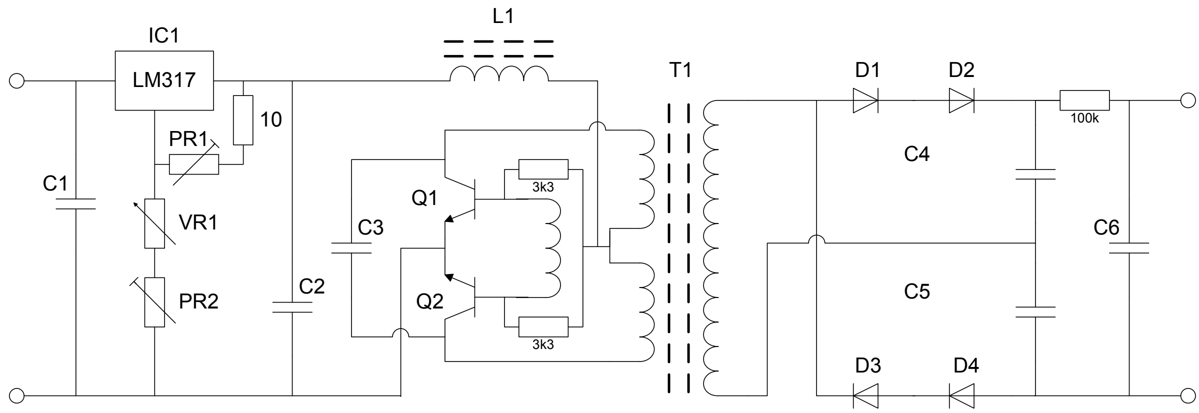
G8RPI CCFL BASED HV SUPPLY

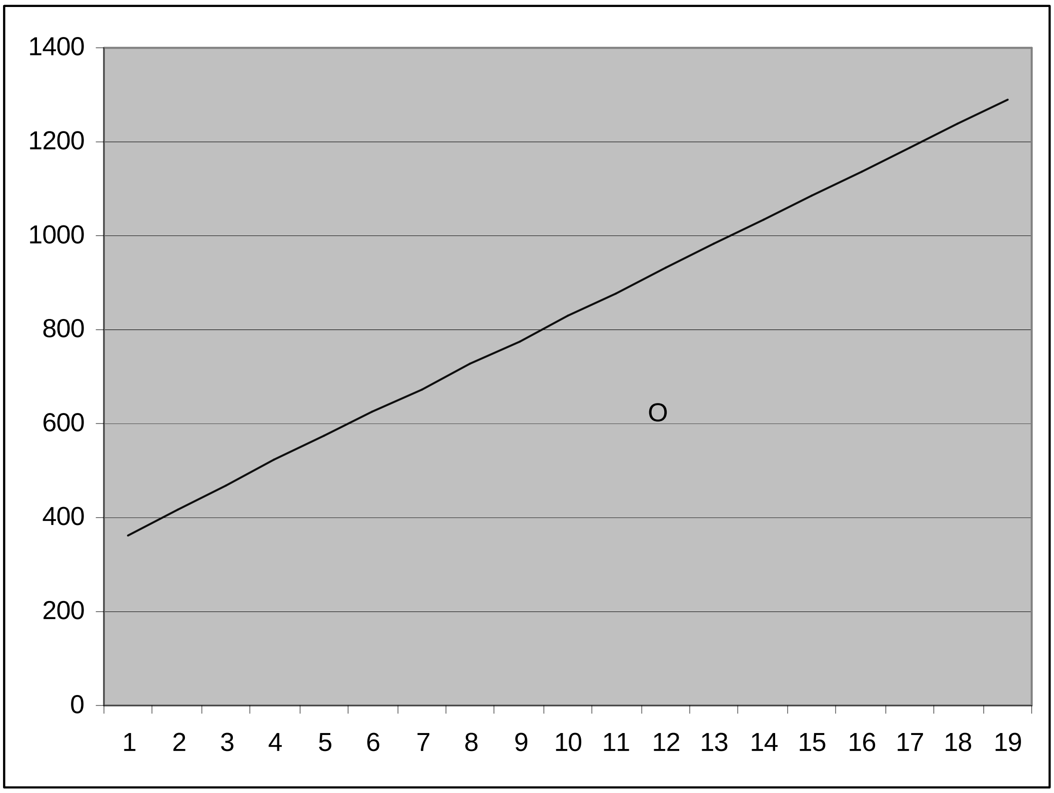


This design, while it looks simple, is based on much research and testing. It utilises components from a 12V input, two tube output, CCFL inverter of the type used for PC case modifications. These are available on the internet and ebay. In the UK Maplin sell a suitable unit, stock number A49GN http://www.maplin.co.uk/cold-cathode-invertor-99522 .

