# Direct Heated Triode Filament Regulator

***System Design Considerations and Installation manual***

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| Version | Date | Notes |
|---|---|---|
| 7 | 2015-3-12 | V7, add transmitter types |
| 5 | 2014-8-19 | V5 original |
| 1 | 2010-9-30 | Original |

****Note that each type of DHT has an Assembly Note to give details of PCB build, and recommended transformer voltages for each DHT, e.g. 300B or GM70 etc. Please check website.**

Topics Contained in this application note:

- Providing the perfect dc supply for the regulator;
- Heatsinking to keep the TO-220 transistors cool and reliable;
- Connecting the regulator to the dht, and adjusting to suit your filament;
- Mechanical and drilling dimensions.

# WARNING:

**Installing this unit involves work on equipment carrying High Voltage that can be instantly lethal. Build at your own risk. The seller of this product does not accept responsibility for any damage or harm of any sort incurred by the builder.**

## Building a Power Supply (Raw dc).

The regulator is shipped without any rectifier or reservoir/filter capacitors, so constructors must create one. EACH DHT must have its own transformer, rectifier, capacitors, and regulator- Sharing between two DHTs will give bad sound!

**Voltage Requirements.** The power supply must give a minimum voltage which should be held even when the local mains supply is at its expected low level (e.g.: -10%). Usually this is 3.5V (minimum) above the filament voltage, measured *while the normal filament current flows*. If the voltage is too high, the transistors will dissipate more heat, which must be radiated from big heatsinks.

The table below shows the Versions of Coleman regulator that have been tested and qualified. The allowable Raw_dc supply voltage range, and the recommended transformer secondary voltage and VA-rating for each case is given. Hammond Transformers can be obtained almost anywhere in the world, so I have made suggestions for a Hammond version, to use with the different DHTs (Table 2).

**Table 1: Model Lineup, Current Adjustment Range, DC Input Voltages:**

| **Model:** | **Filament Current** | | **dc Supply Voltage** | |
|---|---|---|---|---|
| **DHTs** | *[A]* | ***Min [V]*** | ***Nominal [V]*** | ***Max [V]*** |
| GM70; 20V | 2.7-3.3 | 23.5 | 24.5 | 28 |
| 845, 211, 813: 10V dc Types | 3.25 or 5 | 13.5 | 14.2 | 17 |
| 3C24 | 3.0 | 11 | 12.3 | 14 |
| PX25/<br>KR300Bxls | 1.8-2.1 | 8.0<br>8.5 | 9.2<br>9.5 | 10.5<br>11.5 |
| 2A3 | 2.5 | 6.9 | 7.5 | 8.4 |
| 46 | 1.75 | 6.9 | 7.5 | 8.4 |
| 45 | 1.5 | 6.9 | 7.5 | 8.5 |
| 300B | 1.2-1.3 | 8.5 | 9.2 | 11 |
| 10Y, 801A | 1.25 | 11 | 12 | 14 |
| #26 | 1.05 | 6 | 6.7 | 8.2 |
| RE604 | 0.58 | 8 | 9 | 11 |
| 4P1L | 650mA | 6.6 | 7 | 8.2 |
| TFK Aa, Ba | 500mA | 8.0 | 8.8 | 10 |
| 71A, 01A, 3A/109 | 250mA | 8.3 | 9.2 | 12 |
| LP2 | 200mA | 6 | 7 | 14 |

**Ripple voltage.** The Coleman Regulator uses a Gyrator to reduce the ripple from the raw DC supply. The acceptable incoming ripple depends on the dht, but for preamp use, it should be kept to 100 -150mV peak-to-peak or less. Remember that the MINIMUM voltage of the supply input [Min V in Table 1] is measured at the low point of the ripple voltage [the trough].

