



## 2011 APPLICATION NOTEBOOK

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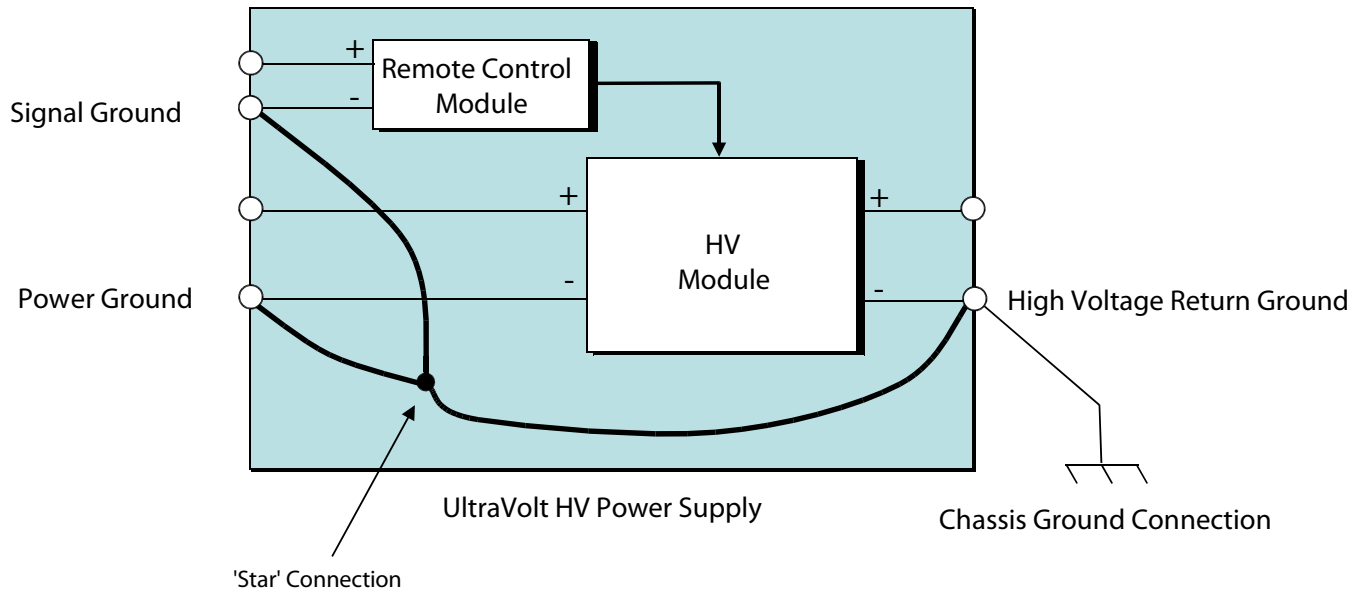
 **ULTRAVOLT, INC.**  
Making High Voltage Easier!®

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**Introduction**

UltraVolt HV Power Supplies have three ground terminals — a High Voltage Return Ground, a Signal Ground and a Power Ground — as depicted in Figure 1.



**Figure 1. Ground Paths in an UltraVolt HV Power Supply**

Note that inside the HV Power Supply these three grounds connect at a single node denoted by ‘Star Connection’ in the figure. When the HV Power Supply is connected to the load, each of the three grounds must connect separately to three corresponding terminals at the load. The grounds must connect separately to the three corresponding terminals at the load so that if a high voltage arc occurs — or any kind of high-voltage discharge — the arc energy will travel via the single chassis ground connection to the High Voltage Ground Return because it is the only ground that is directly connected to the chassis ground.

If the other two grounds were directly connected to the chassis ground and the high-voltage arc were to enter the power supply, it is highly likely that the power supply would be damaged. However, since the arc energy is returning via the Chassis Ground Connection, it enters only the HV Module where each of the components has been selected to withstand the high-voltage energy. If the arc were to travel through any of the other grounds, it would enter low-voltage circuitry which would be unable to survive.

**Performing the Isolation Tests**

These tests are performed using an Ohmmeter to confirm that the three grounds are connected together only at the Star Connection in the HV Power Supply, which is to say that none of the grounds interconnect within the load. The tests (there are six of them) are specified in Table 1. When performing the ‘Load Disconnected’ tests, make sure all leads from the HV Power Supply are disconnected from the load.

**Table 1. Isolation Tests — at the Load Terminals**

Tests		Signal Ground to Power Ground	Signal Ground to High Voltage Return Ground	Power Ground to High Voltage Return Ground
Load Connected	Fig. 2a	Continuity <sup>1</sup>	Continuity <sup>1</sup>	Continuity <sup>1</sup>
Load Disconnected <sup>2</sup>	Fig. 2b	Isolated <sup>3</sup>	Isolated <sup>3</sup>	Isolated <sup>3</sup>

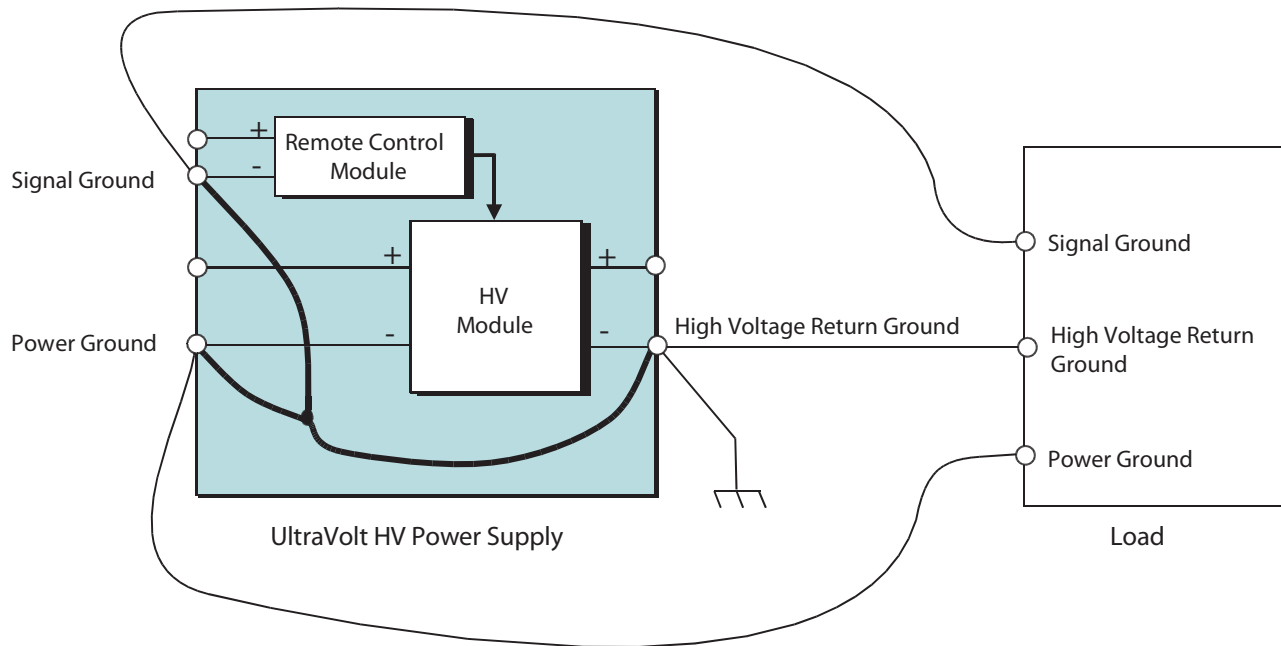
**Notes**

1. Resistance of 0.5 ohm, or less
2. Make sure that all connections between the load and the HV Power Supply are removed.
3. Resistance of 10 megohms, or more

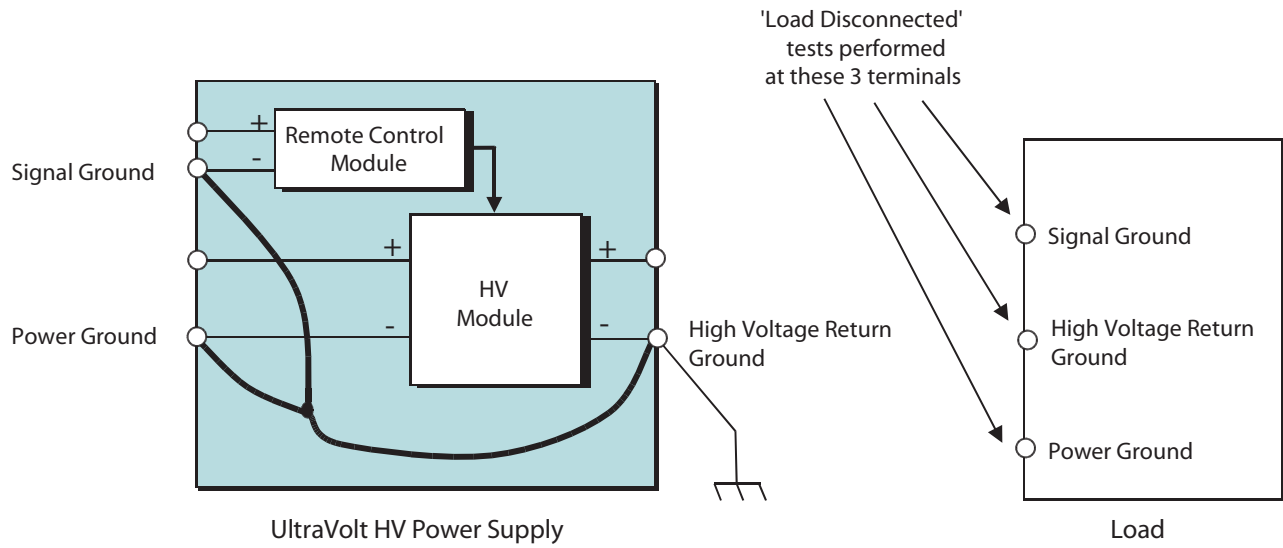
If the power supplies pass all of these tests, the Isolation Tests are successful, confirming that there are no connections between any of the three ground returns either within the load or at the load ground return terminals themselves.

If any of the 'Load Disconnected' tests fail, the circuitry within the load must be checked and any internal connections between the ground return terminals removed. Upon making modifications repeat the 'Load Disconnected' Isolation Tests as outlined in Table 1 to confirm that isolation between the three ground return terminals within the load has indeed been established.

After completing the aforementioned modifications, if any of the Load Disconnected tests fail or if any Load Connected tests fail, please contact UltraVolt Applications Engineering for further support.



a) Grounds — Load Connected



b) Grounds — Load Disconnected

**Figure 2. Isolation Tests**

*For an in-depth discussion of grounding and protection methods, refer to UltraVolt's Application Note 16, which can be downloaded from our website at [www.ultravolt.com](http://www.ultravolt.com)*

# Interfacing with UltraVolt High Voltage Power Supplies Models A, AA, C, 10A-25A, 30A-40A, and F Series

## Introduction

In this Technical Note, we provide tips for interfacing with the interconnection pins and leads of the UltraVolt high-voltage power supply series identified above. This document augments the data sheets for each of the series. Complete product data sheets can be found by visiting [www.ultravolt.com/products](http://www.ultravolt.com/products).

A few items of note about UltraVolt's high-voltage power supplies:

- The AA Series is similar to the A Series, but is smaller; the A Series has lower ripple.
- The C Series is intended primarily for charging capacitors and for applications that require fast rise time and low overshoot.
- The F Series is based on the A Series, but contains additional circuitry to reduce output ripple voltage.

## An Overview of the Connections

**Pin 1 – Input-Power Ground Return:** This pin is the Input-Power Ground for all the high-voltage power supplies in these series. Be sure to return the high-voltage (HV) load to HV Return.

**Pin 2 – Positive Power Input:** This pin is the Positive Power Input. The majority of the power supplies covered in this Technical Note are 24V input nominal. 4 watt power supplies are 12V input nominal. All models covered here are capable of a wide input operating range (from 9V through 32V input) with proper de-rating; refer to the individual models' data sheets for details.

**Pin 3 –  $I_{out}$  Monitor:** This pin serves as the  $I_{out}$  Monitor pin, as depicted in Figure 1. Scale factors vary and are unique to each model. The HV Multiplier in each high-voltage power supply is grounded through the  $R_{sense}$  resistor, as shown in Figure 1. The HV Feedback resistors and the HV Test Point resistors are returned to ground and are seen by the power supply as an internal load. This internal load is the source of an offset on the  $I_{out}$  monitor that must be accounted for when making output current measurements. Refer to the individual models' data sheets for details.

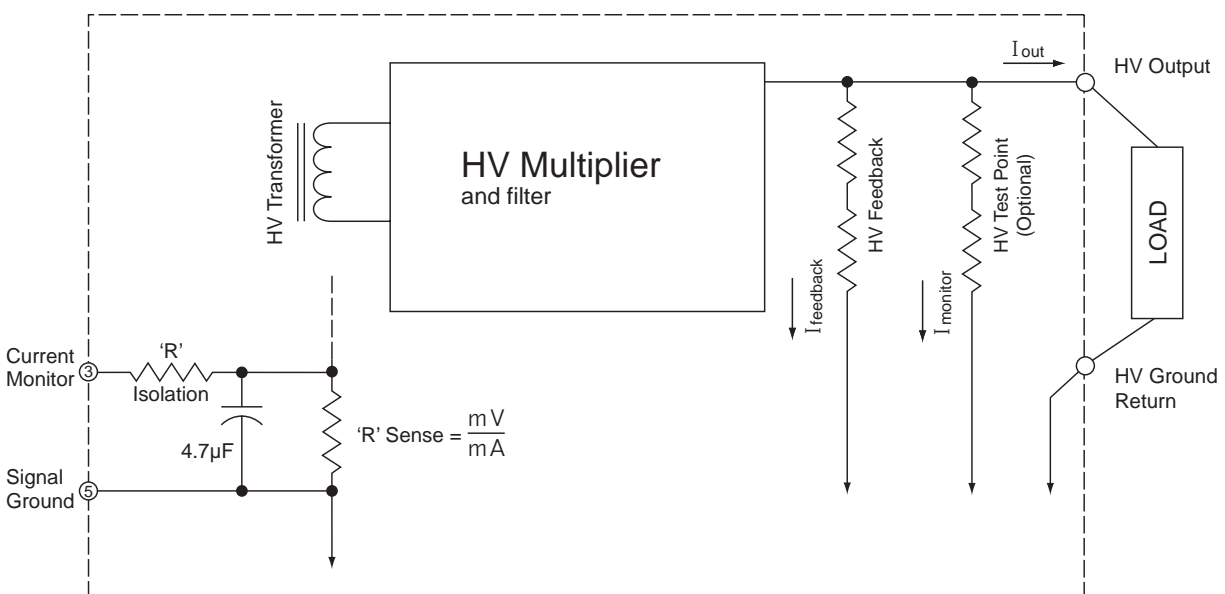


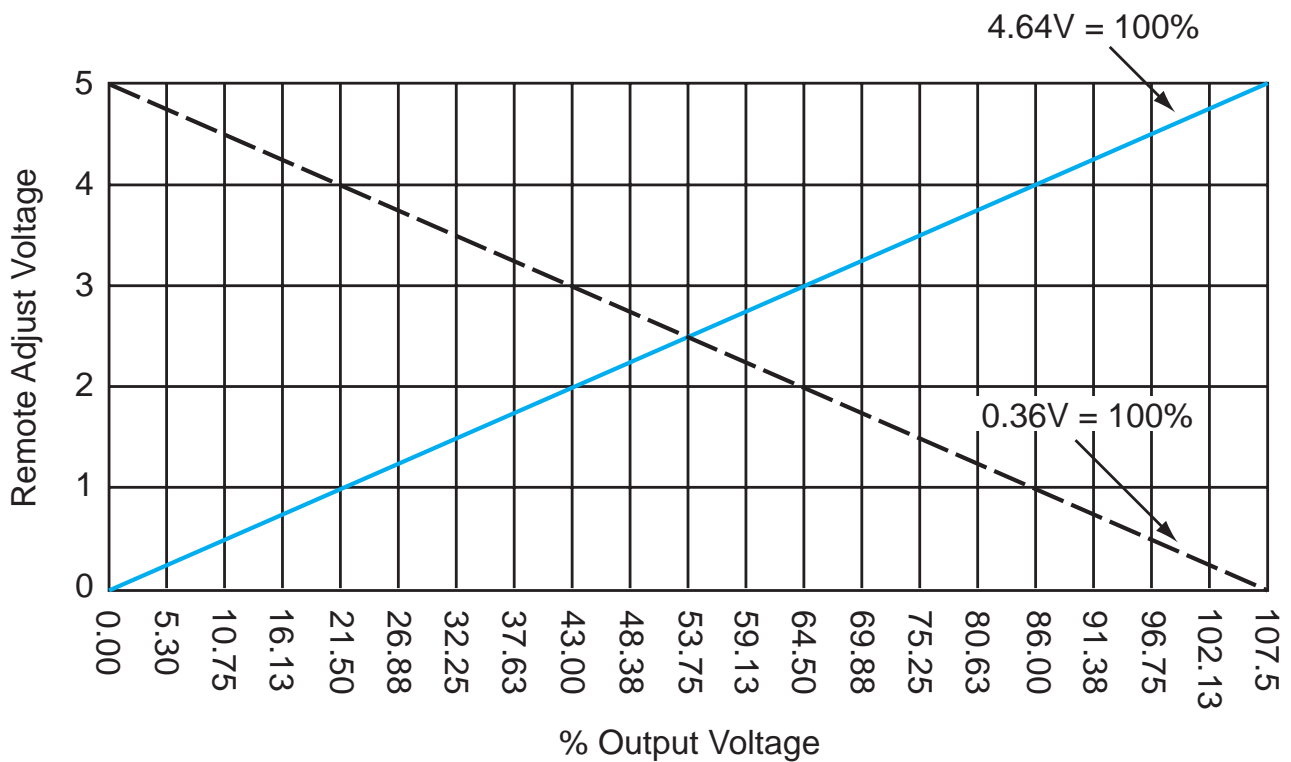
Figure 1. Current Monitoring Circuitry — a Simplified Diagram

**Pin 4 – Enable/Disable:** The enable function is the same for all models. A HIGH signal enables and a LOW signal disables the output. If pin 4 is left open, the power supply defaults to an enabled state.

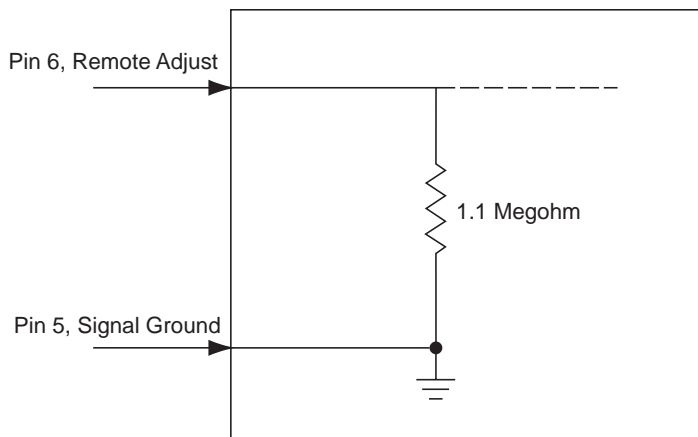
**Pin 5 – Signal Ground Return:** The signal ground should be used as the reference point for both the remote adjust and the monitors. Do not return the HV load here. If input current is allowed to flow through the signal return path, offsets and errors may occur in the control and monitoring functions.

**Pin 6 – Remote Adjust Input:** The remote adjust pin allows the high-voltage power supply to be programmed from 0% output voltage to 107.5% of nominal voltage. Positive power supplies are scaled so 4.64V on the remote adjust will result in 100% of output voltage, while 5.00V will provide a maximum of 107.5% of nominal voltage. The remote adjust pin has an input impedance of 1.1MΩ; this resistor to ground is provided to program the power supply to zero output if the control pin is left open. See Figure 3A.

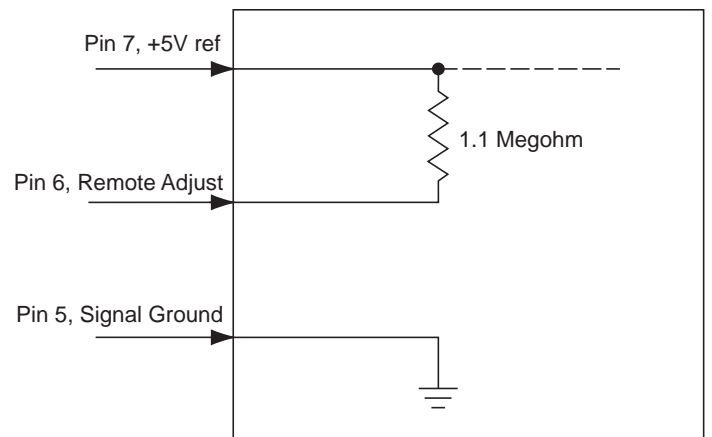
A negative power supply has the opposite sense on the control voltage (see Figure 2 below). 0V on the remote adjust programs the power supply for 107.5% of rated voltage and 0.36V provides 100% output. Driving the remote adjust pin to 5.00V on a negative power supply will program zero output voltage. A 1.1MΩ resistor pull up provides zero output voltage if the control pin is left open. See Figure 3B.



**Figure 2. Remote Adjust Inputs — Negative and Positive High Voltage Supplies**



A) Positive UltraVolt HVPS



B) Negative UltraVolt HVPS

**Figure 3. Remote Adjust Inputs**

**Pin 7 – +5VDC Reference Output:** A +5VDC reference voltage is provided for programming the power supply. The reference voltage has an output impedance of 464Ω. See the data sheet of your model for characteristics.

**Pin 8 – HV Ground Return:** Internally, the Power Ground, the HV Ground, and the Signal Ground are common. The high-voltage load return should be connected here.

**Pin 9 – HV Ground Return or E<sub>out</sub> Monitor (Output voltage monitor):** The function of this pin depends on the model of your HV power supply. The standard A Series does not have an E<sub>out</sub> Monitor unless it is ordered with the –Y5 option. The E<sub>out</sub> Monitor is standard on AA, 10A through 40A, and C Series power supplies.

The E<sub>out</sub> Monitor, when present, is accomplished with a high-voltage divider resistor set. The scale factor is model dependent and will be either 10:1, 100:1, or 1000:1 ratio. The divider resistor set is designed to be properly scaled with a 10MΩ input-impedance meter connected to the circuit. It is possible to shunt the lower divider resistor to create different scale factors. The resistor values are available in the model-specific data sheets.

**Pin 10 and 11 – HV Output:** The high-voltage output is provided on these pins for output voltages up to 6kV. Output voltages above 6kV are provided on an 18-inch flying lead in place of these pins.



# Interfacing with UltraVolt High Voltage Power Supplies High Power C Series & High Power 8C-30C Series

## Introduction

In this Technical Note, we provide tips for interfacing with the interconnection pins and leads of the UltraVolt High Power C and High Power 8C–30C Series. This document augments the data sheets for each of the series. Complete product data sheets can be found by visiting [www.ultravolt.com/products.htm](http://www.ultravolt.com/products.htm).

A few remarks about these UltraVolt series:

- The High Power C Series delivers 0 to 125 volts through 0 to 6 kV at power levels of 60-watts, 125-watts, or 250-watts maximum.
- The High Power 8C–30C Series deliver 0 to 8 kV through 0 to 30 kV at power levels of 60-watts or 125-watts maximum.

## An Overview of the Connections

**Pin 1 and 8 – Input Power Ground Return:** These pins are the Input Power Ground for the 60-watt and 125-watt models. 250-watt units have a separate power connector to handle the higher input currents. Refer to the specific data sheets for details.

**Pin 2, 9, and 10 (HPC 60W or 125W) – Positive Power Input:** These pins are the Positive Power Input for the 60-watt and 125-watt 1/8C through 6C units. The input voltage range is 23Vdc to 30Vdc; however, these power supplies will perform over a wider range of input voltage with proper de-rating. See the data sheet for de-rating information.

**Pins 2 and 9 (HP 8C–30C) – Positive Power Input:** These pins are the input power for 8C through 30C units. The input voltage range is 23Vdc to 30Vdc; however, these power supplies will perform over a wider range of input voltages with proper de-rating. See the data sheet for de-rating information.

**Pins 2, 9, and 10 (HPC 250W) – No connection:** These pins are not used in the 250-watt High Power C Series. All 250-watt units have an additional 4-pin connector to handle the higher input current. Refer to the data sheet for details.

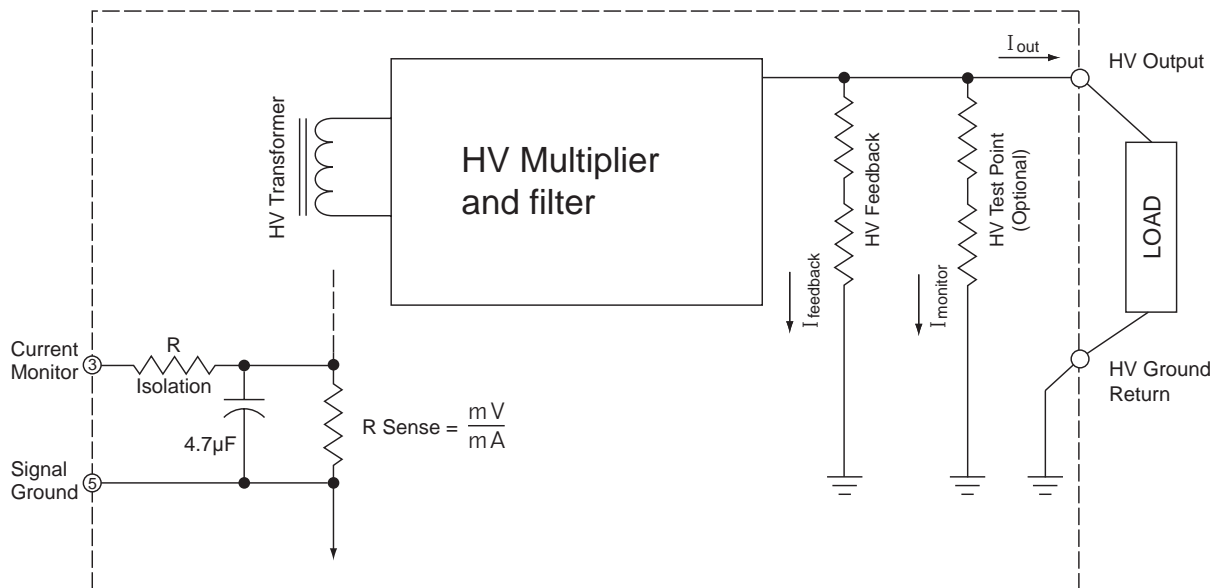


Figure 1. Current Monitoring Circuitry — a Simplified Diagram

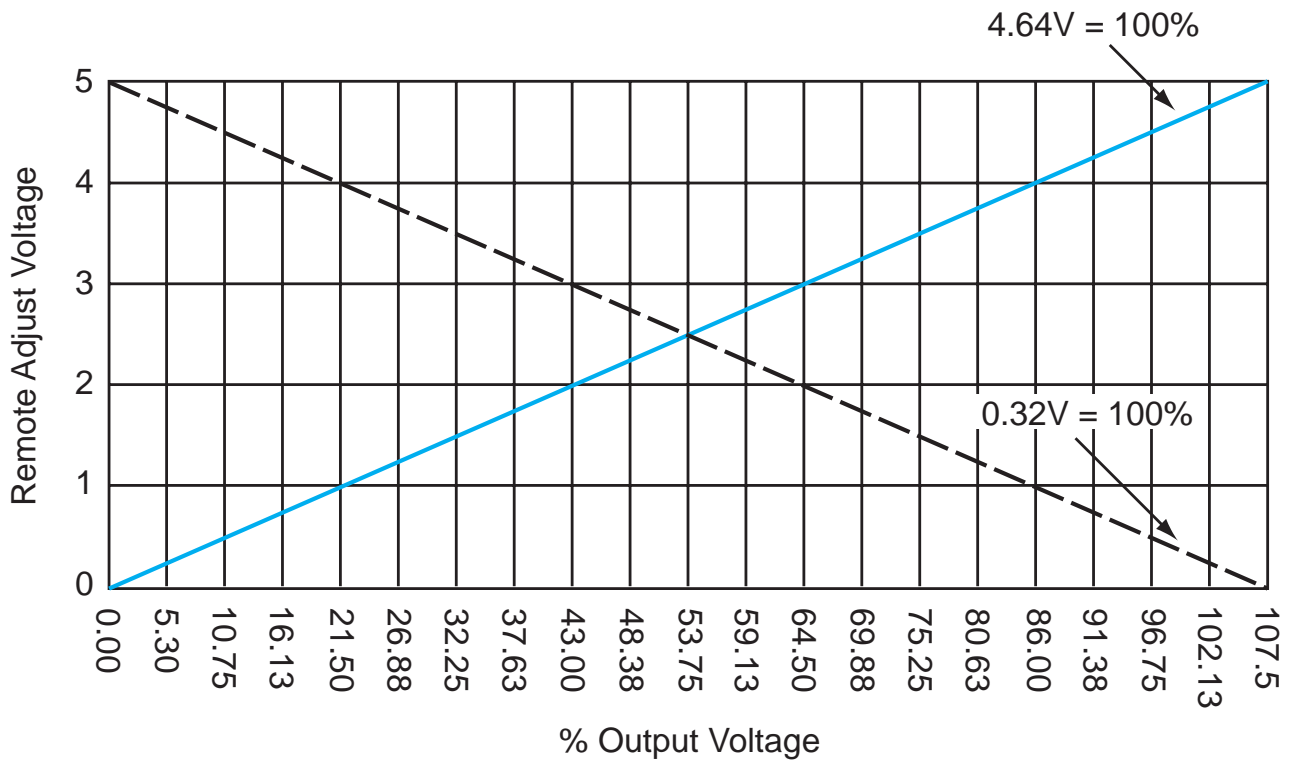
**Pin 3 – I<sub>out</sub> Monitor:** This pin serves as the I<sub>out</sub> Monitor pin, as depicted in Figure 1. Scale factors vary and are unique to each model. The HV Multiplier in each high-voltage power supply is grounded through the R<sub>sense</sub> resistor, as shown in Figure 1. The HV Feedback resistors and the HV Test Point resistors are returned to ground and are seen by the power supply as an internal load. This internal load is the source of an offset on the I<sub>out</sub> monitor that must be accounted for when making output current measurements. Refer to the individual models' data sheets for details.

**Pin 4 – Enable/Disable:** The enable function is the same for all models. A HIGH signal enables and a LOW signal disables the output. If pin 4 is left open, the power supply defaults to an enabled state. The data sheet has detailed information on logic levels.

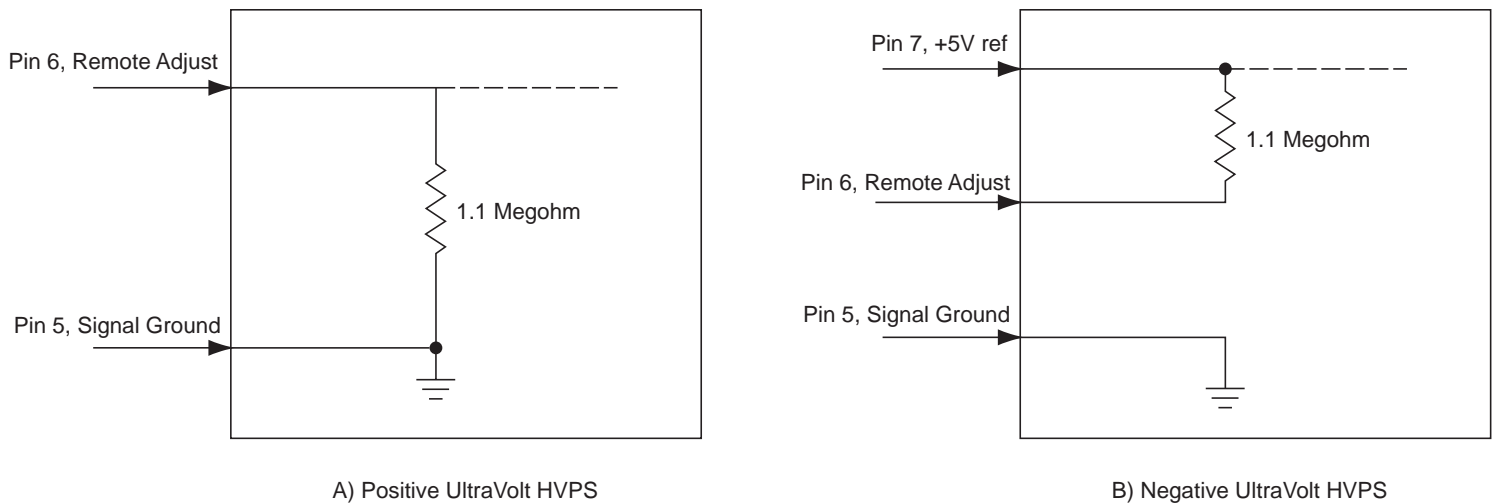
**Pin 5 – Signal Ground Return:** The signal ground should be used as the reference point for both the remote adjust and the monitors. Do not return the HV load here. If input current is allowed to flow through the signal return path, offsets and errors may occur in the control and monitoring functions.

**Pin 6 – Remote Adjust Input:** The remote adjust pin allows the high-voltage power supply to be programmed from 0% output voltage to 107.5% of rated output voltage. Positive power supplies are scaled so 4.64V on the remote adjust will result in 100% of output voltage, while 5.00V will provide 107.5% of full voltage. The remote adjust pin has an input impedance of 1.1MΩ; this resistor to ground is provided to program the power supply to zero output if the control pin is left open. See Figure 3A.

A negative power supply has the opposite sense on the control voltage (see Figure 2 below). 0V on the remote adjust programs the power supply for 107.5% of rated voltage and 0.32V provides 100% output. Driving the remote adjust pin to 5.00V on a negative power supply will program zero output voltage. A 1.1MΩ resistor pull-up to the V<sub>ref</sub> pin internally provides zero output voltage if the control pin is left open. See Figure 3B.



**Figure 2. Remote Adjust Inputs — Negative and Positive High Voltage Supplies**



**Figure 3. Remote Adjust Inputs**

**Pin 7 – +5VDC Reference Output:** A +5VDC reference voltage is provided for programming the power supply. The reference voltage has an output impedance of 464Ω. See the data sheet of your model for characteristics.

**Pins 11, 12, and 13 – No Connection**

**Pin 14 – E<sub>out</sub> Monitor (Output voltage monitor):** The E<sub>out</sub> Monitor is accomplished with a high-voltage divider resistor set. The scale factor is model dependent and will be either a 100:1 or 1000:1 ratio. The divider resistor set is designed to be properly scaled with a 10MΩ input-impedance meter connected to the circuit. It is possible to shunt the lower divider resistor to create different scale factors. The resistor values are available in the model-specific data sheets.

**Pins 15 and 16 – High Voltage Ground Return:** Internally, the Power Ground, the HV Ground, and the Signal Ground are common. The high-voltage load return should be connected here.

**Pins 19 and 20 – Positive Power Input:** These pins are the input power for 250-watt units due to the higher input current at this power level. The input voltage range is 23Vdc to 30Vdc; however, these power supplies will perform over a wider range of input voltages with proper de-rating. See the data sheet for de-rating information.

**Pins 21 and 22 – Input Power Ground Return:** These pins are the input power return for 250-watt units and must be used as power ground for the higher input currents.

### Introduction

The CP Series high-voltage power supply (HVPS) has unique capabilities which allow it to provide an extended current range and allow the user to regulate the output power directly. This series, while rated for 10 watts maximum output power, provides a 10:1 range in current capability. This means a 10-kilovolt, 1-milliamp power supply can source 10 milliamps at 1 kilovolt. The power supply is limited to 10 watts of output power by a power regulation circuit that can be programmed with a 0 to +10V signal that is proportional to 0 to 10 watts.

The CP provides three operating modes: the user can regulate output voltage, current, or power. The three regulation modes have automatic crossover. An open drain mode indicator is also available; it can directly drive an LED or, coupled with a pull up resistor, provide a logic level. Monitoring is provided for voltage, current, and power. All monitors are buffered, have low output impedance, and are 0 to +10V full scale.

**Pin 1 and 8 – Power Ground:** Use these pins for the input power return. Do not allow input power return current to flow through the Signal Ground connections.

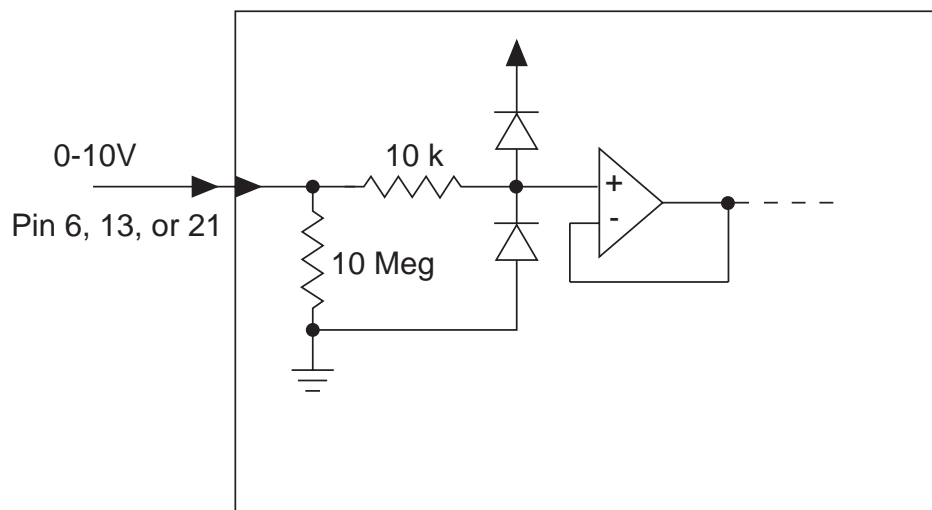
**Pin 2 and 9 – Positive Power Input:** The input power to the CP is +24V nominal with a +/-10% range.

**Pin 3 – Current Monitor:** The current monitor has the same scale factor as the current programming signal. 0 to +10V indicates 0 to 100% of rated current. The current monitor signal is derived internally from the current feedback and is buffered to provide low output impedance.

**Pin 4 – Enable/Disable:** A logic high between 4V and 10V will enable the power supply. A logic low of 4V or less will disable the power supply. The default or open circuit state is enabled.

**Pin 5 – Signal Ground:** The signal ground and power ground are common inside the power supply. This pin should be used as reference for all control and monitoring signals. If input power current is allowed to flow through this pin, offsets can occur which will degrade voltage regulation and monitoring accuracy.

**Pin 6 – Voltage Programming:** A 0V to +10V signal will program the power supply for 0 to 100% rated output voltage. The input impedance for this control pin is 10M $\Omega$ ; a resistor to ground will program the power supply for zero output voltage if this pin is left open. See Figure 1 for a typical programming pin circuit.

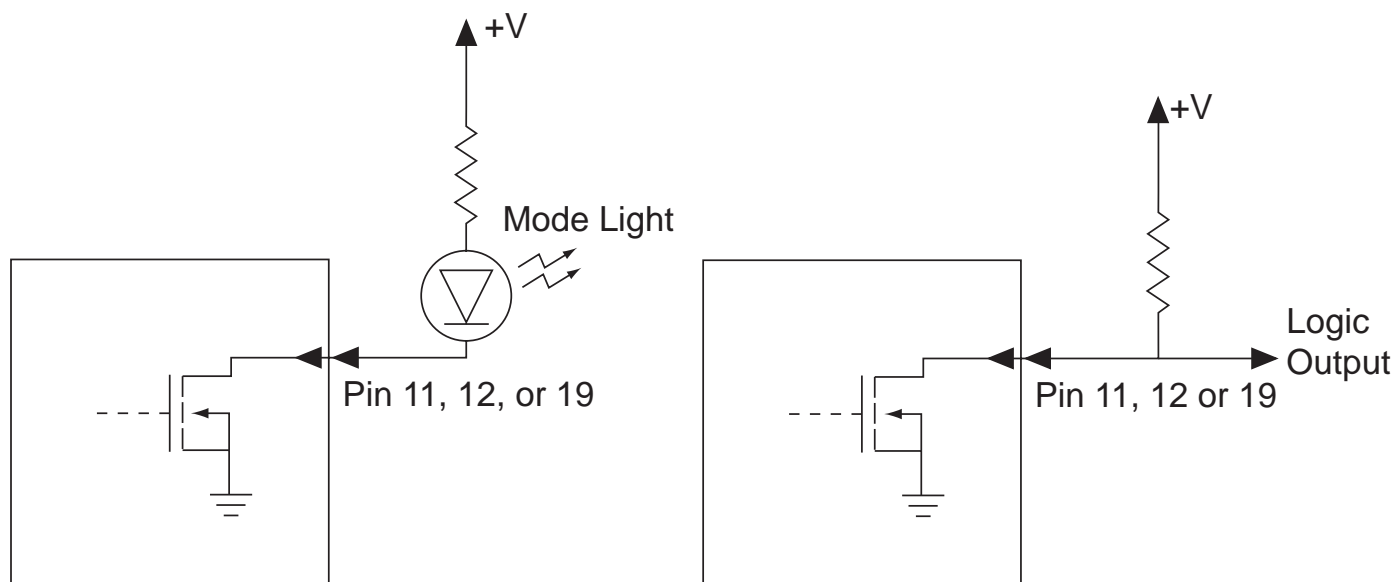


**Figure 1. Typical Programming Input**

**Pin 7 – Reference Voltage:** A precision, low temperature coefficient +10.50V reference voltage is available on this pin. Please see the datasheet for accuracy and temperature characteristics.

