropriate terminals on the 15 pin I/O connector. By adjusting the voltage source from 0 volts (zero output) to 10 volts (full rated output) the desired output can be selected.

### 3.2.2 MONITOR:

Test points are made available at the 15 pin I/O connector for monitoring instantaneous and peak output voltage. 0 to 10V = 0-100% of output. Accuracy is within  $\pm 1\%$ . All test points have output impedance of 1Kohm.

### CAUTION

ALWAYS OPERATE THE UNIT WITH THE COVER ON. A FAN MAINTAINS SAFE OPERATING TEMPERATURE IN THE POWER SUPPLY BY DRAWING AIR OVER CRITICAL COMPONENTS. THE COVER MUST BE ON IN ORDER TO DIRECT THE AIRFLOW OVER THE AREAS THAT NEED COOLING.

### IMPORTANT

IN OPERATION, THE UNIT MUST BE PLACED SO THAT THE AIR INTAKE AND THE FAN EXHAUST ARE CLEAR OF ANY OBSTRUCTION THAT MIGHT IMPEDE THE FLOW OF AIR.

### 3.2.3 CONTROL:

There are two control signals for the CCM supply. These are the INHIBIT and the PROGRAM signals. The INHIBIT signal disables the HV inverter circuit when it is +5v, and enables the inverter when it is 0v. This signal is used as a HV ON / OFF control. The PROGRAM signal is an analog input used to control the magnitude of the HV output (see par. 3.2.1).

### 3.2.4 STATUS:

Status signals are provided at the I/O connector for OPEN CIRCUIT fault, OVERTEMP fault, and GENERAL fault. A fault condition is indicated when any of these signals is 0v, while a normal condition is +15v with 6.8K source impedance. Additionally, a signal is provided that indicates "end of charge" (EOC), when the external load capacitor is fully charged to the program value. Full charge is 0v, while "charge in progress" is +15v with 6.8K source impedance.

TABLE 3-1 I/O CONNECTOR

I/O CONN PIN		SIGNAL
1	Inhibit	+5v = HV inhibit; 0v = HV enable
2	Temp fault	fault = 0v; no fault = +15v through 6.8K
3	General fault	fault = 0v; no fault = +15v through 6.8K
4	HV on indicator	0v = HV ON; HV OFF = +15v through 6.8K
5	Program	0 to +10v = 0 to 4.0KV output
6	Open circuit	fault = 0v; no fault = +15v through 6.8K
	Vout peak hold	Peak output voltage held for approx. 5 seconds
7		(0 to +10v = 0 to 4.0KV)
8	Vout monitor	Output Vmonitor (0 to +10v = 0 to 4.0KV)
9	+15vdc	+15v out at 150mA max (total for pins 9, 11, 12)
10	NC	
11	+15vdc	+15v out at 150mA max (total for pins 9, 11, 12)
12	+15vdc	+15v out at 150mA max (total for pins 9, 11, 12)
13	End of charge	0v = output equal to or greater than prog. value.
14	GND	
15	GND	

# 4 PRINCIPLES OF OPERATION

The CCM series of high voltage power supplies utilize 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 CCM power supply. For details on a specific circuit, consult Spellman's Engineering Department.

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

## 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.**

### 4.1 LINE RECTIFICATION AND FILTERING

AC line voltage of 180vac to 264 vac at 50 – 60 Hz is converted to DC voltage by means of an active power factor correction circuit to produce 400vdc rail voltage for operation of subsequent circuits in the CCM supply. Circuit protection is provided by 25 amp slo-blow fuses on each side of the line. The fuse output is connected to the input of the EMI filter PWB. EMI filter reduces conducted HF noise from the CCM to the mains. The AC line connection terminal block, fuses, and emi filter board are contained in an integral filter box designed to minimize noise interference from both stray electric fields as well as magnetic fields. Output of the EMI filter is connected to a boost choke, which is part of the power factor correction circuit described in a later paragraph. The power factor circuit creates a 50kHz signal, which is applied to the boost choke to increase the AC input voltage to 400v peak, and subsequently rectifies the resultant output to produce the 400vdc rail voltage. The 400vdc rail voltage is then applied to capacitors on the

capacitor board assembly to provide a filtered, low impedance, DC rail voltage for the HV inverter circuit.

