

## App. Note 1: Remote Control of UltraVolt HVPS

Rev: J 1/99

### BASICS OF ULTRAVOLT HVPS OUTPUT VOLTAGE CONTROL

By varying the voltage at the Remote Adjust terminal (pin #6) between 0 and +5V, the UV 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  $107.5\% \pm 2\%$  of the HVPS nominal output voltage rating. For a HVPS of nominal voltage rating  $E_o$ :

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

Note that for a **negative** supply, a Remote Adjust input of 0V yields an output of  $(1.075 * E_o)$  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, as damage to the HVPS will occur. Should a bipolar DAC or OP AMP be used to control the Remote Adjust input, the Remote Adjust input must be protected from negative voltage. This can be accomplished by simply connecting a low voltage Schottky diode between HVPS pins 5 and 6 (anode to pin 5, cathode to pin 6). For more information, see [App. Note #16](#).

The gain from the Remote Adjust input to the HVPS output can be found using:  $(E_o/5) * 1.075$ , with a tolerance of typically  $\pm 1\%$ . Again  $E_o$  is the supply nominal voltage rating. An initial offset of typically  $\pm 1\%$  may also be present.

For example: for a 1kV + $E_o$  unit

$$\text{Gain} = (1000/5) * 1.075$$

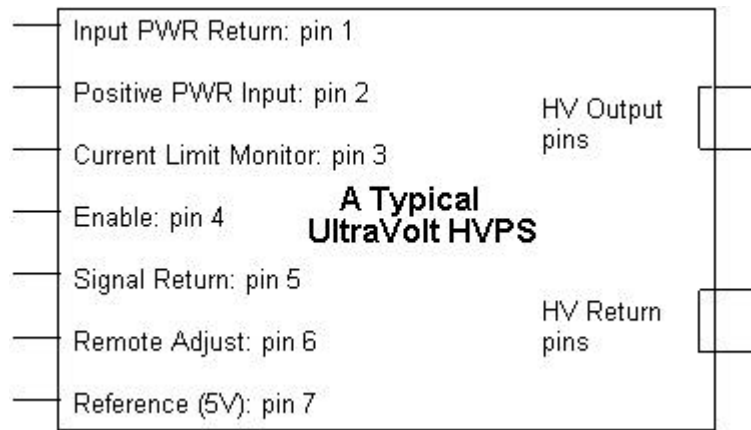
$$\text{Gain} = 215 \text{ V/V} \pm 1\%$$

So for 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 [Conn-Dwg #1](#) or the illustration below



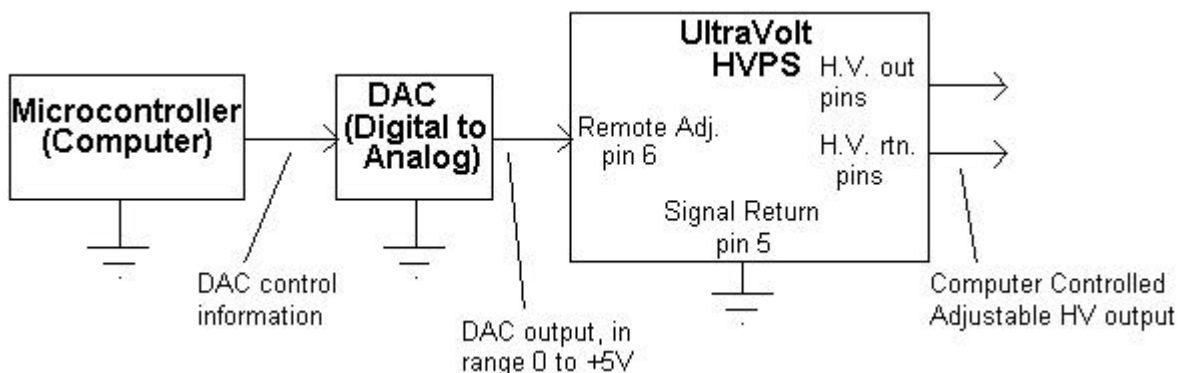
## 1) Voltage Programming

Voltage programming of the UltraVolt HVPS can be done simply through the application of a controlled voltage to the Remote Adjust Voltage Terminal (pin #6). A typical application of voltage programming is the computer controlled adjustment of the HVPS' output voltage. Through the use of a computer controlled DAC (digital to analog converter). Although this method 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.

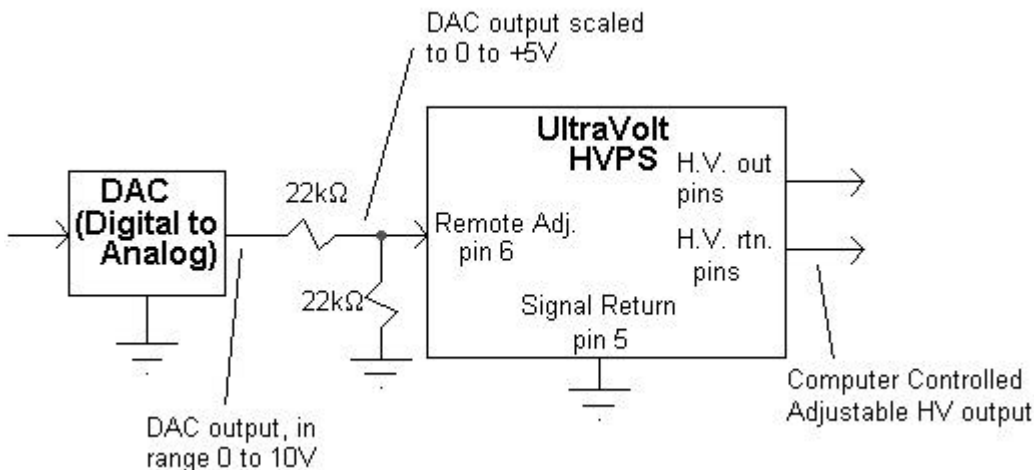
To avoid the need to generate a negative internal LVPS the designers at UltraVolt used the internal +5Vdc temperature compensated reference to create a summing junction with the negative HVPS feedback. This had the additional advantage of keeping the remote programming voltage unipolar instead of bipolar. Therefore it is important with +5Vdc to 0Vdc remote adjust representing 0 E<sub>out</sub> to Max E<sub>out</sub> 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 if using a control circuit such as a DAC utilizing 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 where 0 Volts is expected from the power supply, but is not attainable as 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 +5V references of all the UltraVolt HVPS's together an average V<sub>ref</sub> can be created.



Through the use of a resistive divider, the UltraVolt HVPS can also be programmed with a 0-10V DAC, OP AMP or other control voltage. For divider design purposes, it must be remembered that the input impedance of the Remote Adjust terminal is 1Mohm. An example of a suitable divider for this application is as follows:



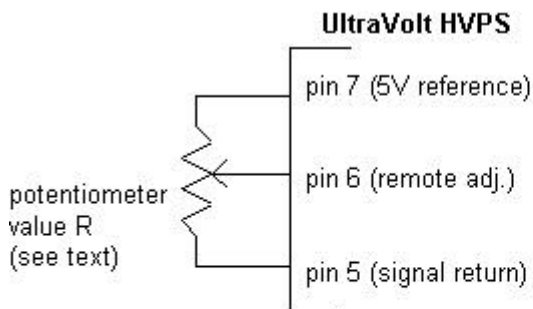
If a circuit design utilizing a negative UltraVolt HVPS must have 0 to +5Vdc control an OP AMP inverter can be used, see Conn-Dwg #17 for a typical circuit.

## 2) Resistive Programming

Because of the high, 1Mohm Remote Adjust input 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 terminal, and hence, control the output voltage of the HVPS. Designs using the 5V reference must compensate for its 464 Ohm output impedance, and it should be remembered that this voltage is thermally compensated. Many variations of resistive dividers are possible. For HVPS with nominal voltage rating  $E_0$ :

a) Output variable from 0V to approximately 107.5% times the rated voltage.

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

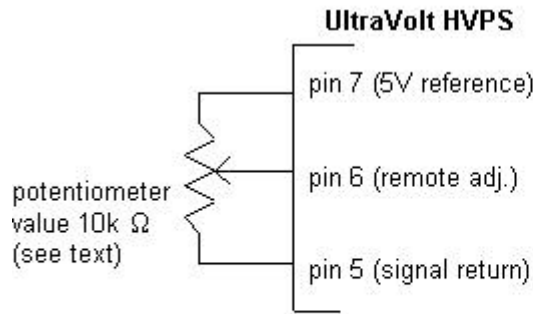


Output: 0V to  $V_{max}$   
 for supply rated  $E_0$  Volts:  
 $V_{max}$  depends upon the current  
 flowing through the 464  $\Omega$  5V ref  
 output resistance and pot. value R  
 so through R,  $I = 5V / (464 + R)$   
 for  $V_{max}$ ,  $V_{pin 6} = 5 - 464 \cdot I$   
 therefore  $V_{max} = E_0 \cdot 1.075 \cdot (V_{pin 6}) / 5$   
 so  $V_{max} = \frac{1.075 \cdot R \cdot E_0}{464 + R}$

The above configuration is the basic method for resistively programming the supply's output voltage. The value of the potentiometer must be chosen to be much smaller than the input impedance of the Remote Adjust input, which is 1Mohm. At the same time, the potentiometer's value must be chosen so as to not draw too much current from the 5V reference supply, keeping in mind its output impedance

of 464ohm. As an example, a 10k ohm potentiometer would 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 25k ohm to 100k ohm would essentially eliminate the voltage limiting previously mentioned.

For example: for a 2kV +E0 unit, with a 10k ohm potentiometer on the remote adjust terminal



Output: 0V to  $V_{max}$   
for supply rated at 2000 Volts:

$$V_{max} = \frac{1.075 * R * E_0}{464 + R}$$

$$= \frac{1.075 * (10k) * 2000}{464 + 10k}$$

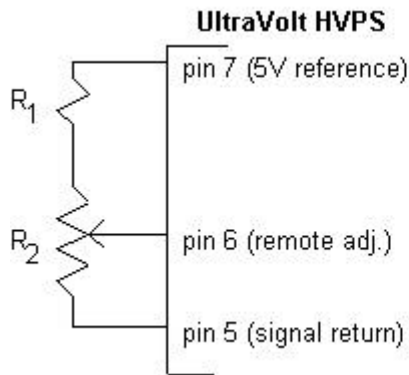
$$= 2055 \text{ V}$$

So with a 10k Ω pot, the 2kV HVPS output voltage is variable from 0V to 2055 V.