**Pin 10 – No Connection**

**Pin 11 – Current Mode Indicator:** An open drain configuration indicates when the power supply is in current regulation. The indicator is an active low and will appear as an open circuit when the power supply is in voltage control, in power control, or in a disabled state. A pull up resistor can be used to create a logic signal, or the pin can be used to ground an LED to provide an illuminated indicator showing the operating control mode. See Figure 2 for usage suggestions.



**Figure 2. Typical Mode Indicator**

**Pin 12 – Voltage Mode Indicator:** An open drain configuration indicates when the power supply is in voltage regulation. The indicator is an active low, and will appear as an open circuit when the power supply is in current control, in power control, or in a disabled state. A pull up resistor can be used to create a logic signal, or the pin can be used to ground an LED to provide an illuminated indicator showing the operating control mode. See Figure 2 for usage suggestions.

**Pin 13 – Current Programming:** A 0V to +10V signal will program the power supply for 0 to 100% rated output current. The input impedance for this control pin is 10MΩ; a resistor to ground will program the power supply for zero output current if this pin is left open. See Figure 1.

**Pin 14 – Voltage Monitor:** The voltage monitor has the same scale factor as the voltage programming signal. 0 to +10V indicates 0 to 100% of rated voltage. The voltage monitor signal is derived internally from the voltage feedback and is buffered to provide low output impedance.

**Pin 15, 16, 17, and 18 – No Connection**

**Pin 19 – Power Mode Indicator:** An open drain configuration indicates when the power supply is in power regulation. The indicator is an active low, and will appear as an open circuit when the power supply is in current control, in voltage control, or in a disabled state. A pull up resistor can be used to create a logic signal, or the pin can be used to ground an LED to provide an illuminated indicator showing the operating control mode. See Figure 2 for usage suggestions.

**Pin 20 – Power Monitor:** The power monitor has the same scale factor as the power programming signal. 0 to +10V indicates 0 to 100% of rated power. The power monitor signal is derived internally from the voltage feedback and the current feedback and is buffered to provide low output impedance.

**Pin 21 – Power Programming:** A 0V to +10V signal will program the power supply for 0 to 100% rated output power. The input impedance for this control pin is 10M $\Omega$ ; a resistor to ground will program the power supply for zero output power if this pin is left open. See Figure 1.

### Introduction

This Tech Note explains how to implement the various controls, programming, and monitoring functions of the E Series precision high voltage power supply. The E Series has models from 1kV to 15kV in power levels from 0 to 4W maximum through 0 to 30W maximum. This series of power supplies has very low ripple, excellent linearity, and very stable temperature characteristics. The control and monitoring functions are available on a standard DB15 female connector. Please see the catalog datasheet for actual specifications; complete product datasheets can be found by visiting [www.ultravolt.com/products.htm](http://www.ultravolt.com/products.htm).

**Pin 1 – Reference Voltage:** A precision, low temperature coefficient +10.00V reference voltage is available on this pin. Please see the data sheet for accuracy and temperature characteristics.

**Pin 2 – Voltage Programming (-) and Pin 3 – Voltage Programming (+):** The E Series voltage programming input is a differential amplifier. A differential input allows the user to avoid voltage regulation problems associated with common grounding with the power input. Both programming inputs have an input impedance of 10MΩ, to ground. If the programming is left unconnected, the output voltage will be set to

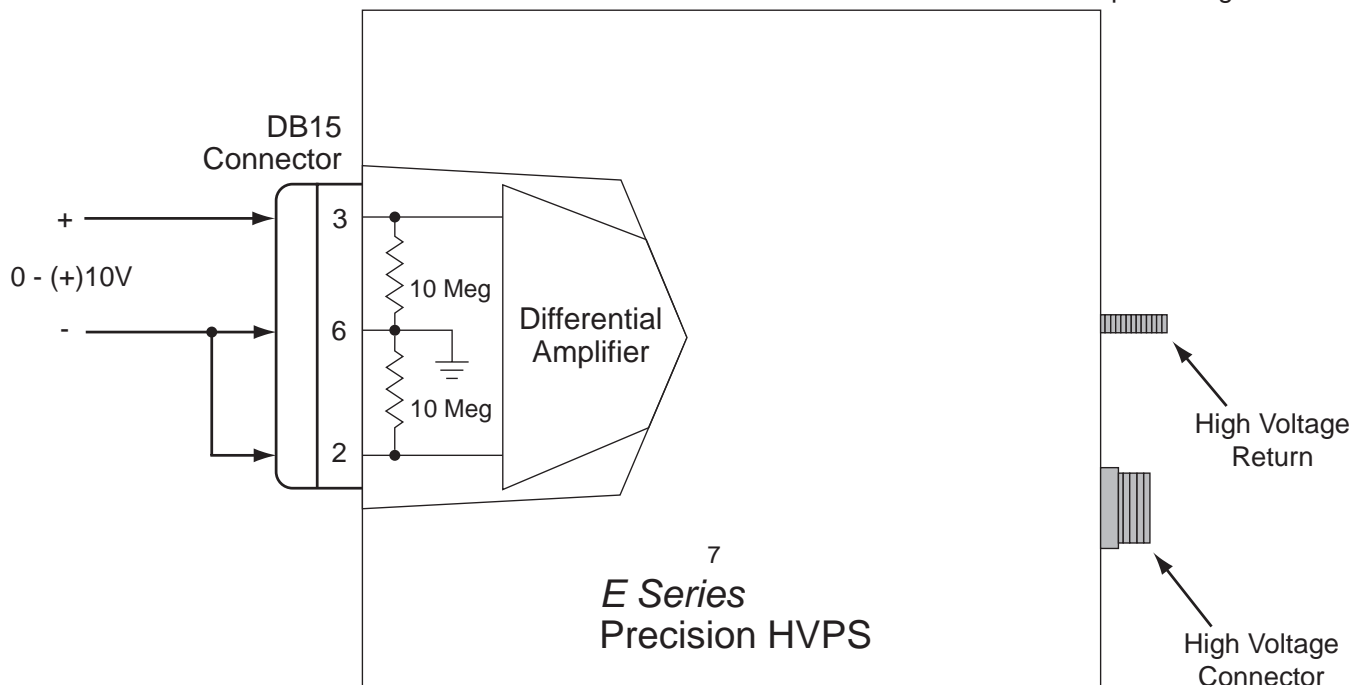
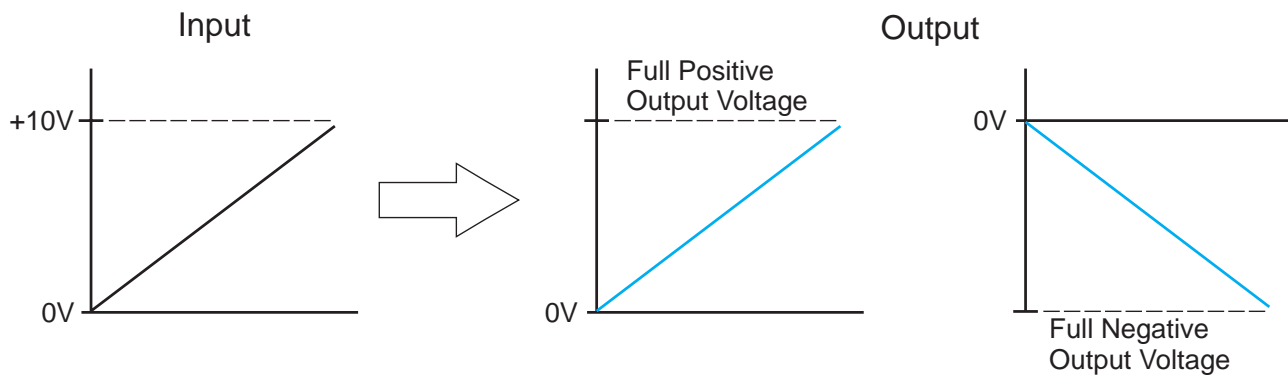


Figure 1. Typical Voltage Programming Configuration

zero. All models are scaled so 10.00V is 100% of rated output voltage. See Figure 1 for a typical circuit configuration.

**Pin 4 – Voltage Monitor:** The voltage monitor has the same scale factor as the voltage programming signal. 0 to +10V indicates 0 to 100% of rated voltage. The voltage monitor signal is derived internally from the voltage feedback and is buffered to provide low output impedance.

**Pin 5 – Voltage Mode Indicator:** An open drain configuration indicates when the power supply is in voltage regulation. The indicator is an active low and will appear as an open circuit when the power supply is in current control or in a disabled state. A pull up resistor can be used to create a logic signal, or the pin can be used to ground an LED to provide an illuminated indicator showing the operating control mode. See Figure 2 for usage suggestions.

**Pin 6 and 15 – Signal Ground:** The signal ground and power ground are common inside the power supply. This pin should be used as reference for all control and monitoring signals. If input power current is allowed to flow through this pin, offsets can occur that will degrade voltage regulation and monitoring accuracy. *A note on grounding: the stud next to the HV output connector should be used as the load return.*

**Pin 7 and 8 – Input Power:** The input power to all E Series HVPS is +23VDC to +30VDC, +24VDC nominal.

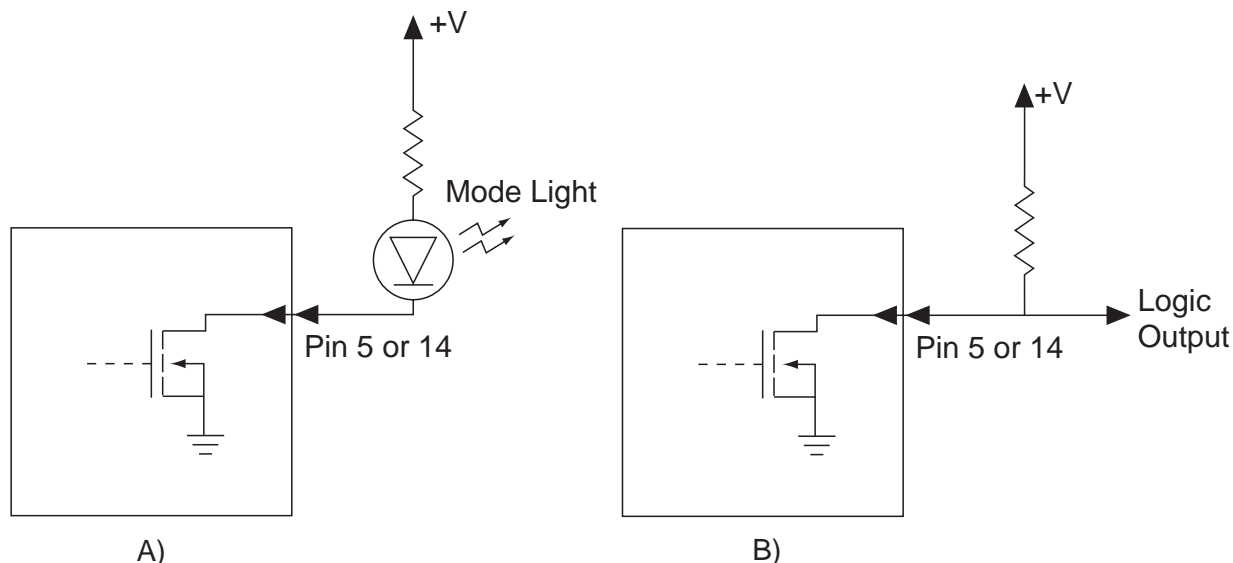
**Pin 9 and 10 – Power Ground:** Use these pins for the input power return. Do not allow input power return current to flow through the Signal Ground connections.

**Pin 11 – Enable:** A logic high between 2.5V and 15V will enable the power supply a logic low between 0V and 1V or an open circuit will disable the power supply. The input impedance is 100k $\Omega$ ; a resistor to ground will disable the power supply when the pin is left open.

**Pin 12 – Current Monitor:** The current monitor has the same scale factor as the current programming signal. 0 to +10V indicates 0 to 100% of rated current. The current monitor signal is derived internally from the current feedback and is buffered to provide low output impedance.

**Pin 13 – Current Programming:** A 0V to +10V signal will program the power supply for 0 to 100% rated output current. The input impedance for this control pin is 10M $\Omega$ ; a resistor to ground will program the power supply for zero output current if this pin is left open.

**Pin 14 – Current Mode Indicator:** An open drain configuration indicates when the power supply is in



**Figure 2. Typical Mode Indicator**



current regulation. The indicator is an active low and will appear as an open circuit when the power supply is in voltage control or in a disabled state. A pull up resistor can be used to create a logic signal, or the pin can be used to ground an LED to provide an illuminated indicator showing the operating control mode. See Figure 2 for usage suggestions.

## **LEDs**

There are two LEDs located just to the left of the DB15 Connector on the front panel. The green POWER ON LED illuminates when power is applied to the E Series. The yellow HIGH VOLTAGE ON LED illuminates when the unit is enabled.

## **High Voltage Connections**

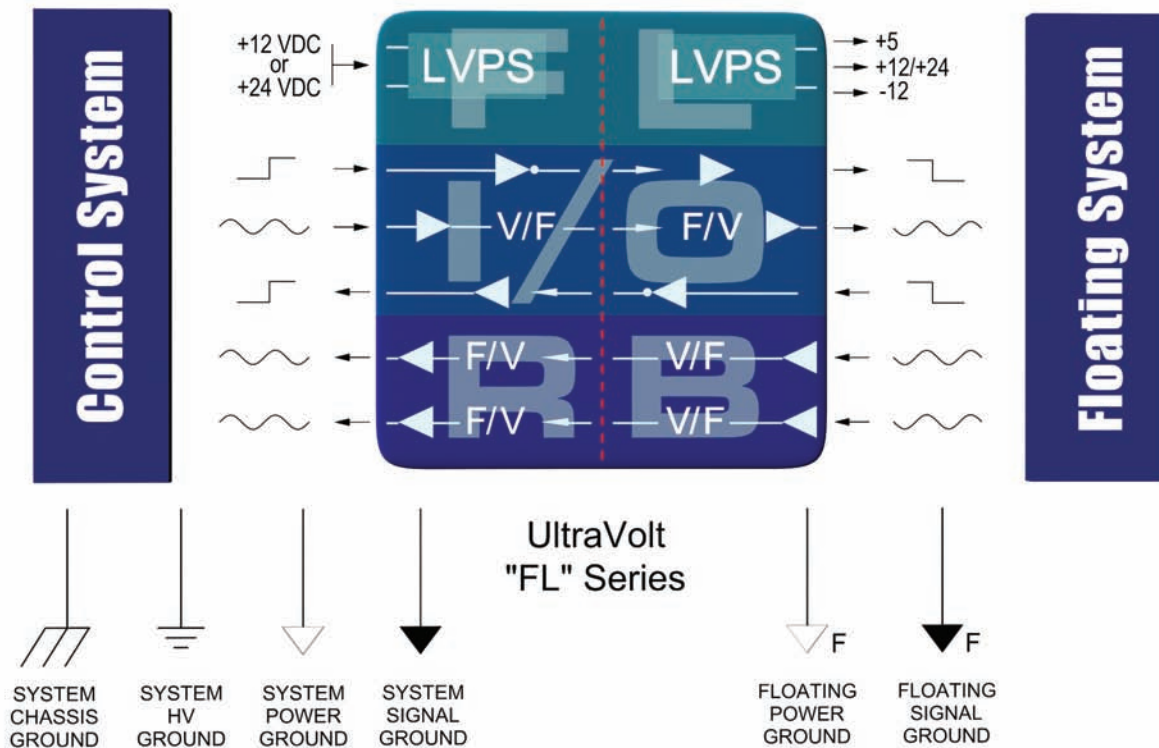
Connect the high voltage load to the High Voltage Connector and the High Voltage Return stud. Do NOT connect the High Voltage Return stud to the signal ground at pin 6. The High Voltage Return stud and the signal ground are connected internally to avoid ground loops.

**Introduction**

15FL power supplies have the unique capability of providing up to 15 kilovolts of isolation between the input and output. These power supplies are low-voltage DC-to-DC converters that provide an isolated 12V or 24V floating power source. 15FL units can be used to float circuitry on a high voltage of up to 15kV. Analog and digital communications are available between the ground-referenced circuitry and the isolated, or floating, circuitry. The most common use of the 15FL is floating one UltraVolt HVPS on the output of another UltraVolt HVPS. When the FL unit is paired with an UltraVolt FIL Series, a filament power supply referenced to the output of a high voltage power supply can be controlled with high levels of precision.

The 15FL uses a 7-pin header for control and power input and another 7-pin header for the isolated power output. When the 15FL is ordered with the -I/O and -R/B options, the interface is provided on a double-row, 14-pin header on both the ground side and the isolated side.

For a higher level of accuracy and linearity as well as an additional analog control channel, see the 15EFL module ([EFL Series](#)).



**Figure 1: Function Diagram of the FL Series**

## Ground-side pin functions

### First row pins:

**Pin 1, Power Ground:** Use this pin for the input power return. Do not allow input power return current to flow through the Signal Ground connections. The Power Ground and Signal Ground are joined internally. There is no electrical connection between these grounds and the floating grounds.

**Pin 2, Input Power:** The input voltage on the 15FL is available at either 12Vdc nominal or 24Vdc nominal. See the [FL Series data sheet](#) for input voltage tolerance and information on de-rated operation outside the normal input voltage range.

**Pin 3, LVPS Enable/Disable:** A voltage between 0V and 3V will disable the 15FL power supply. A voltage between 3.9V and 12V will enable the unit. If the pin is left open, the power supply will default to an enabled state. Grounding the enable/disable pin will disable the unit. The input characteristics can be modeled as a 1k $\Omega$  resistor driving the base of a PNP transistor.

**Pin 4, TTL up channel (-I/O option only):** The TTL up channel is a digital link between the ground-referenced circuitry and the floating circuitry. It is commonly used to drive the enable pin on a floating HVPS. The output of this digital link is Pin 11 on the floating side. This logic channel can be used to communicate serially with a floating microcontroller as well. The threshold for the input is logic low between 0V and 1V and logic high between 2.5V and 15V. The digital links are inverted.

**Pin 5, Signal Ground:** The Signal Ground and Power Ground are common inside the power supply. This pin should be used as reference for all analog signals. If input power current is allowed to flow through this pin, offsets can occur, which will degrade accuracy.

**Pin 6, Analog communications up (-I/O option only):** An isolated analog communication channel is provided on -I/O optioned units. A 0V to 10V signal between this pin and Signal Ground will result in a 0V to 10V signal (floating pin 13) on the isolated side of the 15FL, which is referenced to the floating Signal Ground (floating pin 12). There is no direct electrical connection between the analog input signal and the analog output signal. This function is commonly used to provide the remote adjust voltage to a floating high-voltage power supply (HVPS).

**Pin 7, +5V reference voltage:** The internal +5V reference is provided for external use through a 464 $\Omega$  resistor.

### Second Row Pins (-R/B Option)

The 15FL is available with the -R/B option. This option adds communications back from the floating-side circuitry to the ground side. The -R/B adds the second row of pins on both sides of the unit and provides two analog down channels and one TTL down channel.

**Pin 8, Analog down channel 1 output (+):** This is the output of one of the analog down communications channels; the input is on the floating pins. A 0V to 10V signal input on the floating-side channel 1 will result in a 0V to 10V signal on this pin with reference to the Signal Ground on pin 5.

**Pin 9, Analog down channel 1 output (-):** This pin provides the compliment to the voltage on pin 8. A 0V to 10V signal on the floating-side channel 1 input will result in a 0V to -10V signal on this pin with reference to the Signal Ground on pin 5 corresponding to the voltage on pin 8, but inverted.

**Pin 10, Analog down channel 2 output (+):** This is the output of one of the analog down communications channels; the input side is on the floating pins. A 0V to 10V signal input on the high-side channel 2 will result in a 0V to 10V signal on this pin with reference to the Signal Ground on pin 5.

**Pin 11, Analog down channel 2 output (-):** This pin provides the compliment to the voltage on pin 10. A 0V to 10V signal input on the floating-side channel 2 will result in a 0V to -10V signal on this pin with reference to the Signal Ground on pin 5 corresponding to the voltage on pin 10, but inverted.

**Pins 12, and 13:** No Connections

**Pin 14, TTL down channel output:** This pin is the output of the TTL down channel. The logic is inverted. The output is through an open collector circuit with an internal 1k $\Omega$  pull up to +5V. See the [FL Series data sheet](#) for maximum baud rates.

## Floating-side pin functions:

### First row pins (outside pins):

**Pin 8, Floating Power Ground:** Use this connection as the return for the floating output voltage. This pin is joined internally to the Floating Signal Ground. There is no electrical connection between these grounds and the low-side grounds.

**Pin 9, Floating output power (+12V or +24V):** This is the main output voltage for the 15FL DC-to-DC converter. This voltage output is commonly used as the main input power to a floating HVPS or Filament power supply. Use pin 8 for the power return.

**Pin 10, Floating -15V output:** This is a low current -15V fixed output. This voltage is commonly used as the negative rail on operation amplifiers and other analog circuitry. See the [FL Series data sheet](#) for maximum current draw and voltage tolerance.

**Pin 11, Floating TTL Up out (-I/O option):** This pin is the output of the TTL down channel. The logic is inverted. The output is through an open collector circuit with an internal 1k $\Omega$  pull up to +5V. See the [FL Series data sheet](#) for maximum baud rates.

**Pin 12, Floating Signal Ground:** The floating Signal Ground and floating Power Ground are common inside the power supply. This pin should be used as reference for all floating analog signals. If output power current is allowed to flow through this pin, offsets can occur, which will degrade accuracy.

**Pin 13, Floating Analog up out (-I/O option):** This is the output of the analog up communications channel; the input side is on the ground-side pins. A 0V to 10V signal input on the input at Pin 6 on the ground side will result in a 0V to 10V signal on this pin with reference to the floating Signal Ground on pin 12.

**Pin 14, Floating +5.6V reference:** An internal +5.6V source is provided for external use. Please see the [FL Series data sheet](#) for current capacity.

**Pin 1, Floating Analog Down (+) Input 1 (-R/B option):** This pin is the non-inverting input of a differential amplifier. A 0V to 10V signal between (-) input 1 and (+) input 1 will cause a 0V to 10V signal on the ground-referenced side along with its compliment on Pin 8 and Pin 9.

**Pin 2, Floating Analog Down (-) Input 1 (-R/B option):** This is the inverting input of a differential amplifier referenced above on Pin 1.

**Pin 3, Floating Analog Down (+) Input 2 (-R/B option):** This pin is the non-inverting input of a differential amplifier. A 0V to 10V signal between (-) input 2 and (+) input 2 will cause a 0V to 10V signal on the ground-referenced side along with its compliment on Pin 10 and Pin 11.

**Pin 4, Floating Analog Down (-) Input 2 (-R/B option):** This is the inverting input of a differential amplifier referenced above on Pin 3.

**Pin 5, N/C:** No connection.

**Pin 6, N/C:** No connection.

**Pin 7, Floating TTL input down (-R/B option):** This is the input to the digital down link; the output is on Pin 14 on the ground side. The threshold for the input is logic low between 0V and 1V and logic high between 2.5V and 15V. The digital links are inverted.

### Introduction

15EFL power supplies have the unique capability of providing up to 15 kilovolts of isolation between the input and output. These power supplies are low-voltage, DC-to-DC converters that provide an isolated 12V or 24V floating power source. The 15EFL also provides analog and digital communications between the input and output circuitry. The communications is accomplished digitally, providing excellent linearity, stability, and low temperature drift with a resolution of 16 bits.

The 15EFL performs all the functions of the 15FL power supply with the addition of several important features. The 15EFL has an additional analog up channel, as well as 'quiet mode' and 'half quiet mode'.

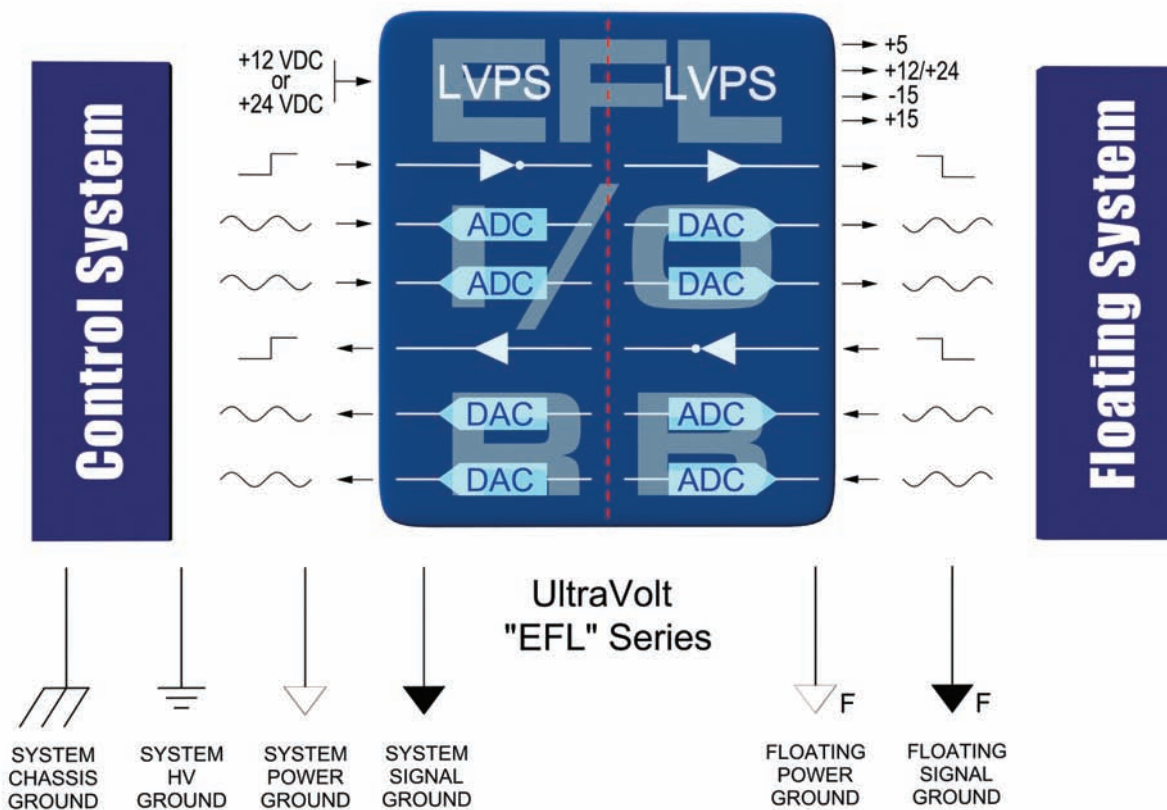


Figure 1: Function Diagram of the EFL Series

### Ground-side pin functions

#### First row pins:

**Pin 1, Power Ground:** Use this pin for the input power return. Do not allow input-power-return current to flow through the Signal Ground connections. The power ground and signal ground are joined internally. There is no electrical connection between these grounds and the floating grounds.

**Pin 2, Input Power:** The input voltage on the 15EFL is available at either 12Vdc nominal or 24Vdc nominal. See the [EFL Series data sheet](#) for input voltage tolerance.

**Pin 3, LVPS Enable/Disable:** A voltage between 0V and 0.8V will disable the 15EFL power supply. A voltage between 3.2V and 5V will enable the unit. If the pin is left open, the power supply will default to an enabled state. Grounding the enable/disable pin will disable the unit. The input characteristics can be accurately modeled as a 1k $\Omega$  resistor driving the base of a PNP transistor.

**Pin 4, TTL up channel input:** The TTL up channel is a digital link between the ground-referenced circuitry and the floating circuitry. This channel is commonly used to drive the enable pin on a floating high voltage power supply (HVPS). The output of this digital link is Pin 11 on the floating side. The threshold for the input is logic low between 0V and 0.8V and logic high between 2.4V and 5.0V. The digital links are inverted and have an internal 10k $\Omega$  pull up.

**Note:** For proper start up of the microprocessor the LVPS Enable/Disable (pin 3) and TTL Up inputs must be driven by an open collector or a pull up resistor with a value greater than 10K $\Omega$ .

**Pin 5, Signal Ground:** The signal ground and power ground are common inside the power supply. This pin should be used as reference for all analog signals. If input power current is allowed to flow through this pin, offsets can occur which will degrade accuracy.

**Pin 6, Analog up channel 1 input:** A 0V to +10V for 24V units or 0 to +5V for 12V units signal between this pin and signal ground will result in a 0V to +10V for 24V units or 0 to +5V for 12V units signal on the isolated side of the 15EFL (floating pin 13) that is referenced to the floating signal ground (floating pin 12). There is no direct electrical connection between the analog input signal and the analog output signal. This function is commonly used to provide the remote adjust voltage to a floating HVPS.

**Pin 7, +5.1V reference voltage:** The internal +5.1V reference is provided for external use through a 464 $\Omega$  resistor.

## Second Row Pins:

**Pin 8, Analog down channel 1 output (+):** This is the output of one of the analog down communications channels; the input side is on the floating pins. A 0V to 10V for 24V units or 0 to 5V for 12V units signal input on the high-side channel 1 will result in a 0V to +10V for 24V units or 0 to +5V for 12V units signal on this pin with reference to the signal ground on pin 5.

**Pin 9, Analog down channel 1 output (-):** This pin provides the compliment to the voltage on pin 8. A 0V to 10V for 24V units or 0 to 5V for 12V units signal input on the high-side channel 1 will result in a 0V to -10V for 24V units or 0 to -5V for 12V units signal on this pin with reference to the signal ground on pin 5 corresponding to the voltage on pin 8, but inverted.

**Pin 10, Analog down channel 2 output (+):** This is the output of one of the analog down communications channels; the input side is on the floating pins. A 0V to 10V for 24V units or 0 to 5V for 12V units signal input on the high-side channel 2 will result in a 0V to +10V for 24V units or 0 to +5V for 12V units signal on this pin with reference to the signal ground on pin 5.

**Pin 11, Analog down channel 2 output (-):** This pin provides the compliment to the voltage on pin 10. A 0V to 10V for 24V units or 0 to 5V for 12V units signal input on the high-side channel 2 will result in a 0V to -10V for 24V units or 0 to -5V for 12V units signal on this pin with reference to the signal ground on pin 5 corresponding to the voltage on pin 10, but inverted.

**Pin 12, Analog up channel 2 input:** A 0V to +10V for 24V units or 0 to +5V for 12V units signal between this pin or signal ground will result in a 0V to +10V for 24V units or 0 to +5V for 12V units signal on the isolated side of the 15EFL (floating pin 6) that is referenced to the floating signal ground (floating pin 12). There is no direct electrical connection between the analog input signal and the analog output signal. This function is commonly used to provide the remote adjust voltage to a floating HVPS.

**Pin 13, Quiet Mode:** The EFL Series uses a digital link to provide the analog communications between the ground side and floating side that has a 16-bit resolution. In applications that are sensitive to noise and variations on the analog output, the quiet mode is used to latch the output DAC and prevent bit jumping. ½ quiet mode latches the up channels, and full quiet mode will latch both up and down channels. The digital up and down links work normally regardless of the quiet-mode status.

The mode pin has an internal 20kΩ pull down resistor; the default condition if this pin is left open is normal operation. The following thresholds apply:

Normal operation: 0V to 0.8V  
Full Quiet Mode: 3.0V to 5.6V  
½ Quiet Mode: -9.0V to -4.0V

**Pin 14, TTL down channel output:** This pin is the output of the TTL down channel. The logic is inverted. A low level input is 0V to 0.55V; a high is from 3.8V to 5.0V. This pin can sink 3mA maximum and source 1mA maximum.

## Floating-side pin functions

### First row pins (outside pins):

**Pin 8, Floating Power Ground:** Use this connection as the return for the floating output voltage. This pin is joined internally to the Floating Signal Ground. There is no electrical connection between these grounds and the low-side grounds.

**Pin 9, Floating output power (+12V or +24V):** This is the main output voltage for the 15EFL DC-to-DC converter. This voltage output is commonly used as the main input power to a floating HVPS or filament power supply, such as the [UltraVolt FIL Series](#). Use pin 8 for the power return.

**Pin 10, Floating -15V output:** This is a low-current, -15V fixed output. This voltage is commonly used as the negative rail on operational amplifiers and other analog circuitry. See the [EFL Series data sheet](#) for maximum current draw and voltage tolerance.

**Pin 11, Floating TTL Up output:** This pin is the output of the TTL up channel. The logic is inverted. A low level input is 0V to 0.55V; a high is from 3.8V to 5.0V. This pin can sink 3mA maximum and source 1mA maximum.

**Pin 12, Floating Signal Ground:** The floating signal ground and floating power ground are common inside the power supply. This pin should be used as reference for all floating analog signals. If output power current is allowed to flow through this pin, offsets can occur which will degrade accuracy above on Pin 1.



**Pin 13, Floating Analog up channel 1 out:** This is the output of the analog up channel 1 communications channel; the input is on the ground-side pins. A 0V to +10V for 24V units or 0 to +5V for 12V units signal on the input at Pin 6 on the ground side will result in a 0V to +10V for 24V units or 0 to +5V for 12V units signal on this pin with reference to the floating signal ground on pin 12.

**Pin 14, Floating +5.1V output:** An internal +5.1V source is provided for external use. Please see the [EFL Series data sheet](#) for current capacity.

**Pin 1, Floating Analog Down (+) Input 1:** This pin is the non-inverting input of a differential amplifier. A 0V to 10V for 24V units or 0 to 5V for 12V units signal between (-) input 1 and (+) input 1 will cause a 0V to 10V for 24V units or 0 to 5V for 12V units signal on the ground-referenced side along with its complement on Pin 8 and Pin 9.

**Pin 2, Floating Analog Down (-) Input 1:** This is the inverting input of a differential amplifier referenced above on Pin 1.

**Pin 3, Floating Analog Down (+) Input 2:** This pin is the non-inverting input of a differential amplifier. A 0V to 10V for 24V units or 0 to 5V for 12V units signal between (-) input 2 and (+) input 2 will cause a 0V to 10V for 24V units or 0 to 5V for 12V units signal on the ground-referenced side along with its complement on Pin 10 and Pin 11.

**Pin 4, Floating Analog Down (-) Input 2:** This is the inverting input of a differential amplifier referenced above on Pin 3.

**Pin 5, +15V output:** This is a low-current, +15V fixed output. This voltage is commonly used as the positive rail on operational amplifiers and other analog circuitry. See the [EFL Series data sheet](#) for maximum current draw and voltage tolerance.

**Pin 6, Floating Analog up channel 2 out:** This is the output of the analog up channel 2 communications channel; the input is on the ground-side pins. A 0V to +10V for 24V units or 0 to +5V for 12V units signal on the input at Pin 12 on the ground side will result in a 0V to +10V for 24V units or 0 to +5V for 12V units signal on this pin with reference to the floating signal ground on Pin 12.

**Pin 7, Floating TTL down input:** The TTL down channel is a digital link between the floating-referenced circuitry and the ground-side circuitry. The output of this digital link is Pin 14 on the ground side. The threshold for the input is logic low between 0V and 0.8V and logic high between 2.4V and 5.0V. The digital links are inverted, and have an internal 10k $\Omega$  pull up.

**Note:** For proper start up of the microprocessor the Floating TTL Down input must be driven by an open collector or a pull up resistor with a value greater than 10K $\Omega$ .

### Introduction

This Tech Note explains how to implement the various control, programming, and monitoring functions of the “HVA” Series Precision High Voltage Amplifier.

### Remote Programming

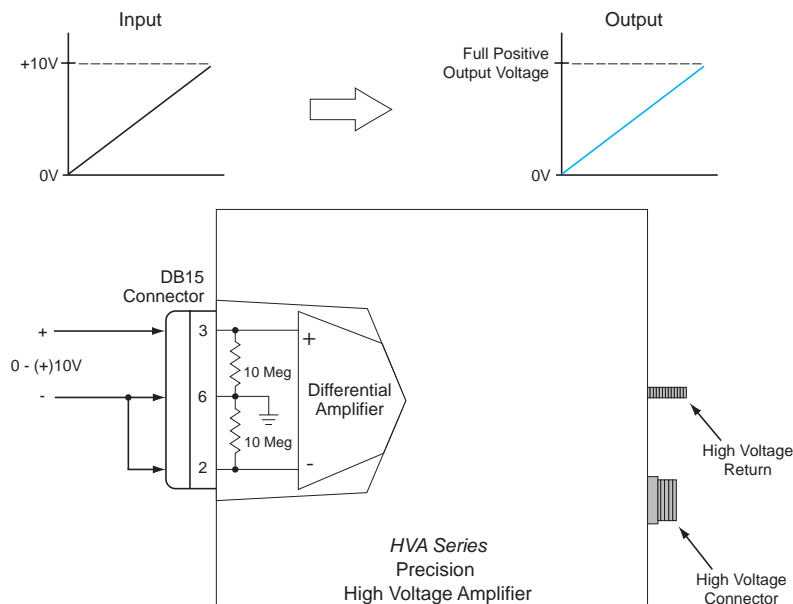
To program the Unipolar Version of the HVA High Voltage Amplifiers a 0 to +10 VDC is required. A 10VDC reference voltage is provided at pin 1 of the DB15 female connector mounted on the front of the HVA. It can be used to source the programming circuitry. In the case of a fixed (non-time varying) output, the programming circuitry could simply be a potentiometer connected to pin 1 and pin 6, with the wiper terminal connected to pin 3 (non-inverting) or pin 2 (inverting) Voltage Programming Pin.

In the following sections, we outline programming of the unipolar versions of the HVA followed by programming of the bipolar versions of the HVA.

As depicted in Figure 1 and in the subsequent illustrations, programming is performed by the appropriate connections to pins 2, 3, and 6 of the input connector. As depicted, the programming input is applied to an internal differential amplifier within the HVA. The inputs are tied to the signal ground within the HVA by 10MΩ resistors. Pin 6 is the signal ground and is connected to the power ground, internally.

### Programming Unipolar HVAs — Positive Voltage Excursions

For positive voltage excursions (as depicted in Figure 1), the 0 to +10 VDC source is connected as shown in Figure 1 with pin 2 tied to the internal ground in the HVA at pin 6.

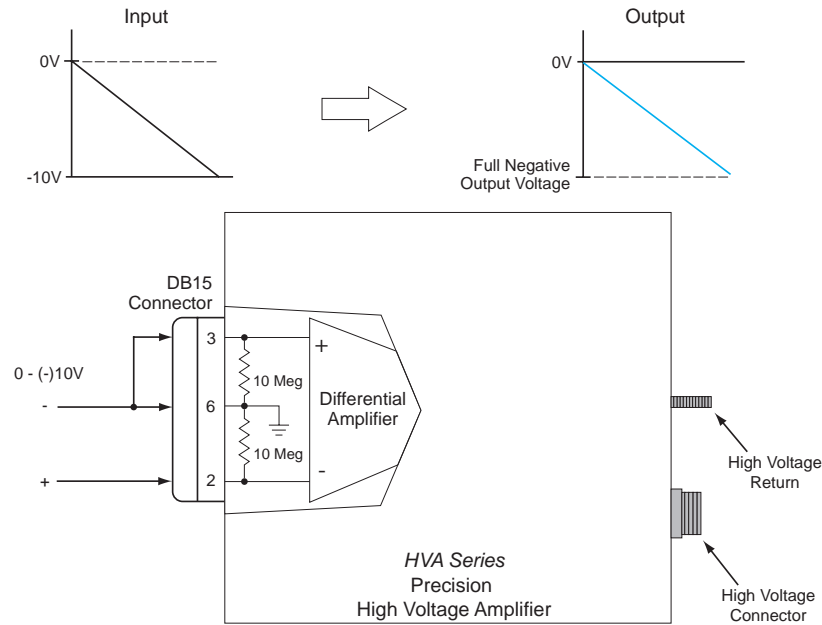


**Figure 1. Programming the Unipolar Version - Positive Voltage Excursions**

## Programming Unipolar HVAs — Negative Voltage Excursions

For negative voltage excursions (as depicted in Figure 2), the 0 to +10 VDC source is connected as shown, with pin 3 tied to the internal ground in the HVA at pin 6.

