Coleman Regulator - DHT Filament Regulator

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**** Read this Note with the PCB Assembly document - see lyrima.co.uk/doc/v8**

WARNING - High Voltage:

Installing this module involves work on equipment carrying High Voltage that can be instantly lethal. The Regulator Supplier does not accept responsibility for any damage or injury of any sort.

1. General Description of the Coleman Regulator for Filament-Heating.

The Coleman Regulator is a purpose-designed Regulator for heating Directly-Heated Electron Tubes. It differs from general-purpose voltage regulators in a number of ways:

1.1. **Control-loop of the Filament Heating power is highly isolated from the music-signal** across the Filament. ***Explanation:*** The Bias voltage of a DHT is skewed by the dc (or ac) filament-heating voltage (example: 5.0V for 300B). This skews the anode-cathode current flow (and gm) toward the +5V end of the filament, where the effective bias (Vgrid-cathode) is lowest. These effects in turn skew the music-signal to be greater at the +5V end of the filament, and so we find a signal voltage forms across the filament terminals. A voltage-regulator cannot distinguish between the feedback and control of the heating voltage (+5V dc) and this music-signal: the control-loop of the regulator will try to cancel-out the music-signal with the low output-impedance of the voltage-regulator. This dissipates some of the anode/plate-signal power, and seriously degrades the sound-quality of the DHT amplifier.

1.2. **Output is a current:** The Coleman Regulator controls current, to avoid this problem, and the control and feedback are not sensed at the filament terminals. The regulator improves the isolation-performance with circuits to separate the control loop even further.

1.3. **Adjustment**: Most DHTs are specified for voltage across the filament. This must be set *exactly*, for long life of the filament emissive-surface. The Filament Current flows in the Filament's Resistance to give a Filament Voltage Vf. The Regulator has a trimmer potentiometer, which must be adjusted to achieve the rated Filament Voltage - measured across the Filament Pins. A 25-turn trimmer gives easy and precise adjustment.

1.4. **Temperature-compensation:** The regulator is temperature-compensated to achieve low drift.

1.5. **Ultra-Low Noise.** The regulator does not use noisy bandgap reference diodes to establish the correct heating power. Discrete transistor design allows the lowest possible noise in the output. The result is measured noise level of 1-12µA rms 20-20kHz (2A heating); giving microvolt-region noise across the resistance of the filament.

1.6. **Wide-Range of voltage and current:** The Coleman Regulator uses discrete transistor design to allow voltages up to 32V at the input. High output voltages are possible: allowing **Filament-Bias** architecture to be used (See AN-Filament-Bias-Supply.pdf for working examples of Filament Bias).

1.7. **Transmitter and Receiver ranges**. Two versions are available, using the same PCB. A high-power **Transmitter** version for filaments with heating Power 10W and above. And a **Receiving-Tube version**, for 10W & lower filaments, having all-plastic power transistors, for easy heatsink mounting.

2. Integrating The Coleman Regulator into your DHT Amplifier.

2.1. **Raw DC supply:** The regulator is shipped without a rectifier or reservoir/filter capacitors, so constructors must build one.

2.2. The easy way is to use the matching *Raw-DC PCB, with diodes and some other components: please see:* lyrima.co.uk/rawdcV1/index.html

2.3. **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.: -5%, 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.

2.4. **Table 2.1: DHT Lineup with Raw DC Supply Voltages:**

Type:	**Filament Current**	**Raw DC Supply Voltage**		
DHTs	*[A]*	***Min [V]***	***Nominal [V]***	***Max [V]***
GM70; (20V)	2.7-3.3	23.5	24	25
845, 211, 813: (10V)	3.25 or 5	13.5	14	15
3C24 (6.3V)	3.0	11	11.5	12
PX25 (4.0V)	2.0	7.8	8.2	9
300B-XLS (5.0V)	1.8-2.1	8.5	9	9.7
2A3 (2.5V)	2.5	6.8	7.2	7.6
46	1.75	6.8	7.2	7.6
45	1.5	6.8	7.2	7.7
WE-300B; 300B	1.1 - 1.6	8.5	9.2	11
10Y, 801A (7.5V)	1.25	11.2	12	12.7
6A3, 6B4G (6.3V)	1.0	9.8	10.3	11
#26 (1.5V)	1.05	6	6.7	7.7
RE604	0.58	8	9	11
4P1L (2.1V)	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	10