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

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

For a positive HVPS:

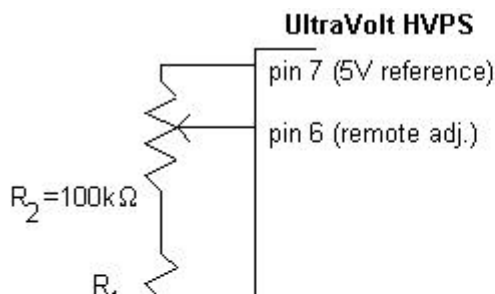


Output: 0V to  $(\frac{R_2}{R_1 + R_2 + 464} V_{out max})$  Volts

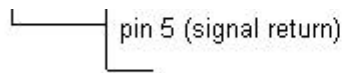
$$V_{out max} = 1.075 * E_0$$

The sum ( $R_1 + R_2$ ) again has to be chosen to be much smaller than the input impedance of the remote adjust terminal (1M ohm) and large enough to not load down the 5V reference supply. For example, ( $R_1 + R_2$ ) could be 50k ohm, and satisfactory operation would result (with a very maximum upper limit of 1.065 times the supply voltage rating).

For example: for a -2kV, -E0 unit, with  $R_2 = 100k$  ohm, HVPS output adjustable up to -1500V. What is the value of  $R_1$ ? What is the minimum output voltage?



Output: up to -1500V  
Choose  $R_2 = 100k \Omega$ , Need  $R_1$   
for a -E0 unit,  $V_{out} = 1.075 * E_0 * (1 - \frac{V_{pin6}}{5})$   
so,  
 $V_{max} = 1.075 * E_0 * (\frac{R_2}{R_1 + R_2 + 464})$



$$V_{\min} = 1.075 \cdot E_0 \cdot \left( \frac{R_1 + R_2 + 464}{R_1 + R_2 + 464} \right)$$

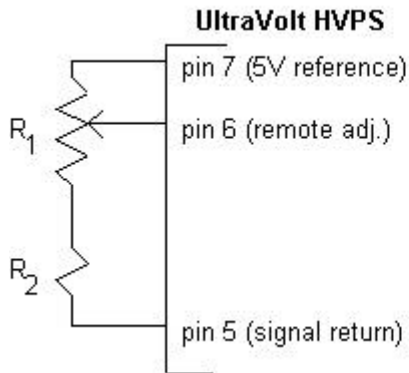
With  $V_{\max} = -1.5\text{kV}$ ,  $R_2 = 100\text{k}\Omega$ ,  $E_0 = -2\text{kV}$

therefore,  $R_1 = 43\text{k}\Omega$ ,  $V_{\min} = -6.95\text{V}$

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 more than 0 volts can be obtained.

For a positive HVPS:

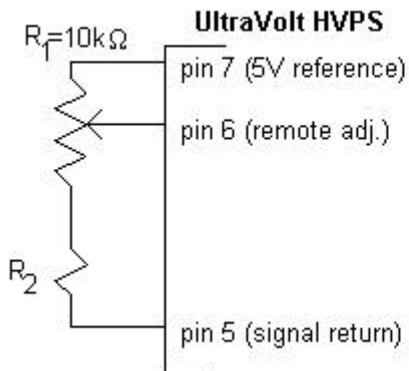


$$\text{Output: } \left( \frac{R_2}{R_1 + R_2 + 464} V_{\text{out max}} \right) \text{ to } \left( \frac{R_1 + R_2}{R_1 + R_2 + 464} V_{\text{out max}} \right)$$

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

The sum ( $R_1 + R_2$ ) again has to be chosen to be much smaller than the input impedance of the Remote Adjust terminal and large enough to not draw too much current from the 5V Reference supply. For example, ( $R_1 + R_2$ ) could be 50k ohm, and satisfactory operation would result (with the maximum power supply system output voltage being 1.065 times the rated HVPS voltage).

For example: for a 2kV + $E_0$  unit with  $R_1 = 10\text{k}\Omega$ , find  $R_2$  so minimum HVPS output voltage is 100V, and find subsequent maximum HVPS output voltage



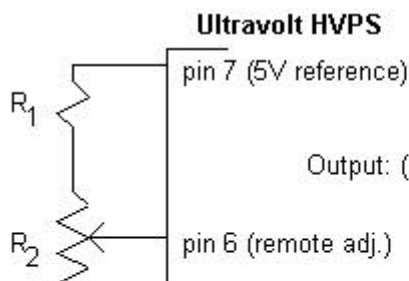
$$\text{Output: } 100\text{V to } \left( \frac{R_1 + R_2}{R_1 + R_2 + 464} V_{\text{out max}} \right)$$

$$\text{so, } 100 = \left( \frac{R_2}{R_1 + R_2 + 464} V_{\text{out max}} \right) \text{ where } V_{\text{out max}} = 2\text{kV} \cdot 1.075$$

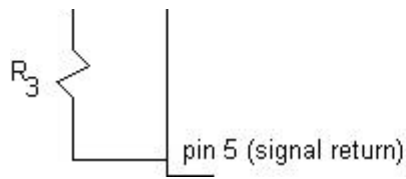
With  $R_1 = 10\text{k}\Omega$  the above formula is satisfied with  $R_2 = 51\Omega$

$$\text{and the maximum output is: } \left( \frac{R_1 + R_2}{R_1 + R_2 + 464} V_{\text{out max}} \right) = 2.06\text{kV}$$

The configurations in b) and c) can be combined to form preset upper and lower boundaries for the adjustable range of the HVPS, again for a positive HVPS:



$$\text{Output: } \left( \frac{R_3}{R_1 + R_2 + R_3 + 464} V_{\text{out max}} \right) \text{ to } \left( \frac{R_3 + R_2}{R_1 + R_2 + R_3 + 464} V_{\text{out max}} \right) \text{ Volts}$$



Although these examples have dealt with either positive supplies, or negative supplies, the same circuits and theory can be used to analyze and 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 of the formulae: 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 Pickup on the Remote Adjust Line

Certain applications of voltage control and resistive control of UltraVolt HVPS will be susceptible to low frequency pickup, such as 60Hz power line pickup. Since 60Hz pickup on the remote adjust terminal can adversely affect HVPS DC performance, it is recommended that for slow rise time, DC bias, or DC power applications a capacitor be placed from the Signal Return Terminal (pin #5) to the Remote Adjust Terminal (pin #6). A capacitor value of  $0.47\mu\text{F}$  to  $1\mu\text{F}$  will eliminate any 60Hz noise that would otherwise be picked up by the Remote Adjust Terminal. A  $22\mu\text{F}$  tantalum capacitor will further reduce low frequency noise.

### Use of the Bi-Functional Enable Terminal

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

The Enable Terminal (pin #4) can be used for three different functions:

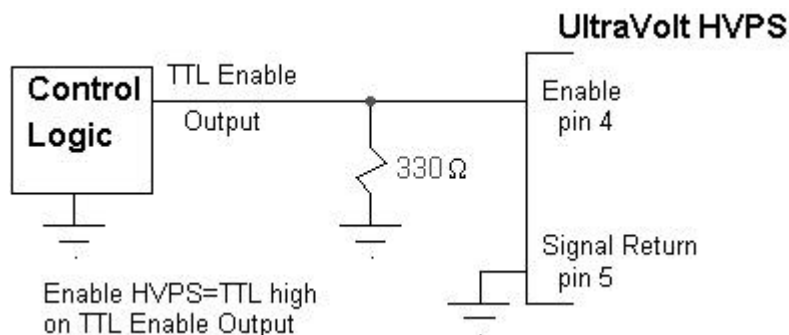
- 1) an enable input
- 2) a disable input
- 3) a current limit status output

As we review these functions, please refer to [Conn-Dwg #2](#).

#### 1) Enable 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 Terminal must sink at least 1mA, and its resulting voltage must be a maximum of  $0.7V \pm 0.20V$  (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 as follows:

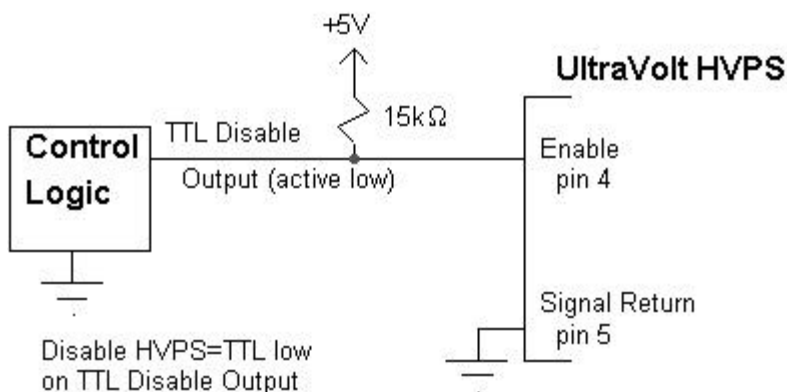


The 330 ohm resistor will ensure that with a low TTL Enable Output signal, the required 1mA will be drawn from the UltraVolt HVPS Enable Terminal thus forcing the HVPS to be in the disabled state. When the TTL Enable Output signal goes high, the HVPS is prevented from sinking the required current and therefore, the HVPS is in the enabled state.

### 2) Enable Terminal as a disable input.

The Enable Terminal can also be configured as a disable input. In this configuration, the Enable 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 Terminal, and thus pulling the Enable 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 level disable signal is as follows:



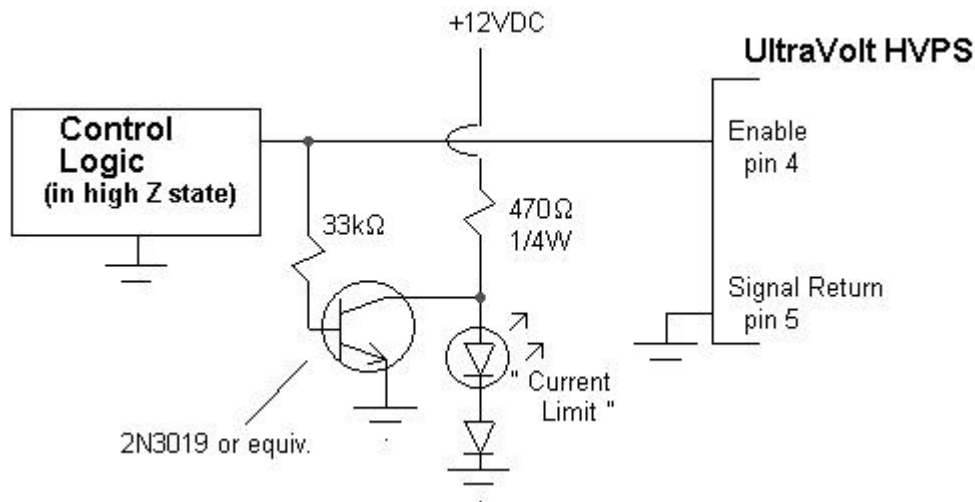
The 15k ohm resistor will ensure that the Enable Terminal stays at a voltage level that will force the HVPS to remain enabled until the TTL Disable Output signal goes low. When the TTL Disable Output goes low, the HVPS is forced into the disabled state. It should be noted that the HVPS has an internal 5.11K pull up to +5 VDC.