## 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.**

The filter caps are initially charged through inrush limiting circuitry located on the Power PWB. An inductor on the output of the capacitor board assembly prevents high frequency inverter circuit noise from being applied to the electrolytic filter capacitors.

### 4.2 POWER FACTOR CORRECTION

Conversion of the AC input power to DC rail voltage is accomplished by means of an active power factor correction circuit. The CCM supply employs a unique topology for the PFC circuit, eliminating the need for the usual bridge rectifier required at the AC input to the circuit. This results in increased conversion efficiency, since the rectifier power dissipation loss is eliminated. In the CCM, the emi filtered AC line power is applied directly to a split coil boost choke, which in turn, is connected to power mosfets Q2, 5,6,and 9 and diodes CR5, 6. Relay K1 is connected in series with one of the boost choke leads with 10 ohm resistor R22 to control the initial turn-on current inrush as capacitors on the capacitor board assembly are charged. During the initial turn-on, the active power factor circuit is not functioning since there is no auxiliary power to operate the circuit. Additionally, there is no load requiring rail current, since the inverter circuit is inhibited during this time. As a result, the rail capacitors can be charged by means of the bridge rectifier formed by CR5, 6 and body diodes of Q2, 5, 6, and 9. Relay K1 contacts remain open during this initial period, so inrush current is limited by R22 to approximately 30 amps peak.

When the charge on the rail capacitors reaches 100vdc, the 24vdc auxiliary supply (U5, 6, T4) on the Power PCB begins to generate 24vdc aux power, which causes the cooling fan to begin operating, and allows circuits on the Control Circuits PCB assembly to begin operating. A delay circuit on the Control PCB assembly actuates relay K1 after approximately one second, causing R22 to be bypassed, and allowing full power operation of the unit. A tertiary winding on T4 is used to generate an isolated 15vdc supply, which powers the active power factor corrector circuits. As the power factor circuits become

active, a 50kHz signal is generated, which is used to switch mosfets Q2, 5, 6, and 9 on and off. When the mosfets switch ON, current is drawn through the windings of the boost choke, producing a magnetic field in the choke core. As the mosfets turn OFF, the resulting collapsing magnetic field in the boost choke core causes an induced voltage to be generated across the boost choke winding, which adds to the AC line voltage waveform to increase the peak voltage to 400v. This is rectified by CR5, 6 and mosfets Q2, 5, 6, and 9 to charge the rail capacitors to 400vdc. The line voltage waveform is monitored by circuits in U1 by means of samples provided by voltage dividers R2-7, and R9-14, resulting in modulation of the pulse width of the gate drive signals to mosfets Q2, 5, 6, 9. In this way, the voltage generated by the boost choke is modulated to maintain a sinusoidal current waveform that is in phase with the AC line voltage waveform. Voltage divider R42-46 provides a feedback sample of the 400vdc rail output for comparison to an internal reference in PWM U1 to control the magnitude of the boost waveform, and consequently, the 400vdc rail voltage.