2.5. **Raw DC Ripple Voltage.** The Coleman Regulator uses a pre-regulator to reduce the ripple from the raw DC supply. The acceptable incoming ripple for preamp use is ~ 100 -150mV peak-to-peak; 300mV for power stages is OK, but please remember that the MINIMUM voltage of the supply input is measured at the low point of the ripple voltage.

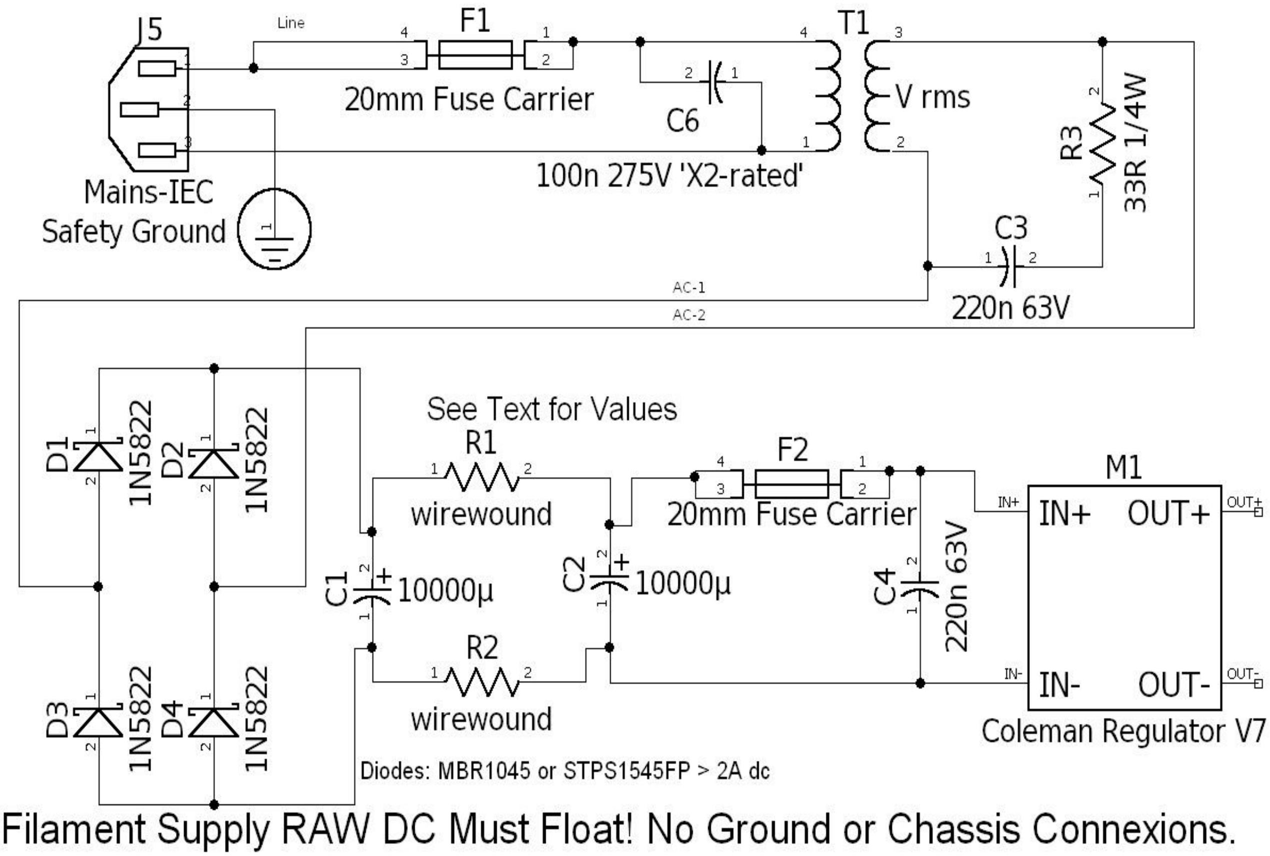
2.6. Raw DC Supply Design - PSUD2 Software. The suggested circuits given in this note have been worked out to give the right voltage for the Coleman regulators to work with. If you can build them exactly (or nearly) the same, the results should be perfect. But if you have different parts at hand, no problem – but please use the Power Supply Designer-2 Software (Web Search: Duncan PSUD2) to verify your design – *using a Constant Current load to represent the dht regulators.*

