Amplitude Modulation Methods and Circuits

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Purpose:

The various parts of this lab unit will be used to explore and verify the operation of the two AM modulation methods using four different AM modulating circuits. In addition, a simple form of AM detection and a novel use of the oscilloscope for percent modulation measurements, will be observed.

Note: The scope waveform can also be recorded if a PC is available. Use a PC with either a GP-IB card or an RS-232 port, and the corresponding plug-on module with the Agilent 54600-Series Oscilloscope. The BenchLink/Suite software package can be used to transfer the waveform to the PC.

Equipment:
- Spectrum Analyzer
- Oscilloscope
- DC Milliammeter
- See Drawings for Parts List (Figs. 1-5)

Part 1.

Simple diode modulation. This part of the lab unit will prove that mixing action can be accomplished by utilizing the nonlinear characteristics of a diode in a high level modulating form.

1.   Carefully wire the circuit of fig. 1 (Jumper wires will be used for S1, S2, and S3). Use your coil from the previous lab assignments and calculate the resonant frequency of the LC circuit. The value F_r equals the initial frequency for E_c.

2.   Set E_c to 4 Vp-p and e_m to 1 Vp-p (make sure the Function Generator is set to HI-Z termination.) Set the scope sweep time to 5 msec/cm and LINE SYNC. With S1 closed and S2 open, probe with the Oscilloscope and draw the waveform at point A. Include in your drawing the P-P amplitude and frequency(s).

3.   Open switch S1 and again measure and record the resulting waveform at point A. What frequencies are present and help form this waveform?

4.   Turn the diode around and observe the waveform again. What can you conclude about the observed?

5.   With S1 still open, close S2. Adjust the frequency of the function generator for maximum signal amplitude. (This occurs at F_0). Again probe with the Oscilloscope, measure, and record the signal observed at point A. List the contributing frequencies that are present in this waveform. How does this differ from the frequencies present in the waveform of step 3 and how by closing S2 did the output waveform change?

6.   Adjust e_m for 50% modulation (e_m = 2V p-p) and draw the resulting waveform indicating E_{max} and E_{min}.

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7. Repeat step 6 for 100% modulation. Explain any problems or discrepancies.

8. While observing the modulation envelope, go back and adjust for the maximum modulation that can be obtained without distortion. Calculate the percent obtainable.

   % mod. = _____

9. Return the modulation to 25% and close S3. Observe and draw the output waveform at Eout. What frequencies are present in this signal? Is there a DC offset present? Explain what was accomplished when adding a circuit with these characteristics. List three (3) names for the circuit added when S3 was closed.

Part 2.

This part of the lab unit will demonstrate low level modulation. As indicated in your text; low level modulation means that the intelligence signal is injected into the base or emitter, or some stage previous to the final output element. Here, you will be modulating a low power LC oscillator.

1. Wire the circuit of fig. 2. Notice that this is the same oscillator that was constructed for lab unit 4.

2. While monitoring E_{out} with the Oscilloscope, adjust E_m for the modulation percentages listed in the table below. Use the equations provided.

   $$E_c \text{ @ 0\% mod} = E_{max} \text{ or } E_{min}, E_{max} = E_{pev(mod)} = E_{p-p(CXR)} (MI + 1)$$

(M_I) %mod	e_M	E_{Max}	E_{Min}	$PT_{(OUT)}$(Calc.)
0				
25				
50				
85				
100				

   Using the data above, does E_m/E_c x 100 = %mod and was it difficult at some point to obtain the correct mod level? Explain the outcome.

3. Using the spectrum analyzer interface circuit, connect the output of the low level modulator with R4 removed and the modulation set to 50% at a frequency of 1000 Hz. Obtain a copy of the frequency domain display for further analysis.
   [*Note:* See appendix for: "Spectrum Analyzer Driver/Interface circuit"]

   Is the modulation level at 50% as calculated from the frequency domain display and is the in-band second order product at an acceptable level?

Part 3.

This part of the lab will demonstrate the use of an OTA op amp to provide low level amplitude modulation. Refer to chapter 2 Modern Electronic Communication by Miller, along with your handouts and lecture notes.

1. **CAREFULLY** wire the circuit of fig. 3, but **DO NOT** apply power. Set E_c to 100 kHz at and amplitude of 2 V p-p. E_m should be set to 0 at this time. NOTE: E_m is adjusted by the Variac. Instructors OK_____

   Apply power. Record the following and determine the gain of this circuit.