### 4.3 HV INVERTER CIRCUITS

The High Voltage Inverter circuits are comprised of IGBTs Q17, 18 connected in a half-bridge configuration with isolated gate drivers. PWM U2 oscillates at approximately 32kHz and produces a square wave output to mosfets Q11, 12 which are connected with T3 in a push-pull configuration from the +15vdc supply. The secondary outputs of T3 are rectified and configured to provide +14 and -10vdc isolated bias supplies for opto-coupler gate drive circuits U3,4 and Q13-16 followers. The opto-couplers receive fixed duty cycle IGBT drive signals from the Control PCB assembly and provide IGBT gate drive of -10 OFF bias to +13v ON bias at the gate-emitter of each IGBT (Q17, 18) at 26 kHz. A diode steering circuit consisting of diodes CR13, 14, and CR18, 19 and associated resistors prevents any possibility of simultaneous turn-on of both IGBTs. At the junction of Q17-e and Q18-c, a 26 kHz waveform is generated whose amplitude is 400v p-p (+ to - rail transition). This waveform is applied to one end of the HV transformer primary winding. The other end of the primary winding is connected to the junction of capacitors C55, 56, which provide a return reference for the transformer, and high frequency bypass for the IGBTs. Gate resistors R89 and R90 are used to intentionally slow the switching voltage transitions of the IGBTs to reduce overshoots and emi caused by stray wiring inductance.

### 4.4 HIGH VOLTAGE CIRCUITS

High voltage circuits consist of the HV transformer and components located on the POWER PCB assembly. The High Voltage transformer is specially designed to have

an equivalent series inductance of 47uH, and a step-up turns ratio of 9.6. 400 volts peak to peak is applied to the HV transformer primary as described in 4.6 above. The secondary of the transformer is connected to resonant capacitors C42-45. The resonant frequency of the circuit consisting of the HV transformer and capacitors C42-45 is 26.598kHz, and the applied waveform from the Inverter circuit is 26kHz, slightly below resonance for stability. The output rectifier is a classic bridge configuration, with capacitor C49 (2000pf) for nominal output filtering and transient reduction. Resistors R83, 84, 78, 79 and R80, 85 divide the high voltage to a low voltage proportional sample compatible with the regulator circuits on the CONTROL PCB. Capacitors C50, 51 provide frequency compensation for the voltage divider for accurate sensing of the HV output waveform. Resistor R85 is an adjustable resistor used to trim the precise response of the voltage divider for high and low frequency balance.

### 4.5 CONTROL CIRCUITS

The Control circuits PCB contains the circuits required for regulation of the HV output, and monitoring of the output voltage for OVERVOLTAGE, OPEN CIRCUIT, OVERTEMP, and OVERLOAD conditions. The control circuits operate on +/- 15vdc power derived from the 24vdc auxiliary supply on the Power PCB board. Green led DS5 on the control board indicates presence of the 24v aux power input to the control circuits (viewable through a front panel access hole). +15vdc power is generated by buck regulator U7, and can be measured at TP5. Negative 15vdc is generated from the +15vdc by voltage inverter U8, and can be measured at TP4.

**Inrush limiter and inverter delay.** When AC power is initially applied to the unit, all circuits remain dormant until the 24vdc aux supply starts up as the RAIL capacitors charge through power PCB R22 to approximately 100vdc. The presence of 24vdc is followed by control board +15vdc, which begins to charge capacitor C7 through R2. When C7 charges to 10v, zener diode CR37 begins to conduct, and causes transistor Q3 to turn on, which actuates power pcb relay K1 to bypass inrush limiting resistor R22, allowing full power operation of the supply. In order to allow some time for the Power factor control circuit to reach full output capability and stabilize the 400v RAIL voltage, a second delay circuit inhibits the HV inverter operation for approximately 1 second following the end of the inrush limiting cycle. Capacitor C10 is initially charged to +10v through R83, CR3 during the inrush limiting cycle, and discharged through R6 when Q3 turns on at the end of the in-rush limiting period. When C10 discharges to +5v, comparator U2-D output switches from +15v (inverter inhibit) to -15v (inverter enable), partially enabling the hv inverter through CR5.