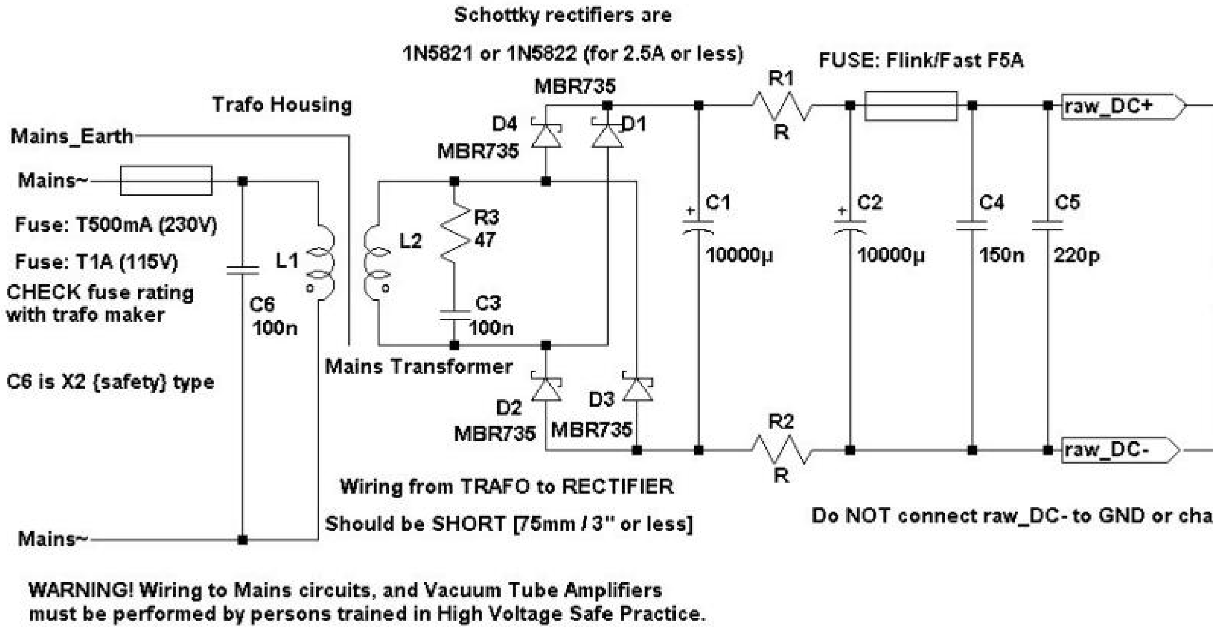
**Approach to Power Supply Design.** The suggested circuits given in this note have been worked out to give the right voltage for the dht regulators to work with. If you can build them exactly (or nearly) the same, the results should be perfect. But if you have some different parts in your junk box, no problem – but please use the Power Supply Designer Software (Visit the Duncan Amplification PSUD2 Website) to verify your design – *using a Constant Current load to represent the dht regulators.*

### Continuous Use

Your DHT amplification will sound so good that you will want to listen for long periods at a time. Please remember that the filament transformer, rectifiers, and capacitors will be working at full load during the whole of this time, and need to be *continuous rated.* Don't choose these parts to work right at the edge of their ratings, or they will have a short life. This applies to any DC heating scheme - (only you would not listen for long to voltage-regulated DC, due to annoying sound).

**Ventilation**: Losses in the transformer winding resistances will heat the transformer: be sure ventilation is adequate for these.

**Schematic of Raw dc Supply.** The schematic shows the nature of the raw dc supply required:




**Mains Fuse.** For a 50VA transformer, a Slow-Blow T500mA fuse in the mains circuit should normally be used in 230V regions, and T1A for 115V regions. This is only a guide, and for safety you should check the recommendations of the transformer vendor. For larger transformers the fuse rating should be scaled higher.

**X2 capacitor C6.** Use this to reduce supply impedance at higher frequencies, and reduce mains noise. Must be safety rated class X2 capacitors.

**Mains Transformer.**

Please use one transformer for each tube, or at least separate windings that are not electrically connected. **DO NOT share L & R channels -** if you do, the effective cathodes will be shorted, which will give serious bias problems, and cross-talk.

The VA rating has to be generous in dc dht amplifiers. The rms secondary current is nearly double the dc current [e.g.: 1.8A for 1Adc]. Also, the conduction angle is very small [due to large capacitors], and they run full load continuously. All these factors add to make the transformer run hot, unless some derating is applied. Especially – transformer with higher current rating has lower winding resistance. A rule of thumb: for each ampere of dc, choose 3A of ac-rating. The transformer's losses will then be smaller [consider I-squared losses in winding resistance!]

