



**AMERICAN HIGH VOLTAGE**  
POWER SUPPLIES FOR THE WORLD

**HAQ Series**

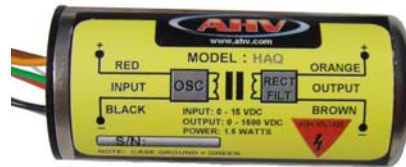
# HAQ Series High Temperature High Voltage Power Supply

## General Description

The HAQ Series high voltage power supplies are designed specifically for use in high temperature environments. They provide isolated outputs of up to 3kV and will operate at 185 degrees C case temperature. The output voltage of the HAQ power supply is directly proportional to the input voltage (0 – 15VDC). The output ripple is typically less than 0.1% at full power load. The two output leads are floating and fully isolated from the input power leads by over 1T Ohm (@ 25 deg C) with less than 50 pF of coupling capacitance. This permits either positive or negative polarity operation. The circuitry incorporates the same high efficiency Royer oscillator designed for our H-25B series which has been in production since 1981. All HAQ's are reverse input voltage and short circuit protected.

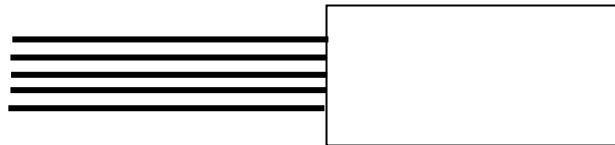
## Features

- Output proportional to Input
- Encapsulated
- 500 VDC to 3,000 VDC available
- 1.5 Watt power
- Metal case for low ripple: 0.1% Vpp



## Connection Diagram

RED: Input +15VDC  
 BLACK: Input return  
 ORANGE: Output +  
 BROWN: Output -  
 GREEN: Case



## Available Models:

### 1.5 Watt Models:

Name	Maximum Output Voltage	Maximum Output Current	1 <sup>st</sup> Year
HAQ – 5	500 VDC	3 mA	2008
HAQ – 15	1,500 VDC	1 mA	2007
HAQ – 30	3,000 VDC	0.5 mA	2008



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## Electrical Characteristics

(at 25 degrees C unless otherwise specified)

Parameter	Conditions	Value			Units
		Min	Typical	Max	
Supply Voltage:	(all models)	2 VDC	15VDC	18 VDC	VDC
Input Current:	No Load:	25	30	35	mA
	Full Load (1.5W):	190	195	210	mA
Output Ripple (max):	No Load (all models):	0.1 %	0.1 %	0.1 %	Vpp
	Full Load (all models):	0.1 %	0.1 %	0.1 %	Vpp
Load Regulation:	No Load to Full Load	25%	30%	35%	V <sub>NL</sub> /V <sub>L</sub>
Output Linearity	No Load		1%		$\frac{\Delta V_{OUT}}{\Delta V_{OUT (ideal)}}$
Output Linearity	Full Load (all models):		1%		$\frac{\Delta V_{OUT}}{\Delta V_{OUT (ideal)}}$
Short Circuit Current:	Input Current:		250	300	mA
Power Efficiency:	Full Load	45%	50%	55%	$\frac{P_{OUT}}{P_{IN}}$
Reverse Input Polarity	Protected to 20 VDC				
Max Temperature Drift:	No Load			600	ppm/DegC
	Full Load			600	ppm/Deg C
Thermal Rise:	No Load (case)			3	degrees C
	Full Load (case)			5	degrees C
Slew Rate (10% - 90%)	No Load			100	mS
	Full Load			120	mS
Slew Rate (90% - 10%)	No Load			200	mS
	Full Load			100	mS
Drain Out Time	No Load (5 TC)			100	mS



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## Physical Characteristics

(at 25 degrees C unless otherwise specified)

Parameter	Conditions	Value	Units
Dimensions	MKS	26 Diameter x 55 Length	mm
	English	1.0 Diameter x 2.15 Length	inches
Volume:	MKS	39.2	cm <sup>3</sup>
	English	1.68	inch <sup>3</sup>
Mass:	MKS	120	grams
	English	4.3	oz
Packaging:	Solid Epoxy Thermosetting	(High Temperature Cyclo)	
Finish	Nickel plated steel case		
Terminations:	Teflon wires #22 AWG (5)		