**HV enable.** The HV inverter is inhibited by +5 to +15v applied through I/O connector JB1-1. An open circuit on this pin will result in a default +15v inhibit via R65. HV

enable is achieved by applying 0v to JB1-1, which biases Q11 off through R29, CR25, allowing PWM U5 to soft start to full programmed output. The HV INHIBIT / ENABLE signal at JB1-1 also drives voltage inverter U2-C, resulting in the HV ON signal at E2 (+5v when HV is enabled). HV ON (+5v) drives Q10 into conduction, illuminating yellow led DS6, and enabling the short circuit sense circuit (see **short circuit** fault below). PWM U5 operates at full duty cycle except for the soft start ramp up of approximately 15 to 20 cycles. Outputs A and B from the PWM U5 drive transistors Q4 and Q6 to provide drive for opto isolators on the Power PCB which supply gate drive to the HV inverter IGBTs. Operating frequency for the PWM is 26 kHz.

**Program and feedback.** Program voltage for the CCM is 0 to +10vdc, and is applied through I/O connector JB1-5. Transient protection is provided by R59 and CR22, and the program voltage is buffered by op-amp U6-D. Buffered program voltage can be measured at TP3. The buffered program voltage is applied to end of charge (EOC) comparator U6-B through resistor R53 as the reference signal for comparison to the high voltage output feedback sample. During the charging cycle of the external HV load capacitor, U6-B output is high state (+15v), back-biasing diode CR19, so that feedback is compared to unmodified program volts. When the charge on the external capacitor reaches the program voltage level, comparator U6-B output switches to -15v, pulling the program reference down by approximately 1%, so that feedback must decrease by 1% before comparator U6-B will switch back to +15v to re-charge the external capacitor to full program value. For DC output conditions, such as no load, or resistive load, this 1% hysteresis is the peak-to-peak ripple value of the output voltage. Output from U6-B is inverted by U6-C to control the ON / OFF state of the hv inverter PWM U5 through CR10 and R119 (+15v at U6-C output is PWM OFF, while -15v is PWM ON). Zener diode CR35 limits the voltage applied to PWM U5 to +5 / -0.7v.

A feedback signal (0 to +10v) from the high voltage circuits on the power PCB is applied to calibration amp U6-A through transient protection components R39 and CR8. Gain of this amplifier is controlled by adjustment of resistor R51 to compensate for variation of the divider ratio on the power board due to the frequency compensation adjustment R85. Compensated feedback voltage can be measured at TP1. Op amp U3-D is an inverter amplifier that may be used if the HV output is configured for negative output voltage. For positive HV output, resistor R100 is installed, and for negative HV output, R100 is removed. The compensated feedback signal is applied to EOC comparator U6-B through R46 for comparison to the program voltage.

**Monitoring.** Compensated feedback is buffered by op-amp U1-D and connected to I/O connector JB1-8 through series 1K resistor R16 for user monitoring of the HV output by means of the compensated sample (0 to

+10v = 0 to 4.0kV output). In normal use, the external output capacitor is repetitively charged, discharged, and re-charged, making measurement of the output voltage difficult. For this reason, a **peak hold** circuit consisting of U1, Q1, and Q2 is provided to deliver a steady output signal, that can be monitored with a DVM, which correlates to the peak value of the output waveform. Feedback voltage is applied to non-inverting U1-A, which charges capacitor C1 through R118, CR2 to the peak value of the feedback waveform. During the charging of C1, the output of U1-A is +15v, which is connected to U1-C, where it is inverted to -15v. This -15v biases Q2 ON through CR4 to quickly charge capacitors C5, 6 to -15v, maintaining Q1 in an OFF state. When capacitor C1 voltage reaches the peak value of the feedback signal (on TP1), the output of U1-A drops to -15v, resulting in +15v at U1-C output, where capacitors C5, 6 are then slowly charged toward +15v through R4. When the charge on C5, 6 reaches approximately +5.7v, Q1 begins to conduct, discharging C1 through R1. Thus, capacitor C1 is charged very quickly to the peak value of the feedback waveform, and discharged slowly after approximately 5-second delay, providing a stable signal for monitoring with a DVM for all operating conditions. The peak hold signal is buffered by U1-B and connected to I/O connector JB1-7 through R3.