2.7. 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 close to their ratings, or they will have a short life, and may get hot. This applies to any DC heating scheme.

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

2.9. Separate Power Chassis? Transformers rectifier & capacitors can take up space, and cause electromagnetic coupling into signal wiring/parts. Mounting them in a separate chassis and connecting to the Amp chassis with 1 - 2 metres of cable (‘umbilical’) can work very well - the Coleman regulator is designed to work perfectly like this. Mount the Regulator near the tube socket, and put **all parts** of the raw dc circuit in a remote chassis, or separate case under the amplifier.

2.10. Schematic of Raw dc Supply:



ATTENTION: Wiring to Mains Supply - and High-Voltage Tube Amplifiers must be performed by persons trained in High voltage Safe Practice.

2.11. Table 2.2: Raw DC Supply Example Components: Diodes, Capacitors, Resistors. Transformer secondary voltage and VA-rating. Hammond Transformers can be obtained almost anywhere in the world, Hammond versions for each DHT are suggested; and I have added Some AnTek AS- series screened toroidals, which are an excellent choice.

DHT	**Raw DC (V)**	**Diodes 4 /channel**	**C1 & C2 (µF)**	**R1 & R2 Ω 2 /channel**	**Transformer** *RMS Ratings*	*Hammond:*	*Antek:*
01A, 71A	9.2	1N5822	4700 16V	0.33 5W	7V 1A	*266G14*	
4P1L	6.9	1N5822	4700 25V	0.68 5W	6.3V 2A	*266J12*	
6P21S	10.6	1N5822	10000 25V	0.68 5W	9V 3A	*266K18*	
26	7.0	1N5822	10000 25V	0.33 5W	6.3V 3A	*266K12*	
6B4G	10.3	1N5822	10000 16V	0.22 5W	9V 3A	*266K18*	*AS0509*
10Y 801A	12	1N5822	10000 25V	0.22 5W	10V 4A	*266L20*	
300B	9.4	1N5822	10000 16V	0.82 5W	9V 5A	*266M18*	*AS0509*
45	7.0	1N5822	15000 16V	0.15 5W	6.3V 5A	*266L12*	
2A3	7.1	MBR1045	22000 16V	0.1 5W	6.3V 6A	*266M12*	
3C24	10.3	MBR1045	22000 16V	0.05 7W	9V 100VA	*266P24*	*AS-1209*
845, 211 10V-3.3A	14.2V	MBR1045	22000 35V	0.15 7W	12V 100VA+	*185F12*	*AS-1212* *AS-2212*
GM70 20V 3A	24.5	MBR1045	22000 35V	0.15 7W	20V 8.8A	*185G20*	*AS-2220*
813 10V 5A	14.2V	**MBR1645**	22000 35V ***4 per ch.**	0.05 7W	12/12.6V 200VA	*185G12*	*AS-2212*

2.12. F1: 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.

2.13. C6: X2(Safety-Rated Mains Capacitor). Use this to reduce supply impedance at higher frequencies, and reduce mains noise. ***C6 Must be a safety-rated capacitor, marked X2.***

2.14. T1: Mains Transformer. Please use one transformer for each tube, or at least separate windings that are not electrically connected. **DO NOT share windings between L & R channels -** if you do, the effective cathodes will be shorted, which will give serious bias problems, and cross-talk.

