Ice ‘n’ Lemon Instrument Amplifier
Part 3

This is an appropriate time to remind would be constructors to respect mains electricity, and that the paragraph in red at http://www.iceamplifiers.co.uk should be considered closely before continuing. It should also be noted that this document assumes a 240V (+6%, - 10%) 50Hz supply.

Formalities aside the construction of linear power supplies is something a first year undergrad should be able to tackle competently. Undergraduate texts such as “The Art of Electronics” by Horowitz and Hill published by Cambridge, covers everything ‘you’ are likely to need to know about linear supplies.

The supply documented herein is designed to operate the ice ‘n’ lemon power amplifier. A general schematic for an unregulated design may look like:

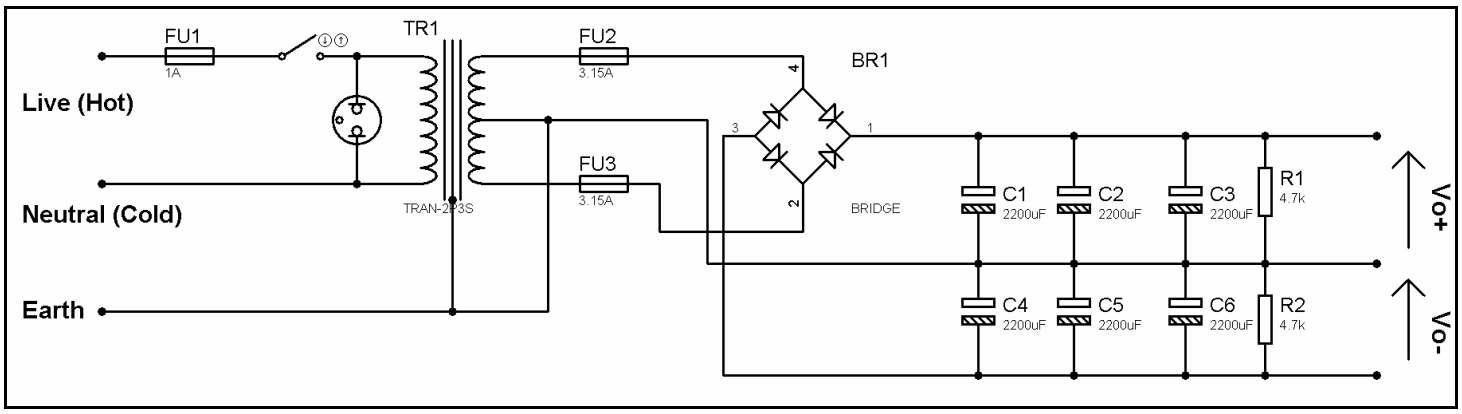


Figure 1: Unregulated Linear Power Supply

From left to right: the fuse FU1 is a line fuse. It protects the supply from itself, (consider the effect of shorting the primary of TR1 without FU1) I used 1A. The switch is a single pole single throw high current toggle switch. DPST’s are unadvisable here be used here. To see why, consider a DPST with a pole and throw in the live and a pole and throw in the neutral. If the armature of pole/throw in the live line failed closed, the equipment would be off, as the neutral pole/throw would still be open, however if the unit is under examination at such a time then the person doing the examining would expose themselves to the transformer which would have a live tapping and one leg of the neon lamp would be live and so would the switch and the fuse. You only have to slip once…

The neon discussed earlier is there only because I prefer them to LEDs and it seems a little wasteful to use a filament lamp. Although, if this supply was for a valve amp it would be more logical to use a 6.3 Volt bulb. Neon’s tend to have strike voltages around 95 Volts and an internal resistor to drop the rest of the

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supply. They are normally marked as 220 ~ 240 AC. Neons used to be used in HF oscillators due to their inductive nature. This poses the question of weather connecting neon across the supply will worsen the noise on the supply… I can't say as I haven't experimented. Although I do know that this amp sounds just fine, in my humble opinion…

In this supply the amplifier being driven supplies to its load a *peak* voltage of 17.88Volts and under this condition will draw to its output 2.235 Amps.

The transformer that we wish to use should step the mains (240Vrms) down to a safe more useful working voltage of say 20Vrms. This decision is based on experience, but the following considerations are always made. In this supply the output voltage will be the peak valve of the secondary winding, as the capacitors will charge to the peak value. The supply will collapse somewhat due to the load applied to it, this will exhibit itself as ripple. The VA rating of the transformer is proportional to the current and voltage and the phase between these two it is required to deliver from all of its secondary winding(s) or The VA rating of the transformer is proportional to the current and voltage and the phase between these two it will sink into all of its primary winding(s).