## Environmental Characteristics

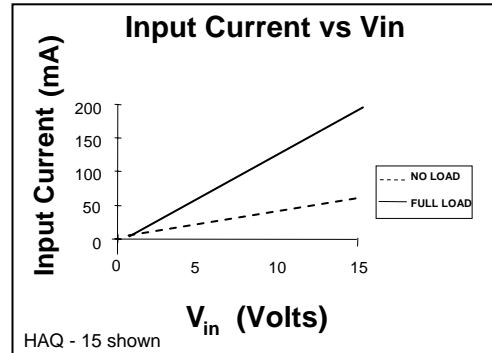
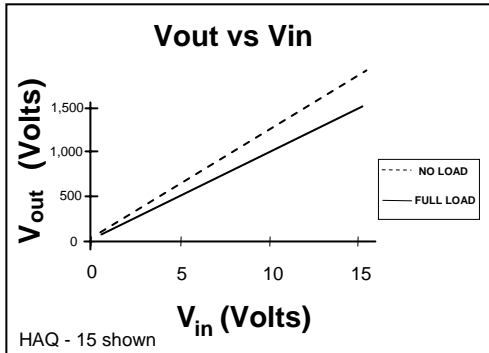
(at 25 degrees C unless otherwise specified)

Parameter	Conditions	Value	Units
Temperature Range	case temperature	-40 degrees to + 185 degrees	Celsius
	case temperature	-40 degrees to + 365 degrees	Fahrenheit
Shock:	MIL-STD-810 Method 516	40 g's	Proc IV
Altitude:	pins sealed against corona	-350 to + 16,700	meters
	pins sealed against corona	-1,000 to +55,000	feet
Vibrations:	MIL-STD-810 Method 514	20 g's	Curve E
Thermal Shock	MIL-STD-810 Method 504	-40 deg C to + 185 deg C	Class 2



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## HAQ Series Performance Charts



## HAQ Series Application Notes

The HAQ Series high voltage power supplies are driven by an input voltage of 1 to 15 VDC. The input current and output voltage as a function of input is shown in the above graphs. There are NO internal connections between the input and output pins. As can be seen from the above, the output voltage is approximately linear with respect to input except near the lower input voltage region. Here, the output drops off rapidly as the input voltage approaches zero with the absolute minimum input voltage needed for reliable starting being 2 VDC. As shown in Figure 1 below, the simple connection of a HAQ unit to a DC source of voltage will provide a high voltage stepped-up output. The input AC bypass capacitor C1 is optional and is utilized to prevent switching spikes from riding back on the input power lines. Values of 0.1 uF to 10 uF are commonly used.

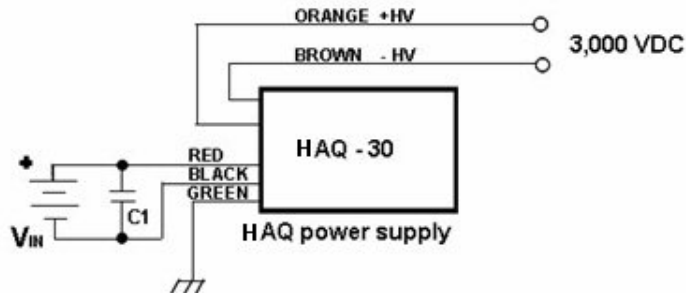


Figure 1: Basic HAQ hookup schematic (side view of HAQ shown)

The output voltage of the HAQ unit may be regulated by incorporating a simple op-amp circuit and linear control device such as an NPN transistor. Here, the output voltage is sensed and compared against an external reference control voltage. For single supply operation, the circuit of Figure 2 may be used for positive output regulation. A high voltage divider is made up of R5 and R6 to divide down the output to a value comparable with the control voltage. The resistor R5 is value is determined by power considerations. A good rule of thumb is to be 10% of the full output load. Too high a value may lead to output drift problems due to operational amplifier input bias current drift. The resistor R5 must be rated for the voltage that it is to step down. Simple high value carbon film resistors are usually avoided because their maximum voltage is limited to 300 VDC. Precision metal film resistors are more stable but also have limiting maximum voltages. It is possible to series several metal film resistors to build up the voltage rating of R5. Capacitor C4 likewise must be rated for the proper voltage. It serves to lower output ripple provide a feed-forward pole in the feedback loop for stability. Capacitor C5, the ground mirror capacitor serves as a lower end of the AC divider formed with C4 and prevents excessive voltage from being fed to the operational amplifier in the case of a shorted output.