### 3) Enable Terminal as a current limit status output.

For this function to be utilized, it is very important that any logic driving the Enable 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 Terminal, a resistor, in the range 47k ohm to 100k ohm, must be placed from the Enable Terminal to ground in order to sink sufficient current.

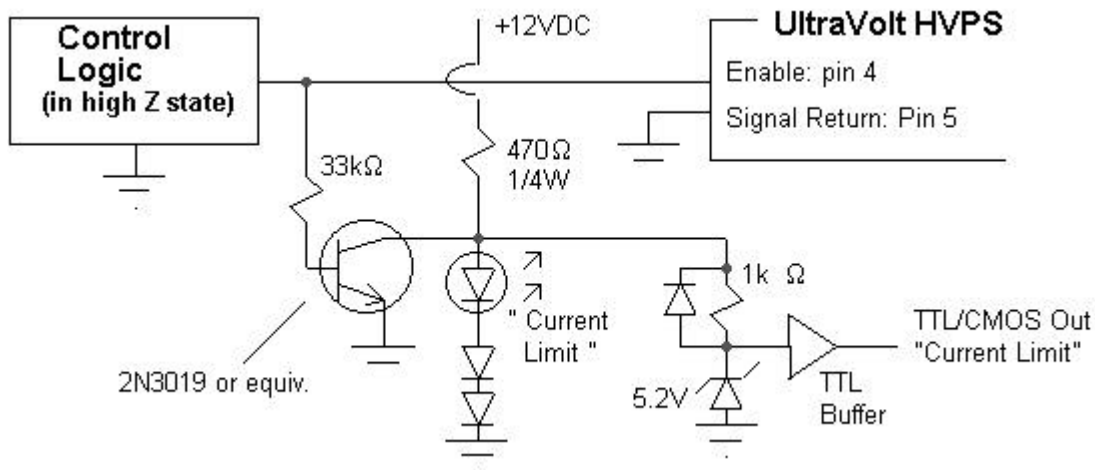
When the UltraVolt HVPS is forced into its current limit mode, the voltage on the Enable Terminal will drop from its pre-current limit value of 5V to its current limit value of 0.5V. After this point the voltage at the terminal will again rise up to 5V, where it will drop back to 0.5V should the power supply continue to be current limited. The on-time of this signal is inversely proportional to the overload placed on the HVPS (a very large load will cause the pulse train present at the Enable Terminal to have a very short on time). The use of this pin in the design of current regulated supplies is discussed in [App. Note #14](#).

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



The above schematic is 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 HVPS.

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 as well. The 5.2V Zener serves to prevent any harmful transients from reaching the TTL Buffer (or any other TTL logic gate). This circuit is ideal for automated systems.

\*\*\* END OF APPLICATION NOTE #1 \*\*\*

## App. Note 3: Electrical Termination & Mounting Configurations of UltraVolt HVPS

Rev: E 10/98

As with any precision electronic device, proper mounting and electrical termination is necessary for the trouble free and reliable operation of the UltraVolt High Voltage Power Supply. Improper electrical termination of UltraVolt HVPS 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 [App. Note #6](#), "Thermal Management of UltraVolt HVPS".

### ELECTRICAL TERMINATION METHODS OF ULTRAVOLT HVPS

The UltraVolt HVPS is usually electrically terminated via a printed circuit board, a wiring harness, or a combination of the two (a sub assembly printed circuit board) according to the mechanical mounting method used. Mechanical mounting methods and design considerations will be discussed below.

#### Printed Circuit Board Termination

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

The UV HVPS can be easily soldered directly to a printed circuit board, as the pin spacing is compatible with the 0.100"/0.200" industry standard header spacing. This method has the immediate advantage of ease of manual mounting; however, it may suffer from service related, and automated assembly drawbacks. As will be discussed below, soldering the UV HVPS directly to the printed circuit board does not replace the mechanical mounting requirement of the HVPS. In all cases, the UV HVPS must be mounted mechanically via one of the methods outlined below.

Sockets are the preferred connection method to UV HVPS for an abundance of reasons. Socket termination greatly improves your ability to troubleshoot your product: allowing for the simplified testing of the UV HVPS 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 (allowing for component level repairs). Socketed connections are also more easily Wave Soldered, or Infrared Re-flowed, as the relatively large mass of the HVPS need not be present during either of these delicate operations.

There are essentially two options for the printed circuit board termination of UV HVPS: *inline machined sockets*, or *press in sockets*. An example of an inline 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 HVPS connector compatibility with different suppliers' products). *Inline*

*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 which are pressed into, then soldered directly to the printed circuit board. Although these sockets require nonstandard size printed circuit board holes and special assembly procedures, this method requires a stock of only one type of socket (with certain HVPS), where at least two different types of inline machined sockets would be required on a design making use of the more specific inline machined sockets.

Should an UV HVPS be mounted onto a printed circuit board (as opposed to being mounted onto a chassis), various thermal considerations arise. For a full discussion of the thermal considerations in the various mounting methods of the UltraVolt HVPS, please see [App. Note #6](#): "Thermal Management of UltraVolt HVPS".

### **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 optimal positioning of the UV HVPS for thermal considerations as well as 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 which 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 should the leads be directly soldered to the UV HVPS, it must be remembered that a reliable method of soldering should be used (such as 'j' hooking the leads around the HVPS pins). Also keep in mind that the pins of the UV HVPS are of high quality gold plated bronze-phosphor material. However, by this material's very 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. As a good rule of thumb, all wiring harnesses, whether connectorized or soldered directly, 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 as the 'wire applied' connector type).

### **General Rules of Thumb for Electrical Terminations to UltraVolt HVPS**

Although not discussed as of yet, the gauge of the wire (or the cross sectional area of the copper track on a PCB board) feeding the UltraVolt HVPS is very important. A power supply wire of a too thin gauge can cause wiring failures, as well as degrading the excellent load regulation and linearity of the UltraVolt HVPS. How thin is a too thin? As seen in the table below (table 1), certain UV HVPS can draw up to 13Amps through the input power pins.

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

*Table 1: A partial list of HVPS and maximum currents  
(see product specific data sheets for specific information)*

The following table (table 2) can be used as a rough guideline to determine the required input supply wire gauge knowing the specific UltraVolt HVPS supply current.

<u>Maximum Continuous Current</u>	<u>Suggested Wire Gauge</u>
20 Amps	10 Gauge (AWG)
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 Supply currents, and recommended supply wire gauges.*

Not surprisingly, choosing a printed circuit board track size is slightly more complex than choosing a specific wire gauge, given a particular current. In printed circuit board applications, the maximum allowable temperature rise of the track becomes an important design consideration. The next table (table 3) is a general guideline for the current carrying capacity of different external, plated, printed circuit board track sizes.

<i>Track Size</i>	<i>Current</i>			
	<b>0.5A</b>	<b>1A</b>	<b>1.5A</b>	<b>2A</b>
1 Ounce Copper (2.4 Mils high)	20 Mils width (10°C temp rise)	50 Mils (10°C)	100 Mils (10°C)	50 Mils (45°C temp rise)
2 Ounce (3.8 Mils)	10 Mils (10°C)	25 Mils (10°C)	50 Mils (10°C)	25 Mils (45°C)
3 Ounce (4.2 Mils)	7.5 Mils (10°C)	19 Mils (10°C)	38 Mils (10°C)	19 Mils (45°C)

*Table 3: Plated Printed Circuit Board Track Sizes and Currents*

As observed from the previous table, printed circuit boards cannot handle large currents unless proper track width and copper weight is used ( for example, PC Board mounting a 125W unit is only recommended when specific care is taken such as a 3 oz. copper PCB with two 75 Mil tracks to the two power pins). Please note that 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 reduce self heating.

Another important point that requires mentioning concerns the presence of multiple pins for apparently the same function. A perfect example of this is the paired input power return pin on the 125W 'C' series. This supply will draw up to 6Amps from the input voltage supply; however, the connector pins are rated for 5.9 Amps maximum. For this reason, on the 125W 'C' series, UltraVolt has 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 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 wire harness connector, which is rated for 10 Amps per contact, 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 your chassis. If you intend to mount a PCB on the top of the chassis mounted 250W units 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 that although the HVPS pins labeled supply ground, signal ground, and HV ground imply a similar function, they are not interchangeable and each should only be used for its own purpose (see [App. Note #1](#) and [App. Note #16](#) for more information).

### **Mounting Configurations of UltraVolt HVPS**

Different mounting configurations are required for different models of UltraVolt HVPS. In all cases, however, supplementary mounting procedures are required; under no circumstances should the UltraVolt HVPS be restrained by its pins alone (the pins cannot withstand lateral shock and will shear should the system be dropped or subjected to long term vibration, as described above).

There are essentially two mounting configurations for low power UV HVPS: Chassis mounting and Printed Circuit board 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 either printed circuit board 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 a relatively high wattage rating class, chassis mounting makes sense, for it allows them to easily dissipate their produced thermal energy. For further discussion on thermal considerations, see [App. 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 make use of 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 incorporating mounting studs (such as the High Power "C" series) should be mounted so as to ensure that each stud can be utilized. Each stud should be held to the chassis using a lock washer and a #8 nut tightened to approximately 8ft-lb of torque. The nuts should be alternately tightened, in an X-pattern, so as to prevent possible harmful mechanical stress on the HVPS case.

In tight mounting locations where you would like to chassis mount an "Eared" 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 printed circuit board mounted or chassis mounted, whichever is preferred.

Should the UltraVolt HVPS be printed circuit board mounted, the HVPS should be held in place through the use of #2 screws threading into the HVPS's two molded-in thermal standoffs. These screws should brace the HVPS to the printed circuit board, ensuring a solid electrical connection to all pins, as well as ensuring a firm mechanical connection between the printed circuit board and the UV HVPS. Should these screw holes not be used, shearing of the UV electrical pins, if placed under severe mechanical stress, may occur.

As noted above, these units may also be chassis mounted using an optional bracket (for 4 to 30W

units). Depending upon the height of the HVPS used (check product data sheets), either the 0.8" high BR001 bracket, or the 0.9" high BR002 can be used to fasten the UV HVPS to the chassis wall. The bracket is fastened to the chassis (using screws), and the UltraVolt HVPS 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 (hence allowing the chassis to become an alternative to an additional separate heat sink), as well as allowing the HVPS to be mechanically secure. 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 [App. Note #6](#).

