EXPERIMENT 4: AMPLITUDE MODULATION

INTRODUCTION:

Amplitude modulation, or AM, is the most basic method of modulation. In this experiment, you'll construct an AM modulator circuit, and make measurements to verify its performance. In addition, you'll be able to transmit audio over nearby AM radio receivers with the finished circuit.

THEORY OF OPERATION:

The *modulator* stage is the one that takes an incoming carrier signal and places intelligence "on top" of it. In AM, the modulator really performs the function of "multiplying" the two incoming signals. The easiest way to acheive this is to deliberately design an amplifier whose gain directly depends on the amplitude of an incoming signal. See Figure 1.

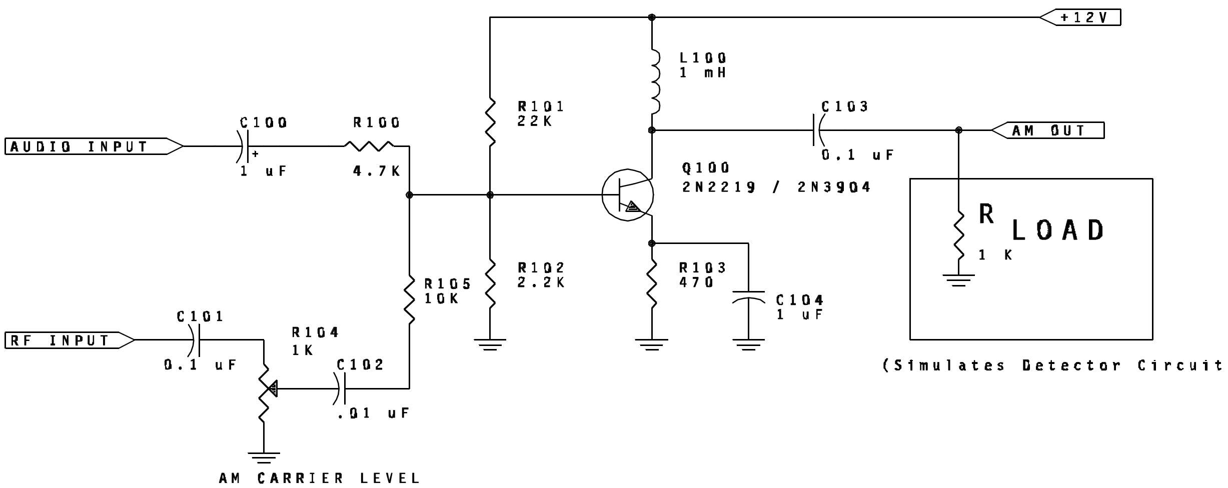

Figure 1 Amplitude Modulator Stage

The amplifier of figure 1 is really nothing more than a class A stage with voltage-divider biasing. The RF carrier signal is coupled into the base through R104, the CARRIER LEVEL control, and C102, a DC blocking capacitor. The inclusion of R104 allows the adjustment of the carrier voltage. The audio signal is coupled into the base through C100, another DC block. Resistors R100 and R105 are isolation resistors; they serve to prevent current from flowing between the AF and RF sources connected to the unit.

The emitter of Q100 is AC-coupled to ground by C104. This capacitor is an *RF bypass*. The function of an RF bypass capacitor is to make an AC ground for RF signals at a particular point in the circuit. Since the emitter of Q1 is at AC ground (but only for the RF signals), we know that the RF gain will be:

$$A = \frac{r_C}{r'_e} = \frac{R_{LOAD}}{(25mV/I_e)}$$

Note that L100 and R103 are not in the equation. By design, the reactance of L100 will be much larger than the load resistance, R_L, so the reactance of L100 will not greatly affect the gain.

R103 has no direct effect on gain either; it is totally *bypassed* by C104. The word "bypassed" means that only DC currents can flow through R103; the AC currents are shunted away by C104. The emitter circuit AC impedance is equal to *r'e* because of the bypassing of R103! Normally, this is not good design practice, because transistor gain will now be dependent on *r'e*. However, in this case, it's exactly what we want!

In essence, this stage is designed so that the intelligence signal will change *r'e*; thus, the intelligence signal will alter the *gain* of the stage, causing amplitude modulation. Let's see how this might happen.

First, notice that the intelligence signal is coupled into the base circuit of the transistor right along with the RF signal. C100 is a DC block, and R100 is an "isolation" resistor, which prevents a large current from flowing between the two low-impedance AC voltage sources (the RF and AF generators). In an actual design, a small RF choke might be used in R100's place.

The audio signal changes <u>very slowly</u> in comparison to the RF signal. This means that the net effect of injecting the audio into the base circuit is to add a slowly-changing DC component to the RF signal. Of course, the audio is "slowly changing" only with respect to the RF signal!

When the intelligence is on a positive peak, therefore, the base voltage *increases*. This means that the emitter voltage (which always follows the base voltage) increases too, which results in *increased emitter current* (I_E). Since the amplifier gain depends on *r'e* directly, any change in I_E will change the gain. Thus, on positive intelligence peaks, *increased* I_E *means increased gain* (decreased *r'e*).

When the intelligence goes negative, it has exactly the opposite effect, and Q100 is driven more towards cutoff. The decreasing emitter current increases r'e; thus *gain decreases when the intelligence is negative.*

What is the overall effect? Since gain is increasing and decreasing in step with the intelligence signal, the RF output amplitude of the circuit of the circuit will also vary in step with the information. In other words, *amplitude modulation* will occur.

Since both audio and RF energies are being introduced into the base circuit, both audio and RF will be in the collector circuit as well. Only the RF signal is desired; the audio must be removed (remember, only the audio is being removed -- not the information, which will be carried in the <u>sidebands</u> above and below the RF carrier). A *high-pass* filter is needed to eliminate the AF portion of the signal. L100 performs this function; it is chosen to have a reactance at least as large as the load resistance at the desired frequency of operation. Below the desired frequency, the reactance of L100 drops, causing the amplifier's gain to drop. In other words, L100 in the collector circuit forms a high-pass filter that causes the circuit to have very little gain at audio frequencies; thus, only the RF portions of the signal pass on to the load.

LABORATORY PROCEDURE:

1. Build the circuit of figure 1. Connect the RF INPUT to the RF OUTPUT of the buffer amplifier. Don’t forget to connect circuit grounds together.

2. Apply power and measure the RF output at R_{LOAD}. It should be about 2 V p-p. If it is not, adjust R104 to set the level correctly.

   The RF output should be a clean sine wave at this point. If it is not, there is trouble in the unit.

3. Apply a 1 KHz sine wave to the AUDIO INPUT and adjust its amplitude until 50% modulation is obtained.

4. Measure the modulated output of the circuit with *respect to the incoming intelligence.* To do this, proceeed as follows:

   a) Connect channel 1 to the intelligence; trigger off channel 1.
   b) Connect channel 2 to the AM output
   c) Use either ALT or CHOP mode (analog scopes only) to get a clear picture.

5. Record the MODULATED OUTPUT of your circuit for 50% modulation, 100% modulation, and more than 100 % modulation. *These should be neatly recorded using graph paper (or ScopeLink) with respect to the intelligence signal.*

   How much audio voltage was necessary for 100% modulation?

6. Tune an AM broadcast receiver to the carrier frequency of the transmitter. (A receiver is available in the Crib.) Couple a long wire (at least 6 feet) to the AM OUT of the circuit. *This step demonstrates that short-range transmission is possible; long-range transmission would merely require additional amplification of the modulated wave with an RF power amplifier.*

NOTE: In the next experiment, an amplifier will be constructed to allow voice transmission.