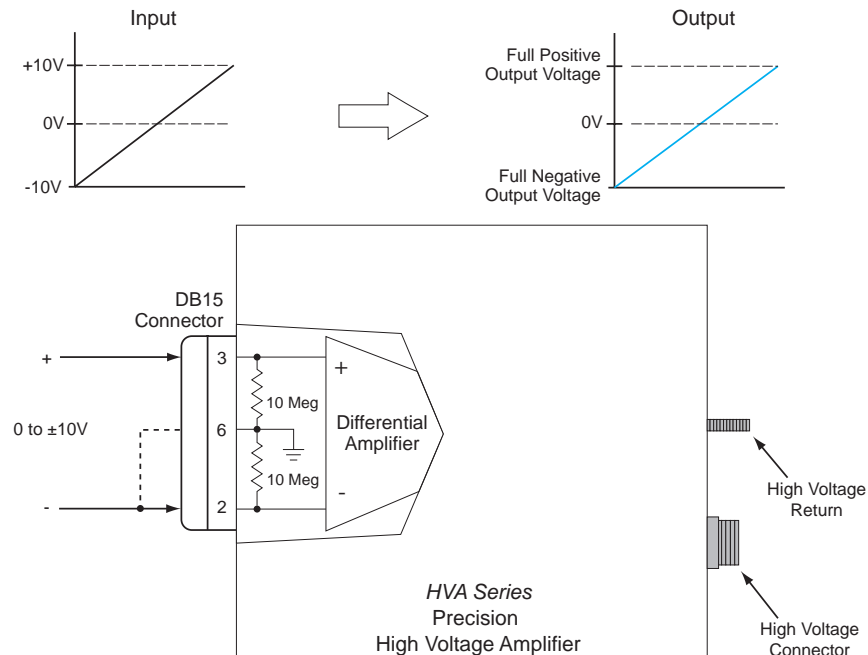
Negative voltage excursions can also be programmed with a -10V signal into the Vprog(+) — pin 3 — with pin 2 tied to the signal ground at pin 6.



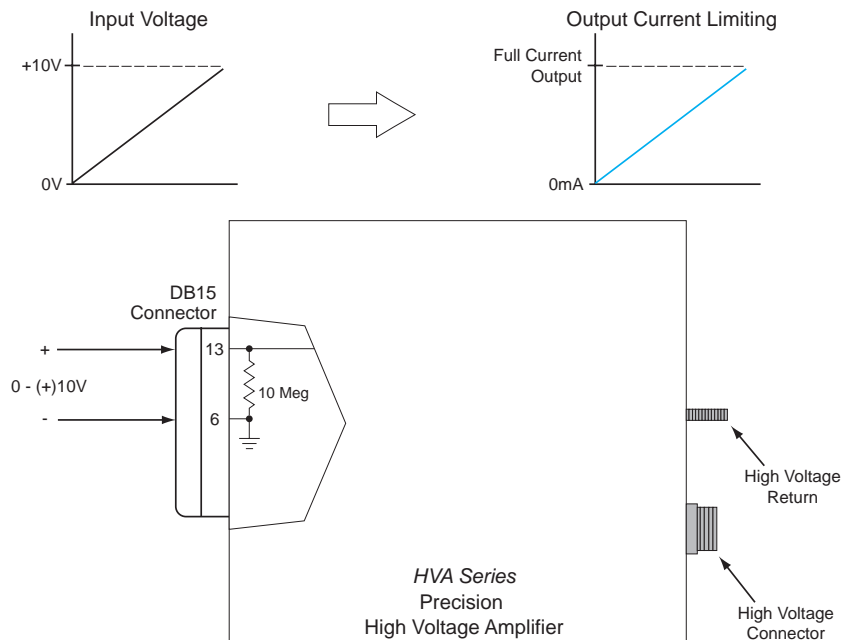
**Figure 2. Programming the Unipolar Version - Negative Voltage Excursions**

## Programming Bipolar HVAs

For a bipolar HVA, a 0 to  $\pm 10$  VDC source is connected (as depicted in Figure 3). The (-) terminal may be grounded at pin 6 (see note 1). If a waveform is required, a bipolar programming signal will yield a bipolar output voltage.



**Figure 3. Programming Bipolar HVAs**



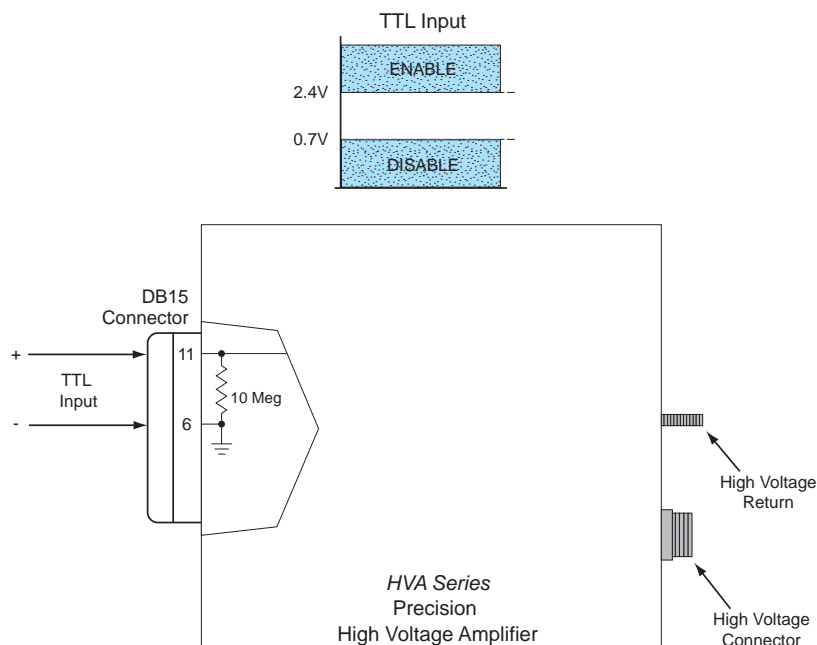
**Figure 4. Current Limiting**

## Current Limit Adjust

To establish current limiting, a 0 to +10 VDC source is connected to pin 13 and pin 6 (signal ground) as shown in Figure 4. Be sure to observe the polarity of the applied signal. The voltage is always positive because the current limiting circuitry seeks the absolute value of the current and limits the value — without regard to polarity. The input characteristic is high impedance with a 10MΩ pulldown to ground.

## Enable/Disable

A TTL output can be connected to pins 11 and 6 (as shown in Figure 5) to enable or disable the HVA. Please note, when no TTL output is connected, the HVA defaults to Disable via the 10MΩ resistor shown in Figure 5, which pulls the TTL input to ground. As a matter of convenience, the Enable can be brought to the Vref at pin 1.

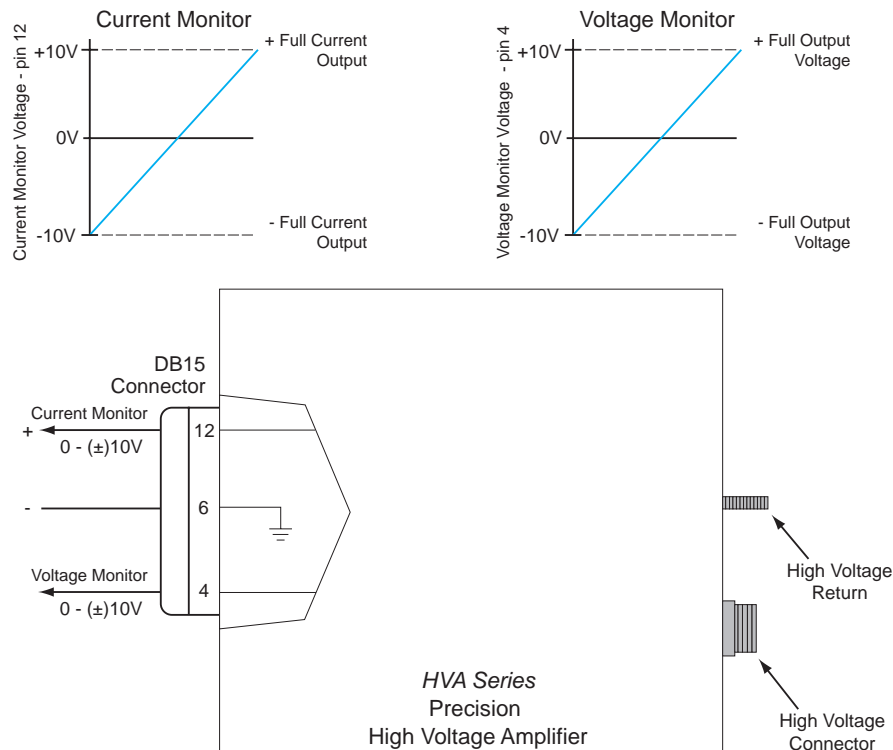


**Figure 5. Enable/Disable**

## Voltage and Current Monitoring

As depicted in Figure 6, monitoring voltages corresponding to the voltage and current delivered between the High Voltage Connector and the 6-32 High Voltage Return stud are supplied at pins 4 and 12, respectively, versus the signal ground at pin 6. Both of these pins are buffered and can provide currents of 1mA, maximum. When the HVA is sourcing current, the current monitoring voltage will be positive; when sinking current, this voltage will be negative.

An accurate representation of the voltage waveform can be viewed with an oscilloscope at pin 4. Please note, the current monitoring circuitry is narrow band, so waveforms at pin 12 are accurate at frequencies of 15Hz or less. The voltage monitor employs a compensated voltage divider and, therefore, has an extended bandwidth.



**Figure 6. Current and Voltage Monitors**

## Reference Voltage

The HVA supplies 0 to +10 VDC  $\pm 0.05\%$  at pin 1 versus the signal ground at pin 6. The maximum delivered current must be limited to 5mA or less.

## LEDs

There are two LEDs located just to the left of the DB15 Connector on the front panel. The green POWER ON LED illuminates when power is applied to the HVA. The yellow HIGH VOLTAGE ON LED illuminates when the HVA is enabled.

## High Voltage Connections

Connect the high voltage load to the High Voltage Connector and the High Voltage Return. Do NOT connect the High Voltage Return stud to the signal ground at pin 6. The High Voltage Return stud and the signal ground are connected internally to avoid ground loops.

### Basics Of UltraVolt HVPS Output Voltage Control

By varying the voltage at the *Remote Adjust Input* terminal (pin 6) between 0 and +5V, the UV high-voltage power supply (HVPS)'s output voltage can be adjusted. The output voltage can be varied over the full range from 0 to the maximum output voltage. By design, the maximum HVPS output voltage is 107.5% ± 2% of the HVPS's nominal output-voltage rating. For an HVPS of nominal voltage rating  $E_0$ :

<u>HVPS Polarity</u>	<u>Remote Adjust Range</u>	<u>Output Voltage</u>
+ $E_0$ (i.e. -P supply)	0 to +5V	0 to $(1.075E_0)V$
- $E_0$ (i.e. -N supply)	+5V to 0	0 to $(1.075E_0)V$

Note that for a **negative** supply, a remote adjust input of 0V yields an output of  $1.075E_0$  volts, not 0V as with the positive supply.

Under **no** circumstances should the *Remote Adjust Input* of either a **positive** or **negative** HVPS be driven below 0V, since damage to the HVPS will occur. Should a bipolar DAC or Op Amp be used to control the remote adjust, the *Remote Adjust Input* must be protected from negative voltage. This can be accomplished simply by connecting a low-voltage Schottky diode between HVPS pins 5 and 6 (anode to pin 5, cathode to pin 6). For more information, see Application Note #16.

The gain from the *Remote Adjust Input* to the HVPS output can be found using:  $((E_0 / 5) 1.075)$ , with a typical tolerance of ± 1%. Again,  $E_0$  is the supply's nominal voltage rating. An initial offset of ± 1% may also be present.

For a 1kV unit,

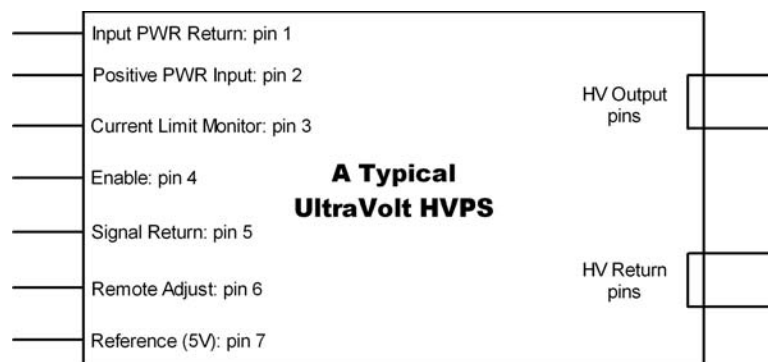
$$\begin{aligned} \text{gain} &= (E_0 / 5)(1.075) \pm 1\% = (1000V / 5)(1.075) \pm 1\% \\ &= 215V \pm 1\%. \end{aligned}$$

With a remote adjust input of 5V, the HVPS output would be 1075V.

UltraVolt power supplies can be controlled through two methods:

- 1) Direct voltage programming
- 2) Resistive programming

As we review these two methods, refer to UV-CONN-1 (Voltage Programming of Remote Adjust with a Potentiometer, DAC or OP AMP) or to the illustration below.



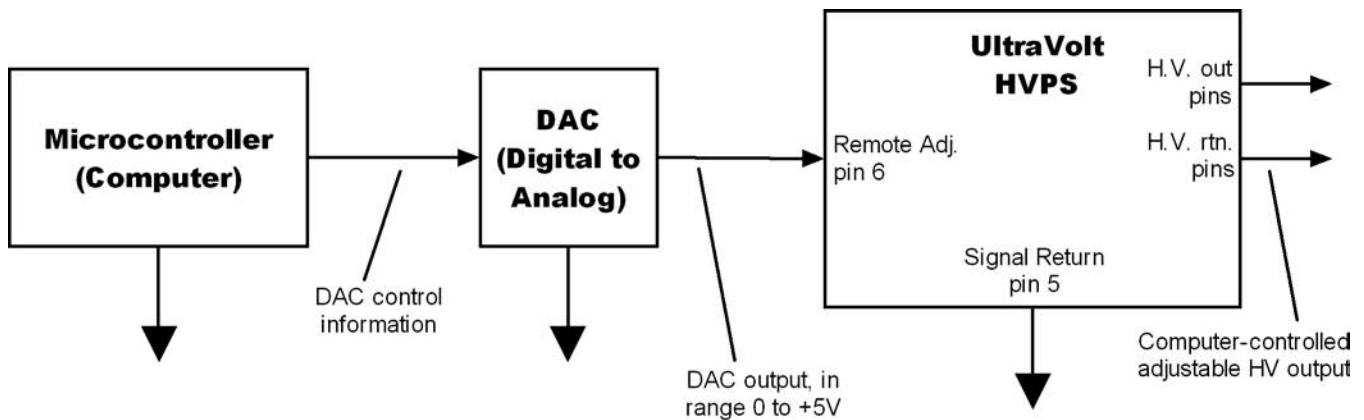
## 1) Voltage Programming

Voltage programming of the UltraVolt HVPS can be done by applying a controlled voltage to the *Remote Adjust Input* terminal (pin 6). A typical application of voltage programming is the adjustment of the HVPS's output voltage through the use of a computer-controlled DAC (digital-to-analog converter). Although this allows for extremely versatile control of the HVPS, designs using this method must compensate for the DAC resolution (the DAC output-voltage step per input-step increment). Should the need arise, a logarithmic DAC may have to be used to increase the resolution over a region of interest at the expense of the other ranges. Of course, the number of input bits to the DAC could also be increased to improve the resolution.

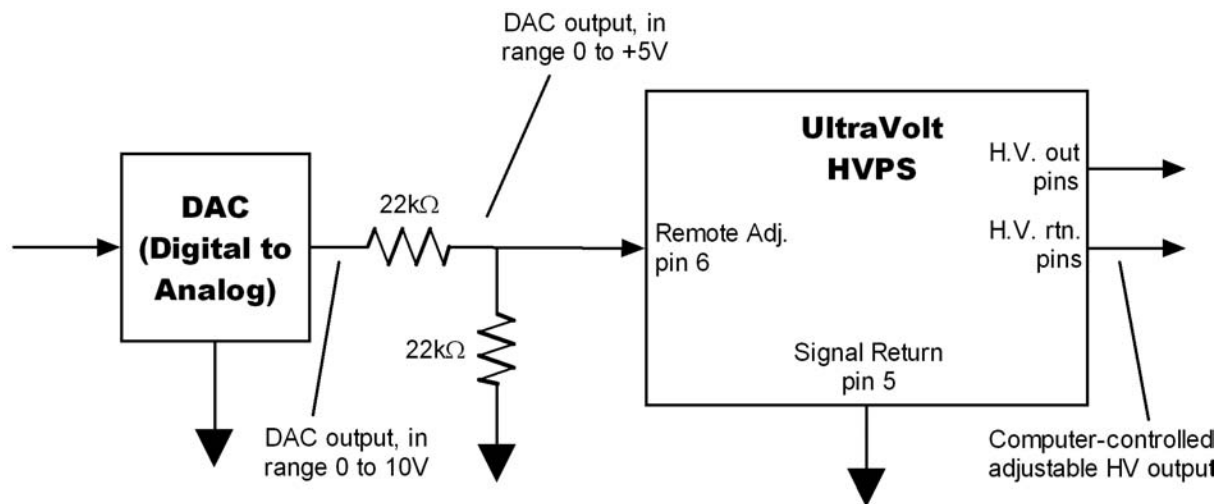
To avoid the need to generate a negative internal LVPS, the designers at UltraVolt used the internal +5VDC, temperature-compensated reference to create a summing junction with the negative HVPS feedback. This also had the advantage of keeping the remote programming voltage unipolar instead of bipolar. Therefore, it is important with a *Remote Adjust Input* of +5VDC to 0VDC representing 0  $E_{out}$  to Max  $E_{out}$  that any programming source equals +5VDC or greater. This will guarantee the HVPS output goes to 0VDC.

If your remote-control circuit uses the +5VDC reference, care should be taken when using a control circuit such as a DAC that uses a reference other than the internal UltraVolt reference. Should the DAC reference be 5.000 volts and the internal UltraVolt reference be at 5.025 volts, then the DAC controls will yield a non-zero output. This may lead to a situation when 0 volts is expected from the power supply but is not attainable, since the DAC output could not be made to equal the 5V reference. This can be avoided by using the HVPS 5V reference output as the DAC reference voltage. If the DAC has an internal reference, an external pull-up can also be added to assure DAC voltages will slightly exceed 5.0V.

In a system with a dual-, quad-, or octal-type multiple DAC, a single voltage reference is used. By tying the +5 volt references of all the UltraVolt HVPSs together, an average  $V_{ref}$  can be created.



The UltraVolt high voltage power supply can also be programmed with a 0–10V DAC, Op Amp, or other control voltage using a resistive divider. For divider design purposes, the input impedance of the *Remote Adjust Input* terminal is 1M $\Omega$ . An example of a suitable divider for this application is as follows:



If a circuit design utilizing a negative UltraVolt HVPS must have 0 to +5VDC control, an Op Amp inverter can be used, see UV-CONN-17 (Simple Remote Adjust Inverter for Negative HVPS) for a typical circuit.

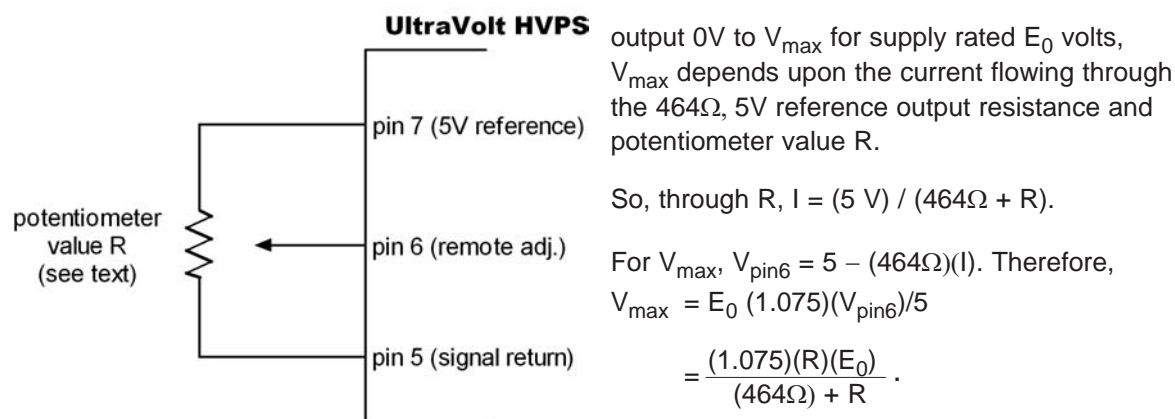
## 2) Resistive Programming

Because of the high, 1MΩ, remote adjust impedance, the UltraVolt HVPS can also be adjusted through resistive programming. In this application, the +5V Reference Output (pin 7) of the HVPS is used. A resistive divider can be used to control the voltage at the Remote Adjust Input terminal and, hence, control the output voltage of the HVPS. Designs using the 5V reference must compensate for its 464Ω output impedance, and it should be remembered that this voltage is thermally compensated.

Many variations of resistive dividers are possible. Below are some example for HVPSs with nominal voltage rating  $E_0$ .

### a) Output variable from 0V to approximately 1.075 times the rated voltage

For a positive HVPS (with a negative HVPS, the formulas change slightly),

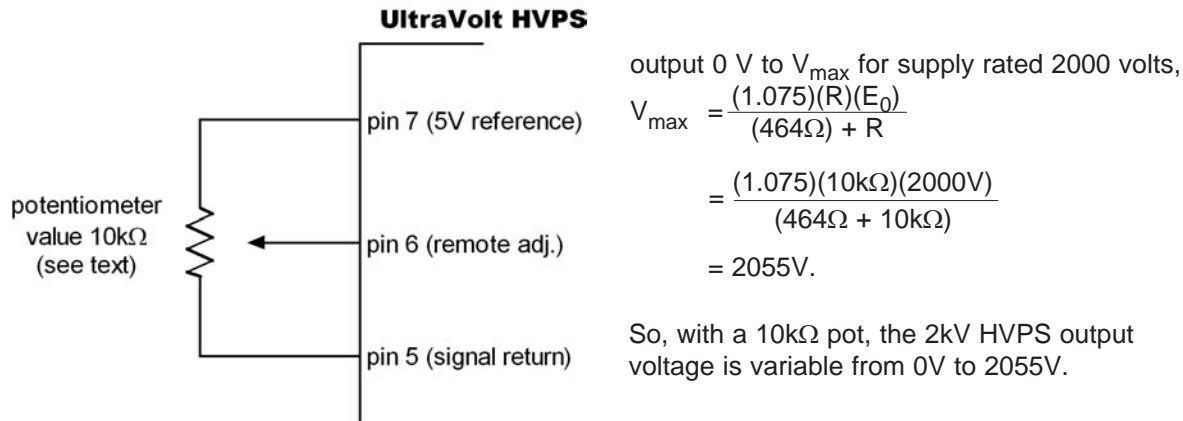


The above configuration is the basic method for resistively programming the supply's output voltage. The value of the potentiometer must be much smaller than the input impedance of the Remote Adjust Input, which is 1MΩ. At the same time, the potentiometer's value must be chosen so it does not draw too much current from the 5V reference supply, keeping in mind its output impedance of 464Ω. As an example, a 10kΩ potentiometer will limit the maximum HVPS output voltage to 1.03 times the nominal rated voltage of the supply, due to its loading of the 5V



reference. A range for the potentiometer of 25–100kΩ would essentially eliminate the voltage limiting previously mentioned.

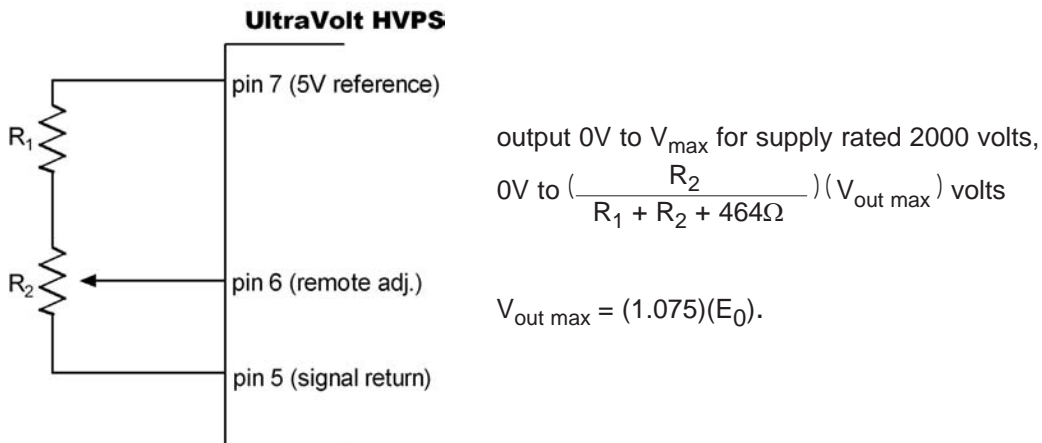
For a 2kV unit with a 10kΩ potentiometer on the *Remote Adjust Input* terminal,



**b) Output variable from 0 to a fixed voltage less than the maximum voltage**

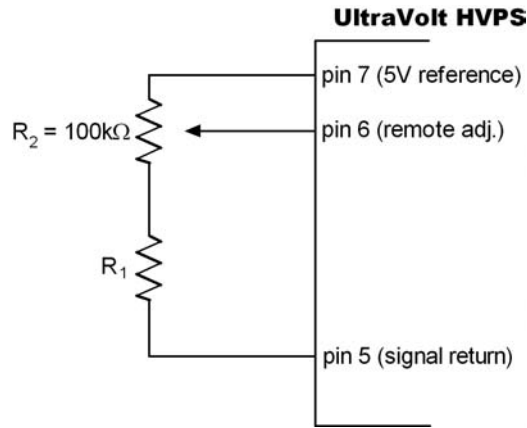
By adding a fixed resistor to the above basic configuration between the potentiometer and the reference 5V supply, a maximum voltage limit of less than the HVPS’s maximum voltage can be obtained.

For a positive HVPS,



The sum  $(R_1 + R_2)$  has to be much smaller than the input impedance of the *Remote Adjust Input* terminal (1MΩ) and large enough not to load down the 5V reference supply. For example,  $(R_1 + R_2)$  could be 50kΩ and satisfactory operation would result (with a maximum upper limit of 1.065 times the supply voltage rating).

For a -2kV ( $-E_0$ ) unit with  $R_2 = 100k\Omega$ , and HVPS output voltage adjustable to -1500V, what is the value of  $R_1$ ? What is the minimum output voltage?



With output up to  $-1500\text{V}$  and  $R_2 = 100\text{k}\Omega$ , find  $R_1$  for a  $-E_0$  unit.  $V_{\text{out}}$  for supply rated 2000 volts,  

$$V_{\text{out}} = (1.075)(E_0)\left(\frac{1 - V_{\text{pin6}}}{5}\right)$$
 So,  

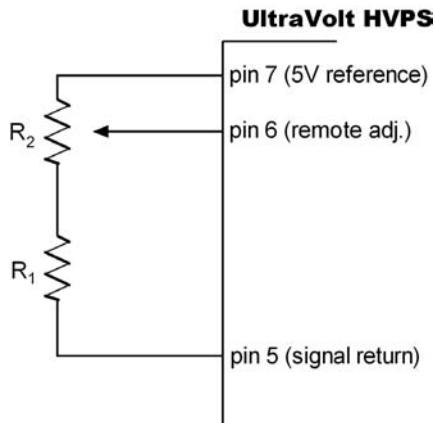
$$V_{\text{max}} = (1.075)(E_0)\left(\frac{R_2 + 464\Omega}{R_1 + R_2 + 464\Omega}\right)$$

$$V_{\text{min}} = (1.075)(E_0)\left(\frac{464\Omega}{R_1 + R_2 + 464\Omega}\right)$$
 with  $V_{\text{max}} = -1.5\text{kV}$ ,  $R_2 = 100\text{k}\Omega$ , and  $E_0 = -2\text{kV}$ .  
 Therefore,  $R_1 = 43\text{k}\Omega$ ,  $V_{\text{min}} = -6.95\text{V}$ .

### c) Output variable from a fixed voltage to the maximum voltage

By adding a fixed resistor between the potentiometer and the signal return of the basic configuration, a voltage minimum of  $>0$  can be obtained.

For a positive HVPS,



output  

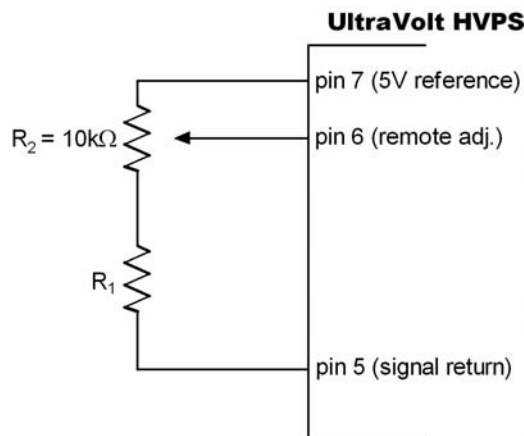
$$\left(\frac{R_2}{R_1 + R_2 + 464\Omega}\right)(V_{\text{out max}})$$
 to  

$$\left(\frac{R_1 + R_2}{R_1 + R_2 + 464\Omega}\right)(V_{\text{out max}}).$$

Note the maximum output voltage is not  $V_{\text{out max}}$  due to the loading of the 5V reference source impedance (of  $464\Omega$ ).

Again, the sum  $(R_1 + R_2)$  has to be much smaller than the input impedance of the *Remote Adjust Input* terminal and large enough not to draw too much current from the 5V reference supply. For example,  $(R_1 + R_2)$  could be  $50\text{k}\Omega$  and satisfactory operation will result (with the maximum power supply system output voltage being 1.065 times the rated HVPS voltage).

For a  $2\text{kV}$  ( $+E_0$ ) unit with  $R_1 = 10\text{k}\Omega$ , what is  $R_2$  when HVPS output voltage is  $100\text{V}$ ? What is the subsequent maximum HVPS output voltage?

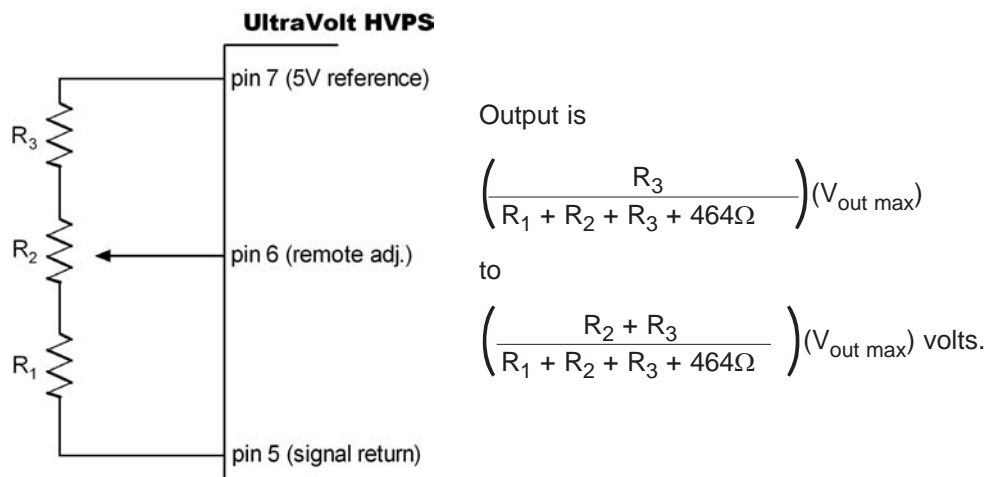


Output is  $100\text{V}$  to  $\left(\frac{R_1 + R_2}{R_1 + R_2 + 464\Omega}\right)(V_{\text{out max}})$   
 so  $100 = \left(\frac{R_2}{R_1 + R_2 + 464\Omega}\right)(V_{\text{out max}})$   
 where  $V_{\text{out max}} = (2\text{kV})(1.075)$ .  
 With  $R_1 = 10\text{k}\Omega$  the above formula is satisfied with  $R_2 = 510\Omega$  and the maximum output is  

$$\left(\frac{R_1 + R_2}{R_1 + R_2 + 464\Omega}\right)(V_{\text{out max}}) = 2.06\text{kV}.$$

The configurations in b) and c) can be combined to form preset upper and lower boundaries for the adjustable range of the HVPS.

For a positive high voltage power supply,



Although these examples deal with either positive or negative power supplies, the same circuits and theory can be used to analyze and to design positive and negative power-supply control systems. Each application noted here can be used with both negative or positive supplies with a slight modification to the formula: the variable  $V_{pin6}$  for positive supplies will be replaced by  $(5 - V_{pin6})$  to yield the output of the negative supplies.

### Reduction of 60Hz Pick-up on the Remote Adjust Line

Certain applications of voltage control and resistive control of UltraVolt high-voltage power supplies will be susceptible to low-frequency pick-up from sources such as 60Hz power lines. Since 60Hz pick-up on the *Remote Adjust Input* terminal can adversely affect HVPS DC performance, it is recommended that a capacitor be placed from the *Signal Ground Return* terminal (pin 5) to the *Remote Adjust Input* terminal (pin 6) on a positive HVPS for slow rise time, DC bias, or DC power applications. For negative HVPSs, the capacitor should be between the *+5VDC Reference Output* (pin 7) and the *Remote Adjust Input* terminal (pin 6). A capacitor value of 0.47–1  $\mu\text{F}$  will eliminate any 60Hz noise that would otherwise be picked up by the *Remote Adjust Input* terminal. A 22 $\mu\text{F}$  tantalum capacitor will further reduce low-frequency noise.

### Use of the Bifunctional Enable Terminal

Should the *Enable/Disable* terminal (pin 4) be left floating (i.e. not connected), the HVPS will stay in the enabled state. However, making use of the *Enable/Disable* terminal allows for the implementation of a few more built-in features of the UltraVolt HVPS.

The *Enable/Disable* terminal (pin 4) can be used for three different functions:

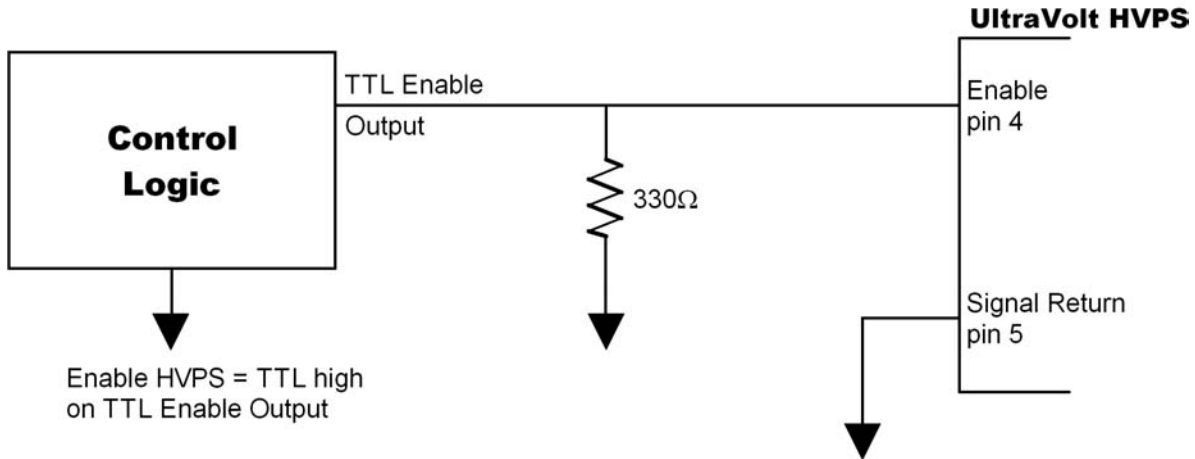
- 1) an enable input
- 2) a disable input
- 3) a current limit status output

As we review these functions, please refer to UV-CONN-2 (*Enable/Disable Control*, also *Current Limit Status*).

1) *Enable/Disable* terminal as an enable input.

To allow the HVPS to be enabled only when an enable signal is present, the HVPS must be set up to be normally disabled (in the absence of an enable signal). To disable the HVPS, the *Enable/Disable* terminal must sink at least 1mA, and its resulting voltage must be a maximum of  $0.7 \pm 0.20V$ , a TTL low.

A method of allowing the HVPS to be remotely enabled only during the presence of a TTL high-level enable signal is shown below.

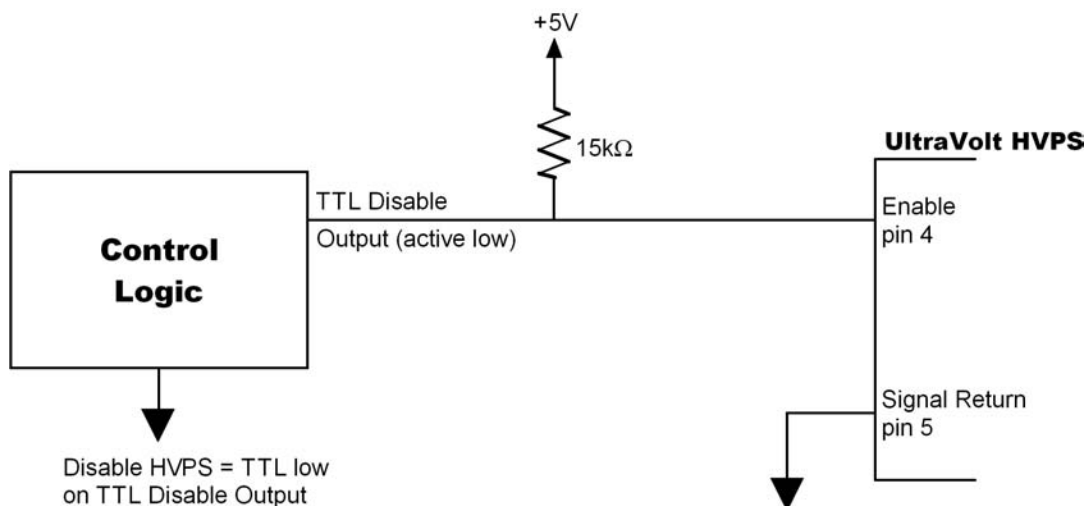


The 330Ω resistor will ensure that with a low TTL Enable Output signal, the required 1mA will be drawn from the UltraVolt HVPS *Enable/Disable* terminal, thus forcing the HVPS to be in the disabled state. When the TTL Enable Output signal goes high, the high-voltage power supply is prevented from sinking the required current and, therefore, the HVPS is in the enabled state.

2) *Enable/Disable* terminal as a disable input.

The *Enable/Disable* terminal can also be configured as a disable input. In this configuration, the *Enable/Disable* terminal must be left high until the disable (a TTL low) signal is sent. Since this input normally floats high, disabling the HVPS can be done by sinking 1mA through the *Enable/Disable* terminal and, thus, pulling the *Enable/Disable* terminal voltage to 0.8V or lower, a TTL low.

A standard method of remotely disabling the HVPS during the presence of a TTL-low disable signal is shown below.