In lower power chassis mount applications an alternate to mounting brackets and plates is available. Since Thermal Interface is less critical, the HVPS can be mounted using a double sided foam tape with acrylic adhesive. These types of tapes are rugged enough to be used in harsh applications such as aircraft manufacture. 3M Scotch brand VHB4929 tape has received extensive testing and is found to be a low cost, low labor assembly solution. It is essential that this mounting system not be used in applications where high thermal resistance would allow a HVPS to overheat. This is the basis of the recommendation that this mounting system only be used with 4 Watt units.

While thermally conductive acrylic tapes are available, they generally are not used as the only method of mounting with 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.

**\*\*\* END OF APPLICATION NOTE #3 \*\*\***

## App. Note 6: Thermal Management of UltraVolt HVPS

Rev: C 6/98

Any electronic device's long term reliability is directly related to how the overall system design allows it to properly dissipate any heat that it generates. Likewise, the long life and reliability of UltraVolt high voltage power supplies 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 and that loss, power used to operate the power supply itself, is usually dissipated as heat. UltraVolt High Voltage power supplies have excellent efficiency ratings (depending upon the model), ranging from 75% to 92% at full output power, delivering full rated voltage and at nominal operating conditions. The remaining fraction of the HVPS 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 through many means. The Acceptance Test Procedure that came with your UltraVolt power supply contains a few common operating points and related data. This data can be used to determine the supply's operating efficiency at various points. Alternately the efficiency of a particular UltraVolt power supply under certain operating conditions can be obtained from our Customer Service Department. Typical operating efficiency is also listed in the power supply's data sheet, from the Efficiency vs. Input Voltage graph. This graph is only a typical value for the various models in that series of power supplies.

The analysis in this application note is 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 UNITS:

A Sample Calculation:

Given: an UltraVolt 2A12-P4, continuously delivering its nominal 2mA at 2KV (**PDCout=4W**) with a nominal 12VDC in.

From the Acceptance Test Procedure, at this operating point (nominal output power, nominal 12V input voltage), the input current was reported as 390mA (**PDCin= 4.68W**).

Find: Heat energy dissipated, and the unit's efficiency.

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

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

$$\text{and, efficiency} = P_{DCout} / P_{DCin}$$

$$\text{firstly, } P_{DCin} = V_{in} * I_{in}$$

$$\dots\dots\dots = (12V * 0.39A)$$

$$\dots\dots\dots = 4.68W$$

$$\text{SO, } P_{\text{heat}} = P_{\text{DCin}} - P_{\text{DCout}}$$

$$\text{.....} = 4.68\text{W} - 4\text{W}$$

$$\text{.....} = 0.68\text{W}$$

$$\text{and, efficiency} = P_{\text{DCout}} / P_{\text{DCin}}$$

$$\text{.....} = 4\text{W} / 4.68\text{W}$$

$$\text{.....} = 86\%$$

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%.

Given: this UV HVPS is of the "A" series (for example, the 2A24-P4), with the standard plastic case. no extra heat sinking. all surfaces exposed to free air

Find: the temperature rise of the power supply's case under these conditions

First, the total surface area (SA) of the standard 4 Watt "A" series must be calculated. From simple geometry, given that the HVPS has 6 sides consisting of 3 sets of 2 equal sides (dimensions from "A" series datasheet, L represents Length, W for Width, and H for Height): Let's also assume the HVPS is mounted in sockets on the PCB.

$$\text{SA} = 2(L*W + L*H + W*H)$$

$$\text{.....} = 2(3.7*1.5 + 3.7*0.77 + 1.5*0.77)$$

$$\text{.....} = 19.11 \text{ in}^2$$

It is universally accepted that 1W will raise 1 in<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**.....

$$\text{delta } T = (P_{\text{heat}} / \text{SA}) * 100(\text{°C} * \text{in}^2 / \text{W})$$

$$\text{.....} = (0.68\text{W} / 19.11\text{in}^2) * 100(\text{°C} * \text{in}^2 / \text{W})$$

$$\text{.....} = 3.56\text{°C}$$

Finally, assuming that the enclosure within which the UVPS is placed has a continuous operating temperature of 40 °C (**T<sub>ambient</sub>**), we would have a final UV HVPS case temperature of 43.56°C (**delta T + T<sub>ambient</sub>**). 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 method. The power supply will also have certain areas which are warmer and areas which are cooler as certain components within the unit dissipate more heat than others. These warm areas are generally referred to as hot spots. Note that mounting this power supply flush onto a printed circuit board would hinder any convection cooling properties along the surface of the power supply facing the circuit board. To account for this, the surface area calculation of this particular case would be carried out by summing the 5 exposed sides, ignoring the cooling effect of the mounting surface. Alternately if the power supply was mounted using sockets onto a circuit board, then the mounting side would allow slight cooling by convection, and this should be accounted for in the calculations (through a scaling factor). A discussion of mounting methods of UltraVolt power supplies appears in [App. Note #3](#).

As seen from the calculations above for a 4W unit running at full rated power, a 4W unit rarely needs any supplemental heat sinking. However a 20W, plastic encased "A" series running continuously at full power would dissipate approximately 3.5W (assuming 85% efficiency, a rough approximation for

exemplatory purposes only, 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 printed circuit board, this would cause a case temperature rise of 26°C, an unacceptable temperature increase in applications with more than a 40°C ambient temperature. The design of 20W "A", as well as all other series of UltraVolt power supplies, facilitates easy interface to a heat dissipation medium. The top surface of the 20W, plastic case "A" 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 manages any internal power supply 'hot spots' which occur because of the different heat dissipations of different components within the power supply itself (as mentioned previously).

Another Sample Calculation:

Given: a 4A24 P20 -H, which is a 4KV 20W supply, delivering 2500V at, say, 3mA (much less than the rated 20W out), drawing .46A from its 24V supply

Find: Heat energy dissipated.

$$\begin{aligned} P_{\text{heat}} &= P_{\text{DCin}} - P_{\text{DCout}} \\ &= (24V * 0.46A) - (2.5kV * 3mA) \\ &= 3.54W \end{aligned}$$

Therefore this power supply will dissipate 3.54W of heat when operated as per the discussed operating conditions (68% efficiency due to the light load). For comparison purposes, the above UV HVPS delivering full output voltage has been analyzed in the appendix of this Application Note providing a typical 89% efficiency example.

Given: the power supply above mounted flush to a printed circuit board, with the -H option heat sink and all sides but the mounting side exposed to free air.

Find: the temperature rise of the power supply's case under these conditions

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

$$\begin{aligned} SA_1 &= 2(LH+WH) \\ &= 2(3.7*0.77 + 1.5*0.77) \\ &= 8.01 \text{ in}^2 \end{aligned}$$

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

$$\begin{aligned} SA_{\text{tot}} &= SA_1 + SA_{\text{hs}} \\ &= 8.01 + 13 \\ &= 21.01 \text{ in}^2 \end{aligned}$$

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

Since we are dissipating 3.54W.....

$$\begin{aligned} \Delta T &= (P_{\text{heat}} / SA_{\text{tot}}) * 100^\circ\text{C} \\ &= (3.54 / 21.01) * 100 \end{aligned}$$

.....= 16.85°C

If the enclosure within which the UV HVPS is placed has a continuous operating temperature of 40°C, we would 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 here have assumed that 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 value of average heat than the calculations here have yielded, and 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 that 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 a HVPS unit which 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 that only sides which have access to free, open air are included in the calculations. If a side is in close proximity to a surface, such as a HVPS mounted with sockets onto a circuit board, a fraction of the actual surface area of that hindered side 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 once only (as for that particular side, the 13 in<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

A Sample Calculation:

Given: an UltraVolt 6C24-P125, and through testing, it was determined that this unit draws 5.9A from its 24V supply while delivering 6KV into its rated load.

Find: if a totally enclosed metal container of dimensions 12" \* 6" \* 4" = 288in<sup>2</sup> total surface area (only the outside of the container is exposed to the outside free air) will sufficiently cool this HVPS mounted to the wall inside the chassis under the above operating conditions. all sides of the metal container are exposed to free air. assume a low thermal resistance interface between the HVPS and the container, and that the container is a good thermal conductor.

So...

**P<sub>heat</sub> = P<sub>DCin</sub> - P<sub>DCout</sub>**

.....= (24V\*5.9A) -125W

.....= 16.6W (88% efficiency)

Here, as the HVPS is mounted inside the enclosed container, the surface of the HVPS will not directly dissipate its heat to the outside air, but will transfer its thermal energy to the chassis. The only surface that can dissipate heat to the outside air would be chassis' surface (the cooling provided by the HVPS' surface inside this container would be negligible compared to the cooling provided by the heat transfer from the HVPS to the chassis wall). So we approximate the dissipating surface area to be 12" X 12" X 2" = 288in<sup>2</sup>.

Since we are dissipating 16.6W.....

$$\begin{aligned} \text{delta T} &= (\text{P}_{\text{heat}}/\text{SA}) * 100^{\circ}\text{C} \\ \text{.....} &= (16.6/288) * 100 \\ \text{.....} &= 5.7^{\circ}\text{C} \end{aligned}$$

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 that the HVPS can transfer its heat to the heat sink, the chassis in the above example, without hindrance. In practice this can be accomplished through the use of an excellent heat conduction medium, such as thermal elastomer (0.010" or 0.020" are popular 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 8 ft\*lbs of torque to ensure the proper 'cold flow' of a thermal elastomer heat conduction medium. Also remember in order to keep the thermal resistance between the HVPS and its heat sink low allowing the greatest transfer of heat, the HVPS should have as much surface area as possible facing the smooth heat sink medium (via the thermal interface).

Secondly, it was assumed that 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 heat sink surface area as a dissipation medium (as 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 (aluminum for example), known for their excellent heat conduction properties.

When cooling a HVPS, many design variables enter into the equation and these can determine how actual implementation is carried out. Airflow is one which is very important, and is unfortunately too complex to fully analyze here. Generally speaking, forced air cooling from a simple fan can drastically reduce the size of heat sink required, as the flowing air more efficiently removes the heat dissipated (by transferring the heat to a larger volume of air and not relying solely on convection). The ambient temperature of the HVPS' 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. Should the HVPS be mounted to a large chassis wall, then it is unlikely that a supplemental heat sink is required. Oddly enough, one of the most important words of advice 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. Fan vents being obstructed, or dust coated, 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 allowing a large safety guardband in your heat calculations will ensure that you will sufficiently cool your HVPS in all conditions it experiences. This can be achieved by simply assuming the power supply will operate in an ambient temperature higher than usually expected.

