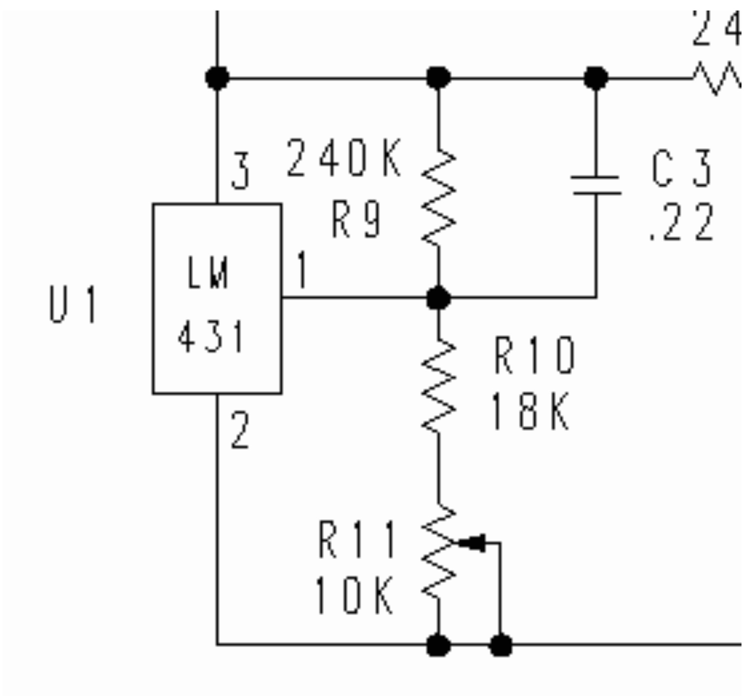
The formulas for R4 were updated at 7:22pm Feb,25 2002.

In this section I will try to explain more clearly how to choose values for the CCS circuits. The circuit reference numbers will be from the Rev 3 schematic.

R1. This is the easy one. We use Ohm's law and solve for "R". The formula is E/I=R. E=voltage I=current and R=resistance. The adjustment range of the voltage reference circuit gives us the range of 20.5 to 32 volts for "E". The mosfet needs about 3 volts for bias so this is why the range is lower than shown in the rev 2 schematic. "I" is the current you want from the CCS. Knowing the range for "E" you can choose a value for R1 that is within the adjustment range of the reference. Having the reference voltage adjustable allows you to use standard value resistors and/or vary the current to see what sounds best in you circuit. Try to choose a resistor that works in the middle of the adjustment range for best flexibility. Keep in mind that the current through the voltage reference part of the circuit has to be added to the current through R1. As this current is low it only shows up as a significant part of the total at low CCS currents.



When I refer to the voltage reference this is the part of the circuit I'm referring to.

Here are some values for R1 and the current range you can expect.

Examples

R1 Value	Minimum current in ma	Maximum current in ma
5000	4.1	6.4
3000	6.8	10.6
2000	10.25	16
1500	13.6	21.3
1000	20.5	32
750	27.3	42.6
500	41	64
350	58.5	91
225	91	142

R3. This is the ugly one. I have put together a formula that works but some of the time you have to guess at some of the values. R3=(B+)-(Vpl)-(Vref+Vb+Vs)/(Is+Ib) Definitions for the formula are listed below. What we are doing is adding up all the voltages starting at ground. By adding the plate voltage of the triode, voltage reference voltage, bias voltage of pentode, and the screen voltage required by the pentode we come up with the minimum voltage required by the circuit as a whole. This voltage isn't the real minimum as there has to be some voltage left to drop across R3. With the small pentodes like the 6AU6, 39-44, 6SD7 I don't think it is a good idea to have the value of R3 less than 20K ohms. The cathode of the pentode sees R3 as a load. With bigger pentodes like 6BQ5, EL34, KT88 you can go to lower values but still should not go below 10K. While experimenting with a 6BQ5 the voltage swing was starting to get limited when the value of R3 was less than 7K. With a low value for R3 the circuit ends up being very sensitive to power supply voltage changes.