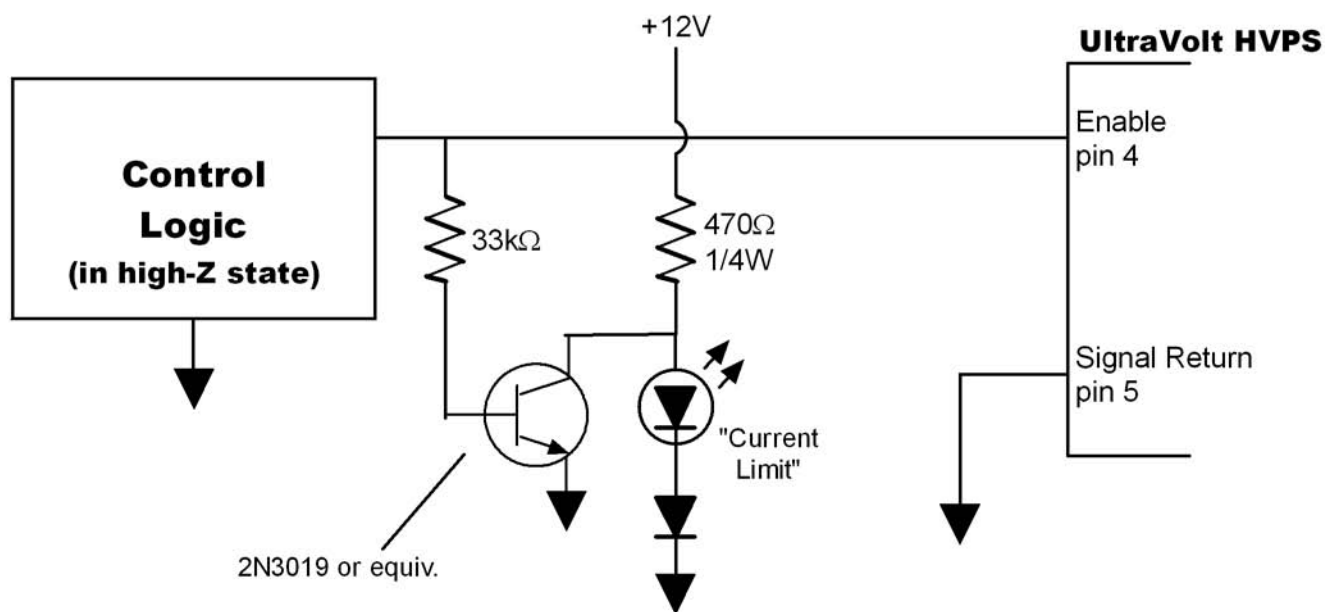
The 15kΩ resistor will ensure the *Enable/Disable* terminal stays at a voltage level that will force the HVPS to remain enabled until the TTL Disable Output signal goes low. When the TTL Disable Output goes low, the high-voltage power supply is forced into the disabled state. It should be noted, the HVPS has an internal, 5.11kΩ pull-up to +5VDC.

### 3) *Enable/Disable* terminal as a current limit status output.

For this function to be utilized, it is very important that any logic driving the *Enable/Disable* terminal be either three-state or open collector output. Any voltage applied to this terminal (i.e. from enable/disable logic) will ‘mask’ the current-limit pulses. To sense the current-limit signal coming out of the *Enable/Disable* terminal, a resistor of 47–100kΩ must be placed from the *Enable/Disable* terminal to ground in order to sink sufficient current.

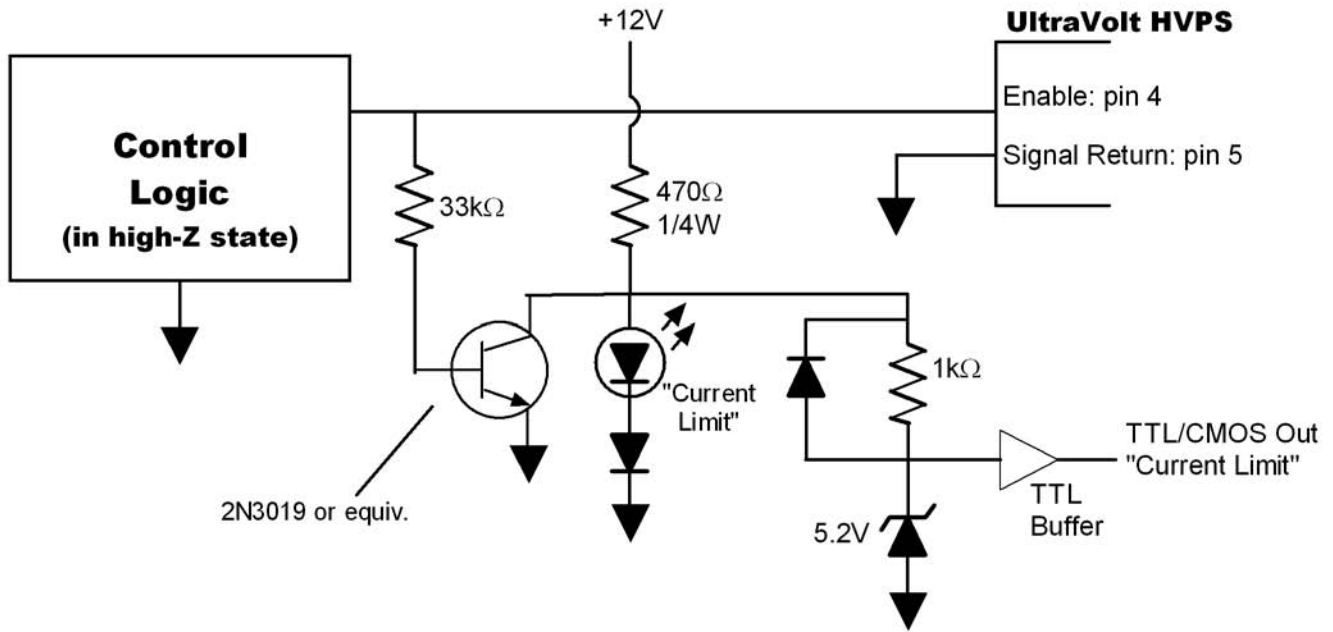
When the UltraVolt HVPS is forced into its current-limit mode, the voltage on the *Enable/Disable* terminal will drop from its pre-current-limit value of 5V to its current-limit value of 0.5V. After this point, the voltage at the terminal will again rise to 5V, when it will drop back to 0.5V should the power supply continue to be current limited. The on-time of this signal is inversely proportional to the overload placed on the high-voltage power supply (a very large load will cause the pulse train present at the *Enable/Disable* terminal to have a very short on-time).

#### a) L.E.D. current-limit status output



The above schematic illustrates a very useful implementation of the current-limit status output. When the HVPS goes into current limit, pin 4 will go low, causing the transistor to turn ‘off’ and the L.E.D. to light. When the HVPS is not operating in current-limit mode, pin 4 will stay high and the transistor will turn ‘on’. This will prevent the voltage across the L.E.D. from being high enough to allow it to light. Hence, the L.E.D. will indicate when the HVPS is operating in current-limit mode. This is a useful front-panel indicator, as well as being a very useful circuit when prototyping and diagnosing new designs incorporating UltraVolt high-voltage power supplies.

b) Logic-level current-limit status output



The above circuit is a slight modification of the one in part a), operating in the same way, except when the L.E.D. is lit the TTL buffer is enabled. The 5.2V Zener diode serves to prevent any harmful transients from reaching the TTL buffer (or any other TTL logic gate). This circuit is ideal for automated systems.

## Electrical Termination & Mounting Configurations of UltraVolt HVPSs

As with any precision electronic device, proper mounting and electrical termination is necessary for trouble-free and reliable operation of an UltraVolt high-voltage power supply (HVPS). Improper electrical termination of UltraVolt HVPSs can cause damage to the electrical connectors of the power supply, resulting in the power supply's failure. Improper mounting of the UltraVolt HVPS can create stresses (both thermal and mechanical) within the HVPS, possibly shortening the operation life of the device. For more information on mounting as it relates to thermal considerations, please see Application Note #6, "Thermal Management of UltraVolt HVPSs."

### Electrical Termination Methods of UltraVolt HVPSs

An UltraVolt HVPS is usually electrically terminated via a printed circuit board (PCB), a wiring harness, or a combination of the two (a sub-assembly PCB) depending on the mechanical mounting method used. Mechanical mounting methods and design considerations are discussed below.

#### PCB Termination

When an UltraVolt HVPS is electrically terminated to a PCB, there are essentially two methods of actual termination: 1) soldering the UV HVPS directly to the PCB and, 2) using a single or dual socket (depending on the model of HVPS utilized). Each method has its advantages and disadvantages; however, using a socket for termination may be preferred for a field-repairable system.

The UV HVPS can easily be soldered directly to a PCB, since the pin spacing is compatible with the 0.100"/0.200" industry-standard header spacing. This method offers ease of manual mounting; however, it may suffer from service-related and automated-assembly drawbacks. As discussed below, soldering the UltraVolt high-voltage power supply directly to the PCB does not replace the mechanical mounting requirement of the HVPS. In all cases, the UltraVolt high-voltage power supply must be mounted mechanically via one of the methods outlined below.

Sockets are the preferred connection method to UV HVPSs for several reasons. Socket termination greatly improves your ability to troubleshoot your product, allowing for the simplified testing of the UltraVolt high-voltage power supply and associated interface circuitry. Socketed connections also make your product more field repairable, allowing the failed interface circuit board or the failed HVPS to be replaced individually (permitting component level repairs). Socketed connections are also more easily wave soldered or infrared re-flowed, since the relatively large mass of the HVPS need not be present during either of these delicate operations.

There are essentially two options for the PCB termination of UV HVPSs: in-line machined sockets, or press-in sockets. An example of an in-line machined socket is the 7-pin, single-row Samtec SS-113-T-13 (see the "UltraVolt HVPS Industry-Standard Mating Connectors" guide for more information on UltraVolt high-voltage power supply connector compatibility with different suppliers' products). In-line machined sockets can be handled and placed like standard electrical components, a definite advantage over other methods of electrical termination. Press-in sockets usually come in the form of single-pin sockets that are pressed into, then soldered directly to the PCB. Although these sockets require nonstandard-size PCB holes and special assembly procedures, this method requires only one type of socket (with certain HVPSs), whereas at least two different types of in-line machined sockets would be required for a design using the more

specific in-line machined sockets.

Should a UV HVPS be mounted onto a PCB (as opposed to being mounted onto a chassis), various thermal considerations will arise. For a full discussion of the thermal considerations in the various mounting methods of the UV HVPS, please see Application Note #6: “Thermal Management of UltraVolt HVPSs.”

### Wiring Harness Electrical Termination

The use of a wiring harness has the obvious advantage of enabling you to mount the UltraVolt HVPS anywhere within your chassis, allowing for both optimal positioning of the UV HVPS for thermal considerations and minimization of overall chassis size. Again, there are two choices for the electrical termination of the HVPS: directly soldering the wiring harness to the UV HVPS or utilizing sockets that match the plugs on the UV HVPS.

As noted previously, sockets are preferred over direct soldering for troubleshooting, field reparability, and relative ease of assembly. However, when soldering leads directly to the UV HVPS, remember to use a reliable method of soldering (such as ‘j’ hooking the leads around the HVPS pins). Also keep in mind, the pins of the UV HVPS are high-quality, gold-plated, bronze-phosphor material. Due to this material’s nature, the pins cannot sustain large lateral forces without damage or fatigue and eventual failure. Therefore, it is recommended that the wiring harness be strain-relieved before connecting to the HVPS. In fact, all wiring harnesses should be strain-relieved before reaching the HVPS pins. The types of wiring harness sockets which can be used are summarized in the “UltraVolt HVPS Industry-Standard Mating Connectors” guide (listed under Type as ‘wire applied’).

### General Rules of Thumb for Electrical Terminations to UltraVolt HVPSs

Although not yet discussed, the gauge of the wire (or the cross-sectional area of the copper track on a PCB) feeding the UltraVolt HVPS is very important. A power supply wire of too thin a gauge can not only cause wiring failures, but also degrade the load regulation and linearity of the UltraVolt HVPS. How thin is too thin? As seen in Table 1 below, certain UltraVolt high-voltage power supplies can draw up to 13 amps through the input-power pins. Table 2 can be used as a rough guide to determine the required input-supply wire gauge, based on the UV HVPS current.

<b>UV Power Supply Rating</b>	<b>Maximum Current</b>
4W (for 12V unit)	0.5A
15W / 20W (24V unit)	1A
60W	3A
125W	6A
250W	13A

Table 1: A partial list of HVPSs and maximum currents (See product-specific data sheets for more information.)



Maximum Continuous Current (Amps)	Suggested Wire Gauge (Gauge (AWG))
20	10
15	11
12	12
8	14
5	16
3	18
2	20
0.8	24
0.5	26
0.3	28
0.2	30

Table 2: A list of HVPS currents and recommended input-supply wire gauges.

Not surprisingly, choosing a PCB track size is slightly more complex than choosing a specific wire gauge, given a particular current. In PCB applications, the maximum allowable temperature rise of the track becomes an important design consideration. Table 3 is a general guide for the current-carrying capacity of different external, plated-PCB track sizes.

PCB track size	Current-Carrying Capacity			
	0.5A	1A	1.5A	2A
1oz. copper (1.4 mils high)	20 mils width (10°C temp rise)	50 mils (10°C temp rise)	100 mils (10°C temp rise)	50 mils (45°C temp rise)
2oz. copper (2.8 mils)	10 mils (10°C temp rise)	25 mils (10°C temp rise)	50 mils (10°C temp rise)	25 mils (45°C temp rise)
3oz. copper (4.2 mils)	7.5 mils (10°C temp rise)	19 mils (10°C temp rise)	38 mils (10°C temp rise)	19 mils (45°C temp rise)

Table 3: Plated-PCB track sizes and currents with temperature rise

As Table 3 illustrates, PCBs cannot handle large currents unless proper track width and copper weight are used. (For example, PCB-mounting a 125W unit is only recommended when specific care is taken — such as a 3oz. copper PCB with two 75-mil tracks to the two power pins.) Please note, a 10°C temperature rise is quite acceptable; however, a 45°C temperature rise is not recommended for continuous use. Track width should be increased to carry the current and to reduce self-heating.

Another important point concerns the presence of multiple pins for the same apparent function. A perfect example is the paired *Input Power Ground Return* pins (#1 and #8) on the 125W “C”

Series. This supply will draw up to 6 amps from the input voltage supply; however, the connector pins are rated for a maximum of 5.9 amps. For this reason, on the 125W “C” Series, UltraVolt paired the supply pins, increasing the rating to a total of 11.8 amps, leaving a larger margin for safety. In order to eliminate possible damage to the HVPS’s pins, each pin of the same function should be externally wired in parallel to spread the current over the required number of pins.

As an aside, the 250W “C” Series will draw up to 13 amps; therefore, the units utilize an AMP mate-and-lock connector, which is rated for 10 amps per contact and 20 amps total for the parallel connection. This connector can easily handle the relatively large currents most likely to be supplied by an off-line switching power supply elsewhere within the chassis. If you intend to mount a PCB on the top of a chassis-mounted 250W unit, please contact UltraVolt Customer Service for the appropriate part-number suffix to specify the PCB power connector with .045” square pins. Also keep in mind, although the HVPS pins labeled *Input Power Ground Return*, *Signal Ground Return*, and *HV Ground Return* imply a similar function, they are not interchangeable and each should be used only for its own purpose (see Application Notes #1 and #16 for more information).

### Mounting Configurations of UltraVolt HVPSs

Different mounting configurations are required for different models of UltraVolt high-voltage power supplies. In all cases, supplementary mounting procedures are required. Under no circumstances should the UV HVPS be restrained by its pins alone (the pins cannot withstand lateral shock and will shear if the system is dropped or subjected to long-term vibration).

There are essentially two mounting configurations for low-power UV HVPSs: chassis mounting and PCB mounting. However, certain case configurations lend themselves more to one mounting method than to the other. High-power units (such as the 125W “C” Series) and lower power units with the -C option have aluminum cases incorporating mounting ears or studs, making them ideal for chassis mounting. Lower power, Mu-metal-shielded, or plastic-enclosed units (i.e. a 4W “A” Series HVPS) have the option of being PCB mounted or chassis mounted (using an optional mounting bracket or -E plate).

### Mounting Units With Built-In Mounting Ears or Studs

As mentioned above, metal-enclosed units with built-in mounting ears or studs should normally be chassis mounted. As many of these aluminum-enclosed units are of relatively high wattage, chassis-mounting makes sense because it allows the produced thermal energy to dissipate easily. For further discussion on thermal considerations, see Application Note #6 on thermal management.

When mounting units incorporating mounting ears (such as the “A” Series units with the -C or -E option), it is good policy to use all 4 mounting holes. This ensures a lower thermal resistance, as well as adequately restraining the relatively large mass of the metal-encapsulated UV HVPS.

Units with mounting studs (such as the High Power “C” Series) should be mounted to ensure each stud can be utilized. Each stud should be held to the chassis using a lock washer and a #8 nut tightened to approximately 8 ftolbs of torque. The nuts should be alternately tightened in an X-pattern to prevent possible harmful mechanical stress to the HVPS case.

In tight mounting locations where you would like to chassis-mount a -E UltraVolt, you might consider putting a louver or tab in the chassis to lock in the inaccessible end of the HVPS, while still bolting the opposite end to the chassis (see below).

## Mounting Units without Mounting Ears or Studs

Units without mounting ears or studs can be PCB mounted or chassis mounted, whichever is preferred.

Should the UltraVolt HVPS be PCB mounted, the HVPS should be held in place using #2 screws threaded into the HVPS's two molded-in thermal standoffs. These screws should brace the HVPS to the PCB, ensuring both a solid electrical connection to all pins and a firm mechanical connection between the PCB and the UV HVPS. If these screw holes are not used, the HVPS's electrical pins may shear when the unit is placed under severe mechanical stress.

As noted above, these units may also be chassis-mounted using an optional bracket (for 4W to 30W units). Depending upon the height of the HVPS used (check product data sheets), either the 0.8"-high BR-001 bracket or the 0.9"-high BR-002 can be used to fasten the UV HVPS to the chassis wall. The bracket is fastened to the chassis using screws. The UltraVolt high-voltage power supply is fastened to the bracket by two #2 screws threaded into the blind screw holes in the connector side of the HVPS. Mounting the HVPS this way allows for a good thermal interface between the power supply and the chassis wall (thus allowing the chassis to become an alternative to a separate heat sink). This also secures the HVPS mechanically. Should the chassis be used as a means to cool the HVPS, a thermal-resistance-reducing interface (such as a thermal elastomer or thermal grease) should be used between the HVPS and the chassis wall. As mentioned previously, thermal management considerations are outlined in Application Note #6.

In lower power, chassis-mount applications an alternative to mounting brackets and plates is available. Since thermal interfacing is less critical, the HVPS can be mounted using a double-sided foam tape with an acrylic adhesive. These tapes are rugged enough to be used in harsh applications such as aircraft manufacture. 3M Scotch® brand VHB4929 tape has undergone extensive testing and has been found to be a low-cost, low-labor assembly solution. It is essential this mounting system not be used in applications where high thermal resistance would allow an HVPS to overheat. For this reason, the tape mounting system should only be used with 4 watt units.

While thermally conductive acrylic tapes are available, they are not generally used as the only mounting method for devices that weigh more than 1 or 2 ounces and are, therefore, not appropriate for use as the only method of mounting an UltraVolt HVPS.

Any electronic device's long-term reliability is directly related to how the overall system design allows it to dissipate any generated heat properly. Likewise, the long life and reliability of UltraVolt high-voltage power supplies (HVPSs) will be enhanced through proper thermal management.

Due to the laws of physics, the process of converting one voltage level to another cannot be done without energy loss; that loss, the power used to operate the power supply itself, is usually dissipated as heat. UltraVolt HVPSs have excellent efficiency ratings, ranging from 75% to 92% at full output power (depending upon the model), delivering full rated voltage at nominal operating conditions. The remaining fraction of the HVPS's input power is converted to heat. Methods of properly dissipating this heat can be found in this application note.

The operating efficiency of a power supply — one of the key variables in thermal calculations — can be determined in different ways. The Acceptance Test Procedure (ATP) that came with your UltraVolt power supply contains a few common operating points and related data. The ATP data can be used to determine the supply's operating efficiency at various points. Alternately, the efficiency of a particular UltraVolt HVPS under specific operating conditions can be obtained from our Customer Service Department. Typical operating efficiency is also listed in the DC Efficiency vs. Input Voltage Range graph of the power supply's data sheet. This graph shows only typical values for the various models in that series of power supplies.

The analysis and several sample calculations in this application note are divided between *Units without user-supplied heat sinks (and -H option units)*, and *Units with user-supplied heat sinks (and other cooling methods)*.

#### Units without user-supplied heat sinks (and -H option units):

An UltraVolt 2A12-P4 is continuously delivering its nominal 2mA at 2kV ( $P_{DCout} = 4W$ ) with a nominal 12VDC input. The input current is reported as 390mA ( $P_{DCin} = 4.68W$ ), based on the ATP at this operating point (nominal output power, nominal 12V input voltage).

We can determine the heat energy dissipated as

$$P_{heat} = P_{DCin} - P_{DCout}$$

where

$$P_{DCin} = V_{in}I_{in}$$

and the unit's efficiency is

$$P_{DCout} / P_{DCin}$$

Solving for  $P_{DCin}$  yields

$$\begin{aligned} P_{DCin} &= V_{in}I_{in} = ((12V)(0.39A)) \\ &= 4.68W. \end{aligned}$$

$$\begin{aligned} \text{So, } P_{heat} &= P_{DCin} - P_{DCout} = (4.68W) - (4W) \\ &= 0.68W. \end{aligned}$$

$$\begin{aligned}\text{Thus, efficiency} &= P_{DCout} / P_{DCin} = (4W) / (4.68W) \\ &= 86\%.\end{aligned}$$

Therefore, this power supply will dissipate 0.68W of heat when operated as per the discussed operating conditions. At this operating point, its DC efficiency is 86%.

For an “A” Series UV HVPS (for example, the 2A24-P4) with the standard plastic case, no extra heat sinking, and all surfaces exposed to free air, calculate the temperature rise of the power supply’s case under these conditions. Assume the HVPS is mounted in sockets on the printed circuit board (PCB).

First, the total surface area (SA) of the standard 4W “A” Series must be calculated. The SA can be calculated from simple geometry, since the HVPS has 6 sides consisting of 3 sets of 2 equal sides. (Dimensions can be found in the “A” Series datasheet, where *l* represents Length, *w* is Width, and *h* is Height.) Solving for surface area we find,

$$\begin{aligned}SA &= 2 (lw + lh + wh) = 2 ((3.7in)(1.5in) + (3.7in)(0.77in) + (1.5in)(0.77in)) \\ &= 19.11in^2.\end{aligned}$$

It is universally accepted that 1W will raise 1in<sup>2</sup> approximately 100°C for all surface area exposed to free, still air (assumptions made for simplicity). Since we are dissipating 0.68W,

$$\begin{aligned}\Delta T &= (P_{heat} / SA)(100^\circ\text{C} \cdot \text{in}^2 / \text{W}) = (0.68W / 19.11in^2)(100^\circ\text{C} \cdot \text{in}^2 / \text{W}) \\ &= 3.56^\circ\text{C}.\end{aligned}$$

Finally, assuming the enclosure within which the UV HVPS is placed has a continuous operating temperature of 40°C ( $T_{ambient}$ ), we have a final UV HVPS case temperature of 43.56 °C ( $\Delta T + T_{ambient}$ ). Thankfully, this value is comfortably below the recommended maximum “A” Series operating temperature of 65°C. In practice, the actual case temperature may be slightly different than the expected value, depending upon the mounting of the power supply and the heat dissipation properties of that mounting.

The power supply will also have certain areas that are warmer and other areas that are cooler because certain components within the unit dissipate more heat than others. These warm areas are generally referred to as “hot spots.” Note, flush-mounting this power supply onto a PCB will hinder any convection cooling along the surface of the power supply that faces the circuit board. To account for this, the SA calculation of this particular example is carried out by summing the 5 exposed sides, ignoring the cooling effect of the mounting surface. Alternately, if the power supply is PCB-mounted using sockets, then the mounting side will allow slight cooling by convection; this should be accounted for in the calculations using a scaling factor. A discussion of mounting methods for UltraVolt high-voltage power supplies appears in Application Note #3.

As seen in the calculations above, a 4W unit running at full rated power rarely needs any supplemental heat sinking. However, a 20W, plastic-encased “A” Series running continuously at full power will dissipate approximately 3.5W, assuming 85% efficiency (which is a rough approximation used only for this example; do not use this number for your own calculations). Without any supplemental heat sinking and with one surface of the power supply mounted onto a PCB, the case temperature will rise 26°C, an unacceptable temperature increase in applications with more than a 40°C ambient temperature. The design of 20W “A” Series, as well as all other UV modular HVPSs, facilitates easy interfacing to a heat-dissipation medium. The top surface of the 20W, plastic-case “A” Series is actually a 0.062”-thick aluminum plate, which will efficiently conduct heat to an external heat-sink medium, such as a chassis wall or other customer-supplied

heat sink. This aluminum plate also helps regulate internal power supply hot spots, which occur because of the heat dissipations of different components within the power supply itself (as mentioned previously).

A 4A24-P20-H (a 4kV, 20W supply) delivering 2500V at 3mA (much less than the rated 20W out), draws .46A from its 24V supply. Solving for  $P_{heat}$

$$P_{heat} = P_{DCin} - P_{DCout} = ((24V)(0.46A) - (2.5kV)(3mA)) \\ = 3.54W.$$

Therefore, this power supply will dissipate 3.54 watts of heat when operated, according to the operating conditions (68% efficiency due to the light load). For comparison purposes, a 4A24-P20-H running at full output voltage has been analyzed in the appendix of this Application Note, providing a typical 89% efficiency example.

For the previously mentioned power supply, flush-mounted to a PCB, with the -H (heat sink) option, and with all sides except the mounting side exposed to free air, calculate the temperature rise of the power supply's case.

First, the **exposed** surface area of the standard 20W "A" Series must be calculated. From simple geometry (dimensions from "A" Series datasheet), the SA of the sides exposed to free air (neglecting the mounting and the heat sink sides) can be calculated as

$$SA_1 = 2(lh + wh) = 2((3.7in)(0.77in) + (1.5in)(0.77in)) \\ = 8.01in^2.$$

The -H heat sink adds approximately another 13in<sup>2</sup> of surface area, so the total exposed still-air surface area is

$$SA_{tot} = SA_1 + SA_{hs} = (8.01in^2) + (13in^2) \\ = 21.01in^2.$$

It is again assumed that 1W will raise 1in<sup>2</sup> of surface area approximately 100°C (in still air, which we will assume here for simplicity).

Since we are dissipating 3.54W, we can calculate  $\Delta T$  as

$$\Delta T = (P_{heat} / SA_{tot})(100^\circ C \cdot in^2 / W) = (3.54W / 21.01 in^2)(100^\circ C \cdot in^2 / W) \\ = 16.85^\circ C.$$

If the enclosure within which the UV HVPS is placed has a continuous operating temperature of 40°C, we will have a final UV HVPS average case temperature of 56.9°C. (Again, due to the differing heat dissipations of certain components within the power supply, certain regions of the unit will be warmer than others.) Of course, this value is below the recommended maximum "A" Series operating temperature of 65°C.

It is important to consider that all of our calculations have assumed the power supply is supplying a continuous amount of power. Low duty-cycle or pulsed operation of a UV power supply may dissipate a considerably smaller amount of average heat than the calculations here have yielded. In these situations, the HVPS may not need supplemental heat sinking. For example, a power supply operating at a 10% duty cycle will dissipate a small fraction of the continuous full-output dissipated heat (and hence can be operated without supplemental heat sinking).

Note, should these units be operated at less than full-rated output power, their operating efficiency will be less than their potential maximum efficiency. UltraVolt power supplies are designed to operate most efficiently when delivering their full-rated output power.

In summary, when dealing with an HVPS unit that does not have any supplemental heat sinking (or has only a -H heat sink), a few basic rules can be followed to simplify calculations. When calculating the surface area of the unit, ensure only sides that have access to free, open air are included in the calculations. If a side is in close proximity to a surface, such as a high-voltage power supply mounted with sockets onto a PCB, a fraction of the actual surface area of the hindered side(s) should be included in the calculations. If a -H heat sink is used, be sure that its side is summed into the equation for surface area only once (for that particular side, the 13in<sup>2</sup> surface area of the -H heat sink is the surface exposed to air).

#### Units with user-supplied heat sinks (and other cooling methods)

Through testing, an UltraVolt 6C24-P125 is determined to draw 5.9A from its 24V supply while delivering 6kV into its rated load.

Under the above operating conditions, determine whether a fully enclosed metal container of dimensions 12" x 6" x 4" (288in<sup>2</sup> total surface area) will sufficiently cool this HVPS if it is mounted to the wall inside the chassis. (Only the exterior of the container is exposed to the outside free air.) All sides of the metal container are exposed to free air. Assume the container is a good thermal conductor and has a low thermal-resistance interface between the HVPS and the container.

Therefore,

$$\begin{aligned} P_{heat} &= P_{DCin} - P_{DCout} = ((24V)(5.9A)) - 125W \\ &= 16.6W \text{ (88\% efficiency).} \end{aligned}$$

Here, since the HVPS is mounted inside the enclosed container, the surface of the HVPS will not directly dissipate its heat to the outside air. Instead, it will transfer its thermal energy to the chassis. The only surface that can dissipate heat to the outside air is the chassis' surface. The cooling provided by the HVPS's surface inside this container is negligible compared to the cooling provided by the heat transfer from the HVPS to the chassis wall. We approximate the dissipating surface area to be 12" x 12" x 2" = 288in<sup>2</sup>.

Since we are dissipating 16.6W,

$$\begin{aligned} \Delta T &= (P_{heat} / SA_{tot})(100^{\circ}\text{C} \cdot \text{in}^2 / \text{W}) = (16.6W / 288\text{in}^2)(100^{\circ}\text{C} \cdot \text{in}^2 / \text{W}) \\ &= 5.7^{\circ}\text{C}. \end{aligned}$$

A chassis temperature increase of 5.7°C should be quite acceptable under nearly all circumstances. So in conclusion, the HVPS would operate quite satisfactorily from a thermal standpoint.

In the above example, we made some assumptions that will now be discussed. First, it was assumed that a low thermal-resistance interface was used between the HVPS and the chassis wall. This implies the HVPS can transfer its heat to the heat sink - the chassis in the above example - without hindrance. In practice, this can be accomplished using an excellent heat-conduction medium, such as thermal elastomer (0.010" or 0.020" are common thicknesses), double-sided thermal tape, or thermal grease. This heat-conduction medium is then placed between the HVPS and the heat sink, and the HVPS is securely mounted to the heat sink using the proper bracket and/or mounting fasteners. These fasteners are then torqued sufficiently to guarantee the correct contact pressure on the heat-conduction medium. For example, the #8

studs on a 60W unit should be torqued to 8ft · lb of torque to ensure the proper ‘cold flow’ of a thermal-elastomer heat-conduction medium. Remember, in order to keep the thermal resistance low between the HVPS and its heat sink (allowing the greatest transfer of heat), the HVPS should have as much surface area as possible facing the smooth heat-sink medium (via the heat-conduction medium).

Second, it was assumed the heat-sink medium — the chassis wall in the above example — was a good conductor of heat. This assumption simplifies calculations by allowing us to utilize the entire open-air, exposed surface area of the heat sink as a dissipation medium (since the heat to be dissipated is easily conducted to the exposed surface area of the dissipation medium). Not surprisingly, heat sinks are usually made from metals known for their excellent heat conduction properties (such as aluminum).

When cooling an HVPS, many design variables enter into the equation and can determine how actual implementation is carried out. Airflow is one very important variable, and is, unfortunately, too complex to fully analyze here. Generally speaking, forced-air cooling from a simple fan can drastically reduce the size of a required heat sink, since the flowing air removes the dissipated heat more efficiently (by transferring the heat to a larger volume of air and not relying solely on convection). The ambient temperature of the HVPS’s surroundings is also a very important variable. A 15°C temperature increase may be acceptable if the ambient is 25°C, but may be totally unacceptable if the ambient temperature is 60°C (due to other devices within the same chassis dissipating a large amount of heat, for example). The mounting method is another crucial design variable.

If the HVPS is mounted to a large chassis wall, then it is unlikely a supplemental heat sink will be required.

Oddly enough, one of the most important considerations when it comes to cooling design is to allow for a large margin of safety. Even common dust coating a heat sink can drastically reduce its cooling effectiveness. Obstructed or dust-coated fan vents can seriously reduce the cooling efficiency of the fans themselves. The importance of air-vent filters and regular cleaning becomes obvious. Also, load changes (due to slight design changes) can require more power to be delivered from the HVPS and, hence, change its actual heat dissipation. In summary, include a large margin of safety in your heat calculations to ensure your high-voltage power supply cools sufficiently under all conditions. This can be achieved simply by assuming the power supply will operate in an ambient temperature higher than previously calculated.

Although one can carry out thermal calculations using thermal junction analysis and actual thermal resistance values, we have not opted for that method here. While they will yield more accurate results, the methods described here will sufficiently approximate the cooling requirements for your HVPS, given an adequate safety margin. Complex cooling requirements, such as very limited space restrictions with forced-air cooling may require a more in-depth analysis than proposed here. In these cases, we recommend you consult both a text on thermal management and UltraVolt’s Customer Service Department. Remember to keep your UltraVolt HVPS cool, and it will reward you with a long, trouble-free life.



## Surface Area of UltraVolt Models

UltraVolt Model	Total Surface Area (in square inches)
“A” / with -F / with -C / with -F-C	19.11 / 25.26 / 28 / 37.69
“10A” / with -C	20.46 / 29.2
“15A” / with -C	25.26 / 35.4
“20A” / with -C	31.5 / 43.2
“25A or 30A” / with -C	39.93 / 57
“C” / with -C	19.11 / 28
60W/125W “C”	54.28
250W “C”	98.88
“8C - 15C”	98.88
“20C - 25C”	98.88

### Appendix:

A 4A24-P20-H (a 4kV, 20W supply) delivers 4kV at 5mA (the rated 20W out), and draws .94A from its 24V supply, operating at 89% efficiency. The heat energy dissipated is

$$P_{heat} = P_{DCin} - P_{DCout} = ((24V)(0.94A)) - ((4kV)(5mA)) \\ = 2.56W.$$

This power supply will dissipate 2.56W of heat when operated as described above.

For the previously mentioned power supply, flush-mounted to a PCB, with the -H (heat sink) option, and with all sides except the mounting side exposed to free air, calculate the temperature rise of the power supply's case.

First, the **exposed** surface area of the standard 20W “A” Series must be calculated. From simple geometry (dimensions from the “A” Series data sheet), the SA of the sides exposed to free air (neglecting the mounting and the heat sink sides) can be calculated as

$$SA_1 = 2(lh + wh) = 2((3.7in)(0.77in) + (1.5in)(0.77in)) \\ = 8.01in^2.$$

The -H heat sink adds approximately another 13in<sup>2</sup> of surface area, so the total exposed still-air surface area is

$$SA_{tot} = SA_1 + SA_{hs} = (8.01in^2) + (13in^2) \\ = 21.01in^2.$$

It is again assumed that 1W will raise 1in<sup>2</sup> of surface area approximately 100°C (in still air, which we will assume here for simplicity).

Since we are dissipating 2.56W, we can calculate  $\Delta T$  as

$$\Delta T = (P_{heat} / SA_{tot})(100^\circ C \cdot in^2 / W) = (2.56W / 21.01in^2)(100^\circ C \cdot in^2 / W) \\ = 12.2^\circ C.$$

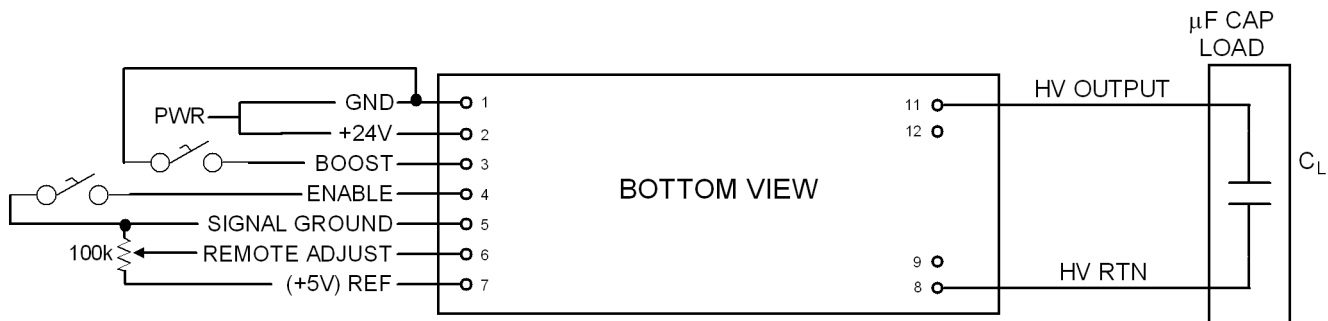
Assuming the enclosure within which the UV HVPS is placed has a continuous operating temperature of 40°C, we have a final UV HVPS average case temperature of 52.2°C. This value is comfortably below the recommended maximum “A” Series operating temperature of 65°C.

UltraVolt’s “A” Series units are designed for DC-bias applications with feedback compensation optimized for dynamic loading. Multiple tuned and untuned LC and RC filters provide low ripple without a need for external capacitors. “A” Series units are applicable to low-speed, capacitor-charging applications. When calculating  $T_{rise}$ , the output charge current available is 66% of rated  $I_{out}$  and capacitance-to-charge should have the “A” Series unit’s internal capacitance added.

UltraVolt’s “C” Series units are designed specifically for pulsed loads and high-speed charging of small and large capacitive loads. DC and AC feedback loops are compensated to provide fast rise time with low overshoot. Current-limit circuits are enhanced to get in and out of limit as fast as possible to maintain high average charge currents while protecting the high-voltage power supply (HVPS) power stage. When calculating “C” Series  $T_{rise}$ , the output charge current available is 100% of rated  $I_{out}$ . “C” Series units have  $\frac{1}{2}$  to  $\frac{1}{10}$  of the filter capacitance of “A” Series units, allowing more energy to go to the load capacitance (see Fig. F in the “C” Series datasheet). When using a “C” Series unit in a DC-bias application, an external capacitor is recommended for filtering.

### CONNECTIONS:

Note: **CAP LOAD MUST RETURN** to HV Ground Return (pin 8).



“20W/30W”

If the HVPS is to be grounded to the case, it should also be grounded via pin 8.

### ENABLE:

Using *Enable/Disable* (pin 4) to activate the power supply after input power has been applied permits the user to use TTL logic to control HV outputs, (i.e. “1” state = ON, “0” state = OFF). This can be helpful in setting up redundant interlocks or shutting off the HVPS prior to firing a high-energy load. It also acts as an easy method to measure rise time by connecting the oscilloscope external sweep trigger input to the *Enable/Disable* (pin 4) prior to generating a positive “1” rise command (see Application Note #1).

### RISE TIME:

Rise times are measured from start of discharge to the time required to rise within 99% of final regulated output. All rise-time data, however, is taken at +24VDC because different input-voltage

sources have somewhat different effects on rise time/overshoot (depending on capacitive load used).

The rise time required to charge an external capacitor load ( $C_L$ ) can be computed in accordance with the formula shown below:

$$T = \frac{(C_L + C_{int}) \text{ Volts}}{(I_{short})}$$

Where:

$T$  = Rise time in milliseconds to within 1% of final value (using an enable command)

$C_L$  = External load capacitance in micro farads

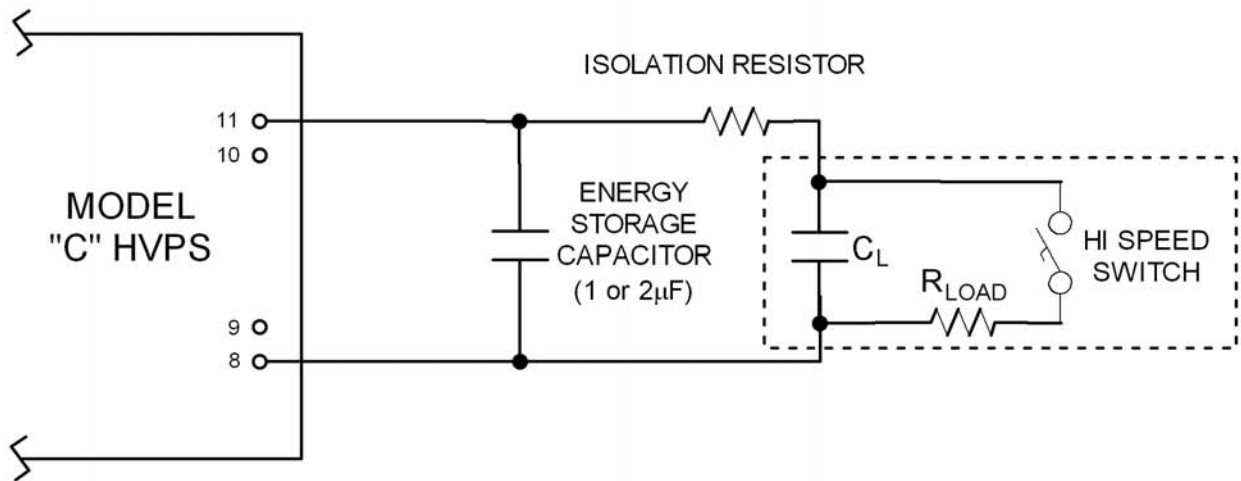
$C_{int}$  = Internal supply capacitance (see UV HVPS datasheet Fig. F)

Volts = Voltage in volts to which the capacitor is charged, starting from 0 volts

$I_{short}$  = The output current of the “C” Series power supply in milliamperes when measured under output short-circuit conditions.