Although one can carry out thermal calculations using thermal junction analysis, and actual thermal resistance values, we have not opted for that method here. Although they will always yield more accurate results, the results from the methods described here will, given an adequate safety guardband, sufficiently approximate the cooling requirements for your HVPS. 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, it is recommended that a text on thermal management be consulted, along with UltraVolt's customer service. Remember that by keeping your UltraVolt HVPS cool, it will reward you with a long, trouble free life.

*Surface Area of UltraVolt Models*

<u>UltraVolt Model</u>	<u>Total Surface Area (in Square inches)</u>
"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

**Appendix:**

Given: a 4A24 P20 -H, which is a 4KV 20W supply, delivering 4KV at 5mA (the rated 20W out), drawing .94A from its 24V supply operating at 89% efficiency.

Find: Heat energy dissipated.

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

Given: the power supply above mounted flush to a printed circuit board, with the -H option heat sink and all sides but the mounting side exposed to free air.

Find: the temperature rise of the power supply's case under these conditions

First the **exposed** surface area of this power supply (ignoring both the heat sink side, and the mounting side):

$$\begin{aligned}
 SA_1 &= 2(LH+WH) \\
 &= 2(3.7*0.77 + 1.5*0.77) \\
 &= 8.01 \text{ in}^2
 \end{aligned}$$

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

$$\begin{aligned}
 SA_{tot} &= SA_1 + SA_{hs} \\
 &= 8.01 + 13 \\
 &= 21.01 \text{ in}^2
 \end{aligned}$$

Since we are dissipating 2.56W.....

$$\begin{aligned}
 \Delta T &= (P_{heat}/SA_{tot}) * 100^\circ\text{C} \\
 &= (2.56/21.01) * 100 \\
 &= 12.2^\circ\text{C}
 \end{aligned}$$

Assuming that the enclosure within which the UV HVPS is placed has a continuous operating temperature of 40 °C, we would 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.

**\*\*\* END OF APPLICATION NOTE #6 \*\*\***

## App. Note 10: "C" PRODUCT NOTES

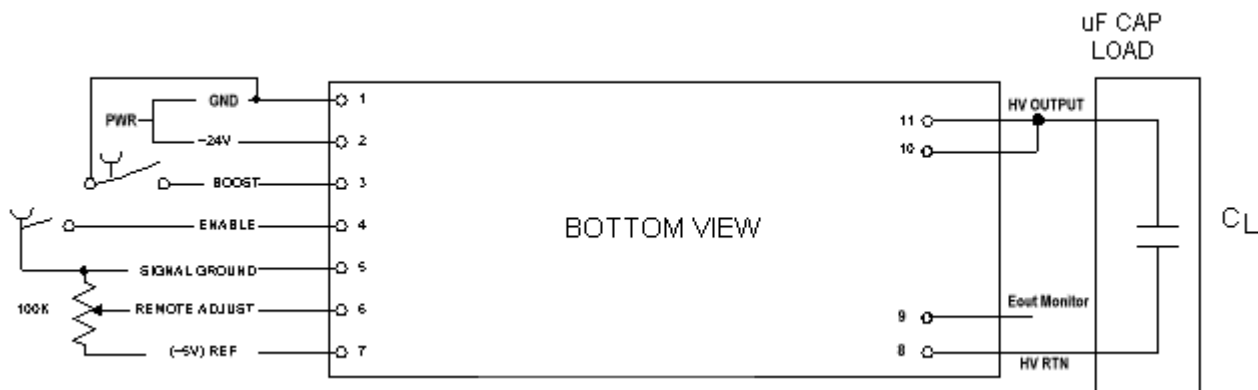
Rev: C 9/21/98

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" units are applicable to low speed capacitor charging applications. When calculating Trise the output charge current available is 66% of rated Iout and capacitance to charge should have the "A" units internal capacitance added.

UltraVolt's "C" series units are designed specifically for pulsed loads and capacitive loads. DC & AC feedback loops are compensated to provide fast rise time with low overshoot. Current limit circuits are optimized to get in and out of limit as fast as possible to maintain high average charge currents while protecting the HVPS power stage. When calculating "C" series Trise the output charge current available is 100% of rated Iout. "C" series units have 1/2 to 1/10 of the filter capacitance of "A" units allowing more energy to go to the load capacitance (See Fig. F in "C" series Data Sheet). 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 RTN Pin 8.**



If the HVPS is to be grounded to the case it should also be via Pin #8.

### ENABLE:

Using Enable (Pin 4) to activate the power supply after input power has been applied permits 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 (Pin 4) prior to generation a positive "1" rise command. (See [App. Note #1](#))

### RISE TIME:

Rise times are measured from start of discharge to the time required to rise to within 99% of final regulated output. All rise time data however, is taken at +24V DC 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 (CL) can be computed in accordance with the formula shown below:

$$T(\text{ms}) = \frac{(CL + C_{\text{int}})\mu\text{f} \times \text{Volts}}{(I_{\text{short}})\text{ma}}$$

where:

T(ms) = Rise Time in milliseconds to within 1% of final value (using an Enable Command)

CL = External load capacitance in micro farads

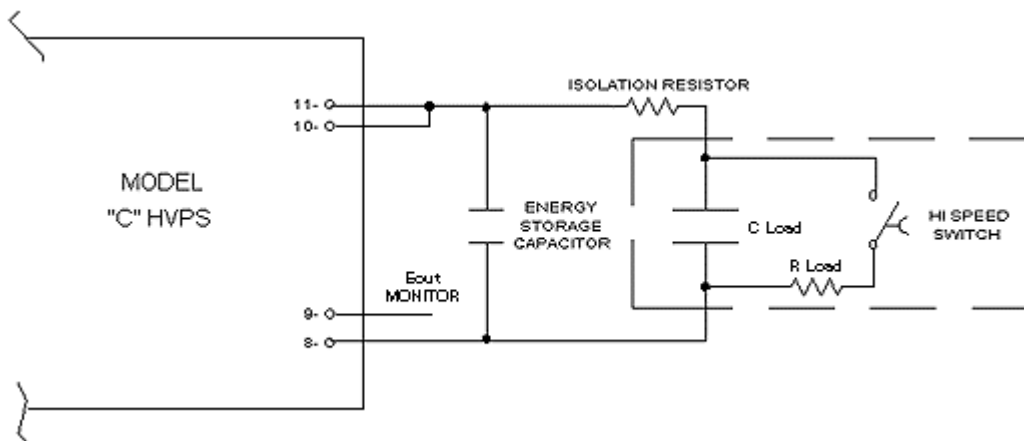
C<sub>int</sub> = Internal supply capacitance (see UV HVPS Data Sheet Fig. F)

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

I<sub>short</sub> = The output current of the "C" model power supply in milliamperes when measured with a milliammeter under output short circuit conditions.

### HIGH CURRENT PULSED APPLICATIONS:

For cases where large transient discharges of small duration are applied to the output of the "C" unit, the user may wish to isolate the "C" power supply from the load CL. This is typically done to place more of an average current demand on the HVPS, 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 RTN (Pins 8 & 9). A 10 ohm; to 1k ohm; resistor can then be added between the HV output and the load CL. This will also reduce the tendency to introduce overshoot in the output wave form that could cause a ringing on the HV output when driving certain types of loads (see diagram below).



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

\*\*\* END OF APPLICATION NOTE #10 \*\*\*

## App. Note 11: Updating from User Regulated Proportional HVPS to UltraVolt's Off-the-shelf Regulated HVPS

Rev: E 9/21/98

In the past, engineers have had to use proportional high voltage power supplies (HVPS) 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:**

UltraVolt's single part solution costs less! Our 4 Watt HVPS is only \$145 in small volume and \$111 in moderate quantities. 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:

- OEM Proportional HVPS
- Host PCB, HV feedback resistor, HV feedback capacitor,
- HV filter capacitor, op amp, stable voltage reference,
- various compensation/trim capacitors and resistors,
- pass transistor, input filter capacitors, and PCB headers
- Assembly and Inspection labor
- Test and Troubleshooting labor

- 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.
- The subassembly manufacturing documentation must be maintained.

### **RELIABILITY ADVANTAGES:**

UltraVolt's single part solution lasts longer! As an assembly, our 4 Watt HVPS has a Mean Time Between Failure (MTBF) of 654,583 Hrs at 55°C and 2,067,917 Hrs at 21°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 HVPS have reduced emissions. Optional wrap around Mu-Metal shielding further reduces EMI & RFI emissions for sensitive applications. The proportional HVPS solution will radiate more noise, both due to its inherent design, along with radiating components spread over a larger surface area. Should you require full shielding, the

proportional power supply along with ALL the regulation circuits will have to be boxed in with a custom shield. Not only will this increase the cost, but it will raise the ambient temperature, increasing drift and reducing component life.

**SIZE:**

UltraVolt's single part solution is smaller! With a footprint of only 5.5 in<sup>2</sup>, along with a volume of 4.3 in<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 12 VDC models producing 4 Watts, and 24 VDC 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 2 resistor scaling, is fully supported.

While providing a brief examination of each of the contributing factors, it is evident that the single component solution has many positive attributes. 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 HVPS will help you to reach your goals.

**\*\*\* END OF APPLICATION NOTE #11 \*\*\***

## App. Note 12: Parallel Operation of Power Supplies

Rev: E 9/21/98

All UltraVolt HVPS can be paralleled for purposes of raising the total output power/current or for redundant power systems. In applications raising the output power the goal is often to get two 4.5in<sup>3</sup> 30W units in the space of one 18in<sup>3</sup> unit, to get 450W to 500W from a pair of 250W units or to get 60W when only 30W units are available. In applications for redundant power the goal is independent operation of the HVPS and connecting them into the system so a single point failure can be tolerated.