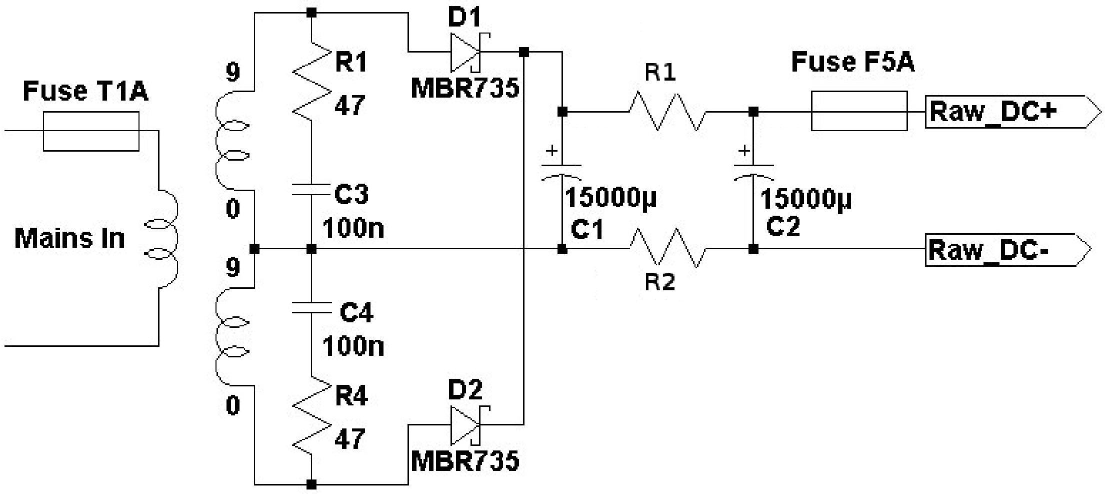
> Choose a standard clamp transformer, with split bobbin design. Unified bobbins (where the primary and secondary are wound on top of each other) are NOT recommended, as they will couple mains noise into the secondary. For the same reason, do not choose a toroidal transformer. If you have one of these unsuitable types in 9V, though, don't buy another – instead, buy a 200VA or larger isolating transformer, or building site tool transformer (only one needed per pair of dht regulator transformers). Connect one side of the isolating transformer's secondary to system ground, and you will get excellent isolation from mains noise.

**Snubber for transformer secondary (R3 & C3).** These attempt to damp out the rectifier recovery current pulses that resonate with the inductance of the transformer secondary. The component values are not critical, but if you wish to optimise this network, you'll need a current probe and a good oscilloscope to monitor the little current peaks in the rectifiers, and adjust parts values to get minimum peaks.

**Rectifiers D1 … D4.** These are schottky rectifiers (for reduced recovery pulses compared to regular rectifiers. For 2A dc and lower, the 1N5821 (or 1N5822), from the Fairchild or Onsemi catalogue (See Farnell or Mouser online catalogues for availability). Be aware that the very short conduction angle (caused by large reservoir capacitors) in this supply mean that the rms current through the rectifiers is high, so if you change any parts away from these recommendations, be sure that you use PSUD2 (see section 1.3) to analyse the rectifier current. You can use higher current rated rectifiers, but avoid high-voltage (60V or more) types, as the forward losses of these is higher.

**Full-Wave Rectifier.**

If your transformer has twin secondaries, you can use a full-wave rectifier, using only two diodes. With some transformers, this arrangement sounds better, perhaps because only one diode switches OFF at a time.




**Reservoir Capacitor C1**. This part must be chosen very carefully. For the #26 dht (1.05A) you can choose 10000uF, or 15000uF, with less ripple for each step up.. However this parameter is not so important as the Ripple Current rating. Nasty unbranded capacitors will not specify the ripple current rating, and this is a sure sign that they will have a short life when operating at Ampere-level currents found in DHT heating: see the value: I(C1) in your PSUDii results. The rms value is required: for 1A dc supplies with 10000uF it is 1.9Arms, slightly more if your capacitor is bigger. Larger capacitors will have larger ripple current ratings. For 2.5 ..3.3A filaments, 2x 10000uF is needed to achieve a Ripple Current handling of ~7A at C1. Please remember: your dht heater is always working at full load, choose a capacitor with a ripple rating higher than the rms current it will carry. Running 1.9A in a capacitor rated for (say) 2A (at 85 deg C) will give a relatively short life, so look for something better. Recommendations include the Panasonic TSUP series which can do 3.78A at 10000uF/16v, or the Samwha HC series, good for 3.32A at 10000uF, 4.5A at 15000uF. “Audiophile” parts should not be necessary. Use multiple smaller capacitors, if preferred, eg 6 x 2200uF/16v Panasonic FC.