We don't know the power factor of the load. (The power factor is the angle between voltage and current waveforms) there is little point in guessing. The usual method is to assume that the power factor is 1. Doing this makes VA and Watts identical, real and reactive power become the same. We can then see that the peak power that will be delivered to the load is approximately 40 watts (17.88 * 2.235). And there are two secondary windings… therefore an 80VA transformer is ***my*** definition of a minimum. In this design a 100VA transformer was used.

Guitar amplifier manufactures like to under rate their transformers spectacularly because they are one of the most expensive parts. Music tends to have a high peak to average ratio. For example occasionally there will be a base drum beat and significant power will be developed in the load, however for the most part the power developed, due to say vocals and guitars is much lower. By this thinking, amplifier manufacturers traditionally under rate their transformers by about 30%. In which case a 56 VA transformer would be used. Note: this is only possible in Class AB and B operation. In class A the full load current flows continuously. There is a further reason for not under rating substantially that applies especially to toroidal transformers. Due to the continuous nature of their core, as apposed to EI that have minute gaps… The average flux density at which a toroidal core will saturate is lower than a core that has some air gaps. (Any air gaps will have a larger reluctance than the probably silicon steel core this will lead to a lower average flux density) When the core saturates many harmonics of the supply frequency are generated. It is common for these to find their way into supply lines and the audio pathway. If enough high frequency harmonics are generated it's not inconceivable that it could pose an EMI problem.

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There will be some ripple on the DC side of the supply due to the limitation of the value of the smoothing capacitors. An equation for calculating the ripple for a half wave rectifying supply is

$Vr = (I \times t) / C$

Where Vr is the peak to peak ripple voltage, I is the peak load current t is period between refreshes of the smoothing capacitors, and C is the capacitance in Farads. We would like to know the value of capacitance required so rearranging the formula leads to

$C = (I \times t) / Vr$

Let us decide that we will allow 7 volts peak to peak ripple on our supply line.

$C = (2.235 \times 0.02) / 7$

$C = 6358$ uF (micro Farads $x10^{-6}$)

This is a rather large value and we can't buy it so let us use 3 x 2200uF, giving 6600uF. It is important to use capacitors whose maximum working voltage will not be exceeded. I used 35Volt types. It is also wise to look into the maximum ripple current. for the type I used from rapid electronics the maximum ripple current was 1700mA. There is normally a factor involved that is proportional to the frequency of operation for 50Hz it is 0.85. so the permissible ripple under the operating conditions that we have is 1445mA. I estimate the ripple current to be, under the worst condition 555mA. Sometimes it is necessary to look at the temperature of operation however it is safe to assume given that in this amplifier the supply is not mounted near any major heat generators that 85°C types will surface.

We are now left with the bridge and the secondary fuses. The secondary fuses are relatively obvious, the transformer is expensive. If for example you should accidentally connect the rectifier wrongly and the secondary is shorted, significant heat will be generated in the secondary winding. The chances are that FU1 will blow and no damage will be done. But there is nothing wrong with a little extra protection.

The bridge could be a sealed unit or possibly a set of four discrete diodes. The choice is yours. I used 4 x 1N4937 which their datasheet specifies them as 1A continuous 30A non repetitive surge 600V RRM. That is really all you need to know. The average current in the any given diode at a suitably long time after switch on and under full load conditions is by spice 1.014A and the spikes are around 12 to 13 Amps. However if preferred you could work out the angle of conduction and find the peak current, then by integration find the average. But spice is just easier. The model comes from the Diodes Inc website and the

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transformer was modelled as two voltage sources with series resistance of 0.1 ohm each. Wiring resistances were not considered. If you think I'm a bit too brave on this point well I guess you might be right, if so, put two diodes in parallel, but don't forget sharing resistors as the diodes won't have the same on resistance… alternatively buy a bridge. There are two other points. Not shown in Figure one is the line filter which I used, it's part of the IEC connector. These are specifically designed for this purpose; just about every component outlet carries them. Secondly, larger power supplies may give EMI trouble due to the rectifier diodes switching, this produces current spikes. Some people like to fit suppression capacitors directly across the legs of the diodes to avoid this.

So far we have considered an unregulated supply. This is very useful for a power amplifier with reasonable to good PSRR. What about a preamplifier? Well most people would agree that linear regulation is essential for pre amps. I find the LM317 and LM337 1.5A (max) variable voltage (1.2 – 37) regulators suitable for this application. They are manufactured by ON Semi and National and possibly others. Sadly the ON and National Pin assignments are different. This caused me great confusion and I blew up the first few devices as I had a mixture of makers. I now use the ON devices as I had more of them to start with. Which ever you use make sure you've got the right datasheet! Figure 2 is adapted from the ON Semi data sheet, with some changes that I feel are necessary.