**Fault monitoring.** HV output is continuously monitored for OVERVOLTAGE, OPEN CIRCUIT, OVERTEMP, and SHORT CIRCUIT conditions. Overvoltage and open circuit faults are latching faults requiring removal of AC power to reset the latch. Short circuit fault is also a latching fault, but can be reset by cycling the HV INHIBIT signal to I/O connector JB1-1. Overtemp is initiated by a thermal switch on the heat sink assembly, and inhibits the HV inverter until the temperature drops approximately 25 degrees C, at which time the HV inverter is re-enabled.

**Overvoltage** is detected when output voltage exceeds 4.0kV by comparator U3-A. The overvoltage latch is set by a transition below ground of U3-A output to U3-B input, and causes led DS1 to illuminate, while inhibiting the HV inverter.

**Open circuit** is detected when HV output exceeds the program set point by 20% or more. This condition occurs if the HV output connector is inadvertently removed when the high voltage is ON, because HV output ripple is high without the external capacitor connected. The open circuit latch is set by a transition below ground of U2-A output to U2-B input, and causes led DS2 to illuminate, while inhibiting the HV inverter. Open circuit fault (logic low) is connected to I/O connector JB1-6 for user monitoring. Normal condition for this signal is +15v through 6.8K

**Overtemp** is detected if the heat sink temperature exceeds 85 degrees C. by means of a temperature switch with normally closed contacts. The thermal switch has a mechanical hysteresis of approximately 25 degrees C. If sink temperature exceeds 85 degrees, contacts will open and led DS3 will be illuminated through R61, R67, while the HV inverter is inhibited. In addition, Q9 will be biased

on to provide a logic low at I/O connector JB1-2 for user monitoring. When the sink temperature cools down by approximately 25 degrees, the switch contacts will re-close, and normal operation will resume. Normal condition for this signal is +15v through 6.8K

**Short circuit** on the HV output can be sustained indefinitely by the CCM power supply, but since the CCM output is essentially a 2.3A current source, there is the possibility of damage to external equipment in the event of a long term short circuit. This is especially true if the output overload is not a zero ohm short. For this reason, the EOC output is sensed by comparator U3-C, and a HV inverter disable is generated if the EOC output does not occur within several seconds following a HV ON enable at I/O connector JB1-1. In operation, the EOC output signal is connected to capacitor Cxx through diode CRxx. When the end of charge output switches to logic low state, Capacitor Cxx is discharged to 0vdc. As the CCM supply charges the external load capacitor, the EOC signal goes to +15v, reverse biasing diode CRxx, and allowing capacitor Cxx to charge toward approximately +9v through resistors Rxx and Rxx. If capacitor Cxx is not discharged again by the next EOC low output before its' charge reaches +5v, the output of U3-C will switch to +15v, disabling the HV inverter

through diodes CR7 and CR11. Since a HV inverter inhibit results in no HV output, there will be no subsequent EOC low outputs, and the condition is thus a latched shutdown. This circuit is disabled during HV INHIBIT (HV OFF) mode (input high at JB1-1) by an hv on signal from U2-C through diodes CRxx and CRxx, which maintains capacitor Cxx in a discharged state during HV INHIBIT. The short circuit latched fault is reset by application of HV INHIBIT (+5v to +15v) at JB1-1.

All of the above described faults are "or'd" together by means of diodes CR12, CR20, CR23, and CR7 to generate a **general fault** signal. Any detected fault will produce approximately +8v at the junction of these diodes (cathodes), which will cause Q8 to conduct, resulting in logic low at JB1-3, and illumination of red general fault led DS4.

## 4.6 OPTIONS

There are no options for the CCM supply presently.

