ENEE 307
Electronic Circuit Design Laboratory
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Wireless Communications-Transmitters

4.1. Wireless Communications: RF Transmitters.

At this stage you have built and understood the RF AM receiver at a specific frequency range you chose (within the AM range) and the task in this lab is to construct a matching transmitter so you can receive your signals.

Before coming to this lab you should have your PSPICE design ready to show to your TA and have studied Chapter 16, band pass filters, with emphasis on LCR resonators (pp 1279-1285), and Chapter 17, signal generators, with emphasis on LC oscillators, in Sedra and Smith 6th Edition. Include your PSPICE design results in your report.

4.1.1. Transmitter Lay-out.

The block diagram of Fig. 4.1shows the main elements of the transmitter. It consists of an audio signal source (such as a microphone, or a CD player), input to an audio amplifier, a modulator, a local oscillator, an RF power amplifier and an antenna. The local oscillator produces the carrier frequency which is then input to the modulator to be mixed with the audio signal to produce the AM signal for the RF amplifier.

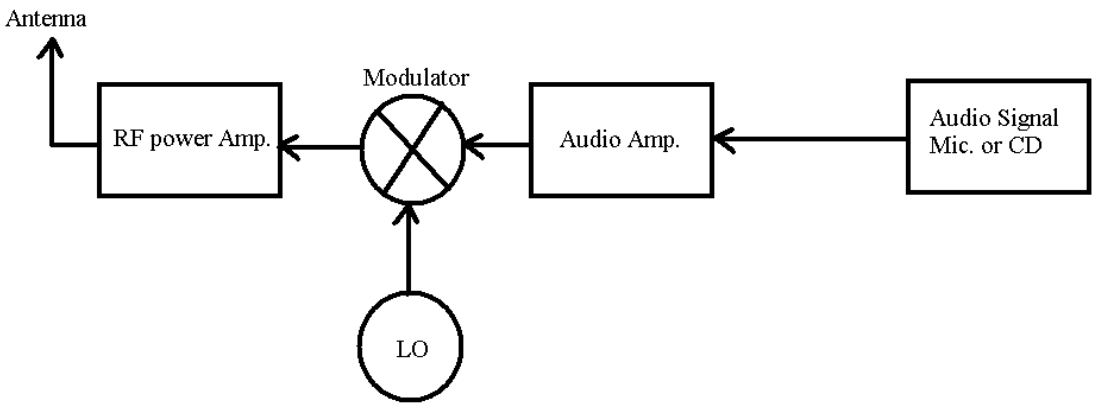

Fig. 4.1. Transmitter lay-out.

In this lay-out the modulator and local oscillator circuits are most important.
The local oscillator provides the constant carrier frequency for the audio signal and can be realized with a typical Colpitts oscillator as shown in Fig.4.2.

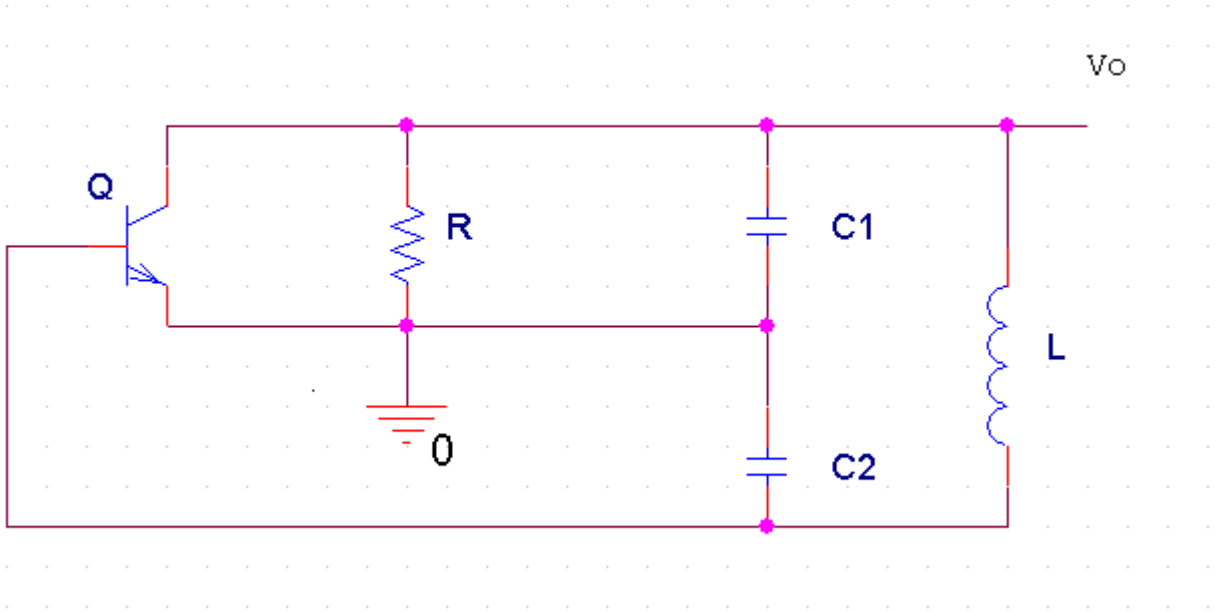

Fig. 4.2. Colpitts oscillator.