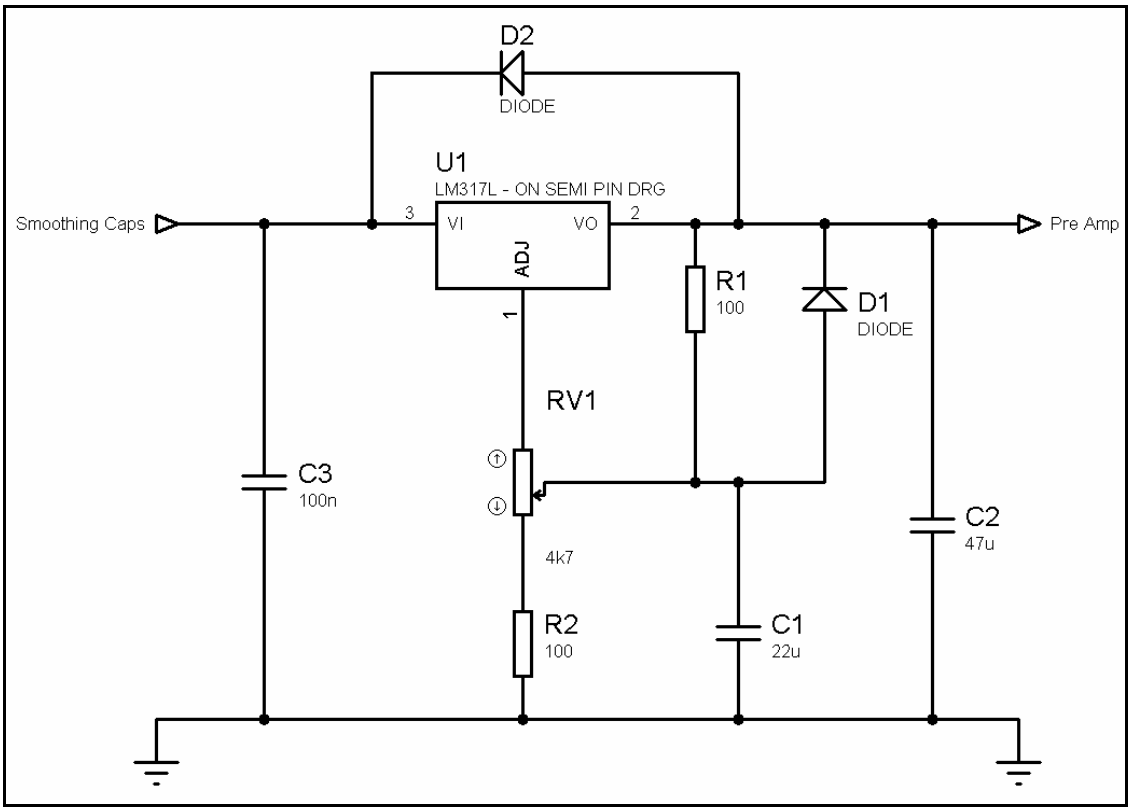


Figure 2: Adapted from ON Semi datasheet

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In the on semi datasheet there is no resistance R2. Under this condition it is possible for significant current to flow in to ground through RV1 if the wiper makes the resistance to earth from the lower leg of R1 nearly zero (by being at the bottom of its range in Figure 2) then around 12.5mA will flow through the wiper on the pot, if like me you use trimpots with carbon tracks you will notice smoke and possibly a small flame under this condition.

This normally renders the trimpot useless, except perhaps as the world's smallest back scratcher if it is attached to a long thin rod. Assuming of course the legs are at 90° to the largest flat surface… to which you would logically glue the rod... anyway…

The solution is in ***my*** case a small resistance R2. The addition of R2 makes the minimum regulated voltage rise to 2.51 Volts however this is not a concern as no Op-Amp runs in the conditions that we desire from anything like that low. It is conceivable to raise R1 sufficiently to make the current flowing in RV1 (when its resistance (wiper to ground) is nearly zero) such that it doesn't cause RV1 to dissipate excessive power. However the actual resistance of RV1 when it is in this position is given by the contact resistance of the wiper and the track end (in my case both are metal). This is ill defined and a meter won't measure it very accurately. There is another reason to keep R1 small, a constant current leaves of pin 1 of the regulator, this constitutes an error term. Raising R1 makes the error more significant. For a full appraisal of the situation read the datasheet. You may then draw your own conclusions. The above circuit was implemented, and it works. If the regulators are only powering the preamplifier laid out in the first document then they will not require heatsinking.

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