Inverter/doubler section.
The transformer, transistors, input choke and resonating capacitor from the CCFL are used. A full wave, balanced voltage doubler is connected to the transformer secondary in place of the original CCFL tube and ballast capacitor. Pairs of diodes in series are used as 1000V fast rectifiers are easier to obtain and lower cost than 2000V. It also reduces the capacitance. I use UF4007 or FR107 1000V 1A fast diodes. Lower current devices can de used but due to popularity the 1A units are cheap and easy to find. Output capacitors are 0.01uF (10nF) 2000V ceramic disc. The 100K resistor and C6 provide additional noise filtering. They can be omitted for GM tube applications. The transistors, resonating capacitor (C3) and input choke from the CCFL are re-used. Typical values are 2SD1616, 0.068uF and 270uH. The transistors need low VCE(sat) for good circuit efficiency.
The circuit configuration is often called a “Royer” inverter. This is typified by the use of a resonant symmetrical circuit and input choke. However Royer’s design (which was for a valve oscillator) was predicated on the saturation of the transformer core to provide switching. Most modern designs use resonance to switch. Saturation gives a square wave output which is much noisier than the sine wave produced by this circuit.
The circuit is operated at lower voltage than the original 12V. Typically less than 4V is required at the input to the inverter (L1) for 1000V output. This ensures linear operation, on core saturation and low noise. In this mode the output of the inverter is proportional to the input voltage over a range of 4:1 or more. Changing the voltage at the input to the inverter allows the output to be set. Figures recorded with a Maplin transformer are shown below.

Input Voltage	Output Voltage	3.2	829
1.4	362	3.4	878
1.6	415	3.6	931
1.8	466	3.8	983
2	525	4.0	1035
2.2	574	4.2	1085
2.4	625	4.4	1137
2.6	673	4.6	1188
2.8	727	4.8	1239
3.0	776	5.0	1291

This gives an input to output voltage ratio of 259:1. The output is plotted below. The slight waviness in the line can be attributed to input voltage setting accuracy. I was using a PSU with 1.2V to 15V range on a single turn pot. The same unit gave 2000V out for 7.75V in, maintaining the ratio within 0.5%. These figures were measured with a 10M ohm load.



OUTPUT voltage for 1.2 to 5V input

To check regulation the output was set to 1500V with a 10M load (150uA). With 3M3 in parallel (2.48M, 6mA) the voltage dropped to 1436V a change of 4.2% for load change of 4000%. This is of course a high load current unlikely to be seen in our applications. For a reduction in load to 1000M (voltage divider probe) the voltage increased to 1528V a 1.9% change.
Ripple was measured at 0. 05mV at 49kHz with a 10M load.
This is very acceptable output performance for our uses.

Current consumption at 1500V with a 10M load was 80mA. This drops with lower voltage and load. One unit I have figures for was 20mA at 900V and 1000M load. If you are running at a fixed voltage and load it may be worth adjusting the resonating capacitor value for lowest supply current. This is not quite as easy as it sounds as the resistance of the meter affects the circuit. I recommend measuring the current at the input to the LM317 regulator. Start by adding a small (0.001 film) capacitor across the existing C3. If efficiency goes up (remember you may have to adjust the input voltage and recalculate if the output voltage changes) add a bit more. If it goes down, switch off, change C3 to the next lower value e.g. 0.047uF, turn back on and start adding capacitance until you find the optimum. Increasing the value of the bias resistors can also help power consumption slightly. 4.7K or 5.6K is normally OK but starting may be affected depending on the gain of the transistors. Using a switch mode regulator at the input in place of the LM317 would also help if you want peak performance.
Test equipment used included a Fluke 80K-40 HV voltmeter probe and a HP P6015 EHT oscilloscope probe.

INPUT/ADJUSTMENT SECTION.

This is just a standard adjustable DC supply. I use the LM317T as it's cheap and easy to apply. It basically maintains its output at 1.25V higher than the adjust pin. This also means a fixed current flows through the adjustment resistors (set be PR! And the 10R in this design) The two preset resistors are there to allow adjustment of the offset and range of the main variable control when used with a 10 turn dial. If you just want set and forget with minimum current, leave out the presets, use a 4K7 preset for adjustment and change the 10R resistor to 1K2.
Otherwise VR1 is 1K, PR1 and PR2 are 500R.
Using a 10 turn potentiometer and dial allows us direct readout in voltage. Handily most of these dials actually go from 0 to 15.0. If for example we want a range of 400V to 1400V (there are 10 turns on the pot so we will always have a span of 1000 for direct reading) the following procedure applies.
1/ from the data above we need about 1.6V for 400V out and 5.4V for 1400V (you may need to make your own input/output ration measurements as they vary with different transformers). This is a span of 5.4-1.6 = 3.8V. So we need 3.8V/1K = 3.8mA of current flowing through the pot to get this span. Therefore PR1 needs to be 1.25V/3.8mA = 330R less the fixed 10R series = 320R or a bit over half way to start with. PR2 needs to be (1.6v-1.25v)/3.8mA = 92R or about 1/5th of it's range. Wind the 10 turn pot counter clockwise to zero resistance, set the dial to "400" and fit to the 10T pot. The dial should now go from 400 to 1400. Set to 1000 and adjust PR1 for 1000V output. Set to 400 and adjust PR2 for 400V out. Set to 1400V and check output if needed re-adjust PR1 for exactly 1400V out, then go back to 400 and re-adjust PR2 for 400V out if necessary.