For the design of the oscillator the conditions are:

$$C_2/C_1 = g_m R \qquad (4.1)$$

$$\omega_0 = 1/[L\, C_1\, C_2/(C_2 + C_1)]^{1/2} \qquad (4.2)$$

L is usually a few μH (1 to 5), the resistor R is a few hundred Ohms (200 to 500), the capacitors a few hundred pF (500 to 1000) and usually for simplicity you may take $C_1 = C_2/2$. Load resistors R_L ought to be much larger than R, and loop gain larger than 1 (usually 3 to 5) is necessary for oscillations to occur.

Oscillator design is usually a trial and error process, and then problems usually focus on drift and stability. So produce a reasonable solution on SPICE, but use the signal generator to provide the carrier frequency. Then if time permits, incorporate the local oscillator in your circuit.

4.1.2. **Modulator.**

The modulator circuit is shown in Fig. 4.3. It consists basically of a differential pair Q_1, Q_2, with the biasing transistor Q_3. Usually the carrier signal is input to the base of Q_1, and the audio modulating signal is input to the base of Q_3.

Following basic diff amp small signal theory we have:

$$V_o = 1/2 g_m R_C V_{b1} \qquad (4.3)$$

and

$$g_m = I_E/V_T = V_{b2}/(R_E V_T) \qquad (4.4)$$

Combining (4.3) and (4.4) we have:

$$V_o = R_C V_{b1} V_{b2}/(2R_E V_T) \qquad (4.5)$$

Which shows that the output is proportional to the product of the two input signals.

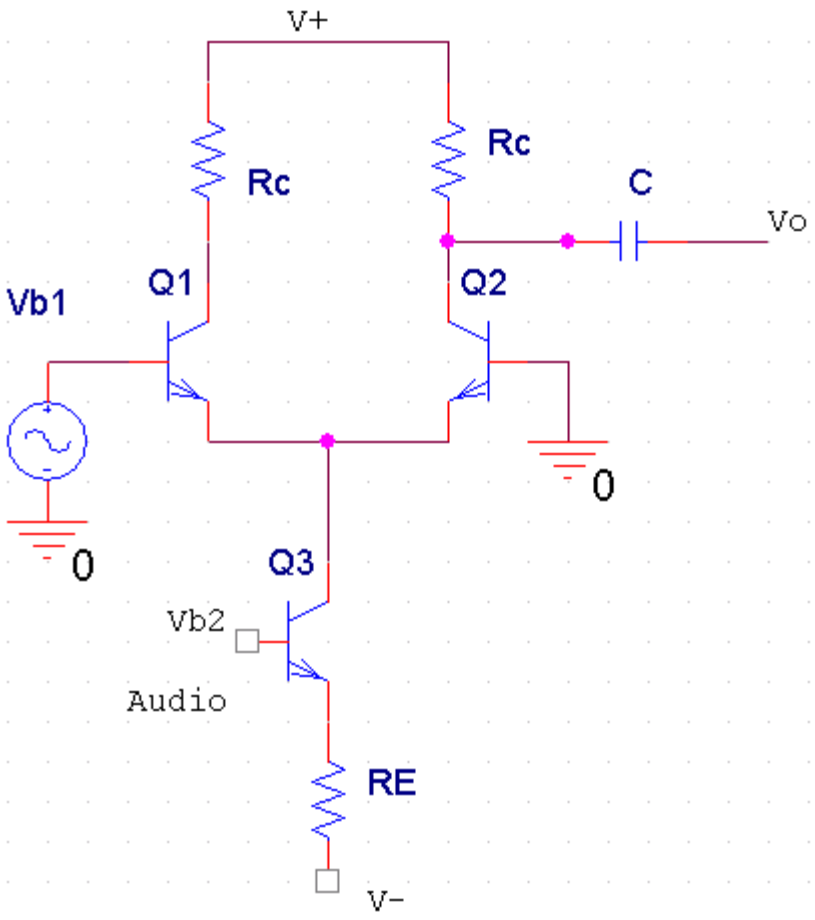

Fig. 4.3. Modulator (mixer) circuit.

1. Design your modulator using SPICE for your chosen carrier frequency in the AM range.
2. Design the diff amp with a gain of around 100, and set the DC bias for max AC swing ($I_E \approx 1mA$).
3. Chose the carrier frequency and check the linearity of your diff amp with frequency.
4. Optimize your SPICE solution for good modulation and compare with what you measure.

4.1.3. Project work.

1. Design using SPICE the local oscillator and modulator for the frequency range of your receiver.

2. Using the design of your audio amp and the RF amp of your receiver, design using SPICE the complete transmitter layout. Include each stage input-output SPICE characteristics, and the overall hypothetical simple input signal from a microphone to show the final output signal.

3. Realize your circuit without the local oscillator circuit and use the signal generator for providing the carrier. Use a single tone audio input to demonstrate modulation and a reasonable output at the end of the RF amp.

4. Use your receiver to receive and demodulate the signal from your transmitter. Do it by hard wire connection of the output to input to avoid antennas. Measure all parameters, and comment on the quality of the received signal, distortion, strength etc. Demonstrate audio signal at the receiver speaker using a microphone, or a CD player.

5. **Extra credit:** Disconnect the hard wires and device an emitting and receiving antenna, place your transmitter close to the receiver and see if you can receive audio.
6. **Extra credit:** Incorporate the local oscillator in your circuit and demonstrate operation.