## HAQ Series Application Notes (continued)

R6 is selected by calculating the resistance divider ration with R5, providing a 5 volt feedback at full output voltage. The input reference bypass capacitor C1 is used to remove any noise feeding to the non-inverting signal pin of the operational amplifier. For maximum temperature stability, R1 should be identical in value to R6.

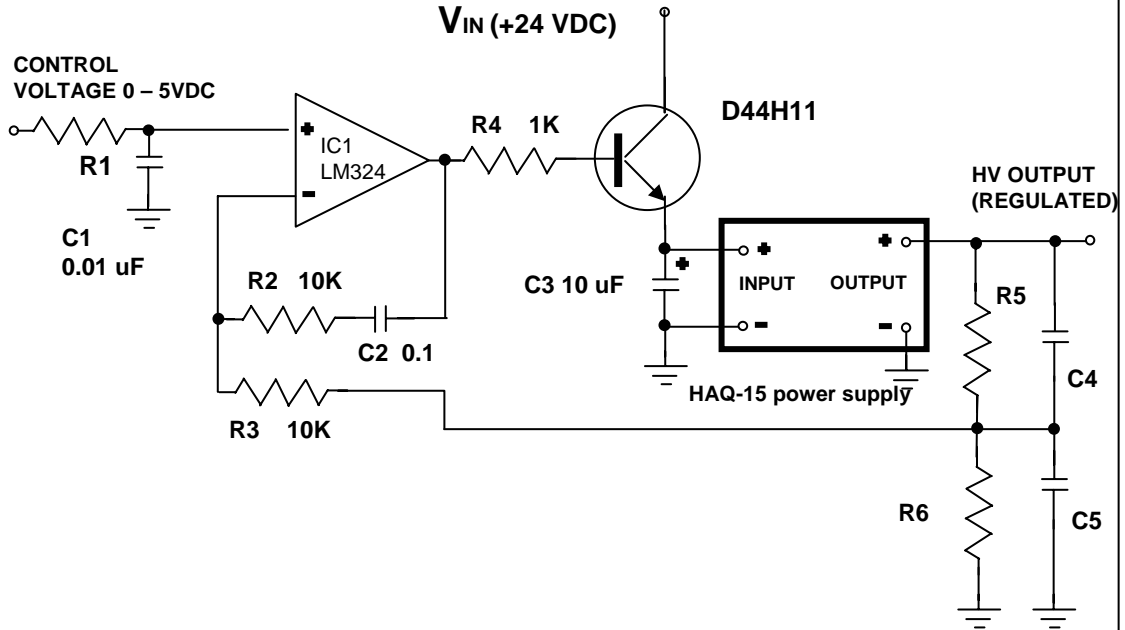


Figure 2: Positive 1,000 Volt Regulator

Resistor R2 and capacitor C2 provide frequency compensation for the amplifier IC1 a common bipolar amplifier is used since its outputs and signal inputs can reach almost to ground. R3 provides protection to the signal inverting input of the opamp in case of a short circuit or arcing condition exists on the HV output. R4 protects the output of the opamp in case of a shorted NPN transistor. Typical values for a 1,000 volt PMT supply are as follows:

AQ:	HAQ - 15
R1:	499K Ohm
R5:	100 Megohms (Slimox 102 - Ohmite)
R6:	499K Ohm
C4:	2200 pF 3kV disc
C5:	0.1 uF 50 V ceramic
IC1:	LM324
Q1:	Power NPN such as D44H11 or equivalent

Typical voltages seen during operation are as follows:

Voltage at junction of R5 and R6:	5V
Voltage at opamp output:	11.3V
Voltage into + supply TC:	10V (depends somewhat on output load)
Voltage of base of Q1:	10.7 V

The power supply feeding the opamp is not shown however it may be connected to the +24V supply and ground. This allows an output from the power NPN transistor to be approximately 10 volts maximum. This is sufficient head room to allow 1,000 VDC from the HAQ power supply. It is always a good idea to bypass the input power pins of the opamp with a 0.1 uF capacitor to reduce the EMI that may damage the opamp if an output arcing condition is suddenly encountered.