2.15. Transformer VA rating should be generous in DC Heating. 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. Hum from the transformer core can be worse, if the loading is too high. A transformer with higher current rating has lower winding resistance. A rule of thumb: for each ampere of dc, choose 3-4A of rms ac-rating. The transformer's losses will then be smaller (I^2R losses in winding resistance).

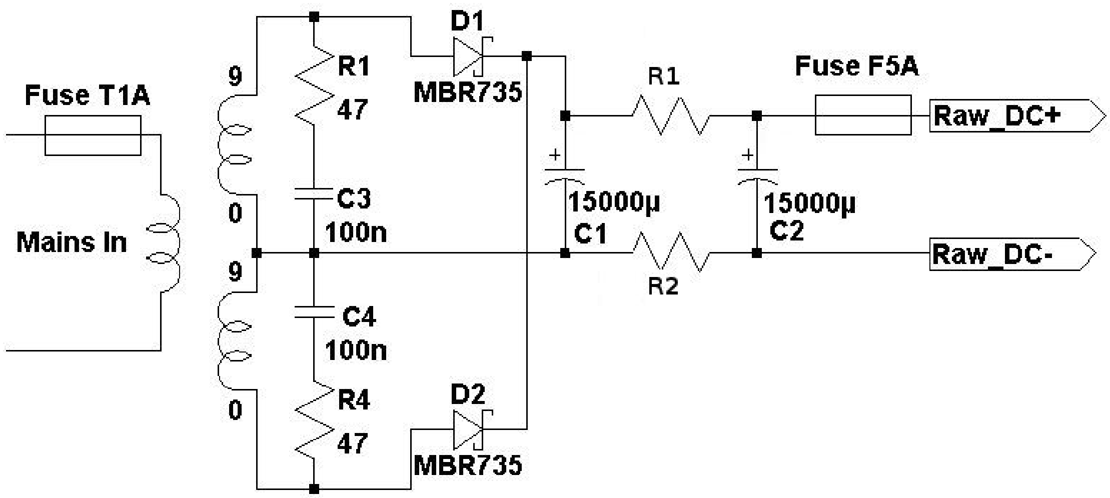
2.16. Choose a standard EI transformer, with split bobbin design. Unified bobbins (where the primary and secondary are wound on top of each other) are NOT recommended, (unless they have an inter-winding screen) as they will couple mains noise into the secondary. For the same reason, try to avoid a toroidal transformer, but again, when a Toroidal has an interwinding screen, like the AnTek AS-series, they are a good choice.

2.17. **Double-Isolating Trafo**. If you have one of these unsuitable types in the right voltage, though, don't buy another – instead, buy a 200VA or larger isolating transformer, or building site tool transformer (only one needed per pair). Connect one side of the isolating-transformer secondary to system ground, and you will get excellent isolation from mains noise.

2.18. **Snubber for transformer secondary (R3 & C3).** These damp the rectifier turn-OFF current pulses that resonate with the leakage-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.

2.19. **Rectifiers D1 … D4.** Schottky Rectifiers: For 2A dc and lower, use 1N5822 (ST and ON-Semi). Above 2A: MBR1045 (many vendors) or better: STPS1545FP. Be aware that the very short conduction-angle (from large capacitors) in this supply mean that the rms current through the rectifiers is high, so if you use other diodes, **please use PSUD2 to analyse the rms rectifier current.** You can use high-current rated rectifiers, but avoid high-voltage (60V+) diodes: the power-loss is increased.