### HIGH CURRENT PULSED APPLICATIONS:

In cases when large transient discharges of small duration are applied to the output of a “C” Series unit, the user may wish to isolate the “C” Series power supply from the load  $C_L$ . This is typically done to place a more average current demand on the high-voltage power supply, keeping peak currents below the HVPS current-limit point. This allows the HVPS to provide the maximum average power to the load by adding a filter cap directly across the *HV Output* (pins 10 & 11) and *HV Ground Return* (pins 8 & 9). A 10Ω to 1kΩ resistor can then be added between the HV output and the load  $C_L$ . This will also reduce the tendency to introduce overshoot in the output waveform, which could cause a ringing on the HV output when driving certain types of loads (see diagram below).



Note: The energy-storage capacitor and the isolation resistor control “pulse droop” during high-discharge-current conditions and average the peak current, thereby reducing the amount of time the HVPS is in peak current limit.

## Updating from User-regulated Proportional HVPS to UltraVolt's Off-the-shelf Regulated HVPS

In the past, engineers have had to use proportional high-voltage power supplies (HVPSs) for their low-power needs. If the application required tight tolerances or output-voltage regulation, engineers built their own regulated HVPS. By placing a control loop around a proportional HVPS, a regulated output voltage with stable characteristics could be maintained. Isolation was generally not an issue, so a specific polarity output was available.

UltraVolt manufactures a line of off-the-shelf standard products incorporating internal regulation circuitry. These switching power supplies help achieve a more cost-effective, reliable, high-voltage power system. Let's examine the different areas where the UltraVolt HVPS contributes to these factors....

### Economic Advantages

What is the cost of the proportional HVPS? While most proportional-regulation solutions are similar, the most basic circuits consist of assembling a minimum of 12 parts into a subassembly. Typically, that consists of the following:

OEM proportional HVPS	stable voltage reference
Host PCB	various compensation/trim capacitors
HV-feedback resistor	various compensation/trim resistors
HV-feedback capacitor	pass transistor
HV-filter capacitor	input filter capacitors
Op Amp	PCB headers

Assembly and Inspection labor  
Test and Troubleshooting labor

Note the impact on overhead where the individual parts listed above must be procured, expedited, received, inspected as parts, kitted, assembled, inspected, tested as a subassembly and burned in. In addition, subassembly manufacturing documentation must be maintained. UltraVolt's single-part solution costs less!

### Reliability Advantages

UltraVolt's single-part solution lasts longer! As an assembly, our 4-watt HVPS has a mean time between failures (MTBF) of 654,583 hours at 55°C. What is the MTBF of the proportional HVPS? Is that calculated at 55°C or 21°C? Does that MTBF factor in the 12 or more components required for regulation?

### Shielding

UltraVolt's single-part solution is easier to shield! All of our HVPSs have reduced emissions. Optional wrap-around Mu-metal shielding further reduces EMI & RFI emissions for sensitive applications. Conversely, the proportional HVPS solution will radiate more noise, due to its

inherent design and because the radiating components are spread over a larger surface area. If the unit requires full shielding, you must also box in the proportional HVPS and ALL of the regulation circuits with a custom shield. Not only will this increase the cost, but it will also raise the ambient temperature, increasing drift and reducing component life.

### Size

UltraVolt's single-part solution is smaller! With a footprint of only 5.5in<sup>2</sup>, along with a volume of 4.3in<sup>3</sup> our HVPS frees up valuable space in your system. If your product is portable, the proportional power supply solution adds to system weight. The proportional HVPS solution also uses up valuable space that could be used to enhance your products.

### Output Power

UltraVolt's single-part solution is more powerful! With 12VDC models producing 4 watts, and 24VDC models producing 20 watts, our HVPS can provide all the power required for your system. Typical proportional solutions have limited output power from 1 to 3 watts.

### Control

UltraVolt's single-part solution is fully compatible! Output voltage can be programmed just like the proportional power-supply solution. Both resistance and voltage programming, along with simple two-resistor scaling, are fully supported.

As you can see from the analysis above, it is evident that the single-component solution has many advantages. Whether your interest is in reducing production cost, raising system MTBF, or finding more space for new circuits, we believe UltraVolt's series of regulated HVPSs will help you to reach your goals.

### Introduction:

It is possible to operate UltraVolt high voltage power supplies in parallel. The method for paralleling two voltage sources depends on the requirements of the application. In this Application Note, we will consider two distinct cases.

In the first case - a capacitor charging system - the power supplies operate as current sources during the charge cycle and switch to voltage regulation only when the capacitor voltage reaches its maximum level. At that time, the power supply sources nearly no current and maintains the capacitor voltage until the next charge cycle begins.

In the second case, we want to operate the power supplies in parallel continuously to achieve twice the power capability of a single power supply. Here, the two power supplies should behave as a single power supply at nearly twice the current capacity.

### Capacitor Charging:

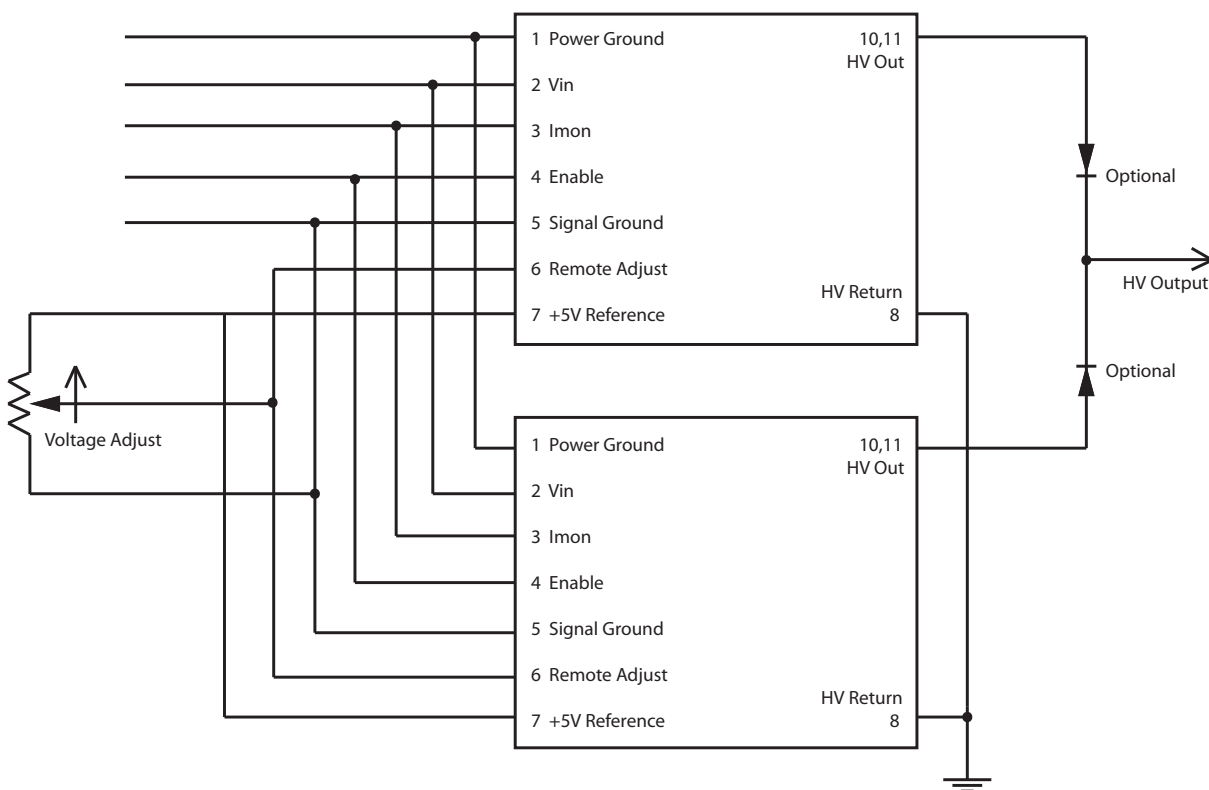


Figure 1

In Fig. 1, the two UltraVolt high-voltage power supplies (HVPSs) have the control pins tied together, providing a single control interface. While charging the capacitor, the HVPSs will be in current limit, allowing the power supplies to operate in parallel well. The power supplies will remain in current limit until the voltage set point is reached, at which time the voltage control loop will take over and maintain the capacitor voltage and the power delivered will drop to zero. The isolation diodes on the output are optional, but will provide some protection in the case of redundant systems.

## Parallel Operation:

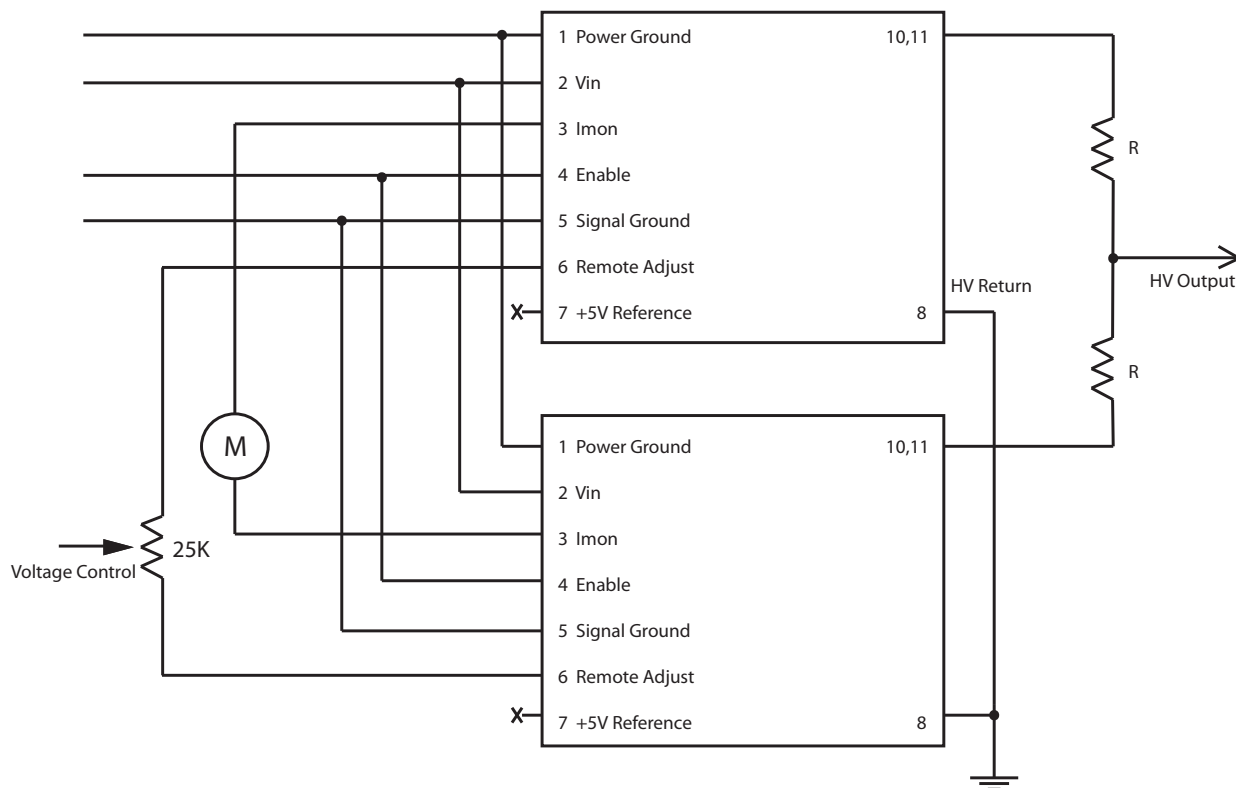


Figure 2

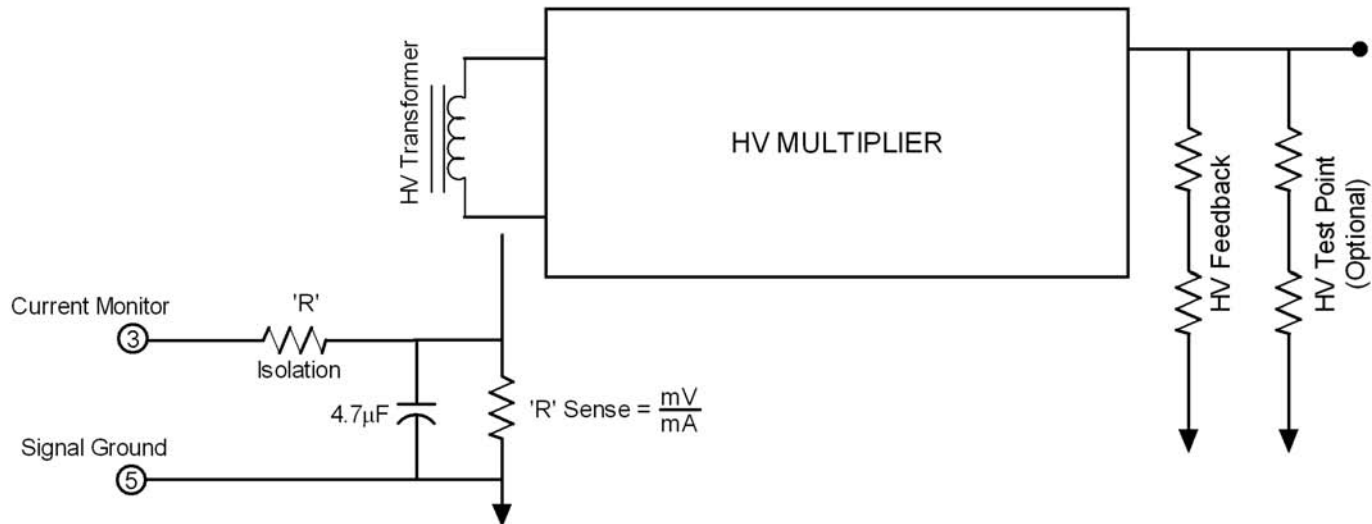
In this configuration (Fig. 2), we want the two power supplies to run continuously in voltage control as a single power supply. The sharing resistors used to sum the outputs help to this end. The closer the two output voltages are to each other the better the sharing will be. This technique works best with two identical power supplies; using dissimilar power supplies is not recommended. Sharing can be improved with the addition of the potentiometer on the voltage control signal and a simple setup procedure.

The 25k $\Omega$  potentiometer works against the input impedance of 1.1Meg $\Omega$  on the remote adjust pin, forming a voltage divider. This gives an adjustment range of about  $\pm 2.2\%$  between the two units. A simple setup procedure should be done with the output of the system loaded. The potentiometer is turned until the meter between the two current monitor pins reads zero; this indicates the two power supplies are sourcing equal currents and the system is balanced. This setup procedure should be done with the system at full load and at output voltages closer to maximum to achieve the best results.

Selection of the output resistors depends on a number of competing factors. As the resistor value is increased, the load sharing improves and the voltage balance becomes less critical – but these benefits come at the expense of higher power loss. For example, if we use two 10A24-P30 power supplies with a maximum output current of 3mA each with 2W balancing resistors running at half their power rating, we have 111k $\Omega$ . Rounding the resistance to a standard value of 100k $\Omega$ ; we lose 300 volts across the resistor and approximately 1 watt at full load current. If this is an unacceptably large voltage regulation error, then smaller resistors can be used and more care should be applied to the balancing setup.

UltraVolt's high-voltage power supplies (HVPSs) have an output-current monitor ( $I_{out}$  Monitor), which allows the total output current of the HV multiplier to be monitored. Note, since the sense circuit is in the return path to the transformer, the current-monitor signal has a sign opposite of the sign of the HVPS. Therefore, a negative HVPS has a positive current-monitor voltage and a positive HVPS has a negative current-monitor voltage.

The current monitor is generated via an internal sense circuit and brought to the output pin through an isolation resistor. The signal can be integrated by connecting a small capacitor between the  $I_{out}$  Monitor and the Signal Ground Return to form an R\*C with the internal isolation resistor. The isolation resistor varies with the HVPS series as does the internal sense-circuit impedance, which varies from model to model. The "A" Series has a 15k $\Omega$ , 1% isolation resistor. The 60W-, 125W-, and 250W-"C" Series units have a 5k $\Omega$ , 1% isolation resistor. The 20W- and 30W-"C" Series units have no isolation resistor because pin 3 is used for grounding (to achieve boost). The  $I_{out}$  Monitor output impedance is therefore very low (varying from 22 $\Omega$  to <1 $\Omega$  depending on the model).



The current monitor indicates all current flowing from the HVPS HV multiplier. This total current is comprised of the external HV load placed on the supply, the internal HV resistor used to provide a feedback signal to regulate the HVPS, and the internal HV resistor for the  $E_{out}$  test point (if the unit is so equipped). To develop a "true" output-current monitor, the leakage current in the HVPS internal resistor(s) has to be subtracted from the current monitor. If the current monitor is fed to a computer through an analog-to-digital converter, this nulling can be achieved in software by using Ohm's Law. To calculate the internal leakage current, divide the output voltage by the total of the internal resistor(s) and subtract that current from the current measured on the current-monitor pin. If the current monitor is used in an analog circuit, a simple analog-summing circuit can be created using the output-voltage monitor as a correction current. The analog-summing circuit is easily implemented, since the polarity of the output-voltage test point is opposite that of the output-current monitor.

It is important to note, the internal-divider leakage current is directly proportional to output voltage and reduces linearly to zero as output voltage is reduced toward zero. The leakage current represents a higher percentage of the current-monitor signal in higher voltage models and a lower percentage in lower voltage models. As an example, the 1/4A24-P30 has an output of up



to 250VDC @ 120mA, and a 2.5MΩ internal-divider resistor with a current of 100μA. The internal current is <0.085% of the output-current-monitor signal, not significant enough in most applications to null out. On the 20A12-P4, the output is up to 20kV @ 200μA and the internal-divider resistor has a current of 40μA. The internal current is >16% of the output-current-monitor signal.

### UltraVolt High Voltage Power Supply Total Internal HV Divider Resistance

<b>“AA” Series Model</b>	<b>4/20/30 Watt</b>
1/16AA	560k
1/8AA	1.1 Meg
1/4AA	2 Meg
1/2AA	5.4 Meg
1AA	40 Meg
2AA	67 Meg
4AA	100 Meg
6AA	151 Meg

<b>“A” Series Model</b>	<b>4/15/20/30 Watt</b>	<b>“A-F” Version</b>
1/8A	1.25 Meg	91.7k
1/4A	2.5 Meg	2.0 Meg
1/2A	5.0 Meg	3.3 Meg
1A	4W/50M, 20/30W 10 Meg	8.3 / 5 Meg
2A	100 Meg	50 Meg
4A	200 Meg	66.6 Meg
6A	300 Meg	75.0 Meg
10A	250 Meg	-
15A	375 Meg	-
20A	500 Meg	-
25A	625 Meg	-
30A	750 Meg	-
35A	2.22 Gig	-
40A	2.22 Gig	-

<b>“C” Series Model</b>	<b>20/30 Watt</b>	<b>60/125/250 Watt</b>
1/8C	909k	990k
1/4C	2 Meg	2.43 Meg
1/2C	3.3 Meg	4.76 Meg
1C	5.0 Meg	9.09 Meg
2C	50.0 Meg	50.0 Meg
4C	66.6 Meg	66.6 Meg
6C	75.0 Meg	75.0 Meg
8C	-	285.7 Meg
10C	-	333.3 Meg
12C	-	375.0 Meg
15C	-	500.0 Meg
20C	-	667.0 Meg
25C	-	770.0 Meg
30C	-	858.0 Meg

## Protection of High-Voltage Power Supplies (HVPSs) in Single and Multiple HVPS Applications

If electrical equipment is exposed to extreme operating environments well beyond its ratings, then its useful life will shorten. Although UltraVolt high-voltage power supplies (HVPSs) have many internal protection mechanisms, there are a few applications in which supplemental external protection circuitry or special mounting procedures are recommended to achieve maximum performance. These special mounting procedures and supplemental circuits will also assure the longevity of the UltraVolt HVPS while it is exposed to these extreme environments.

Different applications will require different supplemental protection circuitry, depending on the anticipated faults the power supply may encounter. The UltraVolt high-voltage power supply has enough internal protection mechanisms, including an internal softening resistor and pulse-by-pulse current limiting, to adequately deal with HV output short-to-ground faults.

Faults and special situations that require supplemental protection circuitry include arcing between supplies of opposite polarity, a higher voltage HVPS arcing to a lower voltage HVPS, plasma discharge through an HVPS, high-speed current spikes, or opposite-polarity voltage spikes. These occurrences require supplemental protection circuitry in order to ensure satisfactory operation of the UltraVolt HVPS.

In addition to the above, there are also recommended mounting and electrical connection procedures which, if applied, will allow maximum reliability from the HVPS.

Special supplemental circuitry and procedures can be divided into two classifications: those applicable to both single and multiple HVPS systems and those applicable to only multiple HVPS systems. High-speed, high-energy pulse-application safeguards are covered in their own section in this application note due to the unique nature of the problems confronted in those applications.

### Special Circuitry and Procedures Applicable to Both Single and Multiple HVPS Systems

It is strongly recommended to connect UltraVolt high-voltage power supplies electrically using the proper sockets, either PCB mounted or on a cable harness. Connections can, however, be made by soldering directly to the pins, as long as a few precautions are followed. When soldering to the pins, the maximum soldering-iron temperature of 300°C (570°F) should be applied for a maximum of 15 seconds. Exceeding these recommended maximums may result in internal damage to the HVPS.

The high-voltage power supply should be mechanically mounted so it does not impart any undue stress to its case, while allowing the HVPS to transfer its heat - if applicable to your particular unit - to an external heat sink using a thermal pad, paste, or grease. If a heat sink is required, see Application Note #6 on thermal management.

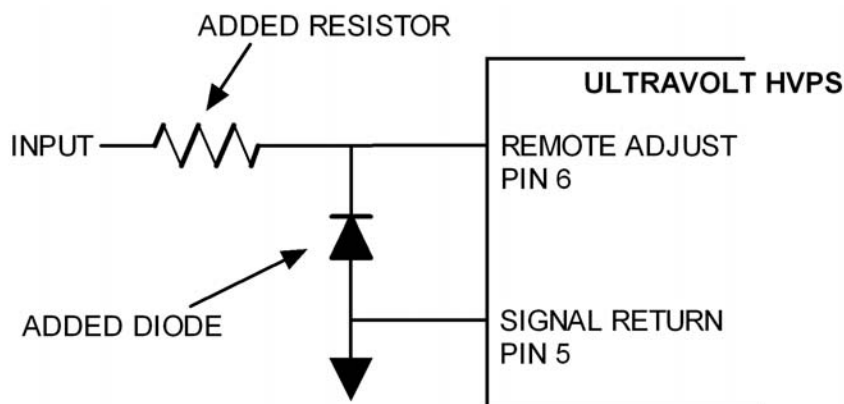
Regarding the supply-power and control-signal low-voltage sections of the UltraVolt HVPS, as long as a few guidelines are followed, trouble-free operation of the HVPS will be attained.

The supply voltages of UltraVolt HVPSs should never exceed the absolute maximum: 32V maximum supply input for 12V, 24V, or 28V units. The supply power for the high-voltage power supply should be fused and equipped with a tranzorb rated for approximately 32V.

In certain configurations, a voltage of greater than 5V may need to be applied to the *Remote Adjust Input* terminal (pin 6). These configurations usually involve negative HVPSs in which the user does

not use the internal 5V reference, but still needs to adjust the HVPS's output voltage to 0 volts. In any case, the voltage applied to the *Remote Adjust Input* terminal (pin 6) must not exceed 6 volts for an extended amount of time, since this will cause excessive internal stress to the HVPS.

In no case should the *Remote Adjust Input* terminal (pin 6) be taken to less than -1VDC, since this will damage the high-voltage power supply. In applications where there is a possibility of the remote adjust input going negative, external protection circuitry must be employed to ensure the reliability of the HVPS. This protection circuitry consists of a current-limiting resistor in series and a shunt diode to ground.



The added shunt diode is a standard low forward voltage drop diode (for example, the low-cost 1N4001), and the added resistor is chosen to limit the current (for example, a 1kΩ resistor would limit a -5V input remote adjust input to 5mA).

A voltage greater than 6V should not be applied to the *5VDC Reference Output*. Should this occur, excessive heating within the HVPS will result.

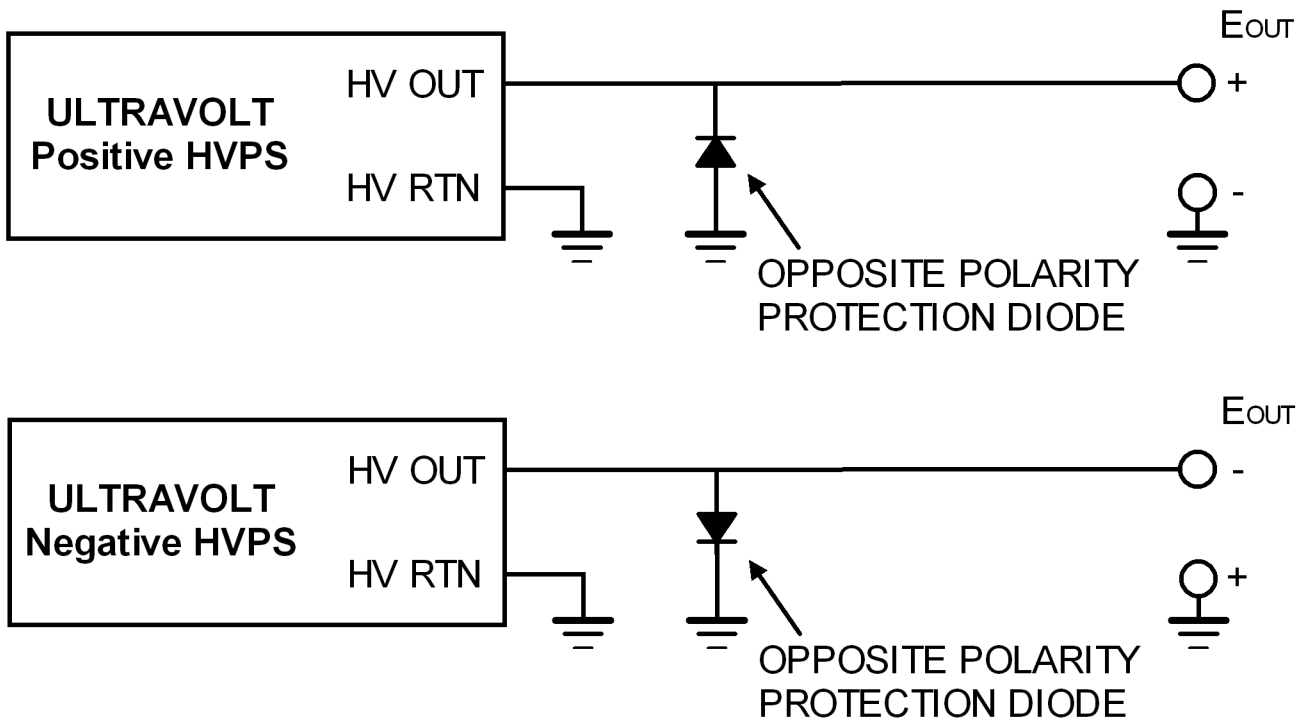
The signal-return pin must not be allowed to carry a large amount of current, but it can safely carry the return currents for the signal voltages. However, should this pin also carry the supply return current, instead of allowing this current to be safely carried by the *Input Power Ground Return* pin, damage may be done to the HVPS. Although the *Input Power Ground Return* and *Signal Ground Return* are internally connected, the *Signal Ground Return* pin cannot be used as an alternative for the *Input Power Ground Return* pin.

### Special circuitry and procedures applicable exclusively to multiple HVPS systems

As long as no faults can occur, multiple UltraVolt high-voltage power supplies can reliably form a multiple-voltage power-supply system. For long-term reliability and performance however, it is recommended that multiple HVPS systems have supplemental protection circuitry added to each supply to protect the high-voltage power supplies against normal fault conditions. Since each UltraVolt HVPS is fully short-circuit protected, only interactions between HVPSs of different polarities, or of very different voltages, need to concern the designer.

#### A. Protecting an UltraVolt HVPS from another supply of different polarity

Should two supplies of different polarity arc to each other, each HVPS will try to supply its rated current. If the supplies have different current limits, such as supplies of different power ratings but voltages equal in magnitude, the lesser current capable supply may be forced to sink or source current beyond its capability. This scenario will over-stress the lesser current capable supply, possibly damaging it. However, using a simple reverse-biased diode on the output of the HVPS to ground, the UltraVolt high-voltage power supply can be protected from the damage which would otherwise occur from the output being exposed to an opposite polarity, higher current supply.

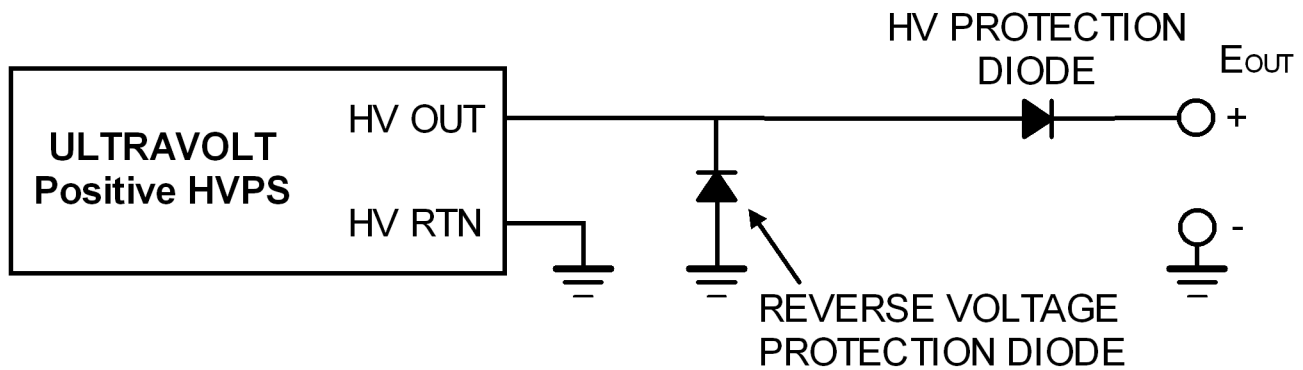


**An example of a multiple HVPS system, see text for component discussion.**

Referring to the above diagram, the reverse-biased ‘Opposite Polarity Protection’ diode must have a reverse-breakdown voltage higher than the highest voltage HVPS of the same polarity in the system. This diode must also be able to carry all of the current of the highest current rated opposite polarity supply.

**B. Protecting an UltraVolt HVPS from another supply of higher voltage**

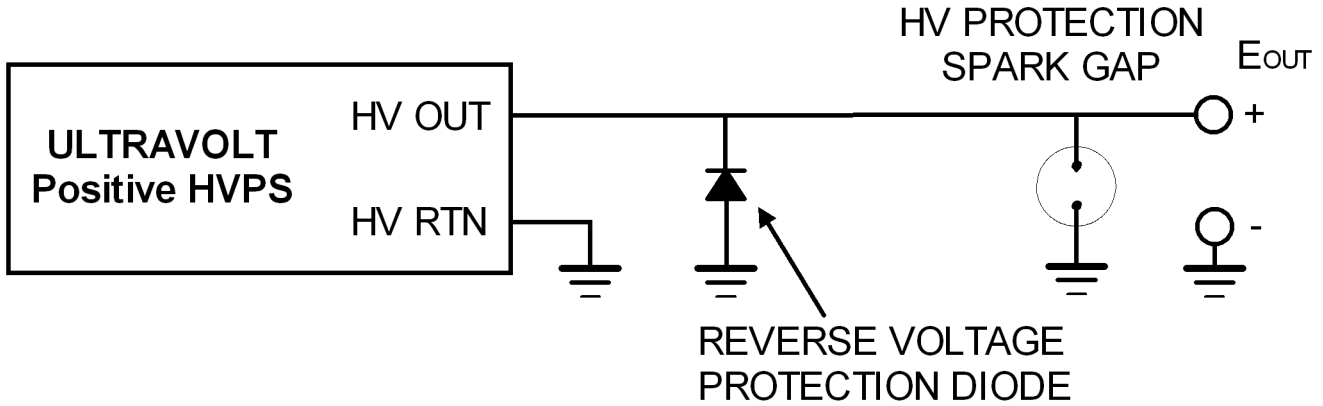
When two supplies of the same polarity but of much different output voltages arc to each other, over-voltage damage can be done to the lower voltage supply. This damage may occur because the output-diode reverse-breakdown voltage rating of the lower voltage supply may not be as high as the output voltage of the higher voltage supply. Potentially, the output diodes of the lower voltage supply could be damaged, causing the HVPS to fail. Although all UltraVolt HVPSs use output diodes that have reverse voltage ratings that are much higher than the voltage rating of the HVPS, they may not handle a high-voltage arc that is many times the voltage rating of the lower voltage supply. This problem is easily solved by adding a high-voltage protection diode to the lower voltage supply.



**Circuit from A. with a HV protection diode added.**

Referring to the diagram, protection from a high-voltage arc can be achieved with a single high-voltage diode. This added diode should have an open-air, reverse-voltage breakdown rating equal to the highest voltage HVPS of the same polarity in the system. The current rating of this diode should be the greater of the maximum current that can be drawn from the protected HVPS or the maximum current that can be supplied by any of the oppositely polarized HVPSs in the system. With this HV protection diode in place, an arc from a higher voltage HVPS will not damage the lower voltage HVPS, since the arc will not have sufficient voltage to reverse breakdown the HV protection diode.

Alternately, a spark gap can be used to protect the supply from arcs originating from a higher voltage HVPS. The arc-over point of the spark gap should be slightly higher than the peak voltage of the HVPS being protected.



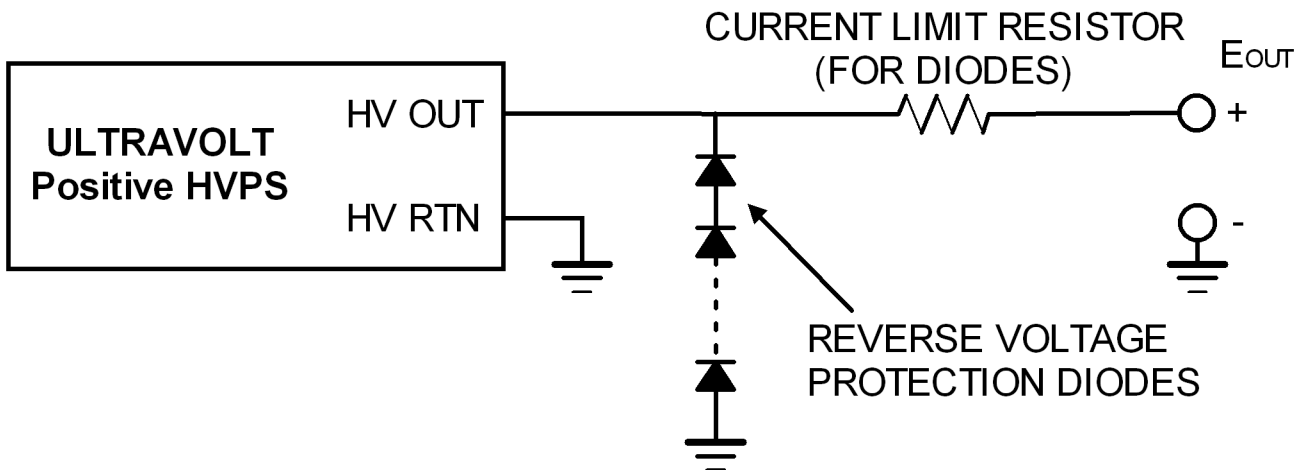
**HV protection diode replaced with a spark gap.**

The spark gap will also protect against plasma-discharge damage to the HVPS. The spark gap device must be rated to discharge all of the energy of the plasma safely.

Protecting an UltraVolt HVPS in high-speed, high-energy pulse applications

High-speed, high-energy pulse applications can create very large current spikes, which could potentially harm the power supply unless the proper precautions are taken. High-speed switching, with its fast rise-and-fall times, will create large high-frequency current and voltage spikes which must be attenuated.

Voltage spikes of the opposite polarity to that of the power supply (for example, from inductive effects) can be easily managed with a couple of high-voltage, high-speed, low forward-voltage-drop diodes and a resistor.



A negative high-voltage power supply will simply have the diodes in the above diagram reversed. The diodes here should have fast switching times, less than 100nS (in order to protect the HVPS from quick, opposite-polarity pulses), low forward-voltage drop (for example, 14V), and a high reverse-standoff voltage rating. The reverse-standoff voltage rating of the diodes utilized determines the number of diodes required. For example, a 10kV HVPS will require three 5kV diodes or one 15kV diode. The current limit resistor's value should be chosen to limit the maximum peak current through the diodes, common values normally being in the 1Ω to 100Ω range (to determine an exact value would require a high-frequency oscilloscope to view the amplitude of the reverse voltage spikes; it is easier to choose the largest resistance value that does not prohibitively degrade HVPS performance, and yet still prevents over-current damage to the diodes).

### Grounding Considerations

Very large current spikes can also be troublesome to high-voltage power supplies. During the initial system configuration and prototyping, voltage levels across external ground connections should be checked and improved (if necessary). It would also be prudent to check the voltage between the *HV Ground Return* and the *Input Power Ground Return* of the HVPS unit. If a noticeable voltage occurs between the *HV Ground Return* and the *Input Power Ground Return*, then an external connection between these pins should be established. As long as the proper precautions are taken, the UltraVolt HVPS will operate under high-speed/high-energy switching applications.

High-voltage-power-supply grounding schemes are critical to assuring proper performance and reliability. Each ground should be connected via a dedicated grounding wire. While all the grounds are common inside the UltraVolt HVPS, in a star-point/single-point ground configuration, it is important to note with high voltage they are never truly "the same." An example is when an HV arc occurs in the system to chassis ground and the HV load has some capacitance. A 1000VDC arc to ground through as little as 1Ω of resistance/impedance will result in a peak surge current of 1000 Amps! Another example is the input current causing a voltage drop between the LVPS and the HVPS. A .01Ω impedance build-up from wiring, connectors, etc. is not uncommon, nor is the 10mV error it creates on the +12 or +24VDC power ground. This error is of no consequence unless you were to use the same ground for your LV control circuitry, where 5VDC on remote adjust may equal an output of 1000V, so a 10mV error would be amplified to 2VDC on the HV output! UltraVolt has directly addressed the need for these various ground connections. With the UltraVolt models it is important to denote the different functions of the grounds.

### **Input Power Ground Return:**

This ground is for the most **direct connection** between the HVPS input power stage ground and the LVPS powering it. After the most direct connection is made, other connections may be made as required. An acceptable, common "other connection" is to take a multi-output LVPS's common ground to UltraVolt's *Input Power Ground Return*. An unacceptable "common connection" would be taking the ground to the HVPS *HV Ground Return*, typically when the *HV Ground Return* is connected to the chassis. This is never recommended due to the peak current that can be created during HV discharge (see paragraph on the *HV Ground Return*).

### **Signal Ground Return:**

This ground is for the most **direct connection** between the system LV control circuitry and the UltraVolt HVPS controls, such as enable/disable, remote programming,  $I_{out}$  Monitor,  $E_{out}$  Monitor and  $V_{ref}$ . A ground wire separate from the ground wire to the HVPS power return should always

be used. An acceptable “other connection” is to take the LVPS ground to signal ground. While this can be done safely, it will introduce LV power ground noise into the signals and should be avoided, if possible. An unacceptable “common connection” is to take the signal ground to the HVPS return pin, typically when the *HV Ground Return* is connected to the chassis. This is never recommended due to the peak current that can be created during HV discharge (see paragraph on *HV Ground Return*).