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## HAQ Series Application Notes (continued)

By varying the control voltage from 1 to 5V, the high voltage output of the HAQ power supply may be regulated. Line and load regulation as good as 0.01% are achievable depending upon physical layout and quality of feedback resistor. To lower the output ripple further, a resistor (carbon composition type) of a high value may be inserted in series with the HV output of the HAQ unit before it continues on in the circuit. A value of 100K Ohm will drop the output ripple to less than 0.2 Vpp. Here the 100 K Ohm resistor works as a filter in conjunction with C4. Higher ripple reduction is achievable with a capacitor added directly to the output pin and ground.

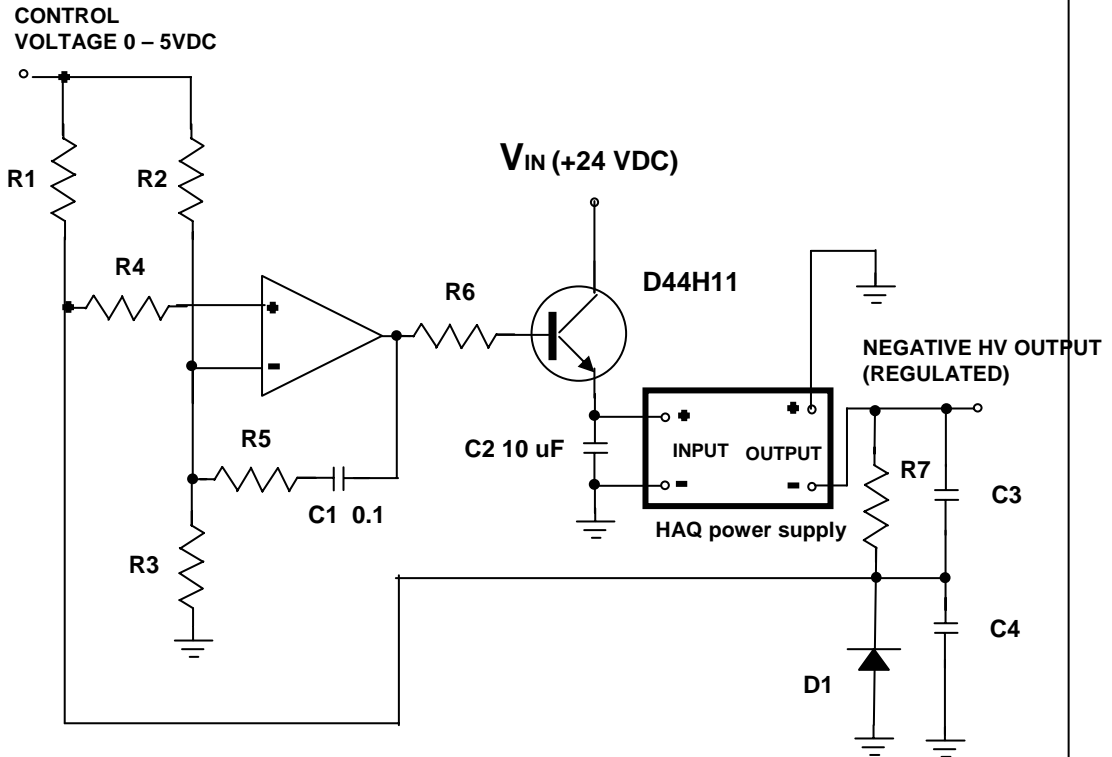


Figure 3: Negative 1,000 Volt Regulator

A regulated negative High Voltage output is easily obtained using the floating output feature of the HAQ unit. Figure 3 utilizes much of the same topology as the positive regulator except that a summing junction is made for operational amplifier IC1. Again, the values of R7 and C3 are selected with respect to the proper HV output parameters. Dissipation in R7 should be limited to less than 10% full load. C3 must be a high voltage capacitor, capable of working at the full output voltage. Diode D1 provides a return path in cast the output is suddenly shorted, protecting IC1 from huge positive spikes on the signal input. Resistors R2 and R3 form a simple divider, their values should be equal. The voltage drop in R1 should be such that at full output voltage the signal at the non-inverting input of IC1 should be exactly half the control voltage. R4 is a simple 10K Ohm limiter. The values of R2 and R3 should be twice that of R1 for good thermal stability. Typical values for a negative 1,000 volts negative output PMT power supply are as follows:

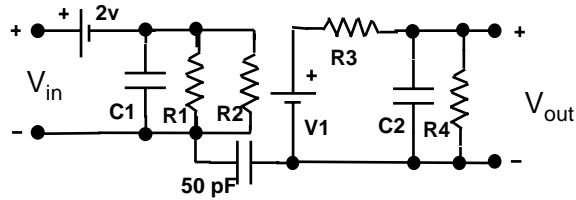
AQ:	HAQ - 15	R5:	10K
R1:	250K Ohm	C3:	2200 pF 3kV disc
R7:	100 Megohms (Slimox 102 - Ohmite)	C4:	0.1 uF 50 V ceramic
R2:	499K Ohm	IC1:	LM324
R3:	499K Ohm	Q1:	Power NPN such as D44H11



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### Equivalent HAQ Circuit Model



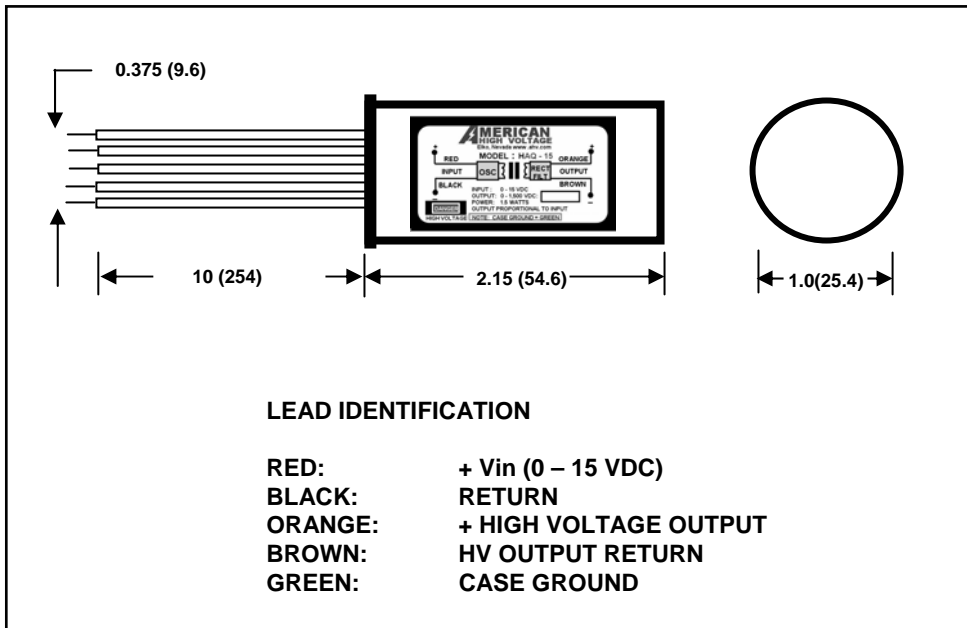
Equivalent HAQ HVPS Circuit Model

- R1 = (300) Ohms
- R2 = (200 / Pout) Ohms
- R3 = (0.2 x Vout<sub>max</sub> / Iout<sub>max</sub>) Ohms
- R4 = (10 x Vout<sub>max</sub><sup>2</sup>) Ohms
- C1 = (10 x 10<sup>-6</sup>) Farads
- C2 = (0.005 x Iout<sub>max</sub> / Vout<sub>max</sub>) Farads
- V1 = (VR2 x Vout<sub>max</sub> / 15) Volts

For example, for an HAQ - 15

- Vout<sub>max</sub> = 1,500 V
- Pout<sub>max</sub> = 1.5 W
- Iout<sub>max</sub> = 0.001 A
- R1 = 300 Ohms
- R2 = 133 Ohms
- R3 = 300K Ohms
- R4 = 25 Megohm
- C1 = 10 uF
- C2 = 1,000 pF

### Outline Drawing: [inches (millimeters)]



### Ordering Information:

**HAQ – XX**

XX = Output voltage

**Example:**

- HAQ – 30: Maximum output = 3,000 V
- HAQ – 5: Maximum output = 500 V