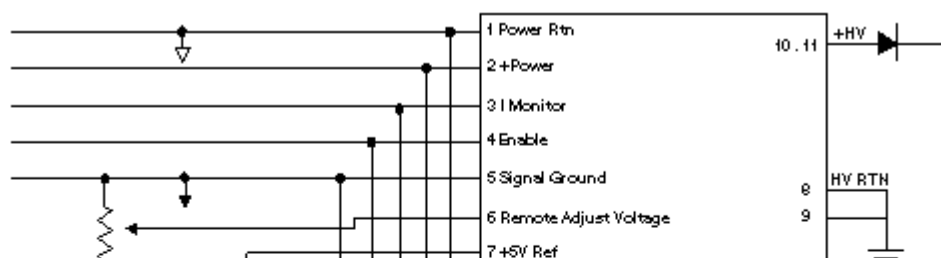
1. Increasing Output Power/Current When a user requires an output current in excess of the maximum rating of a single supply, it is possible to connect two or more units in parallel. This is accomplished by connecting the following pins together:

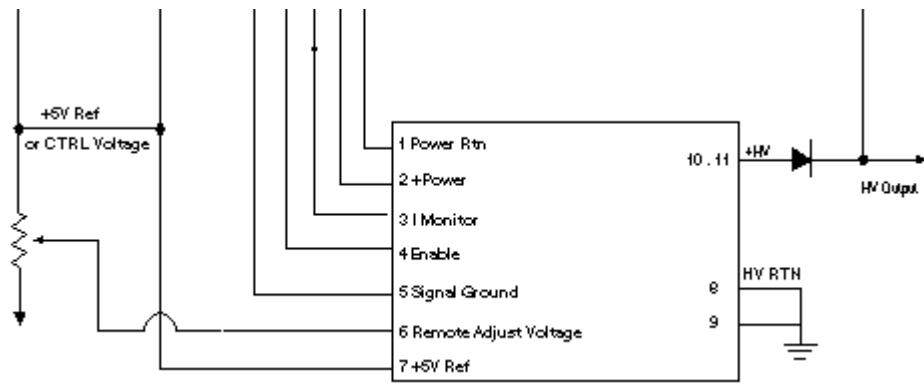
Pin 1 to Pin 1	Power RTN
Pin 2 to Pin 2	+ Power Input
Pin 3 to Pin 3	Current Monitor
Pin 4 to Pin 4	Enable
Pin 5 to Pin 5	Signal Ground
Pin 7 to Pin 7	Reference Voltage
Pins 8/9 to Pins 8/9	HV Return
Pins 10/11 to Pins 10/11	HV Output

In applications requiring only up to 85% to 90% of the total output power/current capacity a single control signal or control pot can be connected directly to both HVPS as trimming is not required.

In applications requiring up to 90% to 98% of the total output power/current capability the trimming of the two supplies becomes more important. If a control signal is to be used it should be connected to the top of the two trim pots. If no control signal is to be used the two pot high sides should be connected to the +5VDC Reference (Pin 7) and the pot low sides to the Signal Ground (Pin 5). The adjustable pot wiper then becomes the source of Remote Adjust Voltage and is connected to Pin 6 of each unit. (See Fig 1.). Adjust each pot so the highest voltage to be used has less than a 1% error between the units output voltages. This sets the units for proper current sharing.

Fig. 1.





2. In cases where redundant power is required, two or more units may be connected in parallel as described in Paragraph 1; however, there should be some additions to further isolate the system. The input power to each supply should have a fuse such as a slow blow or PTC. The remote adjusts, enables, +5V references should be independently used, or joined through diodes or resistors. They should not be directly paralleled in a "true" redundant system.

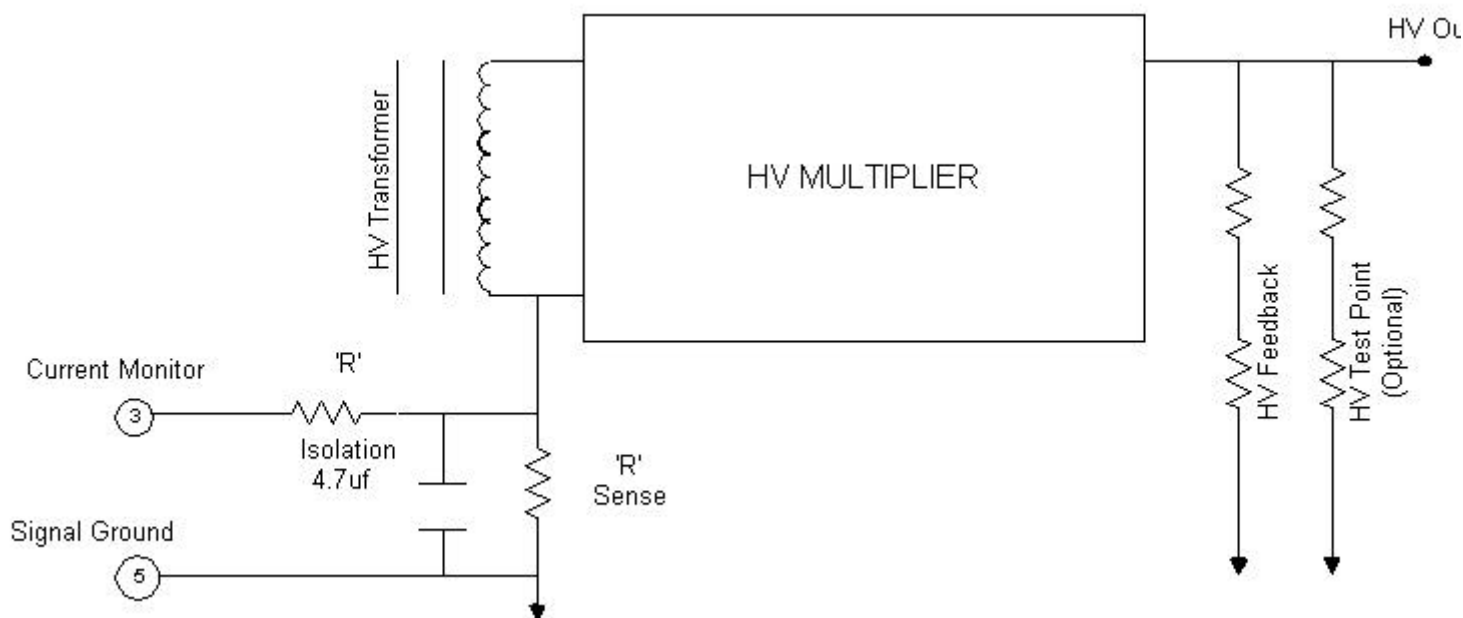
**\*\*\* END OF APPLICATION NOTE #12 \*\*\***

## App. Note 13: UltraVolt High Voltage Power Supply Output Current Monitor

Rev: J 9/21/98

UltraVolt's high voltage power supply (HVPS) units have an output current monitor (Iout Monitor) feature, allowing the total output current of the HV multiplier to be monitored. It is important to note that since the sense circuit is in the return path to the transformer that the current monitor signal has a sign opposite of the sign of the HVPS; I.E., a negative HVPS has a positive current monitor voltage while 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 Iout monitor and signal ground to form an R\*C with the internal isolation resistor. The isolation resistor varies with the HVPS series in addition to the internal sense circuit impedance which varies from model to model. The "C" series have a 15K 1% isolation resistor. The 60 Watt/125 Watt/250 Watt "C" series have a 5K 1% isolation resistor. The 20 Watt/30 Watt "C" series has no isolation resistor since Pin 3 is used for grounding to achieve boost. The Iout Monitor output impedance is therefore very low (varying from 22 Ohms to < 1 Ohm 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 Eout 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 can be achieved in software. By using Ohm's Law to calculate the internal leakage current based on the output voltage divided by the total of internal resistor(s) and subtracting 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 achieved since the output voltage test point sign is opposite to that of the output current monitor.

It is important to note that 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 the higher voltage models, and a lower percentage in the lower voltage models. As an example, the 1/4A24-P30 has an output of up to 250VDC @ 120mA, an a 2.5meg internal divider resistor with a current of 100uA. 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 @ 200uA, and the internal divider resistors a current of 40 uA. The internal current is >16% of the output current monitor signal.

### UltraVolt High Voltage Power Supply Iout Monitor Scale Factors

<u>"A" Series Model</u>	<u>4 Watt</u>	<u>15 Watt</u>	<u>20Watt</u>	<u>30Watt</u>
1/8A	32mA / 73mV	-	160mA / 86mV	240mA / 83mV
1/4A	16mA / 75mV	-	80mA / 80mV	120mA / 81mV
1/2A	8mA / 65mV	-	40mA / 82mV	60mA / 81mV
1A	4mA / 72mV	-	20mA / 85mV	30mA / 82mV
2A	2mA / 63mV	-	10mA / 90mV	15mA / 81mV
4A	1mA / 68mV	-	5mA / 85mV	7.5mA / 75mV
6A	660uA / 52mV	-	3.3mA / 80mV	5mA / 88mV
10A	400uA / 2.3V	1.5mA / 8.0V	-	3mA / 7.7V
15A	270uA / 1.6V	1mA / 5.4V	-	2mA / 5.2V
20A	200uA / 1.3V	750uA / 4.1V	-	1.5mA / 7.75V
25A	160uA / 1V	600uA / 3.2V	-	1.2mA / 6.3V
30A	133uA / .93V	500uA / 2.8V	-	1.0mA / 5.3V
35A	114uA / .71V	-	-	-

<u>"C" Series Model</u>	<u>20 Watt</u>	<u>30 Watt</u>	<u>60 Watt</u>	<u>125Watt</u>	<u>250Watt</u>
1/8C	160mA / 63mV	240mA / 57mV	480mA / 1.2V	1 Amp / 1.2V	2Amp / 1.2V
1/4C	80mA / 73mV	120mA / 60mV	240mA / 1.2V	.5Amp / 1.2V	1Amp / 1.2V
1/2C	40mA / 68mV	60mA / 50mV	120mA / 1.1V	250mA / 1.2V	500mA / 1.2V
1C	20mA / 65mV	30mA / 63mV	60mA / 1.2V	125mA / 1.1V	250mA / 1.1V
2C	10mA / 63mV	15mA / 68mV	30mA / 1.16V	62.5mA / 1.2V	125mA / 1.2V
4C	5mA / 45mV	7.5mA / 67mV	15mA / 1.3V	31.3mA / 1.2V	62.5mA / 1.2V
6C	3.3mA / 53mV	5mA / 72mV	10mA / 1.62V	20.9mA / 1.18V	1.2V
8C	-	-	15mA / 1.3V	15.6mA / 1.1V	41.6mA / 1.2V
10C	-	-	10mA / 1.62V	12.5mA / 1.15V	-
12C	-	-	6.0mA / 1.47V	10.4mA / 1.40V	-
15C	-	-	-	8.3mA / 1.10V	-

Nominal Imonitor Tolerance is ± 10%.  
 On positive HVPS the Imonitor is a negative voltage  
 On negative HVPS the Imonitor is a positive voltage

N/A = Not Applicable

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

<u>"A" Series Model</u>	<u>4/15/20/30Watt</u>	<u>"A-F" Version</u>
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 10Meg	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	2.2 Gig	-

<u>"C" Series Model</u>	<u>20/30 Watt</u>	<u>60/125/250 Watt</u>
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

\*\*\* END OF APPLICATION NOTE #13 \*\*\*



When it is desired to limit the output of the HVPS, a 5K rheostat connected pot can be connected from the Remote Adjust Pin 6 to either Signal Ground Pin 5 (for P units) or the +7.1V zener voltage (for N units).