**C1 airflow:** C1 is working hard carrying the ripple current, so be sure it has space all around it for cooling airflow. Heat shortens life of electrolytics.

**C2.** Carries a lower ripple current than C1, but may as well use the same 10000uF - 22000uF part as C1.

**R1 & R2.** These act to reduce the ripple at the regulator's input, eliminate noise, and reduce the supply voltage to the correct level. For the #26/01A model, 2 pcs of 0.33 Ohm to 0.47 Ohm should give the right output. Buy a number of each of these to try – low cost wirewound resistors are fine for the job, rated at 3W, 5W, 7W etc.

**dc fuse.** The regulator features a current limiter, but short-circuited wiring could bypass this protection and damage the regulator, or even your expensive dht. Or something could overheat & start a fire. Do not take this risk – use a FAST (Flink) F-rated fuse in the position shown. 20mm F3A (or F3.15A) would be a good choice for the <1A models; F5A for 2A filaments, F6.3A for 3-3.5A.

**Filter capacitor C4.** To reduce HF noise, a 150nF (or some other value nearby) capacitor is worthwhile. Use MKT or other film type. Best choice is the stacked type film, rather than wound construction.

**Filter capacitor C5.** To reduce VHF noise, you can experiment with high voltage NPO ceramic chip capacitors.

**TABLE 2. Example Raw dc Parts List for Common DHTs:**

*Parts Quantities are per channel - please double, for stereo.*

| **DHT** | **Nominal V dc** | **Rectifier (4 diodes)** | **C1 & C2 (µF)** | **R1 & R2 (Ω)** | **Trafo** *Hammond type* |
|---|---|---|---|---|---|
| 01A, 71A | 9.2 | 1N5822 | 4700 16V (x2) | 0.33 5W (x2) | 7V 1A *266G14* |
| 4P1L | 6.9 | 1N5822 | 4700 25V (x2) | 0.68 5W (x2) | 6.3V 2A *266J12* |
| 6P21S | 10.6 | 1N5822 | 10000 25V (x2) | 0.68 5W (x2) | 9V 3A *266K18* |
| 26 | 7.0 | 1N5822 | 10000 25V (x2) | 0.33 5W (x2) | 6.3V 3A *266K12* |
| 6B4G | 10.3 | 1N5822 | 10000 16V (x2) | 0.22 5W (x2) | 9V 3A *266K18* |
| 10Y | 12 | 1N5822 | 10000 25V (x2) | 0.22 5W (x2) | 10V 4A *266L20* |
| 300B | 9.4 | 1N5822 | 10000 16V (x2) | 0.22 5W (x2) | 8V 4.4A *266L16* |
| 45 | 7.0 | 1N5822 | 15000 16V (x2) | 0.15 5W (x2) | 6.3V 5A *266L12* |
| 2A3 | 7.1 | MBR1045 | 22000 16V (x2) | 0.1 5W (x2) | 6.3V 6A *266M12* |
| 845, 211 10V 3.3A | 14.2V | MBR1045 | 22000 35V (x2) | 0.33 7W (x2) | 12.6V 8A rms *Hamm'd 185F12* |
| GM70 20V 3A | 24.5 | MBR1045 | 22000 35V (x2) | 0.47 7W (x2) | 20V 8.8A rms *185G20* |
| 813 10V 5A | 14.2V | **MBR1645** | 22000 35V **(x4)** | 0.22 7W (x2) | 12.6V 14A *185G12* |

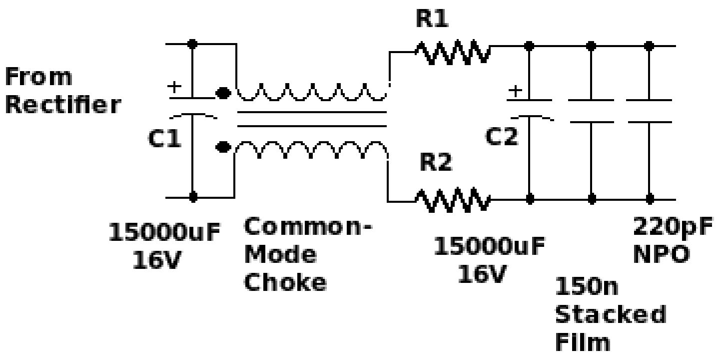
*Parts Quantities are per channel - please double, for stereo.*