### **High Voltage Ground Return:**

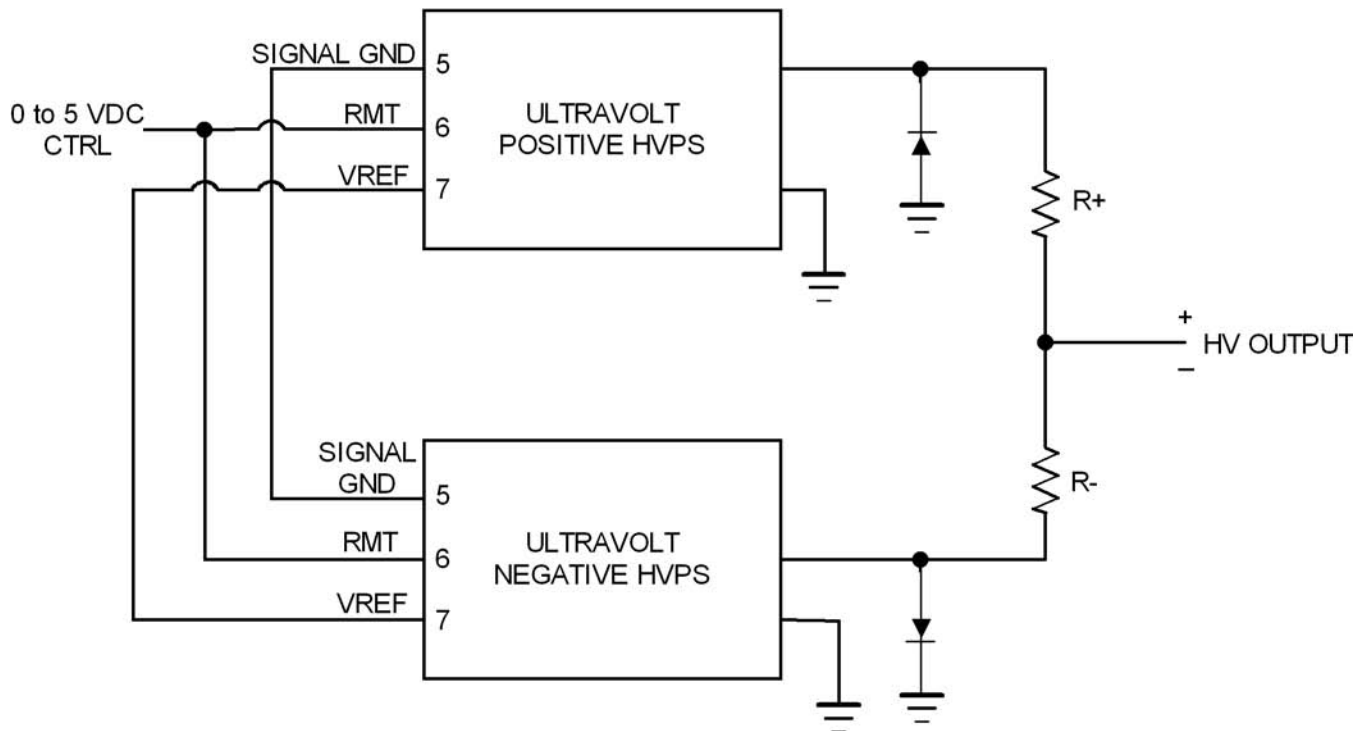
This ground is for the most **direct connection** between the HVPS output stage and the HV circuitry powered by the UltraVolt high-voltage power supply. All HV loads such as capacitors, resistors, tubes, switches, etc. should be returned to this connection. If the LVPS output ground is to be connected to chassis ground, a good technique for safety purposes, the connection to the chassis should be made through the UltraVolt HVPS. This is done by connecting the LVPS output ground to the UltraVolt LVPS input return and the UltraVolt HVPS HV return to the system chassis ground. This is done so if there is an HV arc to the chassis the most direct path for the HV energy is to return to its source, the HVPS output stage, through the HV return. If this is not done, the most direct return path may be through the LV input pins, destroying the LVPS or the HVPS power stage in the process!

These grounds are illustrated in Conn-Dwg #16.

## Polarity Reversing Configurations of UltraVolt HVPSs

In some electronics applications, a particular bias voltage may have to range from a positive voltage to a negative voltage or vice versa. The conventional solution is to utilize a high-voltage relay to reverse the polarity. However, this approach introduces a mechanical element to the system, which dramatically reduces the MTBF of the HVPS sub-system. This application note is presented as an illustration of a simple solution for low-current and electrostatic-bias applications. For higher current applications, contact UltraVolt's customer service department.

The simplest form of electronic polarity reversing is accomplished by using a positive supply and a negative supply, joined together through a pair of series resistors:

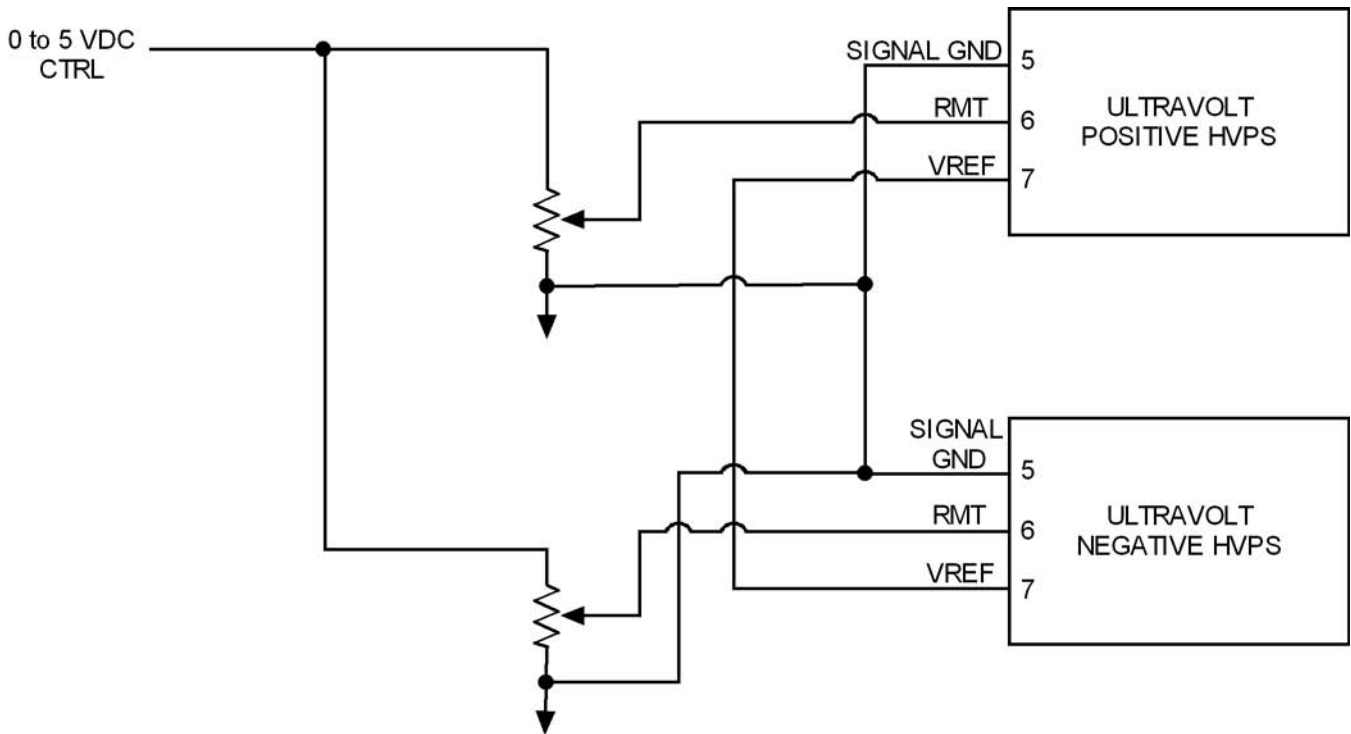


This configuration provides seamless control from 1/2 of the positive supply's maximum output voltage to 0 VDC to 1/2 of the negative supply's maximum output voltage. For example, an UltraVolt 4A12-P4 and 4A12-N4 combination would be adjustable from +2kV to -2kV. The supplies could be of the same voltage capability or could be selected to provide a limited range in one polarity. The resistors can be equal in value to provide an equal voltage range at either polarity, or they can be selected to limit the range of one polarity.

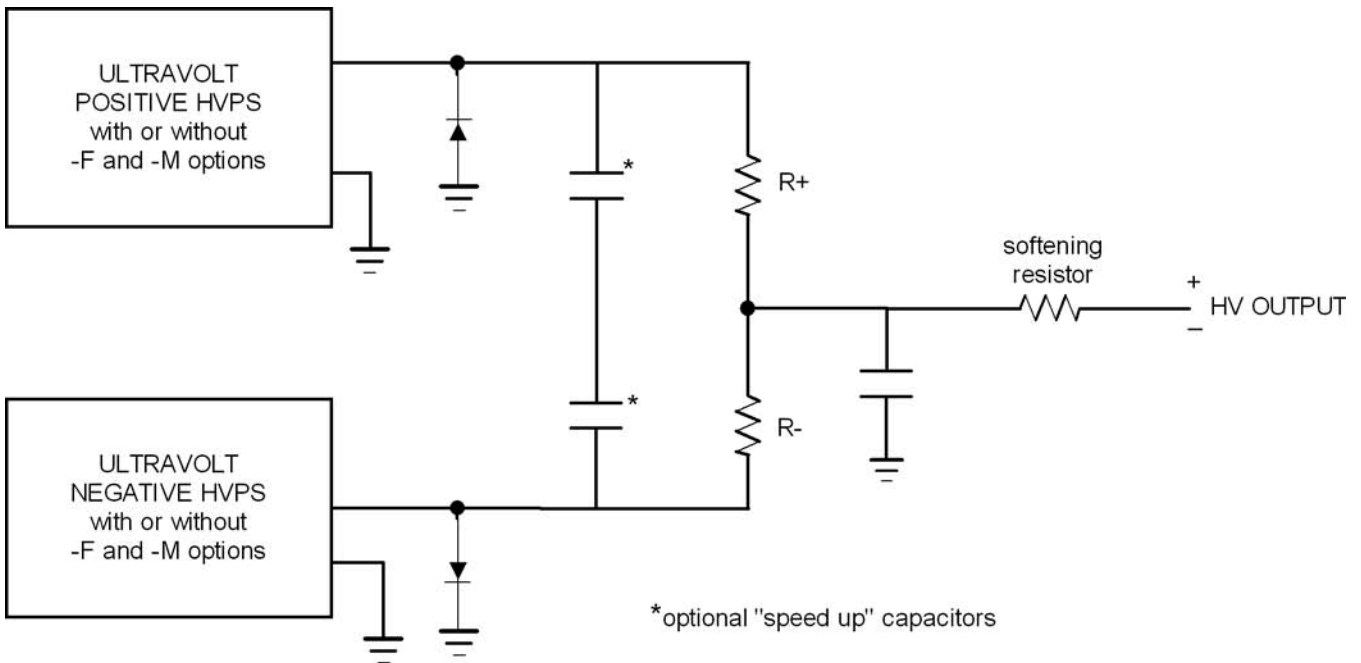
The diodes on the output of each HVPS are provided to sink the reverse current from the HVPS of the opposite polarity before it can reverse bias the circuitry inside the HVPS. These diodes should be rated a minimum of 150% of the maximum voltage, i.e., 6kV diodes when used with a 4kV circuit.

The HVPS control has an initial gain error of  $\pm 1.0\%$ . When tying the control pins of two HVPS together and driving them with a single signal, the error becomes  $\pm 2.0\%$ . This error can be minimized two ways. The first way is to use two independent control signals from two pots or two dacs, corrected to eliminate the error. The second way is to use a single control signal through two 'calibration' potentiometers, one for each HVPS. The potentiometers can be conventional or digitally controlled. These methods are effective whether the goal is 'factory' calibration during initial manufacturing or "recalibration" on each system power-up.





In low-noise systems the UltraVolt HVPS is normally ordered with the -F Ripple Stripper® Output Filter option and with the -M Mu-Metal shielding option. Since the output resistors isolate the HVPS from the load with a high impedance, this impedance can be used as an additional filter element with the addition of a single capacitor and resistor.



## Derating of Aluminum Electrolytic Capacitors in UltraVolt High Voltage Power Supplies

UltraVolt uses conservative derating practices to ensure reliable operation and long lived power supplies. One critical component that has a significant impact on mean time before failure (MTBF) is the aluminum electrolytic capacitor. The capacitors used in UltraVolt power supplies have an operating temperature range of  $-55^{\circ}\text{C}$  to  $+105^{\circ}\text{C}$ . This technical note outlines the part selection practices and derating guidelines UltraVolt uses to maximize the life of the power supply.

Typical electrolytic capacitor data sheets specify a lifetime in hours (usually thousands of hours) at a maximum operating temperature. For example, the capacitor typically used in UltraVolt power supplies is rated at 5000 hours at  $+105^{\circ}\text{C}$ . This part was selected for its long lifetime and high operating temperature.

An electrolytic capacitor is considered to be outside its endurance when one of the following conditions occurs: the capacitance changes by at least 35%, the dissipation factor increases by at least 300%, or the DC leakage current is greater than the initial specified value. These values may vary from manufacturer to manufacturer but are typical parameters used to define the component's lifespan.

The circuit in the high-voltage power supply is designed to tolerate the changes to the capacitor's characteristics and still operate reliably; but these parameter shifts are useful for calculating an expected lifetime of the unit based on operating conditions. The operating temperature of the part is the key factor in determining the expected lifetime. Since most UltraVolt power supplies are fully encapsulated, the entire unit runs at a fairly uniform temperature. In addition to the internal operating temperature of the unit, the capacitor ripple current acting on the ESR (internal resistance of the capacitor) will cause self-heating, which must be taken into account in figuring the lifetime.

As the operating temperature of the capacitor goes down, the expected lifespan increases. The expected lifespan will double for every ten-degree drop in temperature. A typical UltraVolt power supply has a specified maximum operating temperature of  $+65^{\circ}\text{C}$ ; at this temperature, the capacitor lifetime is expected to double 4 times. In other words, a 5000 hour part will last 80,000 hours. If the operating temperature is held to even lower levels - perhaps  $20^{\circ}\text{C}$  over an ambient of  $20^{\circ}\text{C}$  - expected lifespans, conservatively, can be 320,000 hours. In many applications, the power supply is running at a temperature lower than the maximum rated and at an output power also lower than its maximum rated. Accounting for real world operating conditions, selecting the proper capacitor for a well designed circuit can lead to very high reliability and a lifespan of several hundred thousand hours.

The numbers calculated above are based on a well-defined shift in the capacitor's characteristics. These shifts in value do not necessarily represent the point of failure for the circuit. The point of failure for the power supply will be several multiples of the calculated lifespan of the part. The data sheet for the hi-rel capacitors defines lifespan as when capacitance drops by 35%, yet a drop in capacitance of 50% or more can easily be tolerated by the circuit.

There are many other capacitor technologies available, each well suited for particular applications. The aluminum electrolytic capacitor is best suited for applications as it is used in UltraVolt high voltage power supplies. As noted in the discussion above, UltraVolt uses conservative and robust design practices which will provide high reliability and long life.

Ultravolt Regulated High Voltage Power Supply MODELS 1/8A TO 6A ILLUSTRATED

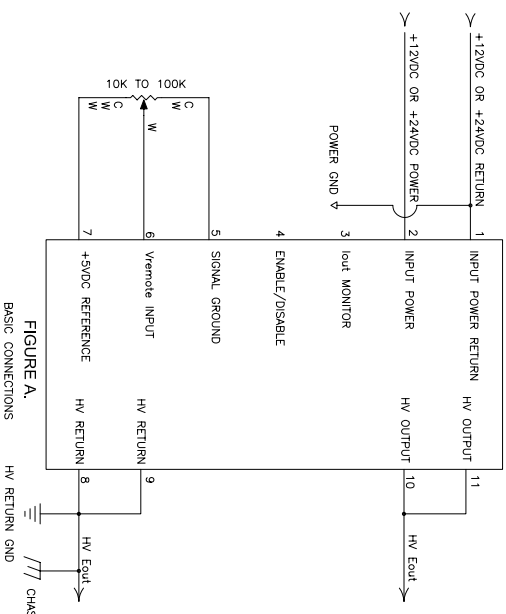


FIGURE A. BASIC CONNECTIONS

Ultravolt Regulated High Voltage Power Supply MODELS 1/8A TO 6A ILLUSTRATED

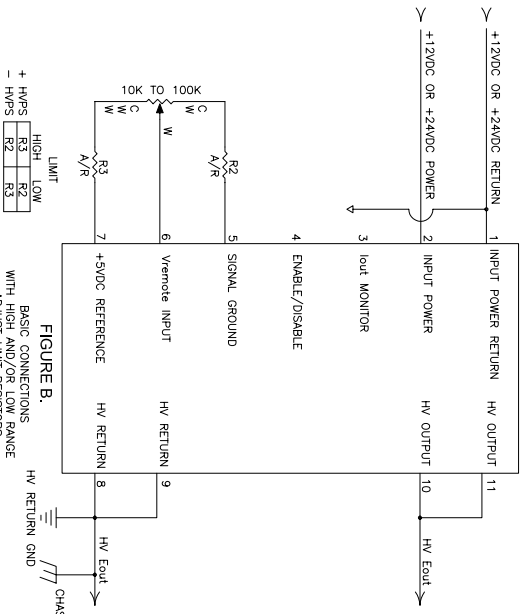


FIGURE B. BASIC CONNECTIONS WITH HIGH AND/OR LOW RANGE ADJUST LIMIT RESISTORS

Ultravolt Regulated High Voltage Power Supply MODELS 1/8A TO 6A ILLUSTRATED

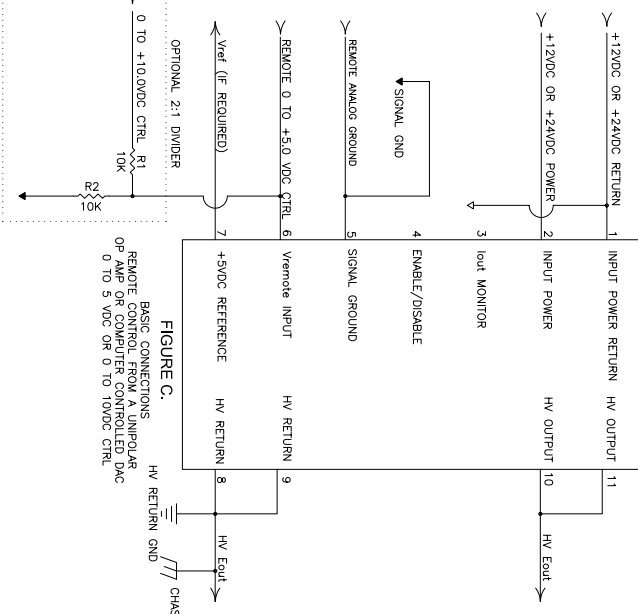


FIGURE C. BASIC CONNECTIONS REMOTE ADJUSTABLE DAC OR AMP OR COMPUTER CONTROLLED DAC

Ultravolt Regulated High Voltage Power Supply MODELS 1/8A TO 6A ILLUSTRATED

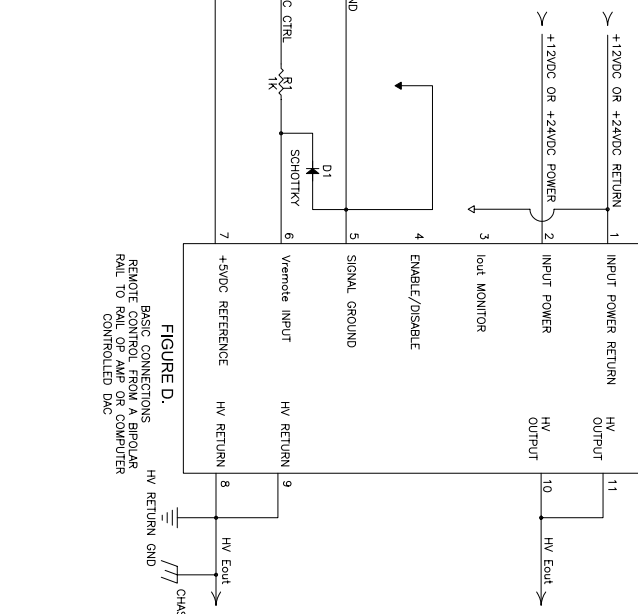


FIGURE D. BASIC CONNECTIONS REMOTE ADJUSTABLE BIPOLAR AMP OR COMPUTER CONTROLLED DAC

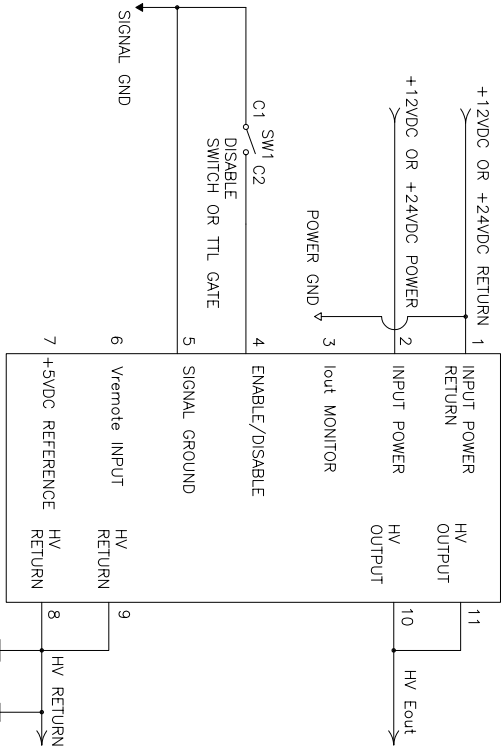
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TYPICAL HVPS CONNECTIONS - OUTPUT PROGRAMMING

NOTES: REFER TO UV APPLICATION NOTES FOR MORE DETAILED INFORMATION  
UV HVPS POWER UNPUT SHOULD NOT EXCEED +32VDC.  
A 0.1uF TO 1.0 uF CAPACITOR CAN BE ADDED FROM REMOTE ADJUST TO SIGNAL GROUND IN HIGH NOISE ENVIRONMENTS.

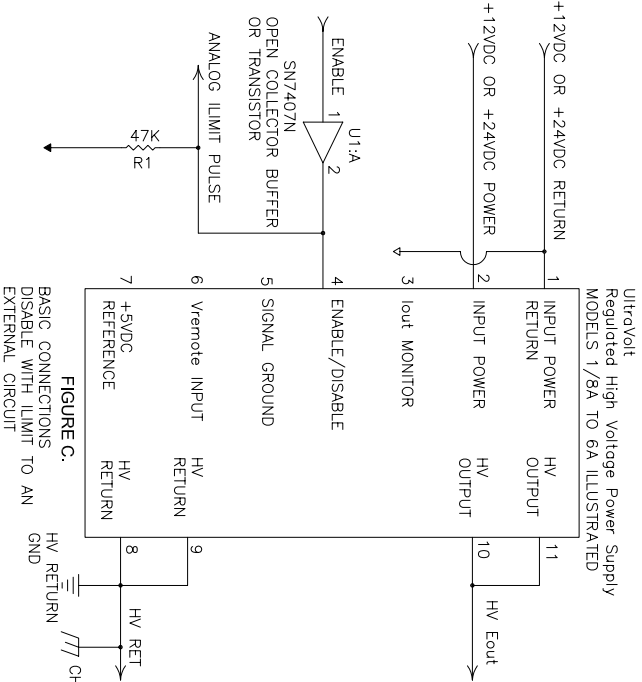
Ultravolt, Inc.  
1800 Ocean Ave. Frnt  
Ronkonkoma, NY 11779  
1-631-471-4444

Size	Number	UV-HVPS-CONN-1	Rev.
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Date	4/19/00	Drawn By	J.T.
Filename	UV-HVPS-CONN-1_rev1.dwg	Sheet	1 Of 1

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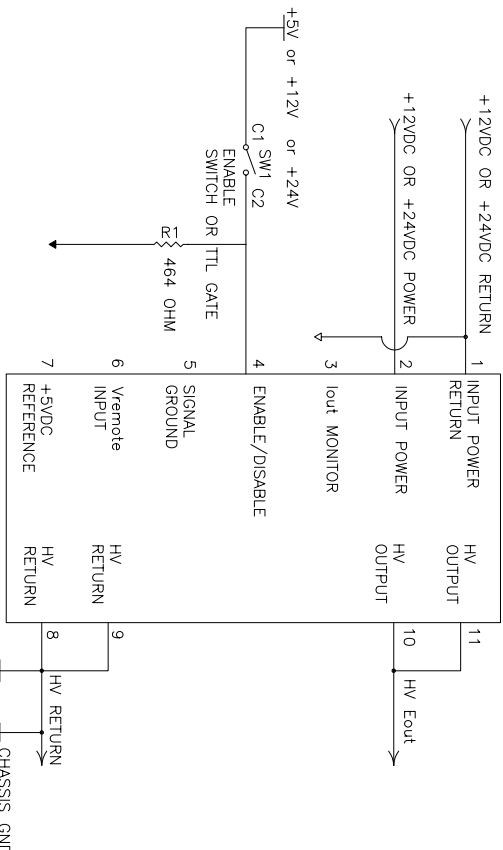


**FIGURE A.**  
BASIC CONNECTIONS  
100:1 OUTPUT VOLTAGE MONITOR  
TO DRIVE A 10 MEG DIMM OR ADC



**FIGURE B.**  
BASIC CONNECTIONS  
WITH HIGH AND/OR LOW RANGE  
ADJUST LIMIT RESISTORS

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Regulated High Voltage Power Supply  
MODELS 1/8A TO 6A ILLUSTRATED



**FIGURE C.**  
BASIC CONNECTIONS  
DISABLE WITH I LIMIT TO AN  
EXTERNAL CIRCUIT

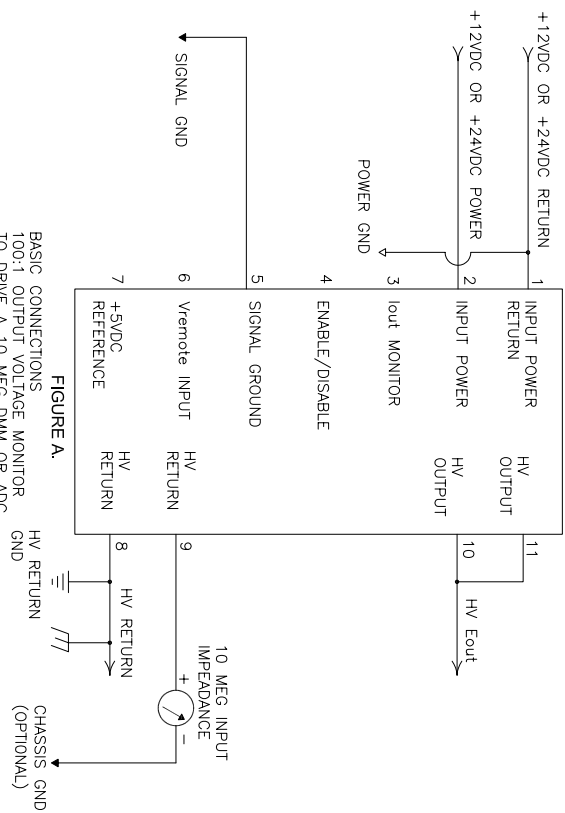
NOTES: REFER TO UV APPLICATION NOTES FOR MORE DETAILED INFORMATION  
UV HVPS POWER INPUT SHOULD NOT EXCEED +32VDC.  
A 0.1µF TO 1.0 µF CAPACITOR CAN BE ADDED FROM REMOTE ADJUST  
TO SIGNAL GROUND IN HIGH NOISE ENVIRONMENTS.

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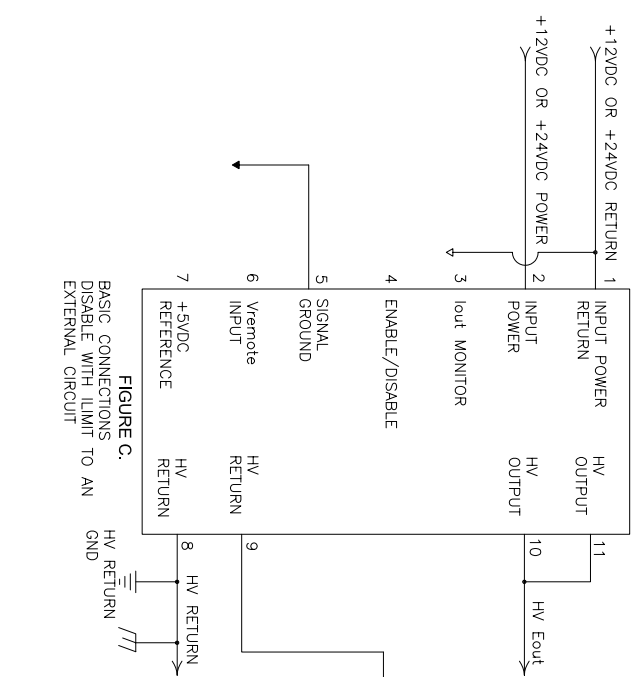
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		Sheet 1 Of 1

Typical HVPS Connections - ENABLE/DISABLE

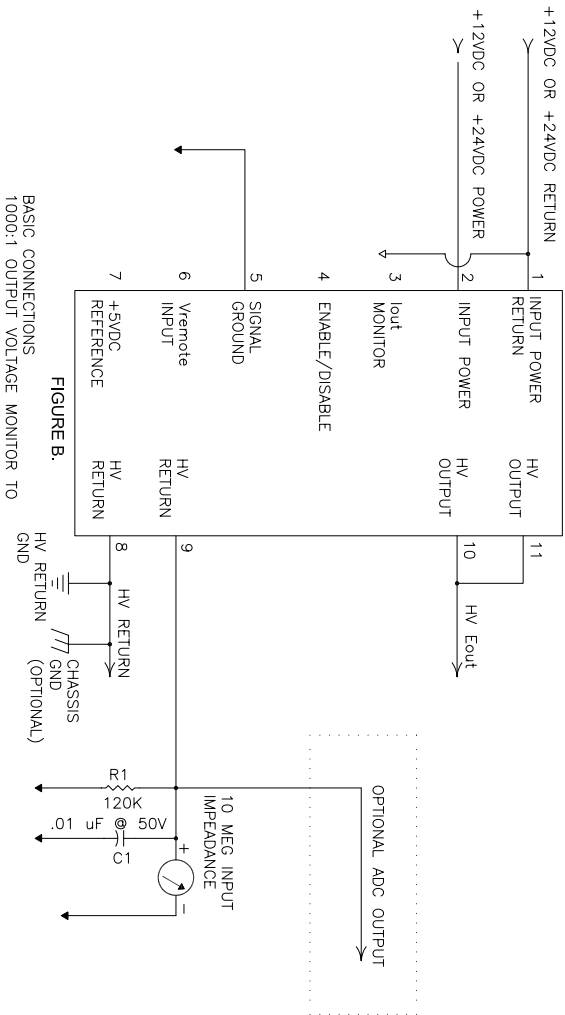
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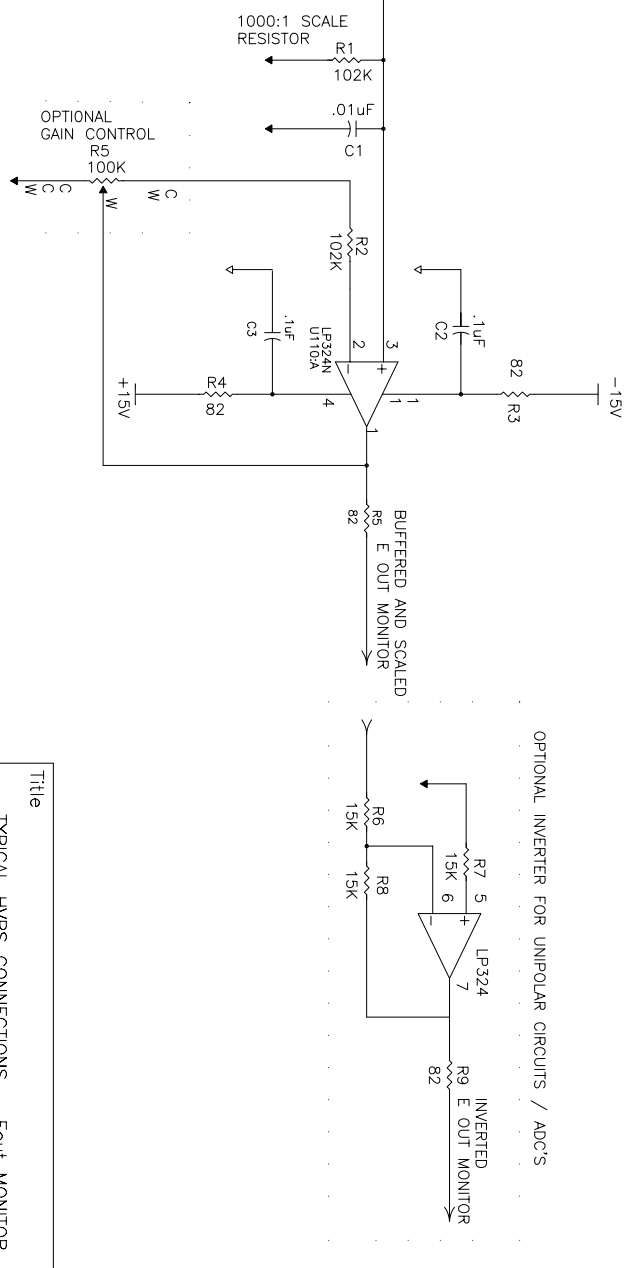
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NOTES: REFER TO UV APPLICATION NOTES FOR MORE DETAILED INFORMATION  
UV HVPS POWER INPUT SHOULD NOT EXCEED +32VDC.  
A 0.1uF TO 1.0 uF CAPACITOR CAN BE ADDED FROM E OUT MON  
TO SIGNAL GROUND TO INTEGRATE THE SIGNAL.

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Title	
TYPICAL HVPS CONNECTIONS - Eout MONITOR	
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A	UV- HVPS-CONN-3
Date	Drawn By
4/26/00	J.T.
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UV-HVPS-CONN-3_rev1.dwg	1 Of 1

Rev. E1

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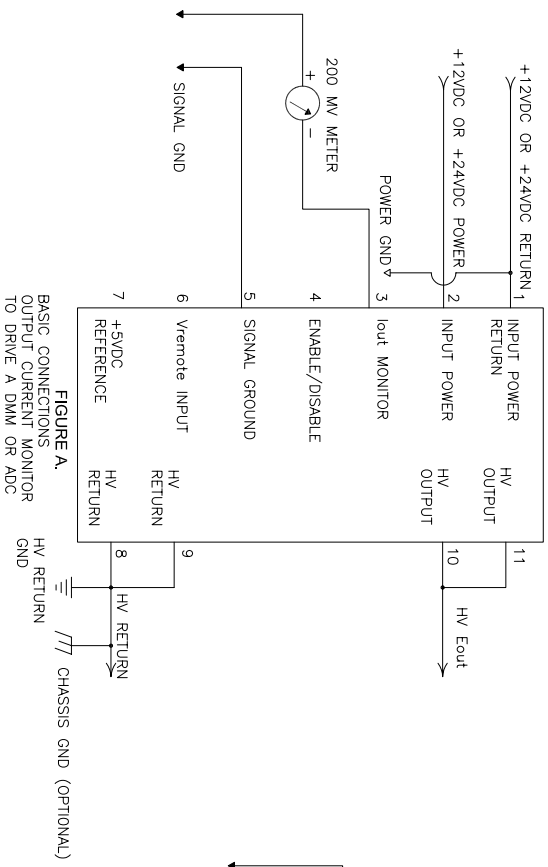


FIGURE A.  
BASIC CONNECTIONS  
OUTPUT CURRENT MONITOR  
TO DRIVE A DMM OR ADC

UltraVolt  
Regulated High Voltage Power Supply  
MODELS 1/8A TO 6A ILLUSTRATED

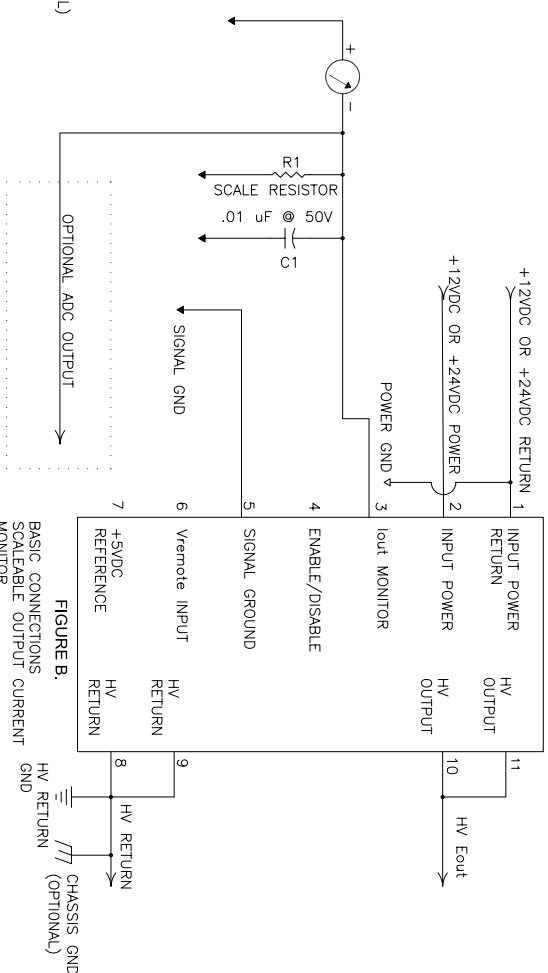


FIGURE B.  
BASIC CONNECTIONS  
SCALEABLE OUTPUT CURRENT  
MONITOR  
TO DRIVE A DMM OR ADC

OPTIONAL INVERTER FOR UNIPOLAR CIRCUITS / ADC's (BI-POLAR OP AMP REQUIRED)

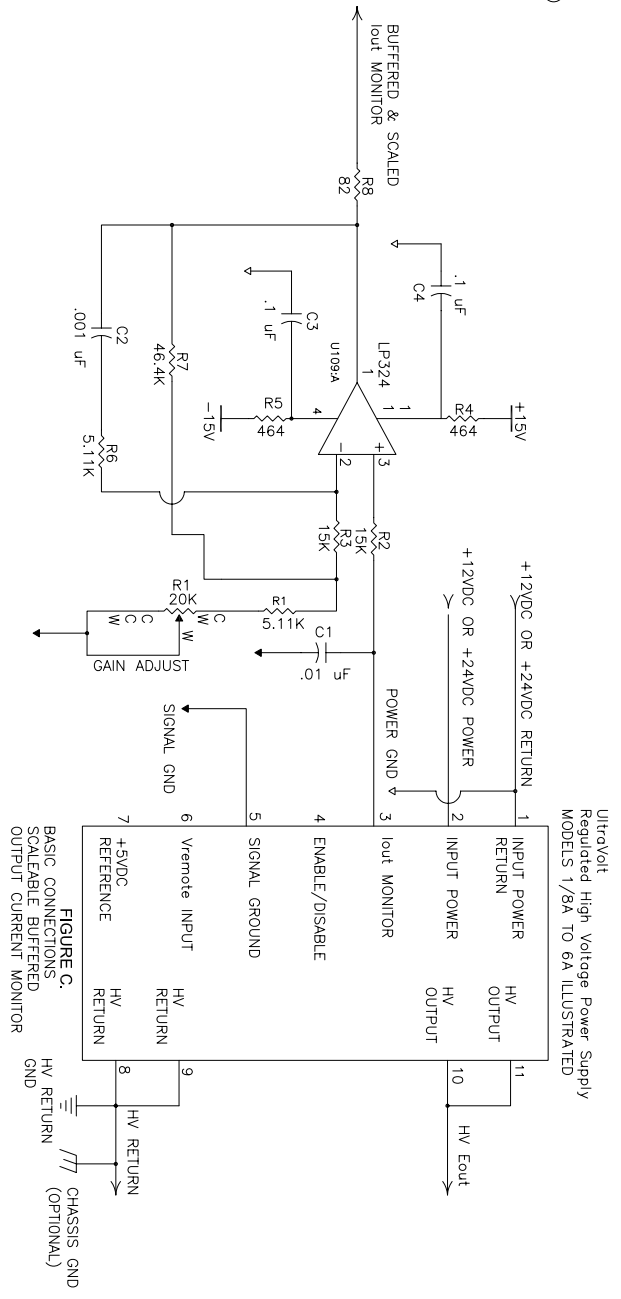
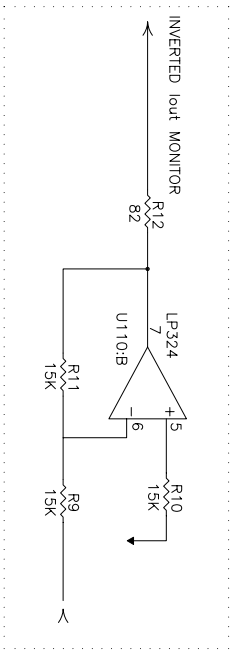


FIGURE C.  
BASIC CONNECTIONS  
SCALEABLE BUFFERED  
OUTPUT CURRENT MONITOR

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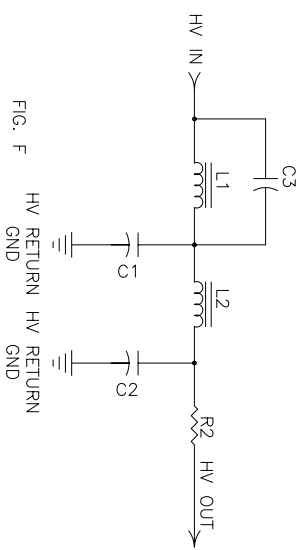
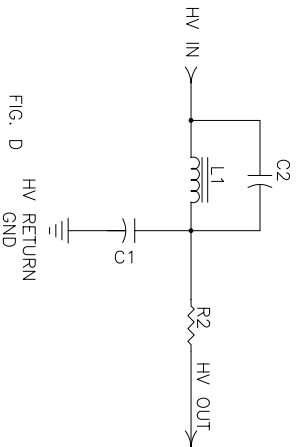
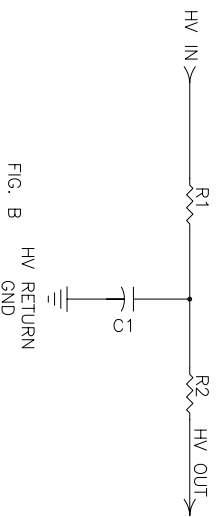
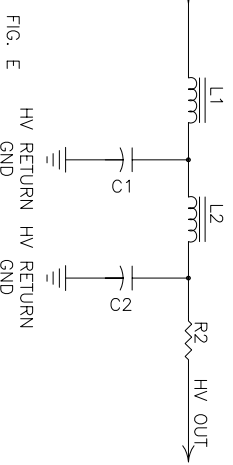
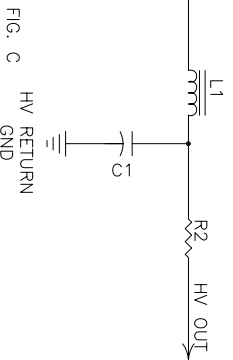
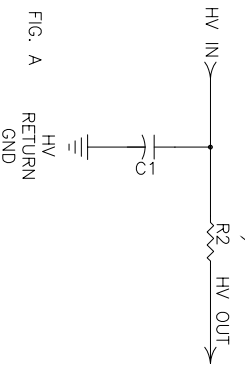
NOTES: REFER TO UV APPLICATION NOTES FOR MORE DETAILED INFORMATION  
UV HVPS POWER INPUT SHOULD NOT EXCEED +32VDC.  
A 0.1uF TO 1.0 uF CAPACITOR CAN BE ADDED FROM I OUT MONITOR  
TO SIGNAL GROUND AND INTEGRATE THE SIGNAL.  
THE I OUT MONITOR SIGNAL IS - FOR A + UNIT & + FOR A - UNIT.