Click [here](#) to see an example of a negative HVPS constant current regulator.

**\*\*\* END OF APPLICATION NOTE #14 \*\*\***

## App. Note 16: Protection of HVPS in Single and Multiple HVPS Applications

Rev: J 1/99

All electrical equipment, if exposed to extreme operation environments well above its ratings, is subject to a shortening of its useful life. Although UltraVolt HVPS's have many internal protection mechanisms, there are a few applications where supplemental external protection circuitry, or special mounting procedures, are recommended to achieve maximum performance. While exposed to these extreme environments, this supplemental circuitry or special procedures will also assure the longevity of the UltraVolt HVPS.

Different applications will require different supplemental protection circuitry, depending upon the anticipated faults that the power supply may see. The UV HVPS has enough internal protection mechanisms, through 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 a 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 afterwards.

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 multiple HVPS systems. High speed, high energy pulse application safeguards are also covered in its 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 that UltraVolt HVPS's be electrically connected 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 HVPS internal damage.

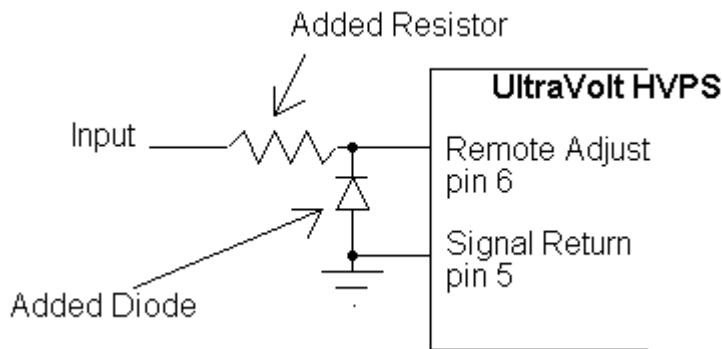
The HVPS should be mechanically mounted so as not to impart any undue stress on its case while allowing the HVPS to transfer its heat, if applicable to your particular unit, to an external heat sink using a thermal pad, paste or grease. If a heat sink is required, see [App. Note #6](#) on Thermal Management.

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 obtained.

The supply voltages of UV HVPS should never exceed the absolute maximum: 32 Volts maximum supply input for 12 Volt, 24 Volt, or 28 Volt units. The supply power for the HVPS should be fused and equipped with a tranzorb rated for approximately 32 Volts.

In certain configurations, a voltage of greater than 5V may need to be applied to the remote adjust terminal. These configurations usually involve negative HVPS's where the user does not make use of the internal 5V reference but still wants to guarantee that the HVPS output voltage can be adjusted to 0 Volts. In any case, the voltage applied to the remote adjust terminal must not exceed 6 Volts for an extended amount of time as this will cause excessive internal HVPS stress.

In no case should the remote adjust terminal be taken to below -1Vdc as this will damage the HVPS. 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 series current limiting resistor 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 1kW resistor would limit a -5V input remote adjust input to 5mA).

A voltage greater than 6V should not be applied to the 5V 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 PWR Return pin, damage may be done to the HVPS. Although the Input PWR Return and Signal Return are internally connected, the Signal Return pin can not be used as an alternative for the Input PWR Return pin.

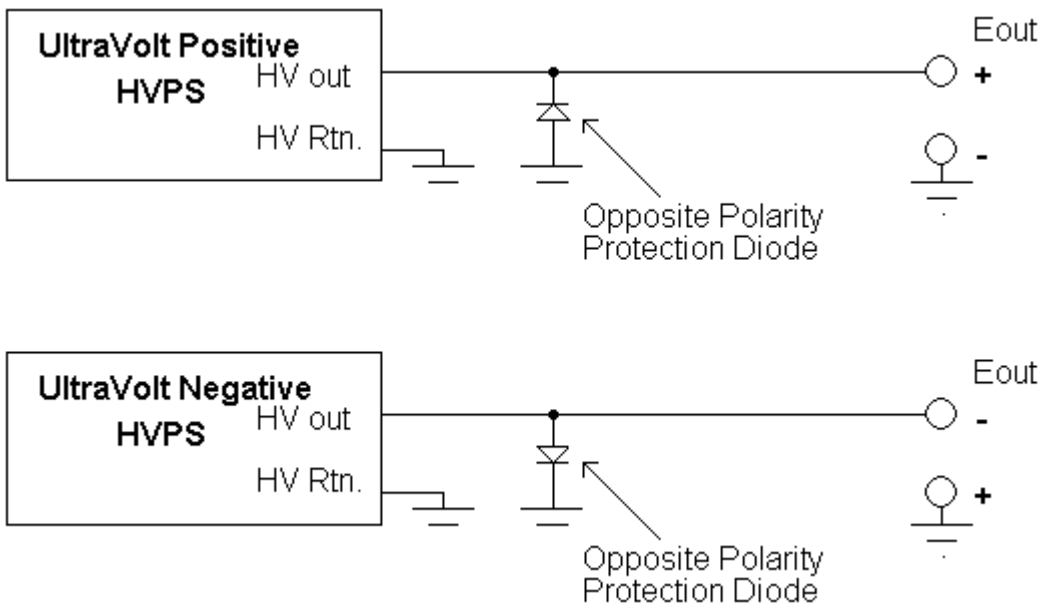
## **SPECIAL CIRCUITRY AND PROCEDURES APPLICABLE EXCLUSIVELY TO MULTIPLE HVPS SYSTEMS**

As long as no faults can occur, multiple UltraVolt HVPS's 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 HVPS's against normal fault conditions. Since each UV HVPS is fully short circuit protected, only interactions between HVPS's 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, through the use of a simple reverse biased diode on the output of the HVPS to ground, the UltraVolt HVPS can be protected from the damage which would otherwise occur from the output being exposed to an opposite polarity, higher current supply.

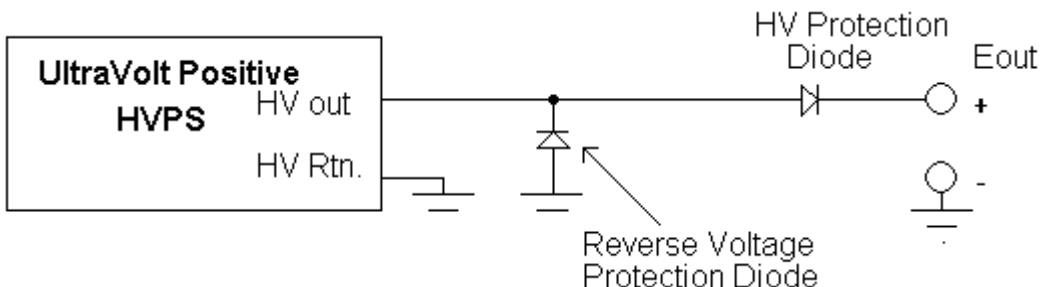


**An example of a multiple HVPS system, see text for component discussion.**

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 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 HVPS's 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 through the addition of a High Voltage Protection Diode to the lower voltage supply.

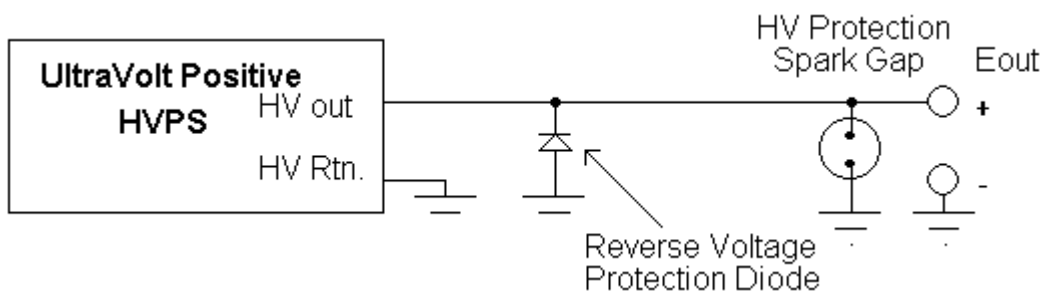


**Circuit from A. with a HV protection diode added.**

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 HVPS in the system. With this HV protection diode in place, an arc from a higher voltage HVPS will not damage the lower voltage HVPS, as the arc would 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.



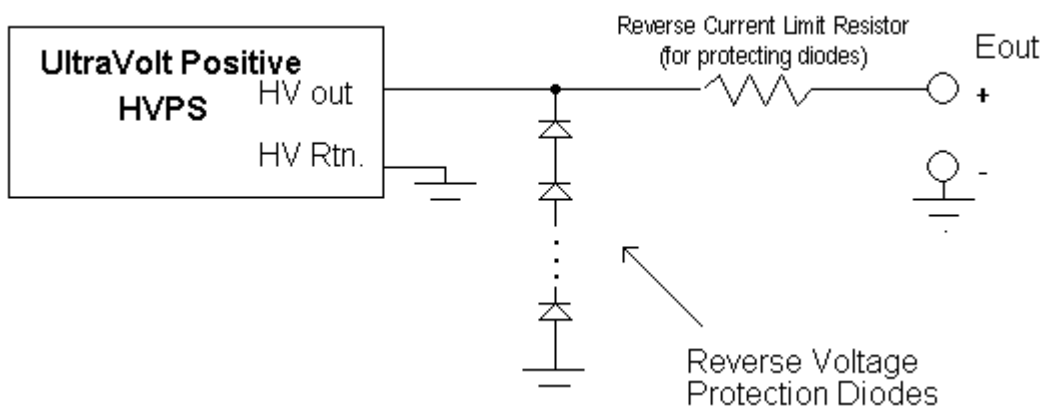
**HV protection diode replaced with a spark gap.**

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

*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 dealt with.

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 HVPS would 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. A 10kV HVPS would require, for example, 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 1 Ohm to 100 Ohm 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 which doesn't 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 HVPS's. 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 Return and the Input Power Return of the HVPS unit. If a noticeable voltage occurs here, 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 in getting proper performance and reliability. Each ground should be connected via a dedicated wire. While all the grounds are common inside the UV HVPS, brought together in a star point/single point ground configuration, it is important to note that with HV they are never truly "The Same". One example is when a HV arc occurs in the system to chassis ground, and the HV load has some capacitance. A 1,000VDC arc to ground through as little as 1 ohm of resistance/impedance would result in a peak surge current of 1,000 Amps! Another example is the input current causing a voltage drop between the LVPS and the HVPS. A .01 Ohm impedance build up from wiring, connectors, etc. is not uncommon, nor is the 10mV error it creates on the +12 or +24 VDC 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 1,000V 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 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 return. An unacceptable "common connection" is to take the ground to the HVPS High Voltage Return, typically when the HV 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 High Voltage Return).