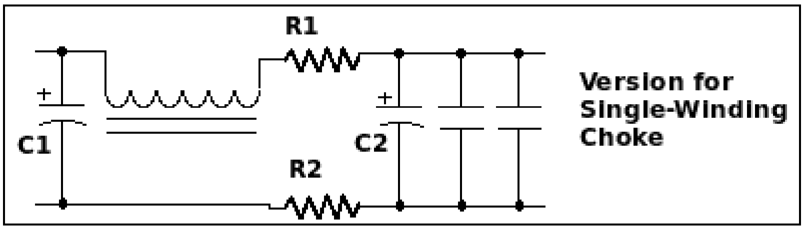
Capacitors should be chosen to support the maximum voltage from the raw dc supply. For 26 and 4P1L, filament bias is a possibility, so 25V or 35V parts are recommended, in case you want to try it.

**Chokes**.

These are not shown in the diagram, and are optional. If you want to experiment with HF noise reduction, use a single choke in series with R1. Or you could try a common-mode choke in series with R1 and R2. Listening tests should guide to whether they are needed – this may depend on the Noise on your mains supply, or Radio Transmitters nearby.

The sketch below shows the suggested method for connecting chokes – for common-mode, or single-winding chokes.

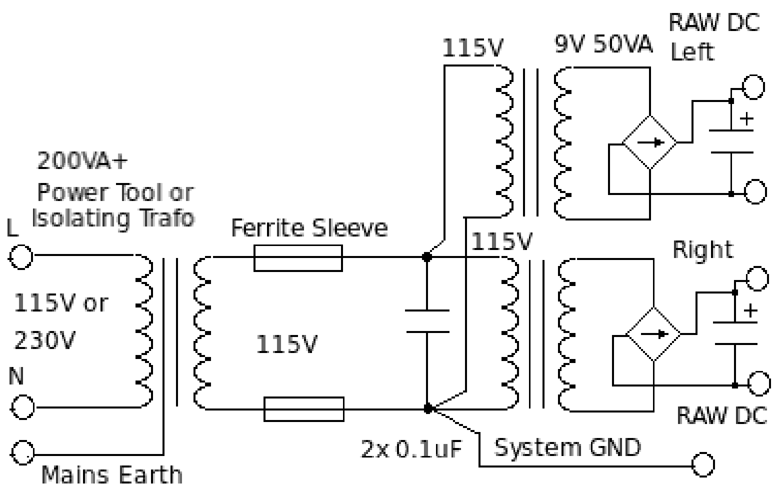



**Isolating Transformer.**

For DIYers with noise problems in Mains Supply, or if you simply want the quietest possible supply (And you can live with heavy weight) you can add and isolating transformer: just a big 230v or 115v primary transformer with secondary115V output.

How to connect it up:



1 **Heatsinking**. Heatsinking is required for all versions of the regulator.

**Do not operate the regulator even for a short time, with no heatsinking for the TO-220 transistors.**

Power Dissipated in the Regulator Transistors. Transistor Q4 (gyrator) dissipates about (1.4V x Ifil) W - regardless of input voltage. Transistor Q5 dissipates a similar level at nominal supply voltage, and a little more when Raw_dc is higher than nominal supply voltage. For the #26 to 300B dht, expect 3.5 to 8W in total for the heatsink to radiate away. For big 3A transmitting tube filaments, 15 to 20W.

Finding a Suitable heatsink. Heatsinks are specified by their Thermal Resistance (K/W - Kelvin per Watt, = Degrees C per Watt). Our goal is to keep the heatsink to a temperature that is safe for the transistors. We also should keep the heatsink at a low enough temperature that it does not set fire to your curtains or other articles near to the amplifier! We should try to keep the heatsink to below 65 deg C, and preferably less.

Small Clip-On Heatsink. With our 26 preamp with 1A or even 1.3A filaments, a little clip-on heatsink like the AAVID THERMALLOY KM75 (75mm/3" wide) achieves about 5K/W or KM100 (100mm/4" wide) gets about 4K/W - are very convenient. A KM75 cooling a 26 regulator at 7W will give a temperature rise of 7W x 5K/W = 35K. If the ambient of the amplifier is 25 deg C your heatsink will reach about 60 deg C. BUT:

Caution: Free Air Circulation required. The values for thermal resistance assume free circulation of air. Mounting the heatsink in a closed chassis will restrict flow, and a bigger heatsink will be needed. It is best to have the heatsink at the back of the amplifier, to lose the heat to the outside air!