   E_{in} = _____ E_{out} = _____

   $Av = E_{out}/E_{in}$ = _____

2. Set E_m to an amplitude of 8 Vp-p. While monitoring E_{out}, adjust VR1 for symmetrical waveform.

3. Adjust E_m for 50% modulation, then measure the amplitude of E_m.

   E_m = _____V p-p (50% modulation)

4. Adjust E_m for 100% modulation and record the amplitude of E_m.

   E_m = _____ V p-p (100% modulation)

5. Reduce the frequency of E_c to 1 kHz, observe and draw the waveform as E_m is adjusted from 0 to 100% modulation.

6. Using your data from steps 3 and 4, determine the min and max I_{abc} currents for 50% and 100% modulation.

   I_{abc} max = (- 11.4 - E_m peak) / R_{abc}
   I_{abc} max = _____50% mod

   I_{abc} min = (- 11.4 + E_m peak) / R_{abc}

   I_{abc} min = _____50% mod

   I_{abc} max = _____ 100% mod

   I_{abc} min = _____ 100% mod

7. Now, calculate Iabc with no modulation.

   I_{abc} = _____ 0 % mod

8. Using the formula $Av = gmR_L$, where $gm = 19.2 \times I_{abc}$ (in msiemans @ 29 degrees C/84 degrees F), calculate the gain of this circuit with no modulation and compare this with the actual gain obtained in step 1 of part 3. Explain any discrepancies.

    Av calc. = _____   Av measured = _____ (from step 1)

9. Using your data from step 6, calculate the max and min gain for 50% and 100% modulation.

    50% mod. Av max = _____   Av min = _____

    100% mod. Av max = _____   Av min = _____

10. Explain briefly in your report how amplitude modulation is accomplished by this circuit.

11. Use the spectrum analyzer to compare this modulator to the one in part 2. Remember, for analysis purposes keep the modulation index and frequency the same as part 2, step 3. This will require some modification on you part. Also, interface without removing R_L.

    Explain why an E_m of 1 kHz is necessary?

Part 4.

In this part a standard oscilloscope is used to display trapezoidal patterns. Trapezoidal patterns are often used for determining; the percent modulation, envelope linearity (sometimes referred to as carrier shift), and the general condition of an AM envelope itself. This is because it is easier to interpret than envelope itself.

The set-up diagram to be used on the circuit from part 3 that will generate the trapezoidal patterns is shown in figure 4. The X and Y mode inputs on the oscilloscope will be used for producing the trapezoidal patterns. With the X-Y mode, the Em signal is applied to the X input and the modulated envelope, from Eout, is applied to the Y input.

1. Using the circuit from part 3, connect the oscilloscope as shown in figure 4.

2. Set the amplitude of the carrier signal generator output voltage to 2 Vp-p, and the frequency to 100 kHz, and set the amplitude of the Em generator to 6 Vp-p. Using both vertical attenuators on the scope (Ch.1 and Ch.2), adjust the input amplitudes for a reasonable looking trapezoid.

3. Draw the trapezoidal pattern observed.

4. Based to the E_{MIN} and E_{MAX} of the waveform, determine the percent modulation.

    %mod. = _____

5. Adjust the amplitude of the modulation voltage until 100% mod. is achieved.

6. Draw the waveform observed in step 5.

7. While observing the trapezoid, adjust VR1 and explain the results. Is there a name for the condition observed?

8. Reduce the amplitude of the modulation voltage until 50% mod. is achieved and draw the resulting waveform.

9. Increase the modulation index to a value greater than one, observe and draw the results.

10. Return the modulation amplitude to the 100% condition and reverse the X-Y inputs at the scope. Describe the effects that occur in relation to the trapezoidal pattern.

11. What can be concluded about this method for AM modulation measurements? Include an interpretation of how the scope produces the coherent pattern.

Explain some other uses for the X-Y inputs.

Part 5.

The concluding part will be spent looking at the more popular form of high level modulation known as Collector Modulation or Heising, named after its inventor. As illustrated in figure 5, the amplifier is biased class C and the output RF signal amplitude is modulated by causing the collector supply voltage to vary with the modulation voltage. This method is capable of producing nearly 100% modulation with reasonable linearity.

