Laboratory #9 (Optional with additional bonus): Design and build an AM Transmitter/Receiver

Prelaboratory

1 JFET: Junction Field-effect transistor
Please refer to the textbook by Sedra and Smith (Chapter 5) for the current-voltage characteristics. There are different types, and the one we are to use in this laboratory is called depletion mode, n-channel silicon JFET.

2 There are many types of JFETs. The one that we have in stock is 2N5457. Study the characteristics of this particular type of JFET and determine the biasing scheme. (The attached datasheet in .pdf format has it all.) That is, determine the voltages that you need to apply to the source, the drain, and the gate, in order to bring the operating point to the middle of the saturation regime.

3 Circuit analysis by PSPICE: The following circuit is an example, and you can and should design your own based on the PSPICE simulation results of yours.

![Circuit Diagram]

The first part is a voltage divider consisting of a resistor (R1) and a JFET (J2), whose gate is properly biased by a two-resistor R2. The gate of the J2 is connected to the modulation signal V_AM and we isolate its dc component by a coupling capacitor C3. The carrier signal (Vcarrier) is fed in from resistor R1. The output signal of this stage is taken out at the drain terminal of the JFET J2 and it is ac coupled (through C1) to another JFET, J3, which is biased in the “common drain configuration” or “source-follower.” The output of J3 is measured through the voltage drop across R5. The “source-follower” circuit characteristics are explained in the Sedra/Smith textbook as well. Please refer to it to understand why we use it here.

4 PSPICE simulation
Use PSPICE or similar CAD tools to simulate the transient behavior. For an example, see the figure below. The carrier is assumed to be 32kHz, with 1Volt amplitude. The AM modulation is at 1kHz, 0.5Volt amplitude. The output voltage (from the source-follower) is shown as a function of time. The envelope does vary and is synchronous with the AM signal applied to the
gate. After you obtain this simulation result, proceed by adjusting the input frequency and amplitude, and observe the output waveform change that it results. Explain why the output waveform’s envelop is asymmetric. Pick other component values to optimize your design.

5. Design the Receiver by using the following stages: (1) antenna plus amplifier to boost up the signal strength, (2) a diode rectifier, (3) a capacitor to filter out the carrier, and (4) a resistor to drain the current fast enough.

6. In your pre-laboratory report, put down your PSPICE simulation results and answer the following questions.

1) Read about JFET. For the following four types of JFET’s, draw the source-drain conductance versus gate voltage to show that you know how to turn the transistor on and off by applying a gate bias. (A) depletion-mode, n-channel; (B) enhancement mode, n-channel; (C) depletion-mode, p-channel; (D) enhancement mode, p-channel. For 2N5457, what are the proper (range of) voltages to the three terminals, if we want to perform linear amplification?

2) What are the three most important characteristics of a source-follower amplifier.

3) PSPICE simulation. Select a JFET first. DC-bias it by (1) shorting the source to common; (2) applying a sine wave (amplitude 0.1Volt, zero dc offset, 1kHz) to the gate; and (3) apply a dc voltage (e.g., 9Volt) to the drain and record the drain current. Demonstrate that the drain current is indeed controlled by the gate voltage. Next, insert a resistor in the drain branch (in between the drain and the dc voltage source) and see that you can read a voltage out of the drain terminal. The phase of this voltage should be out of phase with the gate signal. Change the value of this resistor and observe the effect. What’s the voltage gain?
4) Next, insert a resistor in the source branch (in between the source and the common) and see that you can read a voltage out of the drain terminal. The phase of this voltage should be in phase with the gate signal. What’s the voltage gain?

Actual experiment in the laboratory

1. Use the curve tracer in the ENEE417 laboratory (inner corner in the same room) to measure the three-terminal transistor characteristics of the JFETs first and compare what you observed with that shown in the datasheet. (They should be the same, within a few percent in discrepancy.) Select a few transistors for your team.

2. Wire up the circuit, measure the voltages at various nodes. Measure and record the dc voltages/currents everywhere. Compare with your PSPICE simulation result. If the difference is more than 20%, or when you judge that the measured results are too off, troubleshoot.

3. Send in the carrier frequency. Use the scope to measure the output waveform. Adjust the carrier amplitude and frequency to be, for example, about 1V and 100kHz, respectively.

4. The AM signal can be around 5k-10kHz.

5. Obtain the modulated output waveform. Determine the conditions (biasing, frequency, etc.) for reaching the largest modulation amplitude. (100% modulation is of course the maximum, but you may not reach this condition with your setting.)

6. Tune an AM radio (that you would need to bring from home) and you should be able to pick up the radiation --- you need to add an antenna to the output --- at the modulated frequency. The output antenna is a simple metallic wire (one foot long) shorted to the output. Using the dipole picture, the radiation direction is normal to the direction along the wire antenna.

7. Build your receiver circuit and put it close by and observe the pick-up characteristics. Display the demodulated AM signal on the scope and compare with the original AM modulation.

8. You can use a music source, such as the CD player, to carry out the AM modulation. The picked up signal after AM demodulation should reproduce the music signal. The EE shop has the 3.5mm receptacle that you can solder wires to, and that matches the typical digital portable audio plug.