**Chassis**. But for most constructors, mounting the transistors on the outer structure of the amplifier may well work best. The rear panel could be made from 3 or 5mm Al (⅛" - ¼"), or the top plate or base used. For heatsinking. If the base is used, be sure to allow circulation of air – use 25mm (1") tall feet.

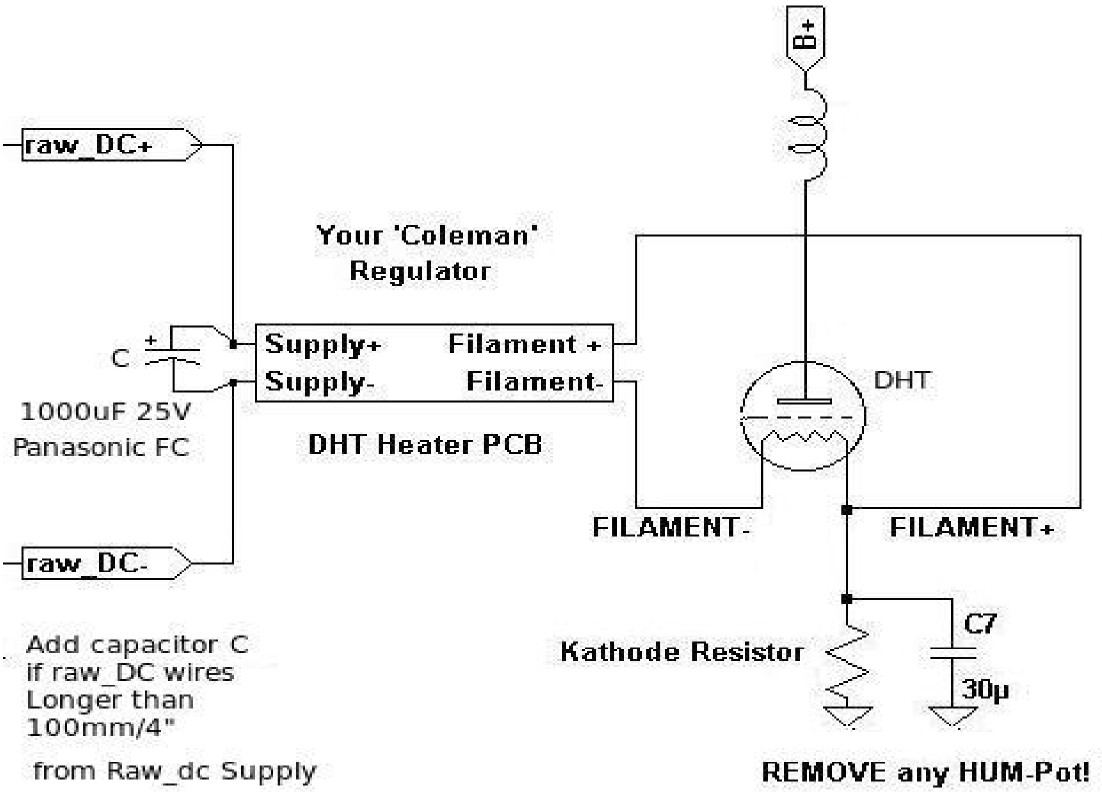
**Test your work:** it is usually worthwhile to measure the temperature of the chassis near to the transistors. An IR Gun-type thermometer is ideal, or a thermocouple probe can be used. BUT, if you use a large area of chassis, say 3mm thick, and 200mm x 100mm (8" x 4") in area, instrumentation will not be needed - the transistors themselves should be cool enough to touch. If this is true for your heatsink, the solution is ideal.

Area of Chassis required. If the chassis is made from 3mm thick Aluminium, or thicker, and exposed to the outside air, the performance will be excellent. To test this claim, a regulator was set up to supply GM70 filaments running 3.3A, mounted on some scrap 3mm Aluminium, 275mm x 100mm (11" x 4") area. The high power heater can operate with this heatsink indefinitely, and only reach about 45 deg C.

**Heat Spreader Bar**. For Transmitters, like 845, GM-70, use of a spreader bar is advisable. Many eBay sellers offer Alu bar in 5mm or 10mm thickness. Buy a length of this [the cost is very low] and mount it between the FETs and the chassis/heatsink. This is especially useful in dealing with the startup thermal pulse – a cold filament shows low voltage-drop, and the supply voltage is applied across the FET Q5 at cold start.