2.20. **Full-Wave Rectifier.** If your transformer has twin secondaries, you can use a



full-wave rectifier, using only two diodes:

2.21. **Reservoir Capacitor C1**. This part must be chosen very carefully. For 1.0 - 1.3A DHT you can choose 10000µF, or 15000µF, giving lower ripple-voltage in the Raw-DC for each step up in value. However, this parameter is not so important as the Ripple Current rating. Unbranded/cheap capacitors may 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. If you use Windows/Linux(WINE) Software PSUD2 (Freeware by Duncan Amplification) you can check the value: **I(C1) rms** in your PSUD2 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 10000µF is needed to achieve a

Ripple Current handling of ~7A at C1. **Please remember:** your DHT heater is always working at 100% load, so 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 10000µF/16V or the Samwha HC series (3.32A at 10000µF, 4.5A at 15000µF). "Audiophile" parts not necessary. Multiple small capacitors are OK, example: 6 x 2200µF/16v Panasonic FM.

2.22. **Capacitor Voltage Ratings** should be chosen to support the maximum peak voltage from the raw dc supply. Leave some safety margin. For 26 and 4P1L, filament bias is a possibility, so 25V or 35V parts are recommended, in case you want to try it.

2.23. **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.*

2.24. **C2.** Carries lower ripple-current than C1, but use the same 10000 - 22000µF.

2.25. **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 typical 1.0A dc filaments, 2 pcs of 0.33 - 0.47Ω should give the right output. Buy a number of each of these to try – low cost wirewound resistors are OK - rated at 3W, 5W, 7W.

2.26. **F2: 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 and start a fire. Do not take this risk – use a FAST (*Flink*) = *F-rated* fuse in the position shown.

2.27. **Example DC Fuses**: 20mm F3A (or F3.15A) would be a good choice for the <1A models; F5A for 2A filaments, F6.3A for 3-3.5A.

2.28. **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. Listening tests should guide to whether they are needed – this may depend on the Noise on your mains supply, or Radio Transmitters nearby.

3. Heatsinking.

Heatsinking is required for all versions of the regulator. Do not power the regulator - even for a short time, with no heatsink for the Power transistors.

3.1. **Power Dissipated** in the Regulator Transistors. Transistor Q4 (gyrator) dissipates about (1.40V x Fil-current Amps) in Watts - 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.

3.2. **Finding a Suitable heatsink:** Heatsinks are specified by their Thermal Resistance (K/W: Kelvin per Watt = °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 50°C, and preferably less.

3.3. 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:

3.4. **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!

3.5. **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-plate used. For heatsinking. If the base is used, be sure to allow circulation of air underneath the chassis – use feet 25mm (1") high, or more.

3.6. **Test your work:**Try to measure the temperature of the transistor Q5. A thermocouple-probe is perfect, and many low-cost digital multimeters have a thermocouple included. If buying a new meter, be sure to get one with this feature.

3.7. **Area of Chassis**.If you use a large area of chassis, 3-5mm thick, and more than 200mm x 100mm (8" x 4") in area, the transistors should be cool enough to touch with your hand. If you can touch the transistors for 10 seconds without burning your fingers, the heatsink is good.

Example: a regulator was set up to supply GM70 filaments running 3.3A, mounted on Alu plate 275mm x 100mm (11" x 4") area. Temperature reached about 45°C over 4 hours.