1. Wire the circuit of fig. 5. Note that this circuit was used in lab 3. **Do Not** insert the DC milliammeter at this time. Set V_{in} to 6 V_{pp} at a frequency equal to F_r of the LC circuit. Set the output of the variac to 0 V. (v mod = 0)

2. Set the scope to "line sync" and the horizontal sweep to 5mSec/cm.

   In your report include a brief definition for "line sync" and explain its operation in relation to other trigger sources available on the oscilloscope.

3. While probing V_{out} with the Oscilloscope, slowly increase the variac voltage until 50% modulation is obtained. It may be necessary to jog the carrier frequency slightly for maximum output.

4. At this time, draw the V_{out} waveform in time alignment with the signal present on the collector of the transistor. Record the amplitudes of these signals.

5. Increase the variac voltage until 100% modulation is obtained. It may be necessary to adjust the frequency of V_{in} for a symmetrical V_{out} waveform.

6. Repeat step 4 and note the peak to peak amplitude of V_{out} in relationship to VCC. How is it possible for V_{out} to be so much greater than the supply voltage? Approximately how much greater is the output voltage as compared to VCC?

    Why is the waveshape of V_{out} different than the shape of the waveform on the collector of the transistor? Is the amplitude the same for both? Explain.

7. Now insert a DC milliammeter in the circuit. Record I_c with V_{in} at the resonant frequency and the Variac set for 0% modulation. Then proceed and do the same for 50%.

    $I_c =$ _____ (0% at F_r)

    $I_c =$ _____ (50%)

    Why or why not was there any change in current for a change in modulation?
    Is this modulator consistent with the theoretical aspects?

8. Now measure I_c with V_{in} set 200 kHz above, then 200 kHz below the resonant frequency.

    $I_c =$ _____ (Fr - 200 kHz)

    $I_c =$ _____ (Fr + 200 kHz)

    Explain why I_c increases when V_{in} is not set at the resonant frequency.

    Was there a linear change in I_c with the linear shift in frequency from resonance? Why or why not?

    What type of amplifier must follow this modulator if higher output power is required?

    Can the circuit be characterized with the spectrum analyzer?
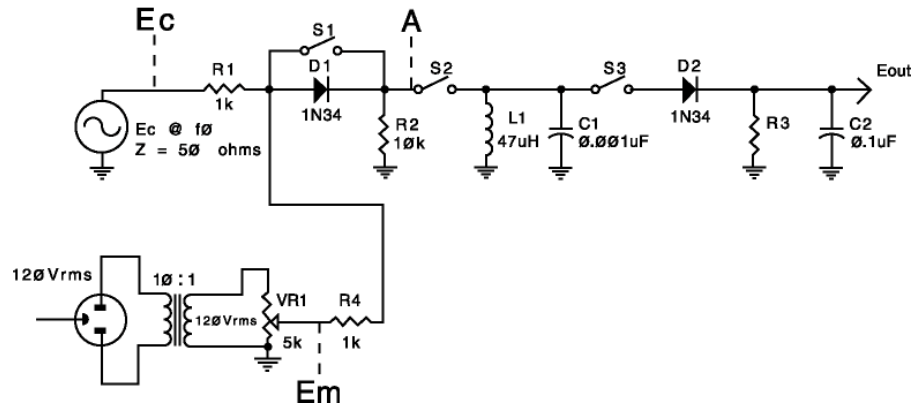
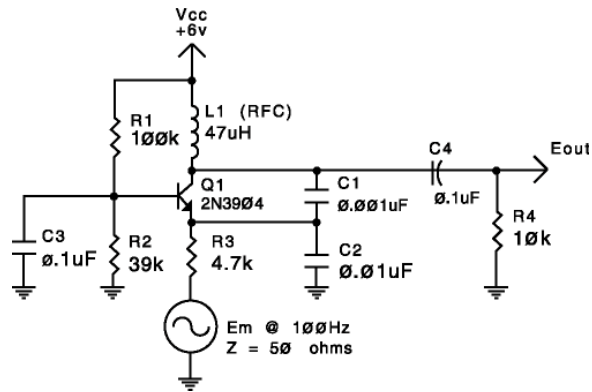# FIGURE 1