KM75. For low power filaments, see the KM75 clip-on heatsink, and download a drawing at: http://uk.farnell.com/aavid-thermalloy/km75-1/heat-sink-to-220-218-3-7-c-w/dp/265214?crosssellid=265214&crosssell=true&in_merch=true&. The ABL version can radiate more heat: http://uk.farnell.com/abl-heatsinks/ppn0750b/heat-sink-to-220-218-3-7-c-w/dp/526885?in_merch=true&MER=i-9b10-00001422

2 **Connecting the DHT to the regulator.** Connecting your new regulator to the power supply, and then to the dht is very simple, see the schematic below:




raw_DC+ and -ve come from the dc power supply you built in the previous section. Connect the power supply feeds to the Supply + and Supply - pads on the regulator board. Connect filament + and filament - to the dht filament terminals. In almost all cases, the filament terminals are equivalent, and either end can be +ve. Some battery-dhts may be polarised, though - check the data sheet to be sure.

**Cathode Resistor**. We normally connect the cathode resistor/capacitor to the positive side of the filament. That's only because many experimenters find that it sounds better, so you could try it either way around to hear if there is any difference. But if you do that, be sure that both L and R channels are the same way round, or the phasing may be wrong.

The Filament current level can affect the bias level of the DHT, ie anode/plate current. Please check the anode current again after the filament current has been satifactorily adjusted.

**Guidelines for Wiring Lengths:**

2.1 Wiring between rectifiers, snubbers, and C1 capacitor: keep these really tight. A 1.2A supply runs 6A pulses through these! The pulses will electromagnetically couple into your signal circuits if these are long!

2.2 Transformer to rectifiers: keep shorter than 75mm, same reason as above.

2.3 Raw_dc wiring from rectifiers/capacitors to Regulator's board: Not so critical, and if you use another capacitor at the regulator end (1000uF, 16V/25v/35v, low impedance power supply grade, eg Panasonic FC, or 220~470uF Sanyo OS-CON), you can make these 2 metre long, and mount in a different chassis.

2.4 Regulator PCB to tube socket: Keep to 200 .. 250mm (8 - 10")

Old Wiring, and Humbucker Potentiometer or capacitors. If ac heating was previously used on your dht amplifier, there may be wiring for a hum-cancelling potentiometer. Remove these wires completely. Nothing should be connected to the dht filament, or the regulator, except as shown in the diagram.

Do NOT Mix Ground and the negative of raw dc filament supply.

**WARNING (1):** ***Do not connect the Input dc supply -ve to the system GND. The Raw dc supply should be floating.*** This could bypass the current control of the filament, and damage your dht, and/or the regulator.

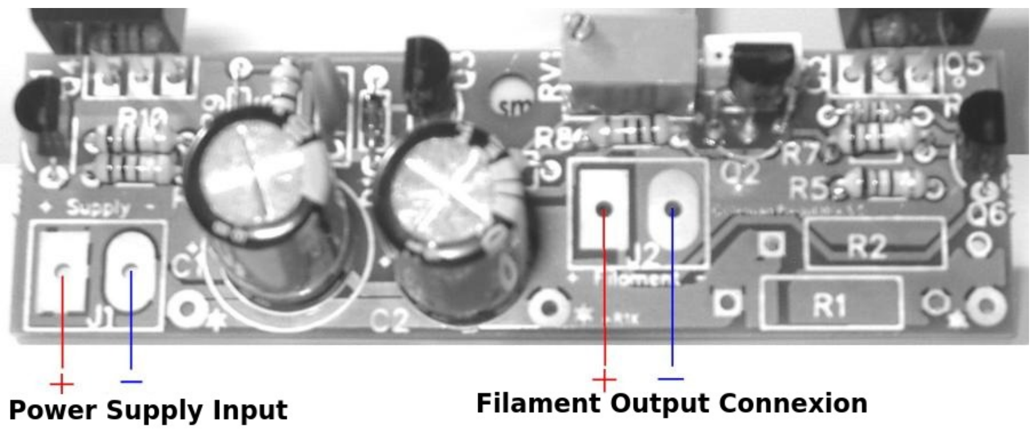
**WARNING (2):** Do not connect a scope probe Ground to the raw dc -ve (when the Regulator output is connected to System Ground, or a cathode resistor - or the same damage could occur.