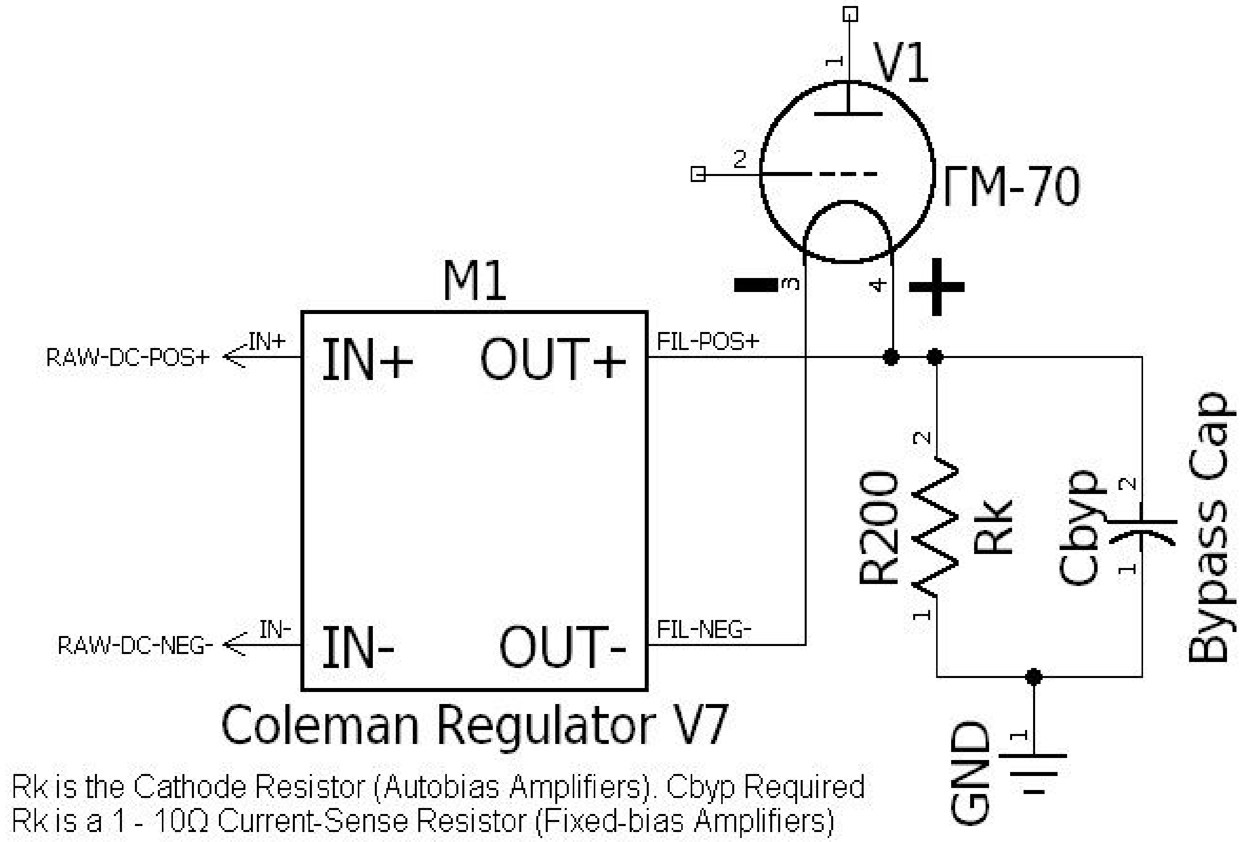
3.8. **Heat Spreader Bar**. For 2.5A+ filaments: 2A3, 845, GM-70, use of a "spreader bar" is recommended. Many eBay sellers offer Alu bar in 6mm or 10mm thickness. Buy a length of this [the cost is very low] and mount it between the FETs and the chassis/heatsink. This is especially useful in dealing 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.

3.9. **Fischer Elektronik** offers many excellent heatsinks of different form-factors, and are widely available (Farnell, Newark, Allied, RS, Rapid (UK), TME (Łódź).

3.10. **KM100**. For low power filaments, see the **KM100 (Maker = Aavid Thermalloy)** clip-on heatsink. Fischer Elektronik have many different shapes of clip-on heatsink, and it is worth taking some time to look through their range.

3.11. **Combination** of Sheet-metal area with a finned heatsink attached near the regulator (other side of the sheet) will also work well.

4. Connecting Your DHT to the Regulator. Connecting your new regulator to the DHT is very simple, see the schematic below:



4.1. **This connexion to the filament** does not follow the traditional pattern of creating a centre-tap (eg from two resistors) and connecting the cathode resistor (Autobias Amplifier) or 1-10Ω current sense resistor (Fixed-Bias Amplifier) to this centre-tap. This method can be used if desired, but the sound will almost always improve with the wiring method shown in the diagram.