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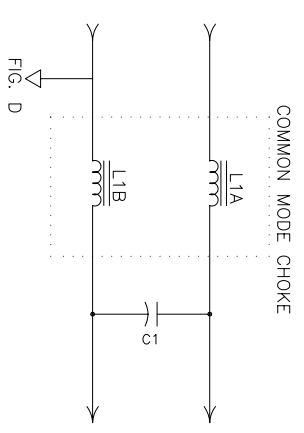
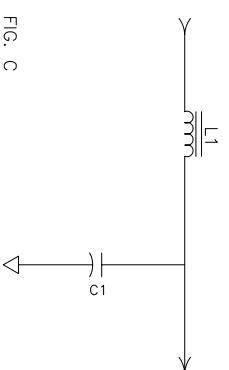
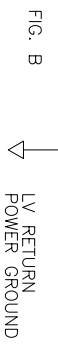
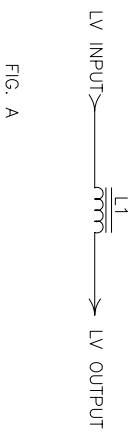
Title		Size	Number	Rev.
TYPICAL HVPS CONNECTIONS - Iout MONITOR		A	UV-HVPS-CONN-4	E1
Date	4/28/00	Drawn By	J.T.	
Filename	UV-HVPS-CONN-4_revE1.dwg	Sheet	1 Of 1	

OUTPUT FILTERS:

HV SOFTENING RESISTOR  
CARBON COMPOSITION  
1/4W TO 2W DEPENDING ON  
SYSTEM



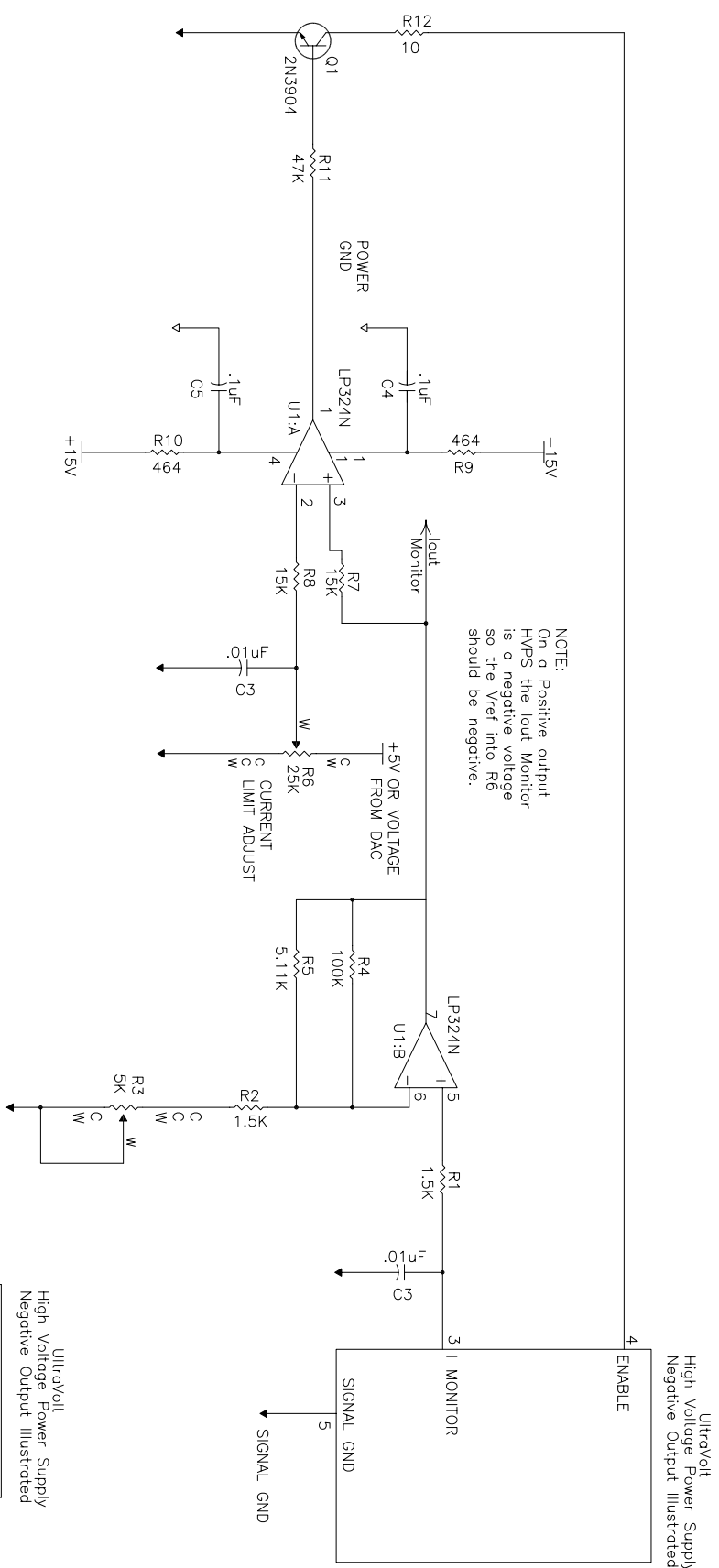
INPUT FILTERS:



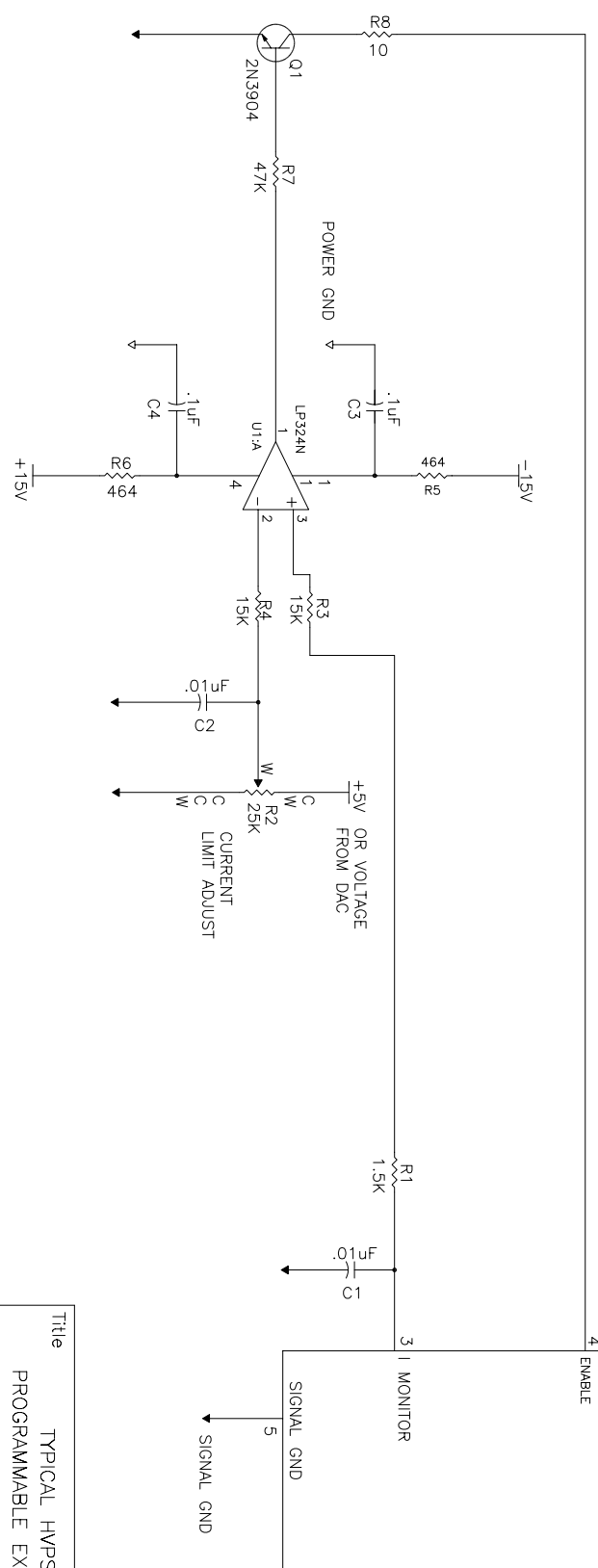
NOTES: ALL HV FILTERS SHOULD HAVE A HV SOFTENING RESISTOR.  
ALL FILTER COMPONENTS SHOULD BE RATED FOR MAX CURRENT AT MAX TEMPERATURE.  
ALL LV HVPS's ARE EQUIPPED WITH AN INTERNAL INPUT L-C FILTER.  
ALL UV HVPS's ARE EQUIPPED WITH AN INTERNAL OUTPUT L-C-R FILTER.  
INPUT FILTER CAPACITORS SHOULD BE LOW ESR ELECTROLYTICS & MAY BE BYPASSED WITH A CERAMIC .1 OR .01 UF CAPACITOR.

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Title		EXTERNAL INPUT & OUTPUT FILTERS	
Size	Number	Rev.	
A	UV-HVPS-CONN-5	E1	
Date	Drawn By	1 Of	1
6/21/00	J.T.		
Filename UV-HVPS-CONN-5_revE1.dwg	Sheet		



NOTE:  
 On a Positive output  
 HPS the Iout Monitor  
 is a negative voltage  
 so the Vref into R6  
 should be negative.



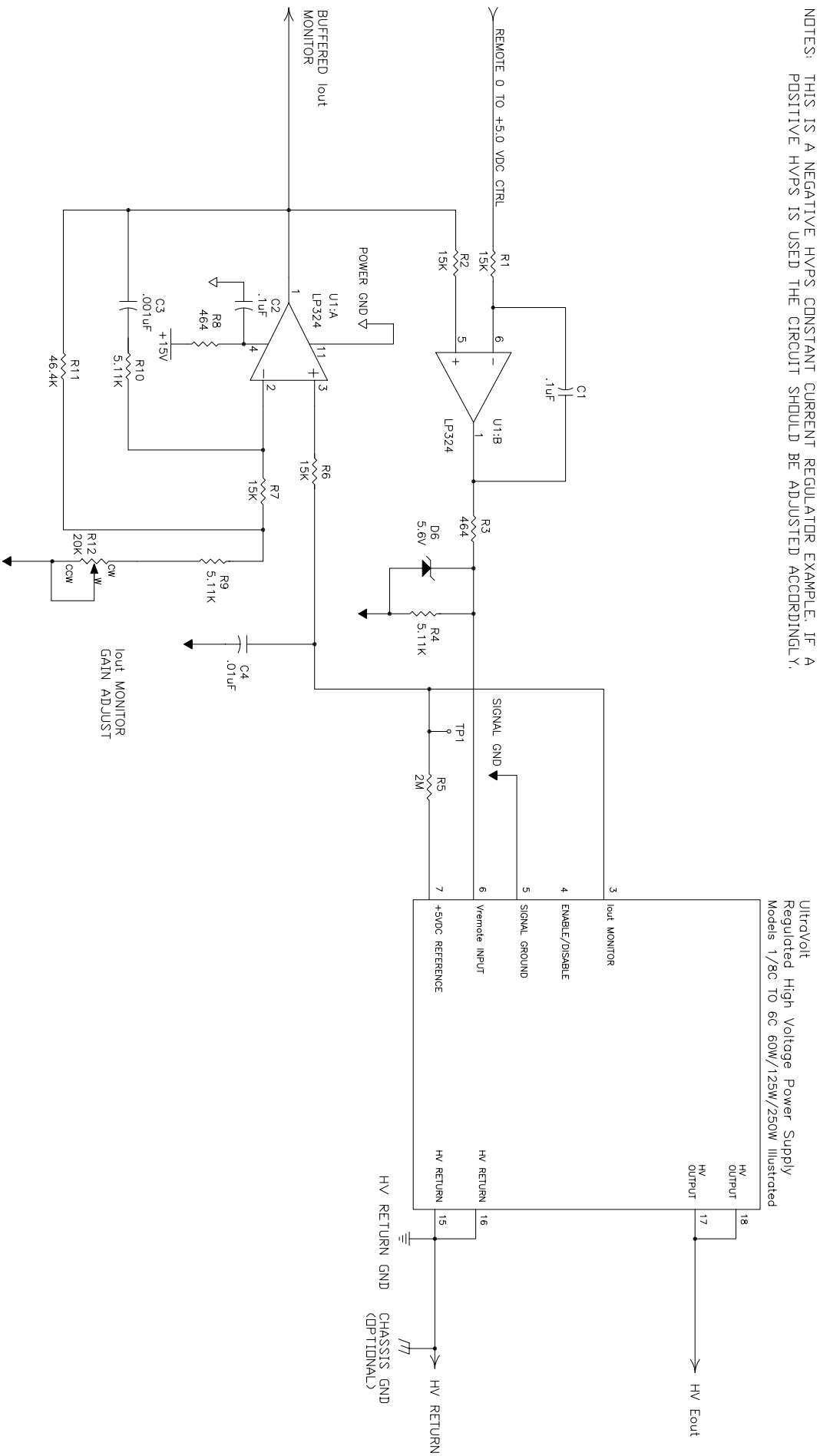
NOTES: REFER TO UV APPLICATION NOTE 13 FOR Iout MONITOR SCALE FACTORS  
 UNUSED OP AMP INPUT SHOULD BE PULLED LOW

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Title		TYPICAL HVPS CONNECTIONS	
Size		PROGRAMMABLE EXTERNAL CURRENT LIMIT	
A	Number	UV-HVPS-CONN-6	
Date	6/21/00	Drawn By	J.T.
File	uv-hvps-conn-6_rev1.dwg	Sheet	1 Of 1
Rev.		E1	

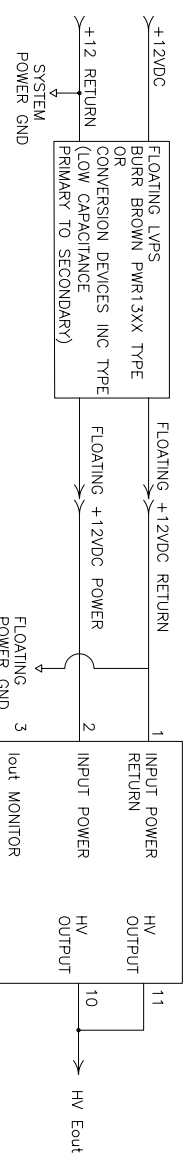


NOTES: THIS IS A NEGATIVE HVPS CONSTANT CURRENT REGULATOR EXAMPLE. IF A POSITIVE HVPS IS USED THE CIRCUIT SHOULD BE ADJUSTED ACCORDINGLY.



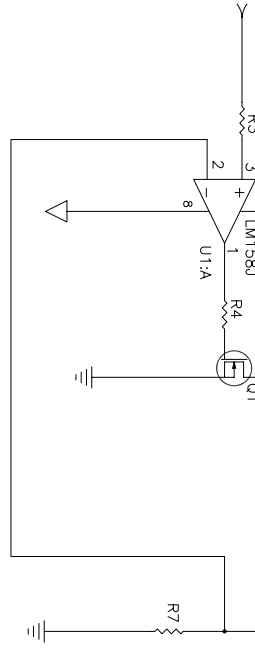
Title			UltraVolt, Inc.	
PROGRAMMABLE EXTERNAL CONSTANT CURRENT REGULATOR			1800 Ocean Ave. Frnt Ronkonkoma, NY 11779 1-631-471-4444	
Size	Number	Rev.		
A	UV- HVPS-CONN-7	E1		
Date	Drawn By	M.Z.		
6/25/00	M.Z.	1		
Filename UV-HVPS-CONN-7.ref1.dwg		Sheet 1 Of 1		

UltraVolt  
Regulated High Voltage  
Power Supply  
MODEL 6A ILLUSTRATED

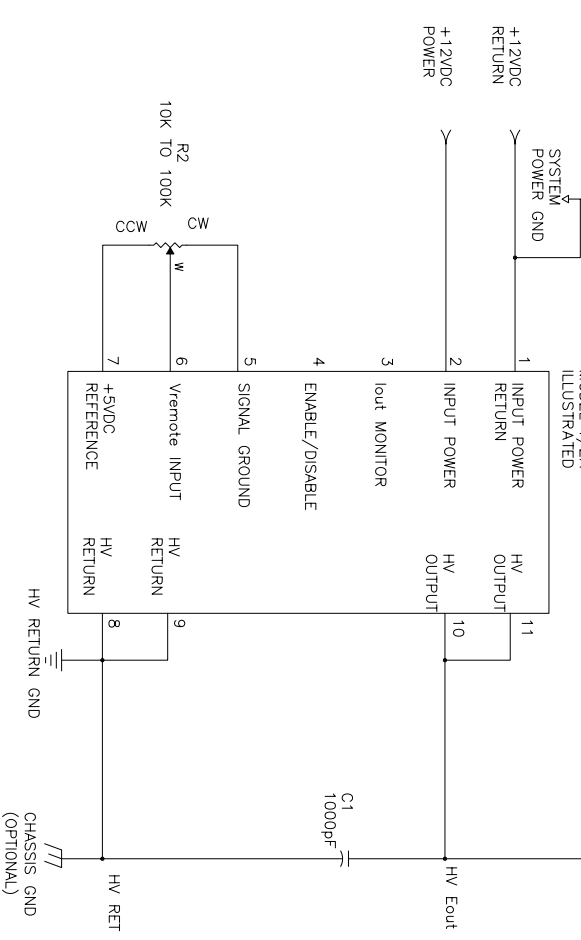


0 TO +400 lo 0 Bias Reference

0 TO +10 TO 0 VDC  
parabola control signal



Divider Ratio to Match  
Amplitude of  
parabola control signal &  
gain required



NOTE: ADJUST R8 AND GROUNDED UV HVPS POWER LEVEL TO  
RAISE FREQUENCY FOR HIGHER FREQUENCY USE HV AMPLIFIER  
SUCH AS AN APEX HV OP-AMP

NOTES: REFER TO UV APPLICATION NOTES FOR MORE DETAILED INFORMATION  
UV HVPS POWER INPUT SHOULD NOT EXCEED +32VDC.  
A 0.1uF TO 1.0 uF CAPACITOR CAN BE ADDED FROM REMOTE ADJUST  
TO SIGNAL GROUND IN HIGH NOISE ENVIRONMENTS.

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Title		DC DYNAMIC FOCUS AMPLIFIER	
Size	Number	UV- HVPS-CONN-9	Rev.
A			E1
Date	8/22/00	Drawn By	M.Z.
Filename uv-HVPS-CONN-9.rwl.dwg		Sheet	1 Of 2

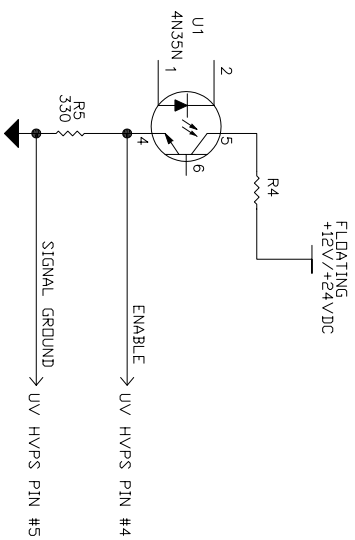


FIGURE C-1:  
FLOATING HVPS CONTROLS  
REMOTE ENABLE

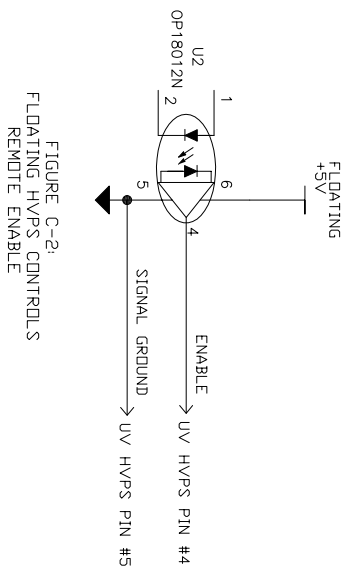


FIGURE C-2:  
FLOATING HVPS CONTROLS  
REMOTE ENABLE

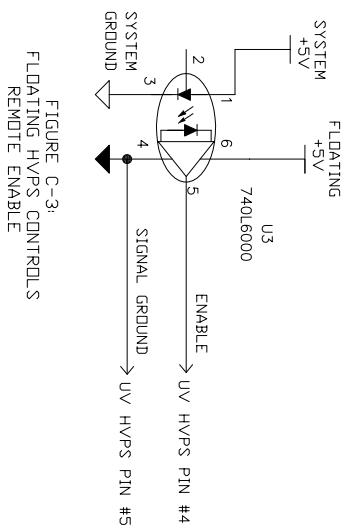


FIGURE C-3:  
FLOATING HVPS CONTROLS  
REMOTE ENABLE

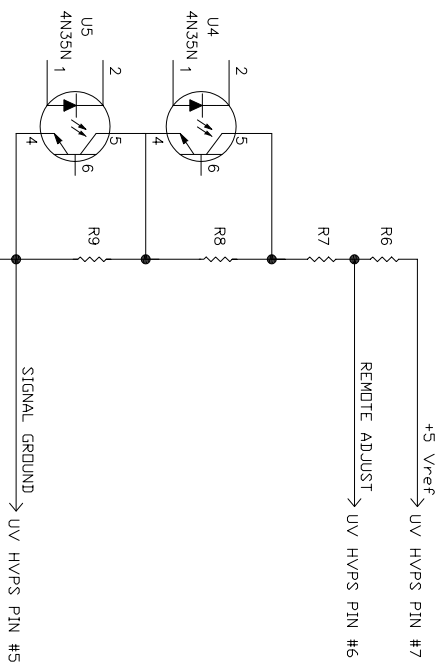


FIGURE C-4:  
FLOATING HVPS CONTROLS  
REMOTE PROGRAMMING  
4 PRESET STEPS

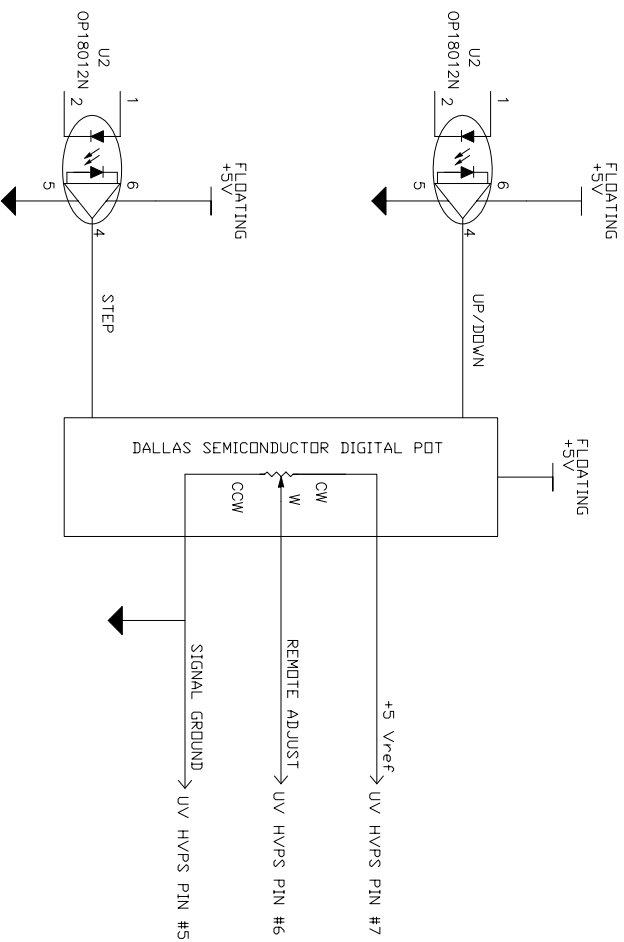


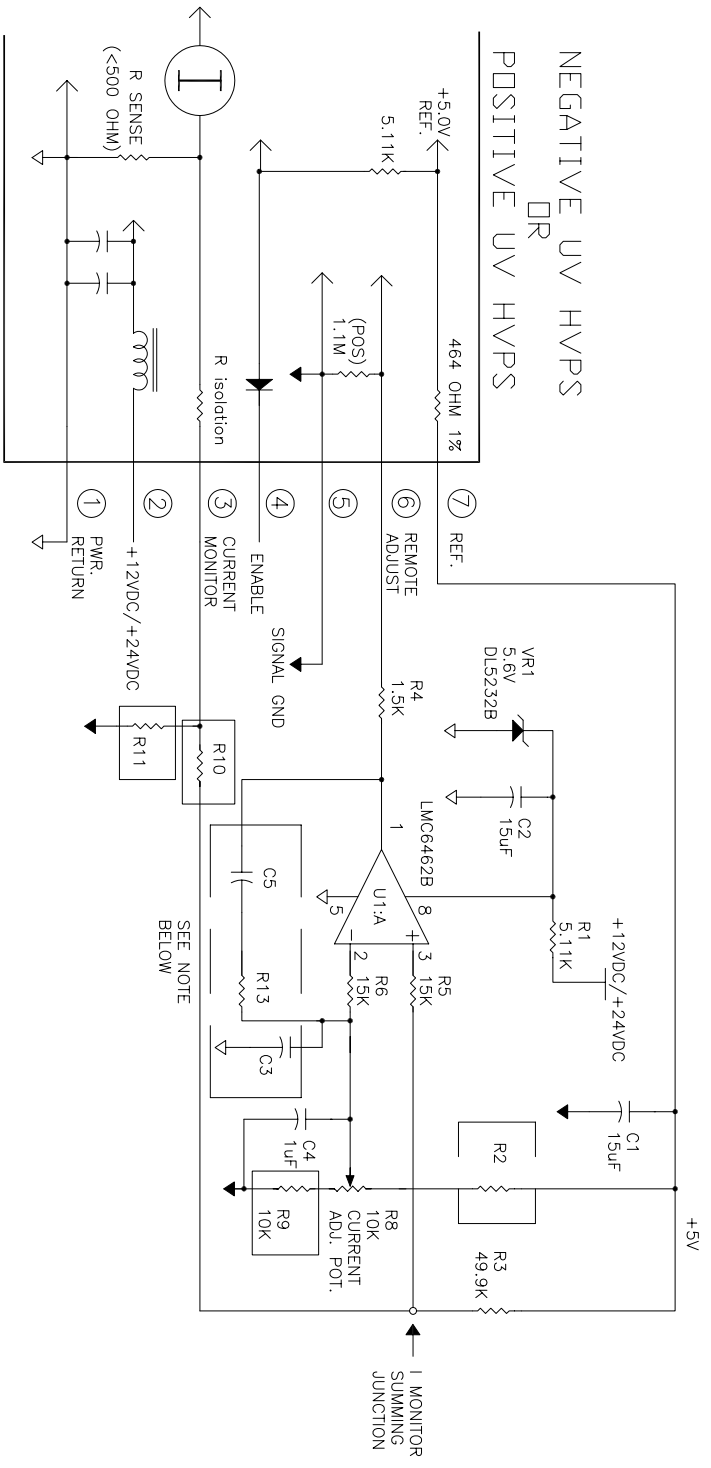
FIGURE C-5:  
FLOATING HVPS CONTROLS  
REMOTE PROGRAMMING  
64 TO 512 STEPS  
(USE A DAC FDR 256 TO 4096 STEPS)

Title  
FLOATING HVPS CONFIGURATIONS

Size		Number		Rev.	
A		UV- HVPS-CONN-11		E1	
Date		Drawn By		M.Z.	
6/12/00		M.Z.		2	
Filename		Sheet		2	
UV-HVPS-CONN-11P2_ref1.dwg		2		2	

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REV	DESCRIPTION	CHKD	APPD	DATE
A	INITIAL RELEASE	SH	FG	5/1/97
B	REVISED EDITION	SH	FG	10/7/98
C	REVISED EDITION	SH	FG	1/4/98
D	REVISED EDITION	SH	FG	6/21/00
D1	REVISED TITLE BLOCK	SRO		12/1/03



MODEL	HVPS	NEGATIVE HVPS I MONITOR	POSITIVE HVPS I MONITOR	R10	R9	R2	R11	R8	VOLTAGE RANGE	N	P	APPROXIMATION OF SUMMING JUNCTION VOLTAGE
1/8 A TD 6 A	15K	0 TD +100mV	0 TD -100mV	0 Dhm	6.8K	22K	--	+0.88 TD +2.16	+1.15 TD +1.23	+1.15 TD +1.07		
10 A TD 35 A	15K	0 TD +8V	0 TD -8V	36K	330	330	15K	+0.15 TD +4.85	+2.32 TD +4.47	+2.32 TD +0.20		
HIGH C	5.11K	0 TD +1.6V	0 TD -1.6V	22K	1.5K	6.8K	--	+0.41 TD +3.14	+1.76 TD +2.79	+1.76 TD +0.71		
LDV C	0 Dhm	0 TD +100mV	0 TD -100mV	15K	6.8K	22K	--	+0.88 TD +2.16	+1.15 TD +1.23	+1.15 TD +1.07		

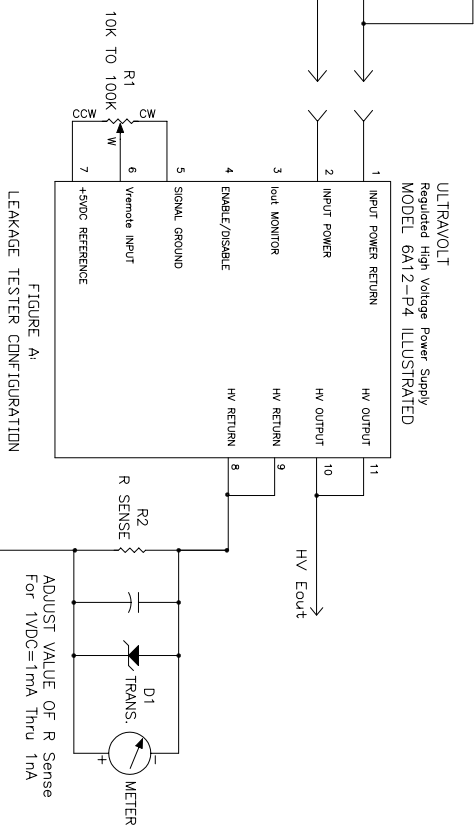
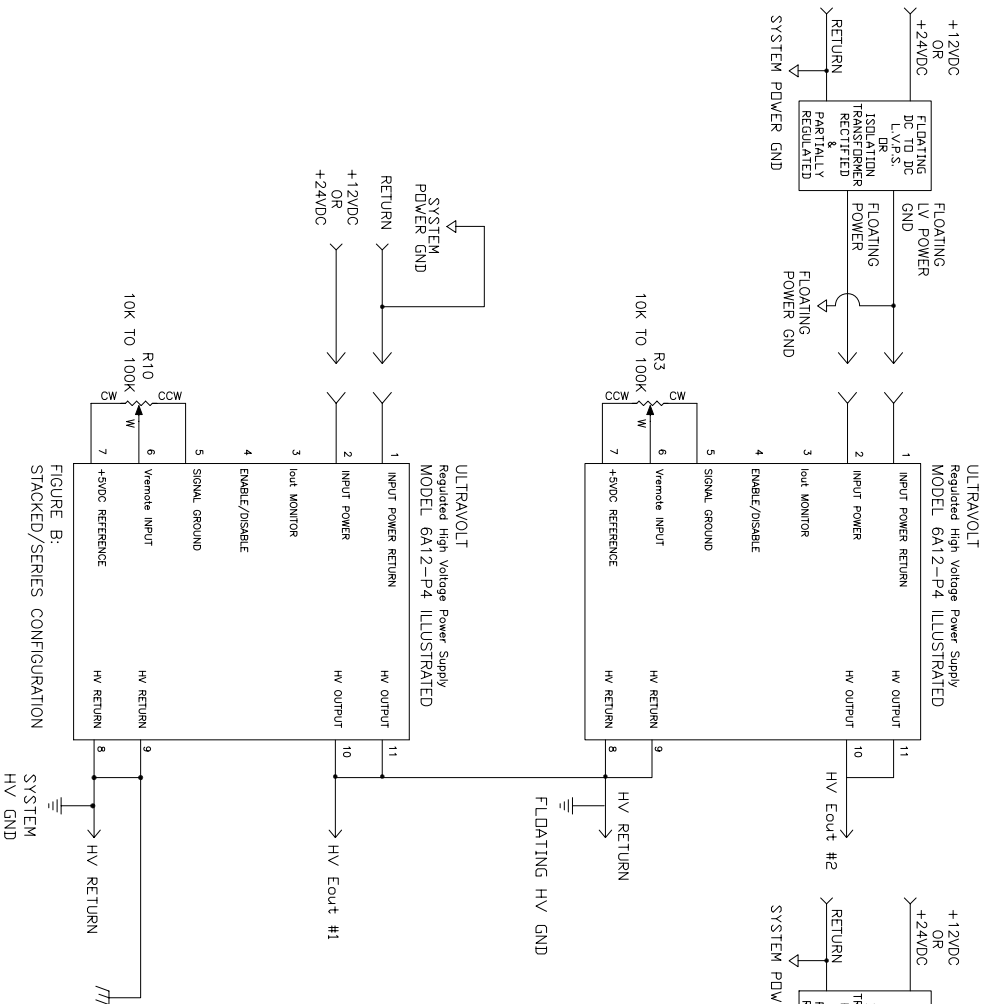
NOTE: TYPICAL VALUES FOR AC COMPENSATION NETWORK ARE: C5(01 uF), C3(001uF), R13(100K)

THIS FULL RANGE IS NOT IN USE BY ALL MODELS.