**CORRECT PLACE FOR GND**: The Actual Filament is grounded if you have fixed bias, or the Cathode-Resistor is grounded if you have Auto-bias.

Connect GND [or cathode resistor] to the tube socket terminal FIL+.

Heatsink is Grounded. The heatsink should be connected to chassis and GND, since the output transistors of the regulator are isolated.

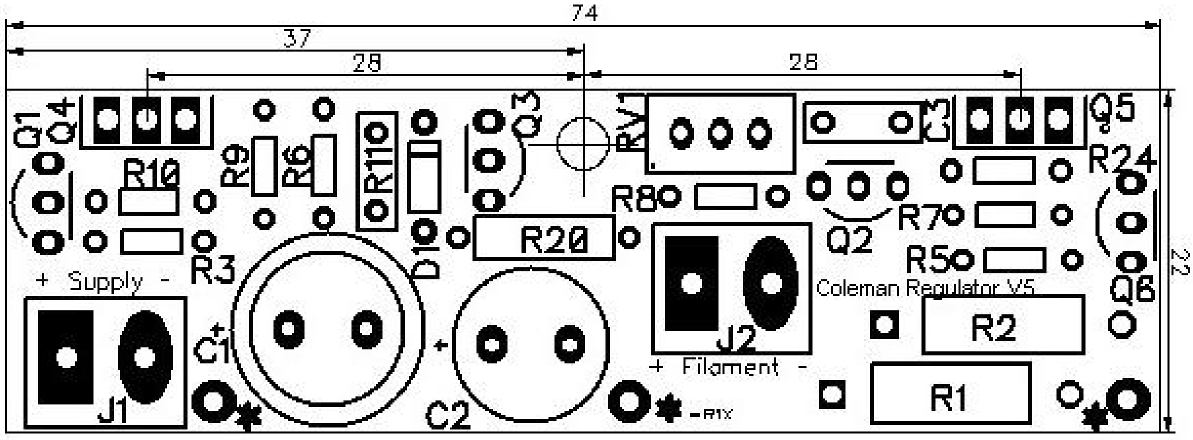
The Wiring Connexions at the regulator can be seen in the photo, to help confirm +ve and -ve, for Supply and for Filament wiring:



**Mounting The Regulator**

Mounting Position: Choose a mounting position that gives access to suitable heatsinking, wiring lengths [see CONNECTING paragraphs]. Also, take care to see that the PCB area has some airflow or ventilation holes. **Do Not Mount such that heat from R1 plays onto the PCB, - ie mount with R1 facing UP.**

To attach your regulator to the chassis and heatsink, see the drawing below:




Drilling: Hole for mounting the PCB is diameter 3.3mm, to allow fixing with M3 screws. Heatsink: holes for the heatsink should be 3.3mm for isolated TO-220 transistors (low current version); 3.7mm for FET versions (eg Transmitting tube) Drill 56mm between centres for the heatsink holes (transistor mounting holes).

PCB is 1.6mm thick. Outline dimensions are 74mm x 22mm.

3 **Adjusting the regulator.** A trimmer is provided because all dhts draw a filament current which may vary from one sample to another. The Coleman regulator sets the CURRENT through the filament, but the data sheet usually specifies the VOLTAGE that must appear across the filament. Therefore, you will always have to adjust the current *until the tube's proper filament voltage appears at the tube socket terminals.* Do not try to set the 'nominal' current shown in data sheets – unless you have and STC 3A/109 triode which has a defined current of 250mA.

Start by turning the trimmer fully anticlockwise [minimum current]. It has 25 turns, to give high precision in adjustment.

Double check all the wiring to the filament, and to the dc supply. Connect a voltmeter across the filament – *measure right at the Tube Socket terminals*. Connect a second meter to the raw dc supply. Apply power to the filament supply. Adjust till the voltage across the filament is a little below the data sheet value. Double check that the raw dc supply is within limits – measure at the regulator's input.

Apply B+. Allow to warm up, and monitor the filament voltage. Filament current *may change a little as the anode current rises*, and adds to the filament current! Keep the adjustment trimmed. Keep monitoring the current, and also the supply voltage - **it is vital that the supply voltage is in the correct range for the regulator.**

Temperature Effect: This is minimized by compensation circuit components in the Regulator. ALWAYS READJUST, if swapping new or different dhts into the tube socket.