Vb= Bias requirement for tube. See table below for ranges. Drop the - sign, i.e. -5 volts bias is Vb=5.

B+= Main power supply voltage.

Vpl= Plate voltage on the tube that the CCS is loading.

Vref= Voltage the voltage reference will be set for. Should be R1*I+3.5V. The 3.5 volts is the turn on (bias) voltage of the mosfet. Enhancement mode n channel mosfets like the IRF510 run with positive bias

Vs= Screen voltage. This is the screen voltage the pentode needs to be able to supply the current you want. If you have the plate curves you might have what you need. In the circuits I have built so far the screen voltages have run from 60 volts when the CCS was supplying 5ma to 135 volts when the CCS was supplying 50ma. The voltage requirement seems to be pretty stable over a wide range of pentodes.

Is= Screen current. If it is specified in the plate curves life is good. This is one we have to guess at often. At low CCS currents (5ma) it can be around 2ma going up to 10ma or more at higher CCS currents (60ma+).

Ib= Voltage reference bias current. This is the current going to the voltage reference. In the Rev 3 circuit it is close to .75ma, set by CR1. In the Rev 2 and earlier circuits use the formula Ib=Vs-Vref/R4 or assume that Ib=1ma and then choose the R4 value by the formula R4=Vs-Vref/1ma.

Suggested bias ranges

Tube
Suggested bias
6AU6
-.5 to -2 volts
6BQ5/EL84
-2 to –5 volts
EL34, KT88,KT90
-4 to –15 volts
Example for R3. 6AU6 set for 6ma. Assume Vpl=90 volts, B+=300 volts, Vb=1, Vref=33.5 (6ma, 5K), Vs=75 volts (GE data book), Is=3ma (GE databook), Ib=.75ma. 300-(90-33.5-1-75)/(3ma+.75ma)=300-199.5/3.75ma=26.8K. Be sure to verify the grid bias as outlined in next paragraph.

If data for screen voltage and/or screen current is not available you can start in the range of 33K to 47K. Measure the grid bias of the pentode. If it is outside of the recommended ranges shown above you adjust R3. Decreasing R3 turns the pentode on harder and causes the grid bias to increase. Increasing the value of R3 turns the pentode on less hard and will cause the grid bias to decrease. Even if you calculate out the value from the data you still need to verify that the grid bias is in the correct range and adjust the value of R3 as needed.

R4. In the Rev 3 circuit the value for R4 is determined by the need to have close to 40 volts across the CCS diode (CR1). The formula would be R4=Vs-40v/.75ma. In the Rev 2 and earlier circuits use R4=Vs/1ma.

Example for R4 Rev 2 and earlier. Assume Vs=90 volts. 90/.001=90K

Example for R4 Rev 3. Assume Vs=100 volts. 100-40/.75ma=80K. Verify in actual circuit and adjust the value of R4 up or down to get close to 40 volts across CCS diode. Not real critical, 25 to 65 volts will work and still have some range to handle power supply voltage variations.

R13. R13 is mostly for output stages. It keeps the mosfet from forcing the pentode into A2 operation and drawing grid current. If the pentode draws grid current it will pull down the voltage on C2 and upset the operating point of the triode. To choose the value for R13 you would need to know the gate to source voltage (Vgs) of the mosfet at the chosen operating current. The circuit can be setup and run with a jumper in place of R13. Measure the voltage between the gate and source (grid and cathode) of Q1. Use extreme caution making this measurement, especially on output stages as the CCS operates at very high voltages. I would suggest using meter leads that have alligator clips on them and connect both of them when the power is off. Power up amp, get measurement, power down amp, disconnect meter leads after you are sure the power supply caps have discharged. R13=(Vgs+.5V)/CCS current. The +.5V term is to guarantee that the pentode has -.5V bias during clipping.

Example for R13. CCS current is 50ma. Vgs is 3.5 volts. 3.5+.5/50ma=80 ohms.