A Voltage Controlled Amplifier

The object of this experiment is to assemble and test a voltage controlled amplifier (VCA) that might be used as a variable gain stage in a compressor, a limiter, or guitar effects box. The variable gain element in the VCA is a JFET operated in its linear or triode region. The basic circuit is shown in Figure 1. The drain-source voltage at the JFET is

$$v_{DS} = v_A = v_I \frac{R_2}{R_1 + R_2}$$

For op-amp circuits powered by $\pm 15\,\mathrm{V}$ power supplies, a practical upper limit on the peak input voltage is $12\,\mathrm{V}$. For linear operation of the JFET, its drain-source voltage should not exceed $V_{TO}/2$, where V_{TO} is its threshold voltage. Thus, a design specification for the circuit is

$$12 \frac{R_2}{R_1 + R_2} \leq \frac{|V_{TO}|}{2}$$

The circuit is to be designed so that it has unity gain when the JFET is an open circuit, i.e. when it is pinched off. This requires

$$R_1 + R_2 = R_3$$

In addition, the circuit is to be designed so that the maximum attenuation when the JFET has its minimum resistance is $26\,\mathrm{dB}$ (a linear attenuation of $1/20$). This requires

$$\frac{R_3}{R_2} \frac{r_{ds(\min)} \| R_2}{R_1 + r_{ds(\min)} \| R_2} = \frac{1}{20}$$

where $r_{ds(\min)}$ is the minimum drain-source resistance of the JFET given by

$$r_{ds(\min)} = \frac{1}{2\beta |V_{TO}|}$$

and β is its transconductance parameter. For your JFET, use the design equations above to calculate R_1, R_2, and R_3.

Assemble the circuit using a TL071, TL081, or LF351 op amp. Use $R_A = R_B = 10\,\mathrm{k}\Omega$. Apply a sine wave to the input and a negative dc voltage to v_C. Verify that that gain of the circuit can be varied between unity and $1/20$ by varying v_C over the range $V_{TO} \leq v_C \leq 0$. Do not apply a dc voltage outside this range or the JFET may be damaged. Remember that V_{TO} is negative. Once the circuit is operational, apply a triangle wave to v_I. Connect the x input to the oscilloscope to v_I and the y input to v_O. You should observe an approximately straight line on the oscilloscope whose slope can be varied between -1 and $-1/20$ by varying v_C. Note any curvature in this line. This curvature adds undesired distortion to the signal.

The next step is to linearize the circuit by feeding the voltage $v_{DS}/2 = v_A/2$ back into the JFET gate. The circuit is shown in Figure 2. When the output voltage of A_1 is negative, the gate-source voltage of the JFET is given by

$$v_{GS} = v_A \frac{R_3}{R_2} \frac{R_6}{R_5} - v_C \frac{R_6}{R_4}$$

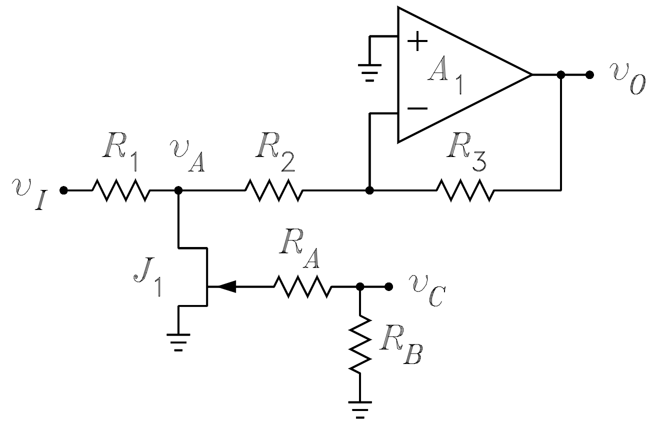

Figure 1: Basic VCA circuit.

The constraints on the elements are

$$\frac{R_3}{R_2}\frac{R_6}{R_5} = \frac{1}{2}$$

$$\frac{R_6}{R_4} = 1$$

With R_5 chosen to be some convenient value (e.g. $R_5 = 10\,\mathrm{k}\Omega$), use these equations to calculate values for R_4 and R_6. Use $R_7 = 10\,\mathrm{k}\Omega$. Note that there is no current through R_7 when $v_{GS} < 0$ so that this resistor has no effect on v_{GS}.

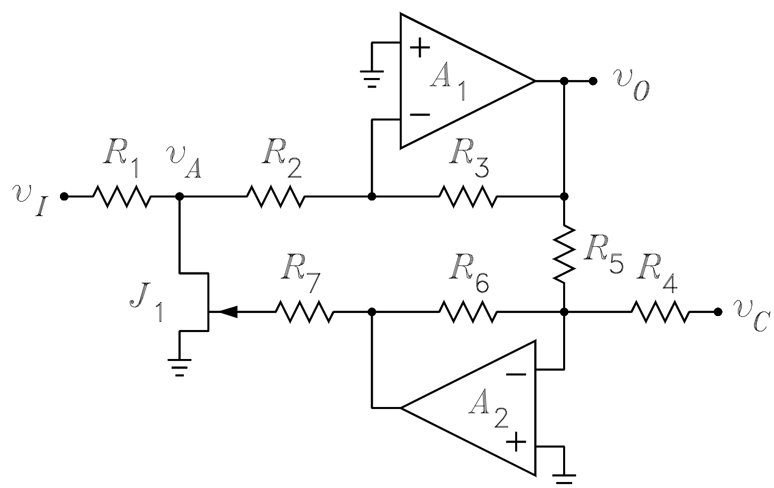

Figure 2: Circuit with the linearization voltage added to the JFET gate voltage.

Assemble the circuit in Figure 2 using the values calculated above. Note that v_C must be positive in this circuit because A_2 inverts the control voltage. Perform the same tests as for the circuit in Figure 2. In the following weeks, the VCA will be used as the control element in a compressor circuit. You should neaten up the circuit so that it occupies no more room on the electronic breadboard than is necessary. This is because the circuits to be added will occupy part of the breadboard.