#### **Signal 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, Iout Monitor, Eout Monitor and Vref. 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 safely done 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 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 High Voltage Return).

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

This ground is for the most **direct connection** between the HVPS output stage and the HV circuitry powered by the UV HVPS. 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 UV HVPS. This is done by connecting the LVPS output ground to the UV LVPS input return, and the UV HVPS

HV return to the system chassis ground. This is done so that if there is a HV arc to the chassis the most direct path for the HV energy is to return to it's 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**.

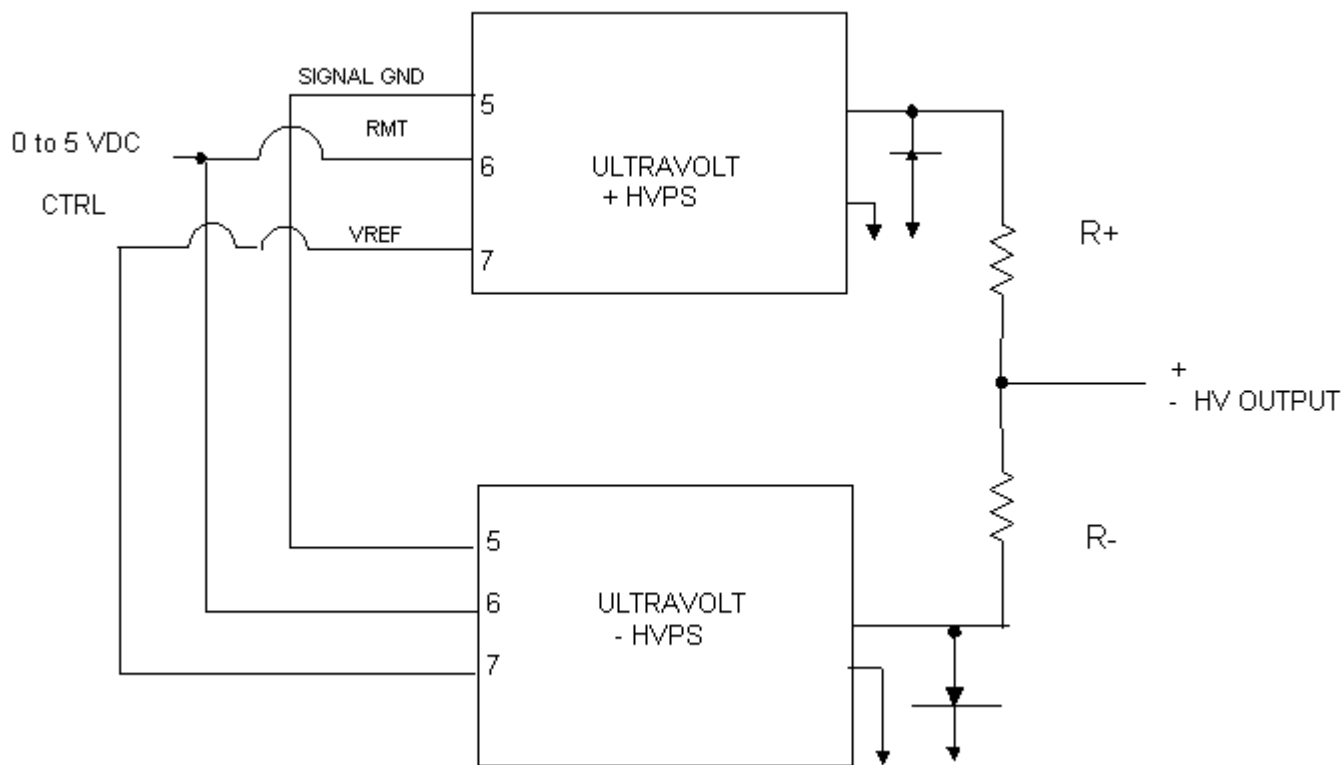
**\*\*\* END OF APPLICATION NOTE #16 \*\*\***

## Polarity Reversing Configurations of UltraVolt HVPS

Rev: C 9/29/98

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 introduces a mechanical element to the system that dramatically reduces the MTBF of the HVPS sub-system. This application note is presented as an illustration of a simple solution for low current & electrostatic bias applications. For higher current applications contact UltraVolts customer service department.

The simplest form of electronic polarity reversing is accomplished with a positive supply and 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 through 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 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 selected to limit the range of one polarity.

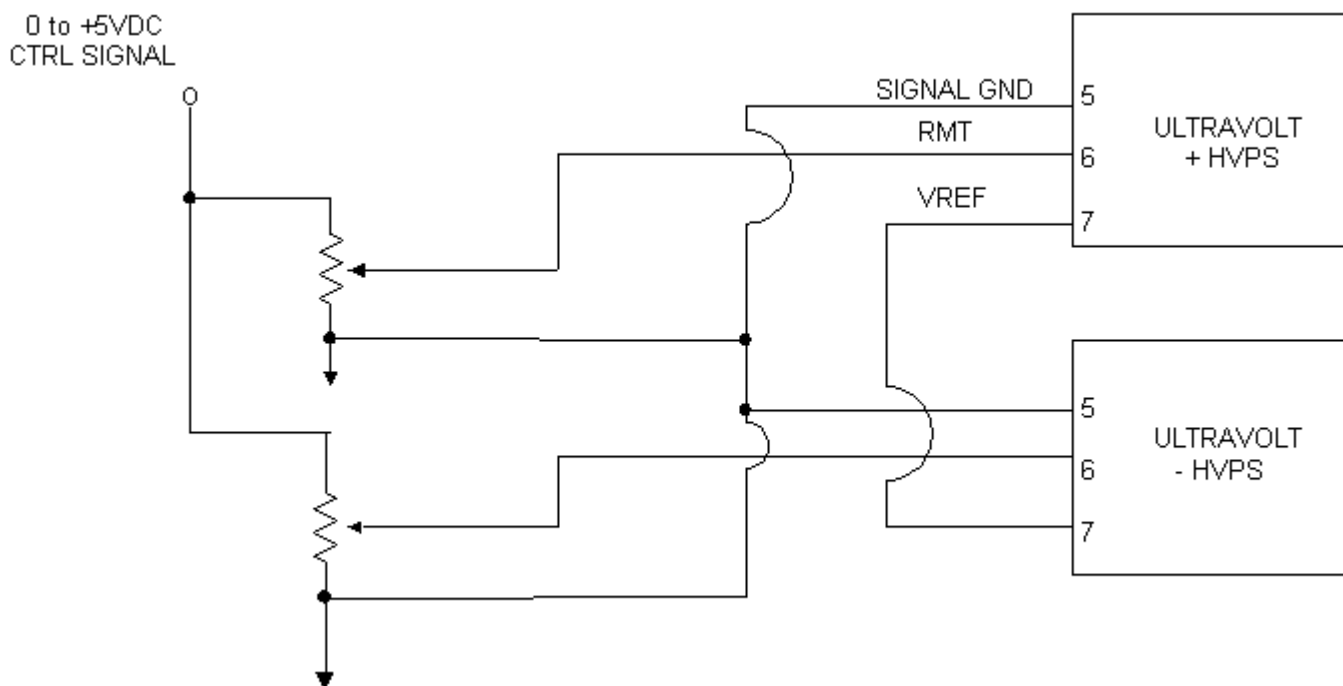
The diodes on the output of each HVPS are provided to sink the reverse current from the HVPS of the opposite polarity before it can reverse bias the circuitry inside the HVPS. These diodes should be

rated a minimum of 150% of the maximum voltage, i.e., 6kV diodes when used with a 4kV circuit.

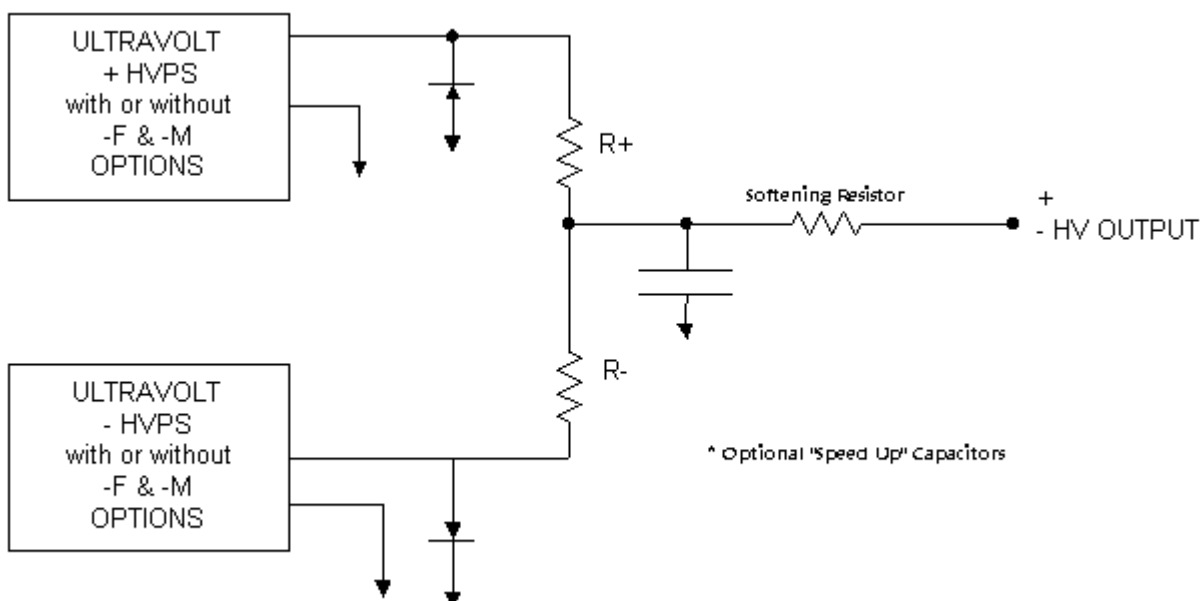
.0%. When tying the control pins of two HVPS's together

.0%. This error can be minimized two ways.

The first is to use two independent control signals, from two pots or two dac's, corrected to eliminate the error. The second is to use a single control signal through two 'calibration' potentiometers, one for each HVPS. The potentiometers can be conventional or digitally controled, such as E<sup>2</sup> pots. These methods are effective whether the goal is a 'Factory' calibration during initial manufacturing or "Re calibration" on each system power up.



In low noise systems the UltraVolt HVPS is normally ordered with the -F Ripple Stripper Output Filter® option, along with the -M MuMetal shielding option. Since the output resistors isolate the HVPS's 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:



**\*\*\* END OF APPLICATION NOTE #19 \*\*\***