# 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. Use compressed air to blow dust out of the inside of the unit. Avoid touching or handling the high voltage assembly. Be sure that the fans are not obstructed and spin freely. The fans have sealed bearings and do not need lubrication. Be sure to replace the top cover before operating for proper cooling.

### 5.2 PERFORMANCE TEST

## WARNING:

**HIGH VOLTAGE IS DANGEROUS.** Only qualified personnel should perform these tests.

High voltage test procedures are described in Spellman 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 measurement 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.

# 6 FACTORY SERVICE

## 6.1 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 6.2. The customer shall pay for shipping to and from Spellman.

## 6.2 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 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 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.

## 6.3 Ordering Options and Modifications

Many of the options listed in chapter 5 can be retrofitted into Spellman's power supplies by our factory. For prices and arrangements contact the Spellman sales department.

## 6.4 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) 435-1600  
FAX: (631) 435-1620  
E-mail: [sales@spellmanhv.com](mailto:sales@spellmanhv.com)  
<http://www.spellmanhv.com>

# **SPELLMAN HIGH VOLTAGE ELECTRONICS**

## **WARRANTY**

**Spellman** High Voltage Electronics ("**Spellman**") warrants that all power supplies it manufactures will be free from defects in materials and factory workmanship, and agrees to repair or replace, without charge, any power supply that under normal use, operating conditions and maintenance reveals during the warranty period a defect in materials or factory workmanship. The warranty period is twelve (12) months from the date of shipment of the power supply. With respect to standard SL power supplies (not customized) the warranty period is thirty-six (36) months from the date of shipment of the power supply.

This warranty does not apply to any power supply that has been:

- Disassembled, altered, tampered, repaired or worked on by persons unauthorized by **Spellman**;
- subjected to misuse, negligent handling, or accident not caused by the power supply;
- installed, connected, adjusted, or used other than in accordance with the original intended application and/or instructions furnished by **Spellman**.

THE FOREGOING WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING THOSE OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

The buyer's sole remedy for a claimed breach of this warranty, and **Spellman's** sole liability is limited, at **Spellman's** discretion, to a refund of the purchase price or the repair or replacement of the power supply at **Spellman's** cost. The buyer will be responsible for shipping charges to and from **Spellman's** plant. The buyer will not be entitled to make claim for, or recover, any anticipatory profits, or incidental, special or consequential damages resulting from, or in any way relating to, an alleged breach of this warranty.

No modification, amendment, supplement, addition, or other variation of this warranty will be binding unless it is set forth in a written instrument signed by an authorized officer of **Spellman**.

### **Factory Service Procedures**

For an authorization to ship contact **Spellman's** Customer Service Department. Please state the model and serial numbers, which are on the plate on the rear panel of the power supply and the reason for return. A Return Material Authorization Code Number (RMA number) is needed from **Spellman** for all returns. The RMA number should be marked clearly on the outside of the shipping container. Packages received without an RMA Number may delay return of the product. The buyer shall pay shipping costs to and from **Spellman**. Customer Service will provide the Standard Cost for out-of-warranty repairs. A purchase order for this amount is requested upon issuance of the RMA Number (in-warranty returns must also be accompanied by a "zero-value" purchase order). A more detailed estimate may be made when the power supply is received at **Spellman**. In the event that the cost of the actual repair exceeds the estimate, **Spellman** will contact the customer to authorize the repair.

### **Factory Service Warranty**

**Spellman** will warrant for three (3) months or balance of product warranty, whichever is longer, the repaired assembly/part/unit. If the same problem shall occur within this warranty period **Spellman** shall undertake all the work to rectify the problem with no charge and/or cost to the buyer. Should the cause of the problem be proven to have a source different from the one that has caused the previous problem and/or negligence of the buyer, **Spellman** will be entitled to be paid for the repair.

### **Spellman Worldwide Service Centers**

For a complete listing of **Spellman's** Global Service facilities please go to:  
<http://www.spellmanhv.com/customerservice/service.asp>