FIGURE 2

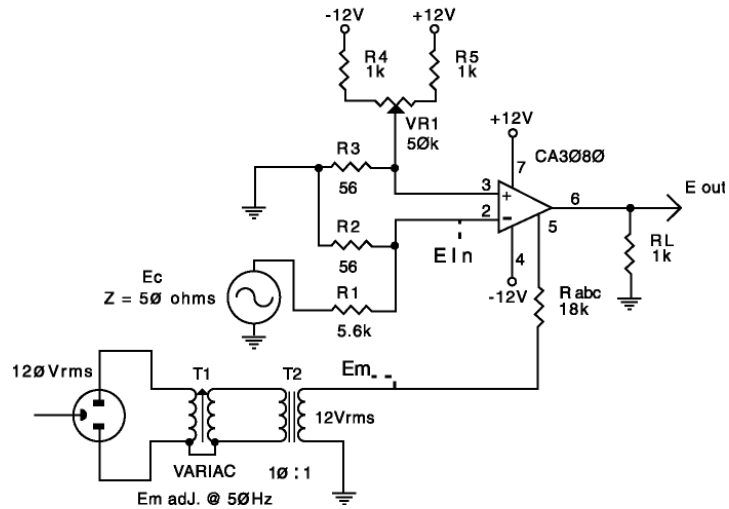Figures I-3 for
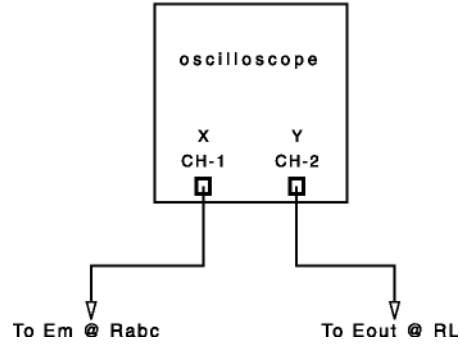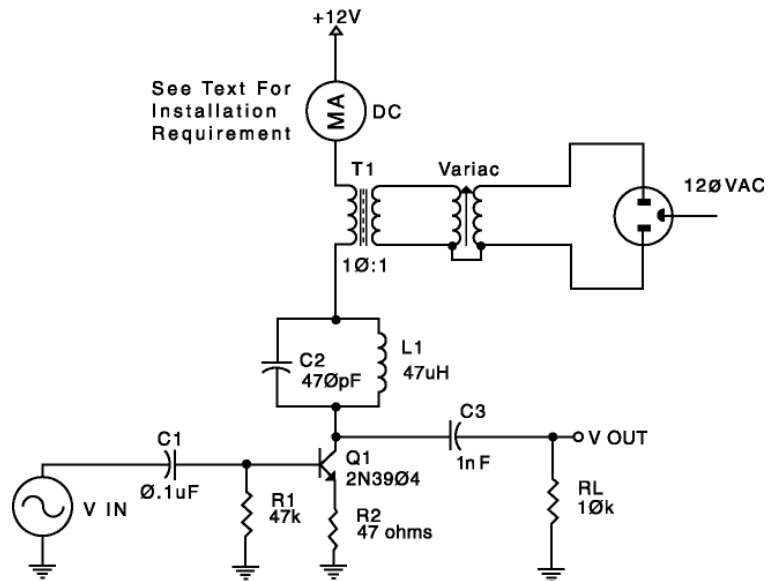Agilent 33120A

FIGURE 3

Agilent 33120A

FIGURE 4

FIGURE 5

Spectrum Analyzer Driver/Interface Circuit

Purpose:

The following exercise will include assembling and testing a circuit that will be used to interface a circuit under test and a spectrum analyzer. The typical circuits that are experimented with in lab generally have higher impedances than the input of test equipment used for analysis. Another lacking trait is also their low power. Therefore the purpose is two-fold; one is to impedance match and the other is to increase the drive current for improved empirical analysis.

Equipment:

•   Spectrum Analyzer
•   Oscilloscope

At the heart of this circuit is Analog Devices more recent high performance wide band operational amplifier. At unity the AD811 offers a -3db bandwidth of 140 MHz. This is a current feedback amplifier optimized for use in high performance video and data acquisition applications. Since it employs a current feedback architecture, its closed-loop -3dB bandwidth is dependent on the magnitude of the feedback resistor. The desired closed-loop gain and bandwidth, and varying the feedback resistor (R_4) to tune the bandwidth, and varying the gain resistor (R_3) to get the correct gain. The values chosen must be made carefully to obtain reasonable gain for some selected bandwidth. It is suggested to follow the recommendations listed in the device data sheet.