4.2. **Explanation**: A 'centre-tap' of resistors is used in most DHT amplifiers, because it gives good cancellation of noise conducted by the filament heating-current. With ordinary dc heating, the centre-tap provides important reduction in noise. But with a purpose-designed current-driven Filament Regulator, the noise is so low that this noise-rejection is not necessary. The noise level from the Coleman Regulator varies a little with the heating power, but below 2A the measured noise is in the region of 1-12µA rms 20Hz-20kHz (multiply by filament resistance to obtain the noise voltage). This noise level is not perceptible even for high-gain RIAA phono-stages, and so the extra noise-rejection is not required.

4.3. Comparative listening tests usually show a preference for the use of the FILAMENT + side of the filament used as the return-path for the cathode-current. Please feel free to experiment with other connexions (centre-tap, FILAMENT -) as return paths, but note that the bias is affected: the DHT is biased 5V hotter (more anode current) for FILAMENT + (5V filaments). Please adjust the grid bias or autobias resistor value, before testing.

4.4. The 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 tube's filament inputs are symmetrical, and either Pin can be +ve or -ve. Some battery-dhts may be polarised, though - check the data sheet to be sure.

4.5. Wiring: Guidelines for Lengths.

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

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

4.8. **Raw-DC wiring** from rectifiers/capacitors to Regulator's board: you can make these up to 2 metre long, and mount in a different chassis.

4.9. **Regulator Output to tube socket:** Keep to 200 .. 250mm (8 - 10")

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

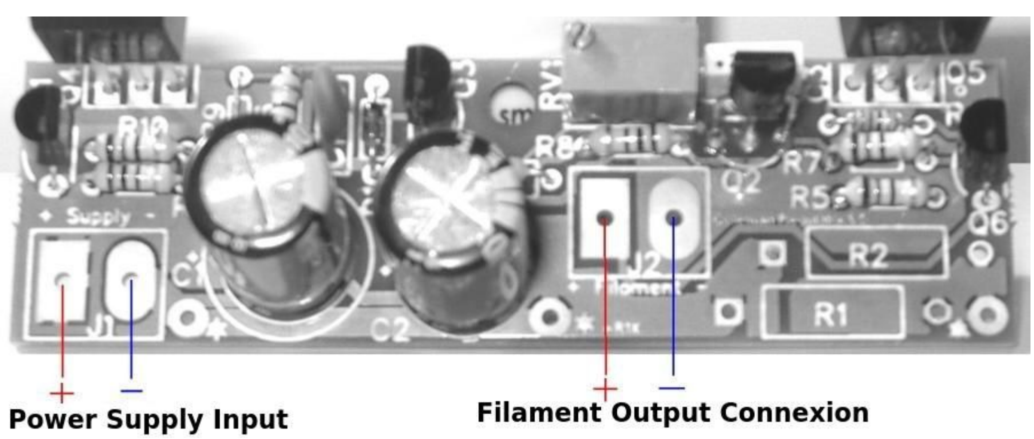
4.11. **VERY IMPORTANT:** Do NOT Connect Ground to the negative of Raw DC supply.

4.12. **WARNING (1):** ***Do not connect the Filament Raw DC (-ve) to the system GND. The Raw dc supply should be floating.*** A connexion, or leakage-current, from Ground (the high-voltage 0V) to Raw dc Negative could bypass the current control of the filament, and damage your dht, and/or the regulator. **Check with a meter before powering ON.**

4.13. **WARNING (2):** Do not connect an Oscilloscope probe (or other instrument) Ground - which may be connected to Safety Ground - to the raw dc -ve … or the same damage could occur.

4.14. **CORRECT PLACE FOR "GND"** Should call this 0V(HV) - the Anode/Plate supply 0V. The Filament+ is connected to 0V(HV) if you have fixed bias; with Cathode-bias/ auto-bias the cathode resistor connects to Filament+ at one end, and to 0V(HV) at the other end.