Size	Number	Rev.
A	UV - HVPS-CONN-10	D1

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Date 6/14/00  
Filename UV-HVPS-CONN-10.rpt.dwg  
Sheet 1 Of 1



NOTE: ULTRAVOLT ISFL12 FLOATING HOT DECK LVPS CAN ALSO BE USED FOR FLOATING ELECTRONICS

Title		FLOATING HVPS CONFIGURATIONS	
Size	Number	UV- HVPS-CONN-11	Rev. E1
A			
Date	6/13/00	Drawn By	M.Z.
Filename	UV-HVPS-CONN-11Pl_Rev1.dwg	Sheet	1 Of 2

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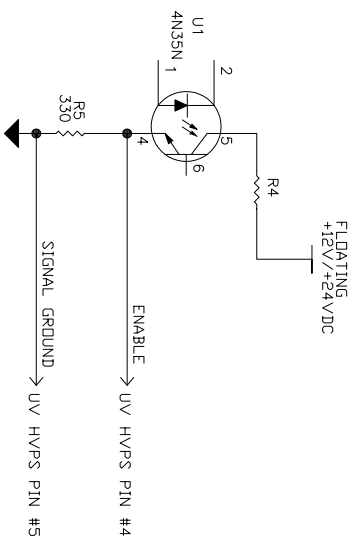


FIGURE C-1:  
FLOATING HVPS CONTROLS  
REMOTE ENABLE

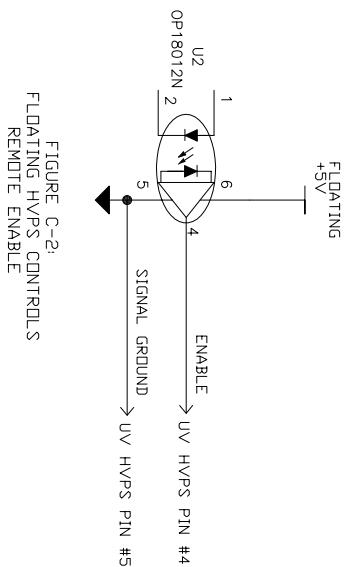


FIGURE C-2:  
FLOATING HVPS CONTROLS  
REMOTE ENABLE

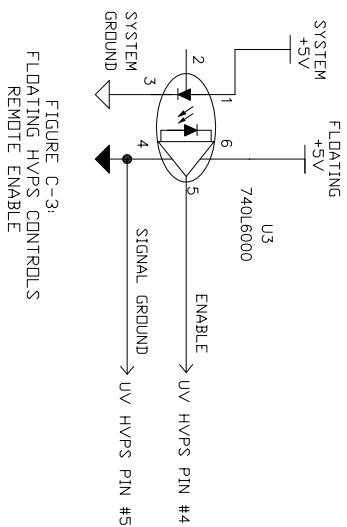


FIGURE C-3:  
FLOATING HVPS CONTROLS  
REMOTE ENABLE

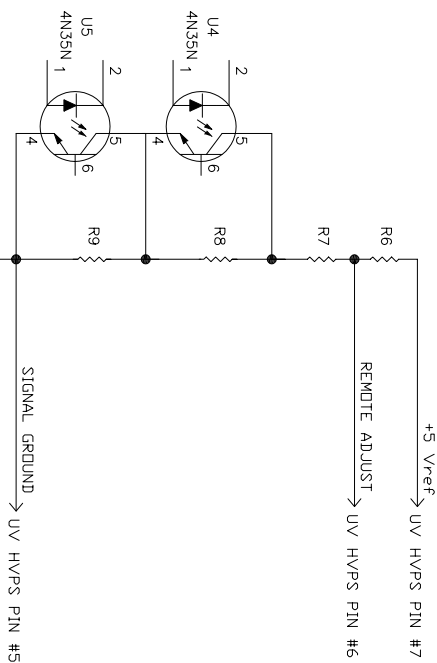


FIGURE C-4:  
FLOATING HVPS CONTROLS  
REMOTE PROGRAMMING  
4 PRESET STEPS

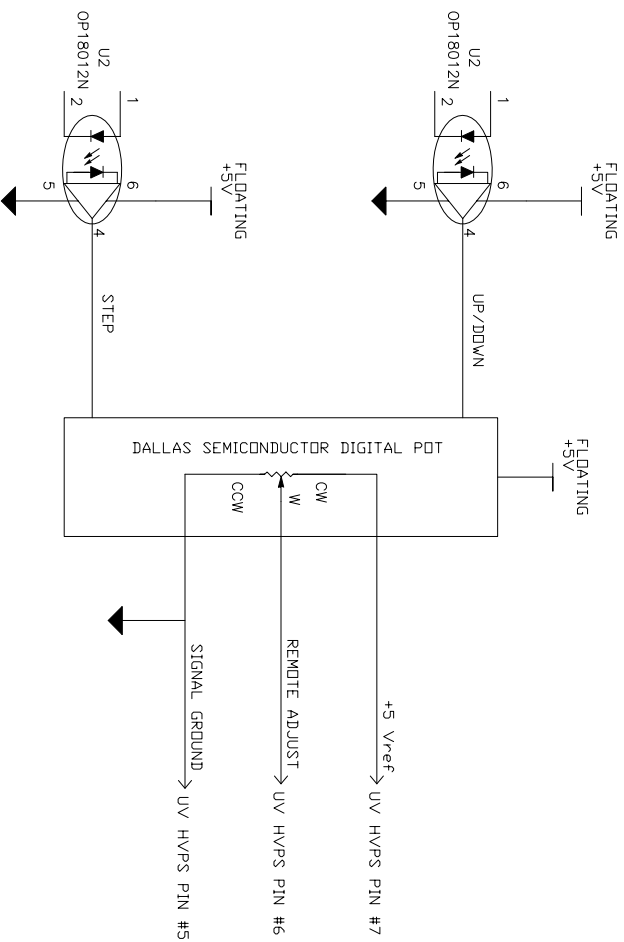
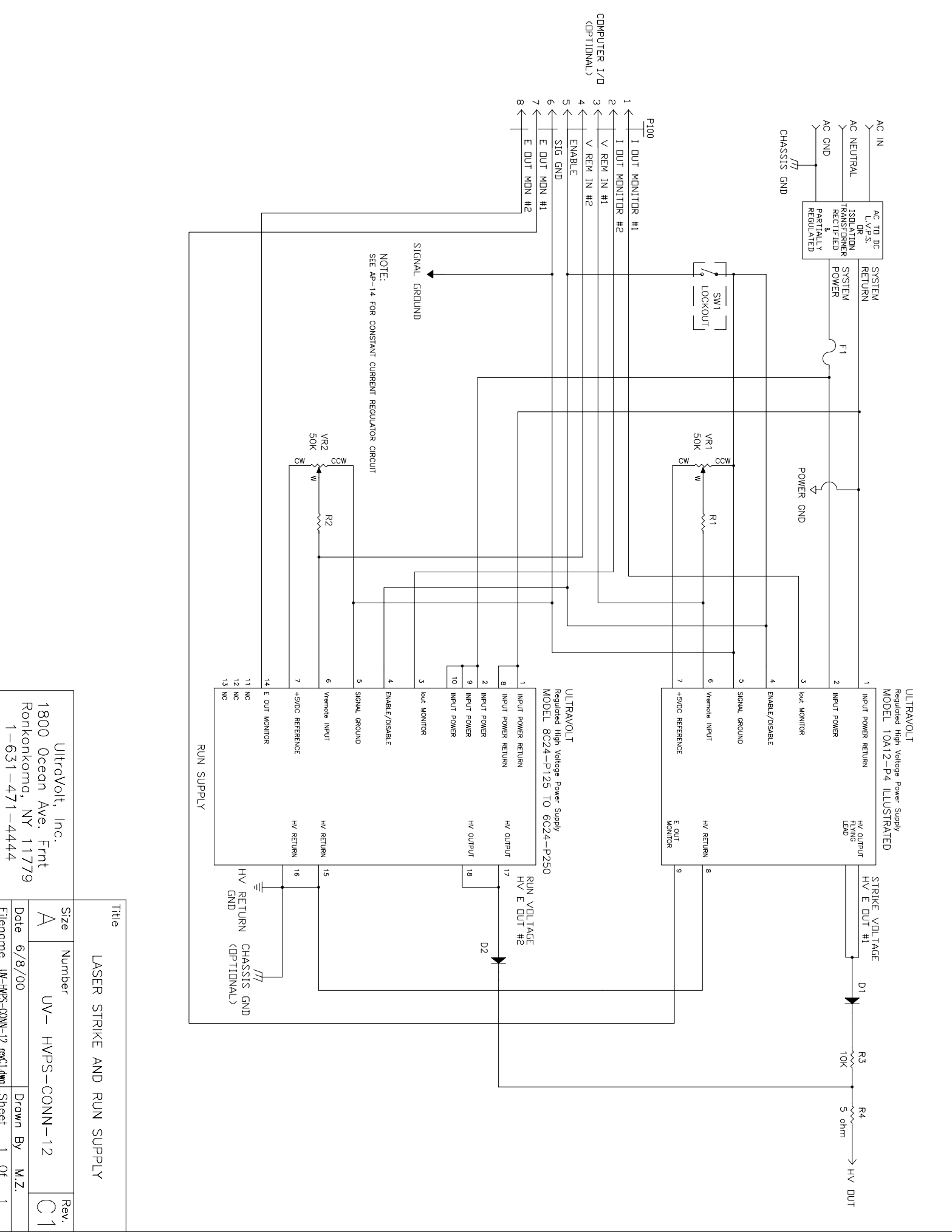


FIGURE C-5:  
FLOATING HVPS CONTROLS  
REMOTE PROGRAMMING  
64 TO 512 STEPS  
(USE A DAC FDR 256 TO 4096 STEPS)

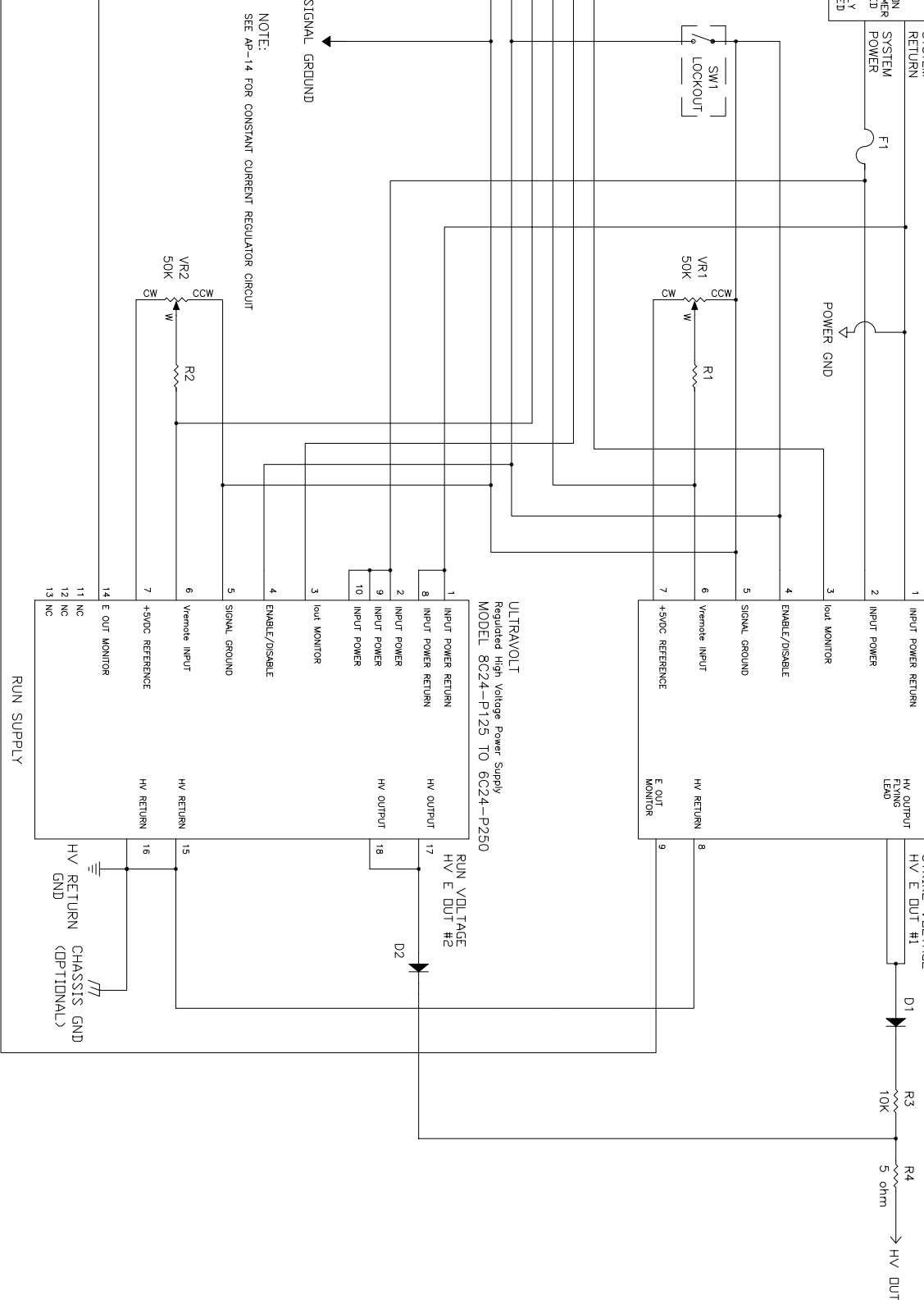
Title  
FLOATING HVPS CONFIGURATIONS

Size		Number		Rev.	
A		UV- HVPS-CONN-11		E1	
Date		Drawn By		M.Z.	
6/12/00		M.Z.		2	
Filename		Sheet		2	
UV-HVPS-CONN-11P2_ref1.dwg		2		2	

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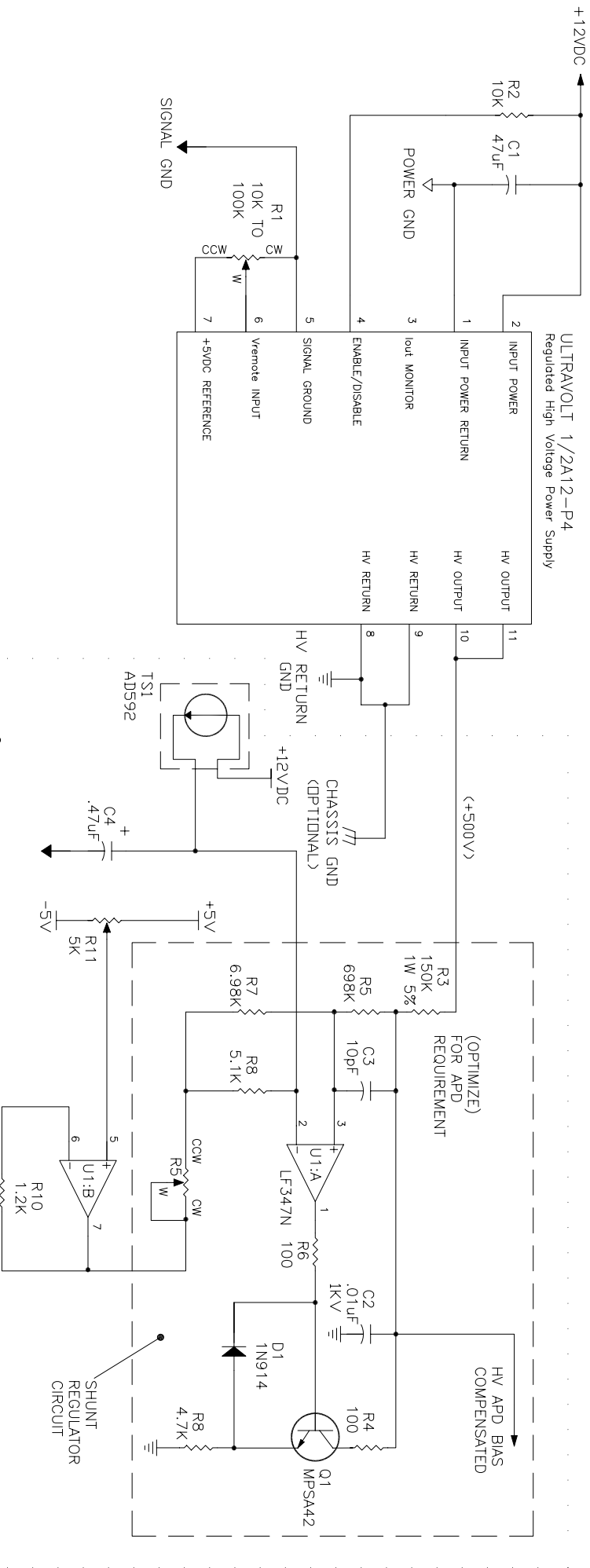


ULTRAVOLT  
Regulated High Voltage Power Supply  
MODEL 10A12-P4 ILLUSTRATED



Title		LASER STRIKE AND RUN SUPPLY	
Size	Number	UV- HVPS-CONN-12	Rev. C1
Date	6/8/00	Drawn By	M.Z.
File Name	UV-HVPS-CONN-12.rpt.dwg	Sheet	1 Of 1

UltraVolt, Inc.  
1800 Ocean Ave. Frnt  
Ronkonkoma, NY 11779  
1-631-471-4444

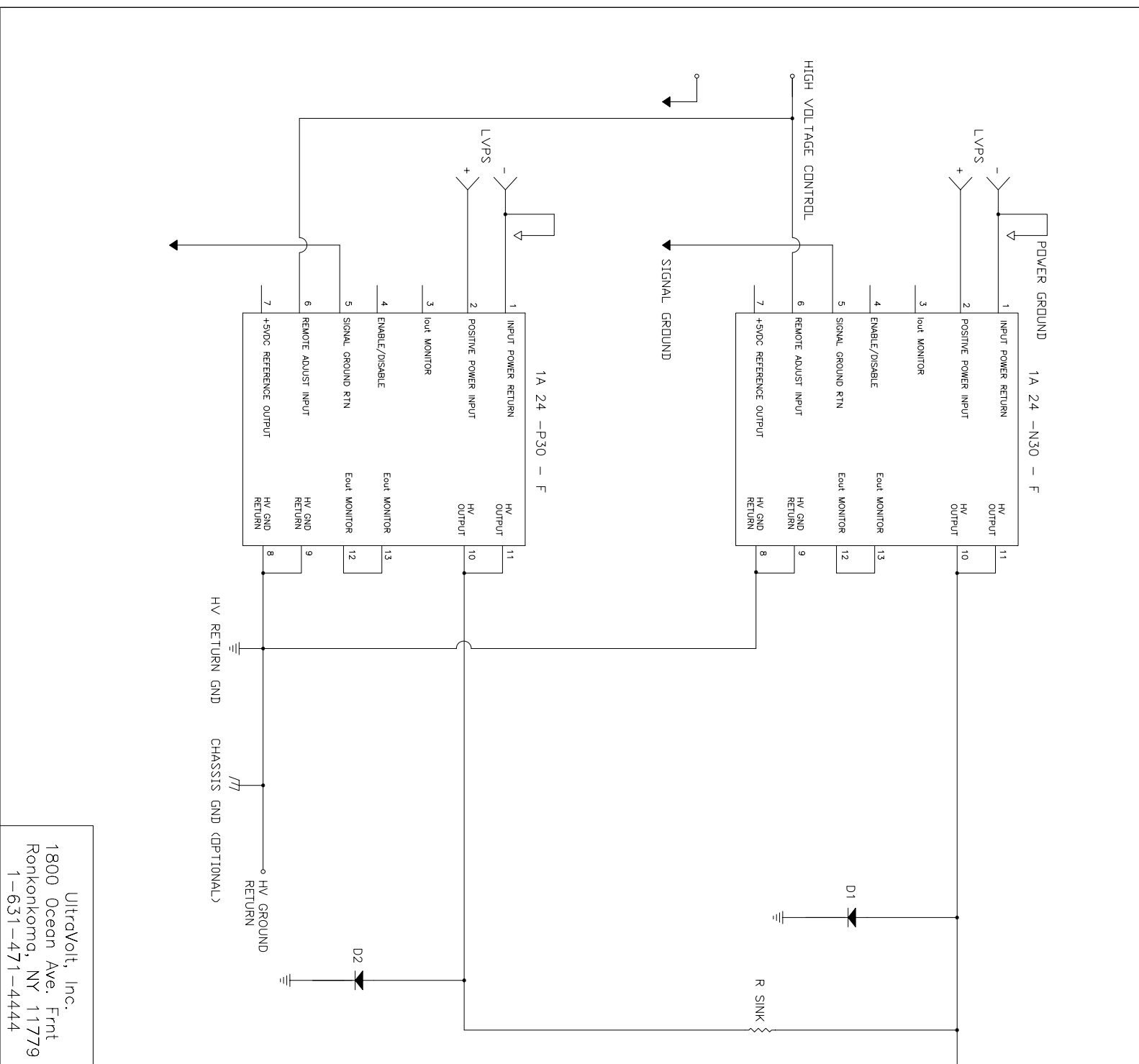


REPEAT THIS  
CIRCUIT

Title TEMPERATURE COMPENSATED APD BIAS SUPPLY AND SHUNT REGULATOR

UltraVolt, Inc. 1800 Ocean Ave, Frnt Ronkonkoma, NY 11779 1-631-471-4444	Size A	Number UV- HVPS-CONN-13	Rev. C1
Date 6/8/00	Drawn By M.Z.	Sheet 1	Of 1
Filename UV-HVPS-CONN-13.revC1.dwg	Sheet 1	Of 1	

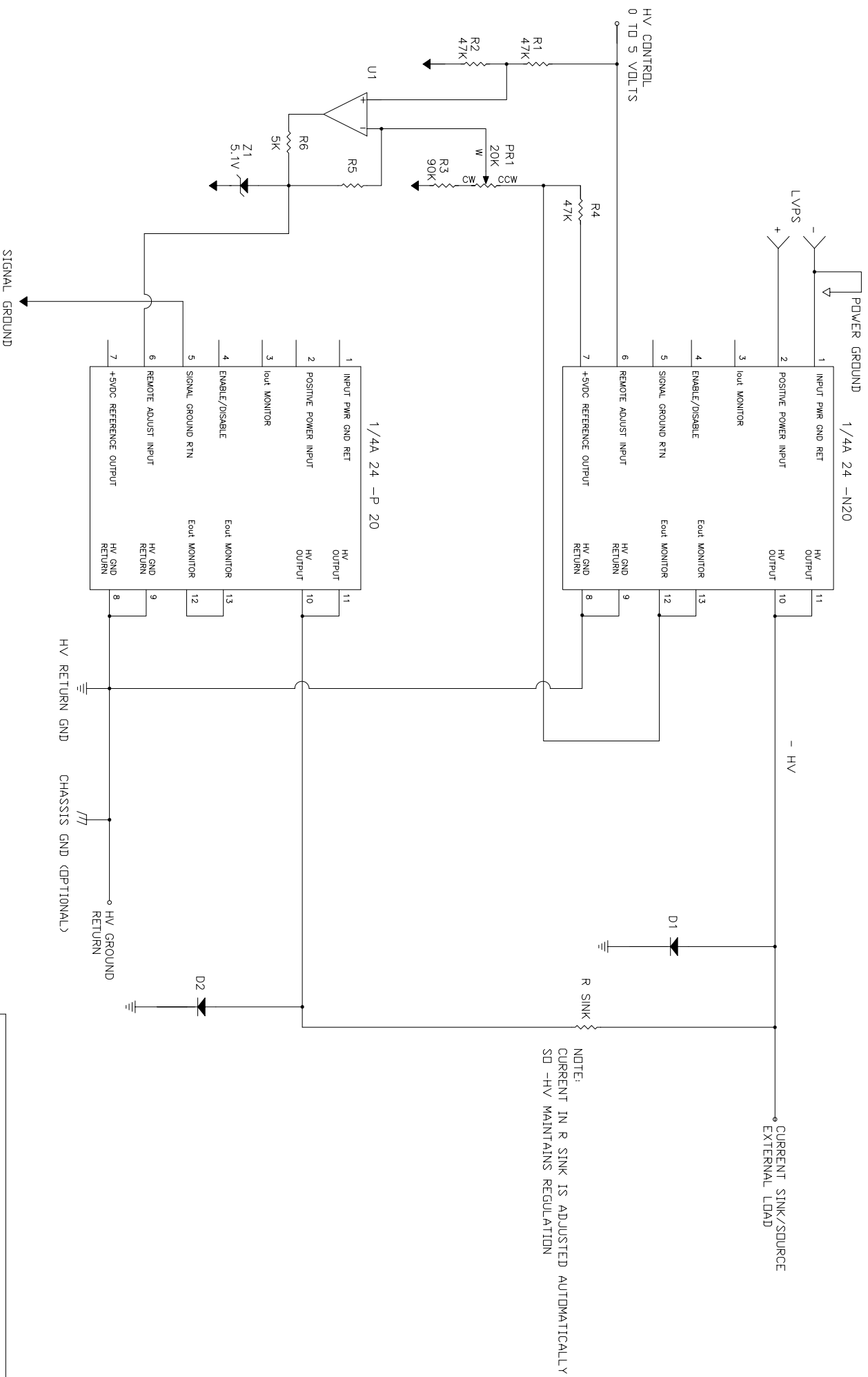




VOLTAGE AND CURRENT IN R SINK IS MAINTAINED AT ALL OUTPUT LEVELS.  
 EXAMPLE: External load current + 20mA to -10mA  
 R SINK = 100K  
 VOLTAGE ACROSS R SINK = 1075 KV  
 CURRENT IN R SINK = 10.75mA

Title			CONTINUOUS HV LOAD / PULLDOWN (PASSIVE SINK)		
Size	Number	Rev.			
A	UV- HVPS-CONN-14	B1			
Date	6/5/00	Drawn By	M.Z.		
Filename	UV-HVPS-CONN-14P1_revB1.dwg	Sheet	1	Of	2

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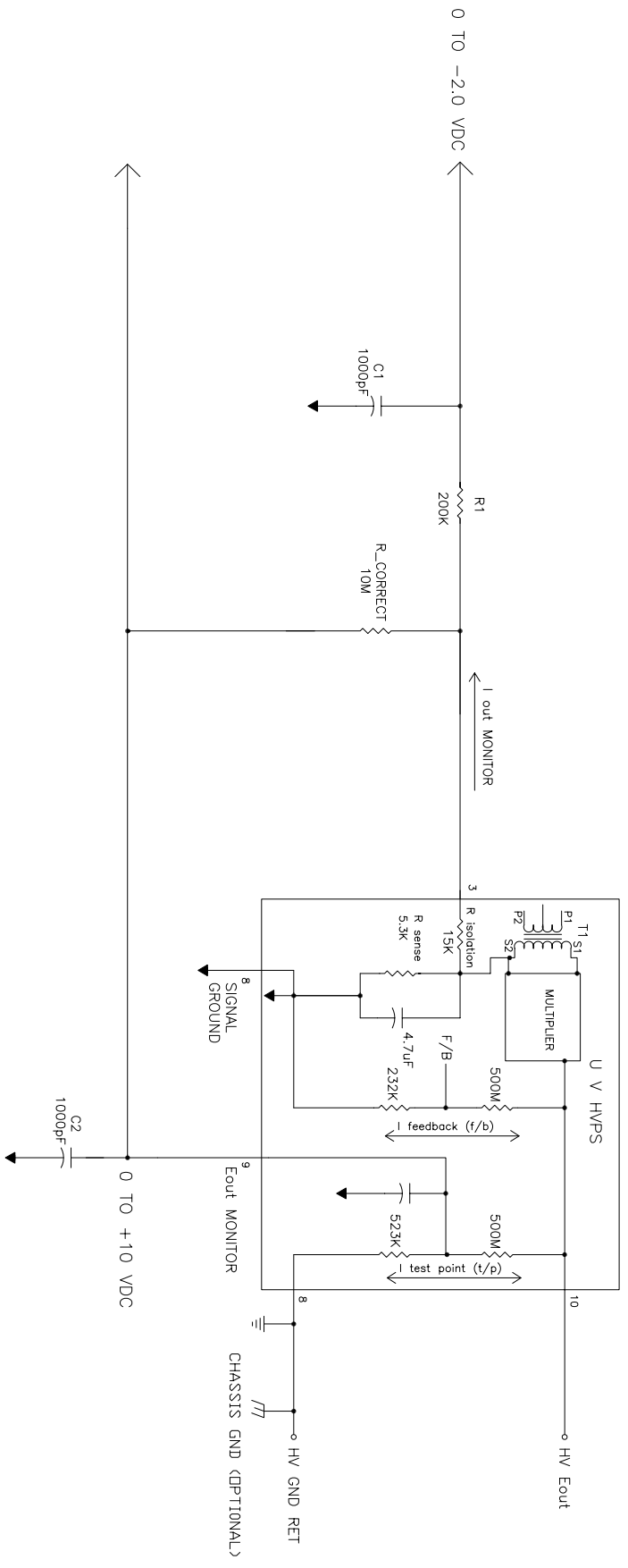
NOTE:  
 CURRENT IN R SINK IS ADJUSTED AUTOMATICALLY  
 SO -HV MAINTAINS REGULATION

Title ACTIVE HV LOAD / PULLDOWN  
 (REGULATED SINK CIRCUIT)

Size Number UV - HVPs-CONN-14 Rev. B1

UltraVolt, Inc.  
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Date 6/5/00 Drawn By M.Z. Sheet 2 Of 2  
 File name UV-HVPs-CONN-14P2\_revB1.dwg



$$(1 f/b + 1 t/p) * R \text{ sense} = E \text{ error}$$

$$\frac{10KV}{500M + 523K} = 1 f/b = 0.000020 = 20\mu A$$

$$E \text{ error} = I \text{ correction}$$

$$\frac{10KV}{500M + 523K} = 1 t/p = 0.000020 = 20\mu A$$

$$R \text{ isolation} = 15K + 200K = 215K$$

$$E \text{ out Monitor} = R \text{ correction} = 5.3K \text{ ohms}$$

$$I \text{ correction} = 20\mu A$$

$$(20\mu A + 20\mu A) * 5.3K \text{ ohms} = E \text{ error} = 212mV$$

$$212mV = 1 \text{ correction} = 0.986\mu A = 986nA$$

$$R \text{ isolation} = 15K + 200K = 215K$$

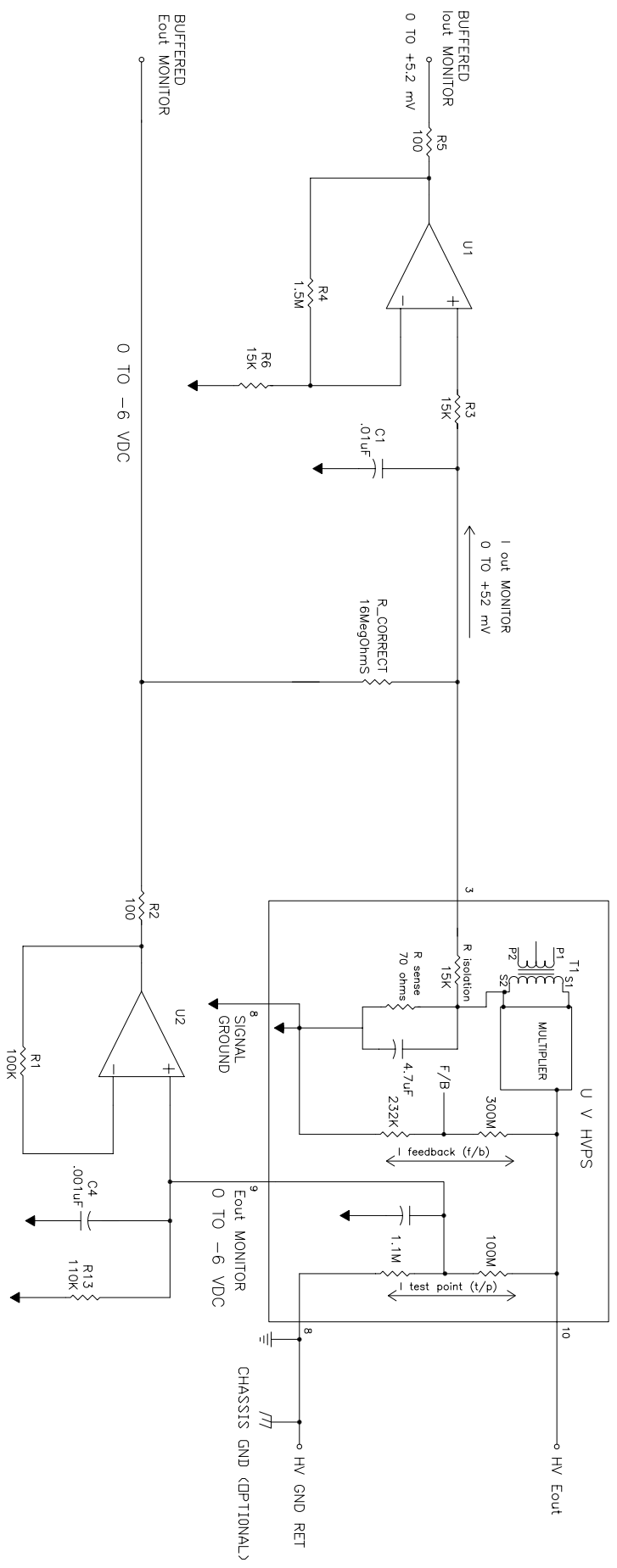
$$E \text{ out Monitor} = R \text{ correction} = 10V = 10.14mV$$

$$I \text{ correction} = 0.986\mu A$$

Title  
 BUFFERED TRUE Iout MONITOR  
 AND BUFFERED Eout MONITOR

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 1-631-471-4444

Size	Number	Rev.
A	UV- HVPS-CONN-15	C1
Date	Drawn By	
6/5/00	M.Z.	
Filename	Sheet	Of
UV-HVPS-CONN-15P1_Rev1.dwg	1	3



$$(1 f/b + 1 t/p) * R \text{ sense} = E \text{ error}$$

$$\frac{6KV}{300M + 232K} = 1 f/b = 0.000020 = 20\mu A$$

$$E \text{ error} = I \text{ correction}$$

$$\frac{6KV}{100M + 100K} = 1 t/p = 0.000060 = 60\mu A$$

$$R \text{ isolation} = 15K$$

$$E \text{ out Monitor} = R \text{ correction}$$

$$R \text{ sense} = 70 \text{ ohms} \quad R \text{ isolation} = 15K$$

$$I \text{ correction} = 15K$$

$$(20\mu A + 60\mu A) * 70 \text{ ohms} = E \text{ error} = 5.6mV$$

$$5.6mV = 1 \text{ correction} = 0.373\mu A = 373nA$$

$$15K$$

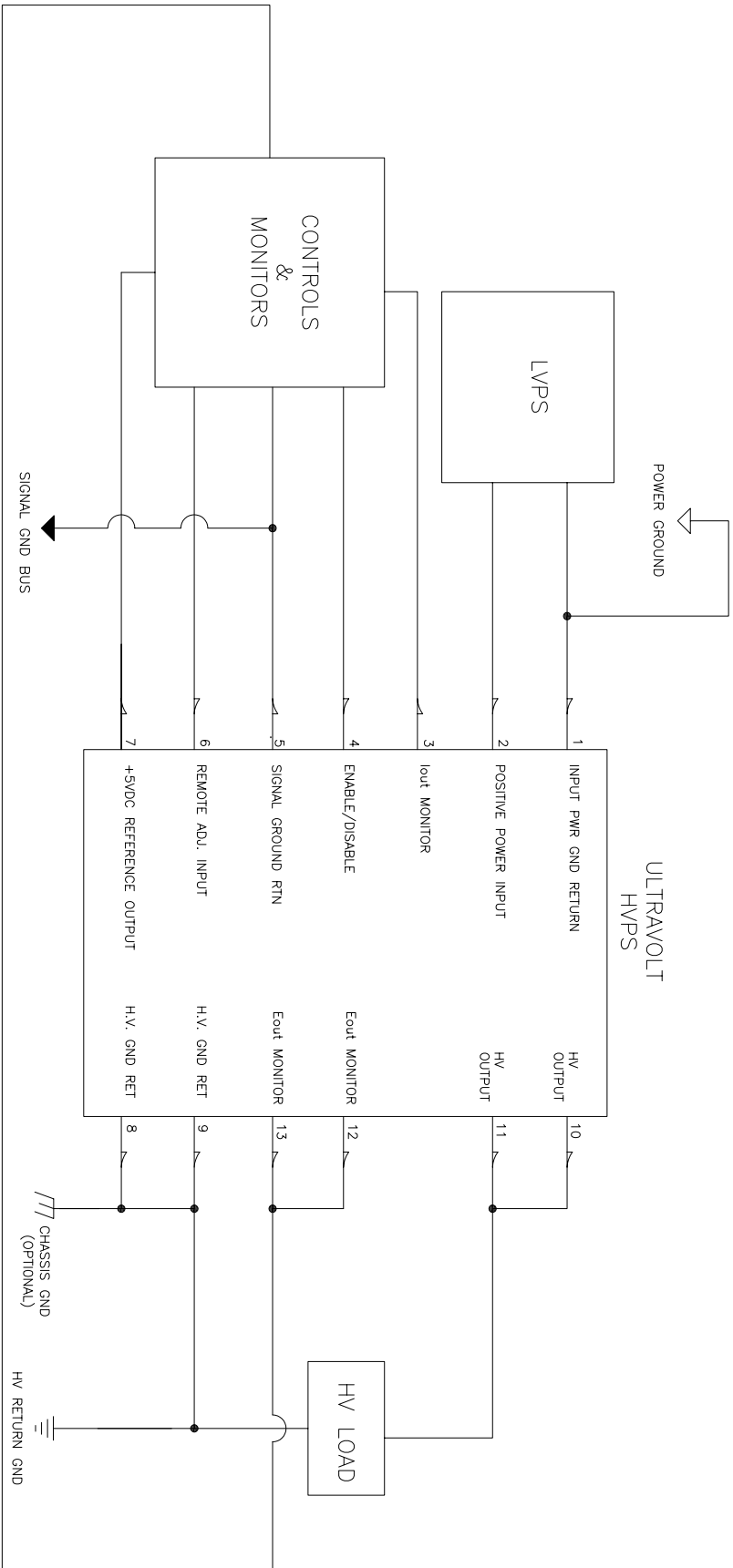
$$6V = R \text{ correction} = 16M$$

$$0.358\mu A$$

Title  
UV-HVPS-CONN-15

UltraVolt, Inc. 1800 Ocean Ave. Frnt Ronkonkoma, NY 11779 1-631-471-4444		Size A	Number UV- HVPS-CONN-15	Rev. C1
Date 6/5/00	Drawn By M.Z.	File name UV-HVPS-CONN-15P2_rev1.dwg	Sheet 2	Of 3



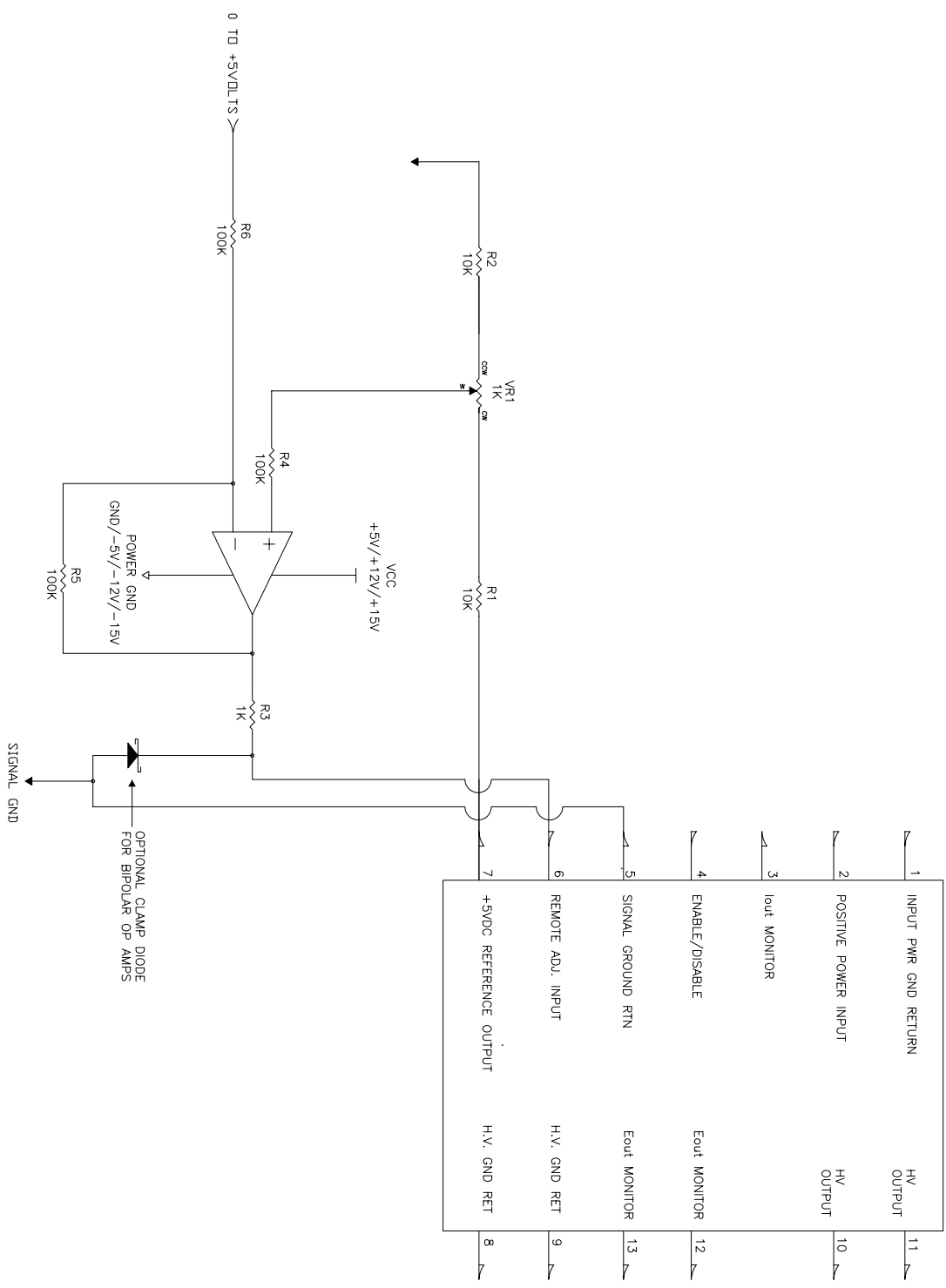


NOTES: REFER TO UV APPLICATION NOTES FOR MORE DETAILED INFORMATION  
 UV HVPS POWER INPUT SHOULD NOT EXCEED +32VDC.  
 A 0.1uF 1.0 uF CAPACITOR CAN BE ADDED FROM REMOTE ADJUST TO SIGNAL GROUND IN HIGH NOISE ENVIRONMENTS.

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Title		RECOMMENDED HVPS GROUNDING CONFIGURATION	
Size	Number	UV-HVPS-CONN-16	Rev.
A			B1
Date	6/1/00	Drawn By	M.Z.
Filename	UV-HVPS-CONN-16_revB1.dwg	Sheet	1 Of 1

UV NEGATIVE HVPS



Title  
SIMPLE INVERTER DRIVE FOR NEGATIVE HVPS

UltraVolt, Inc.  
1800 Ocean Ave. Frnt  
Ronkonkoma, NY 11779  
1-631-471-4444

Size	Number	Rev.
A	UV-HVPS-CONN-17	B1
Date	6/1/00	Drawn By
Filename	UV-HVPS-CONN-17_revB1.dwg	M.Z.
		Sheet 1 Of 1