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



4.16. **Starting the Filament Regulator for the first time.** The Regulator will have been tested with a dummy load (resistor) when you assembled it (See the ASSEMBLY PDF manual). Now that it is connected to the filament of the tube, you can apply power to the regulator - but the Anode/Plate supply (B+, High Voltage) must remain OFF for this first test.

4.17. **Adjusting the regulator: Background.** The Regulator is fitted with a trimmer (potentiometer) 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 rated filament voltage appears at the tube socket terminals.*** Do not try to set the 'nominal' current shown in data sheets – unless you have a some original WE tubes (example: 101D-104D) or STC 3A/109 triode which has a defined current of 250mA. These early filaments defined a rated current, rather than the more usual rating of Voltage to define the heating requirement. You can measure the Filament Current by measuring the voltage across R1: I=V(R1)/(R1||R2 Ω).

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

4.19. 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.

4.20. **Now Apply Anode/Plate supply (B+)**. Monitor the filament voltage continually. Filament Voltage *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 (see Table 2.1).

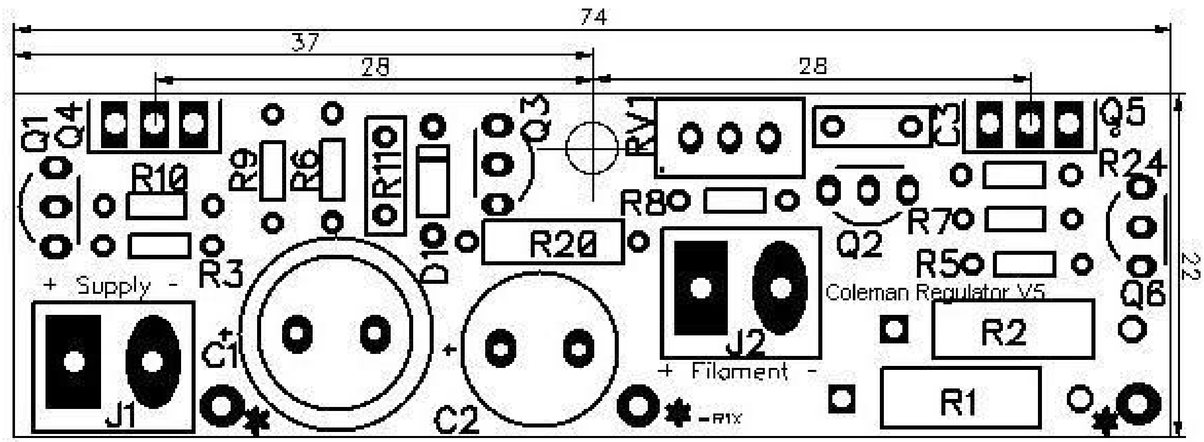
4.21. Temperature Effect: This is minimized by compensation circuit components in the Regulator. **ALWAYS READJUST the Filament Voltage** if swapping new or different DHTs into the tube socket.

4.22. **Startup Sequence of the amplifier in normal use**: The bias of the amplifier should be sequenced up, each time the amplifier is started. The DHT should NOT be biased at normal/high anode-current when the filament is only half-warm, or the emissive surface of the filament will be damaged. This damage may not be easily detected, but the lifetime of the tube is at risk. The safest method is to apply a high negative bias to the DHT grid so that the anode/plate current is at (or nearly) zero mA. This bias should be held until the time when the filament voltage reaches the rated value.

5. Mounting The Regulator

5.1. **Mounting Position:** Choose a mounting position that gives access to suitable heatsinking, wiring lengths (see CONNECTING Section 4). Also, take care to see that the PCB area has some airflow or ventilation holes. **Do Not Mount such that heat from R1 convects onto the PCB - mount with R1 facing UP.** The position of R1 can be changed to meet this requirement, and the wire-length of R1 can be extended to 25-35mm on each side, without problems.

5.2. **Drilling and Mounting drawing:**



5.3. **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).

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