

## Experiment 3

### Amplitude Modulation and Envelope Detection

#### 1. Objectives:

- To provide a familiarization with the use of a multiplier-circuit unit to generate an amplitude-modulated (AM) signal, with an adjustable modulation factor(m).
- To examine both time & frequency displays of an AM signal.
- To measure the percentage modulation (m %), and the percentage of total power in both sidebands and in the carrier versus the modulation index (m).
- To investigate the use (& limitation) of envelope detection in demodulating AM signals.

#### 2. Prelab Assignment:

1. The output voltage ( $V_{out}$ ) of a four-quadrant multiplier unit is given as:

$$V_{out} = 0.1V_x \cdot V_y,$$

where  $V_x$  &  $V_y$  are the separate input voltages to the multiplier unit. Let

$$V_x(t) = 2 + \cos(2000\pi t)V$$

$$V_y(t) = 5 \cos(20000\pi t)V.$$

- (a) Determine the expression for the AM signal  $[V_{out}(t)]$ . Sketch and label both time & frequency domain descriptions of the multiplier's output signal.
  - (b) Calculate the modulation index & the percentage modulation for the AM signal. What are the values of the percentage of total power in both sidebands and in the carrier?
  - (c) What changes would you make to the input signals to maximize the percentage of total power in the sidebands of  $V_{out}(t)$ ?
2. (a) Sketch and label the voltage transfer function  $[V_o \text{ versus } V_i]$  for the circuit shown in Fig(1), assume ideal op amps with  $V_{sat} = \pm 8 \text{ V}$ .
  - (b) Sketch the waveform of  $V_o(t)$ , when  $V_i(t)$  is equal to the output voltage of the multiplier unit in Q1.
  - (c) Repeat part(b), when the AM signal at the input of the circuit in Fig(1) is over-modulated, ( $m > 1$ ).

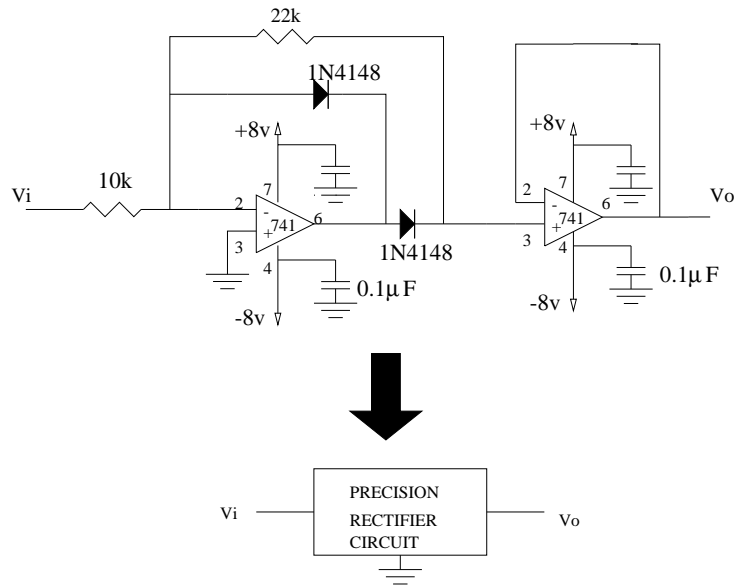


Figure (1)

### 3. Equipment:

- Model SR760 FFT Spectrum analyzer
- Oscilloscope Tektronic TDS 340A
- Function generators CFG 253
- Multiplier module
- LPF module
- Dual dc - power supply  $\pm 8V$  (RPI bench P/S)

### 4. Procedure:

#### A Amplitude Modulation

1. Apply a 10V(p-p) sinusoid @ 10 kHz to the Y-input of the multiplier module as shown in Fig(2); apply a 2V(p-p) sinusoid @ 1 kHz [with a +2V dc - offset] to the X-input.

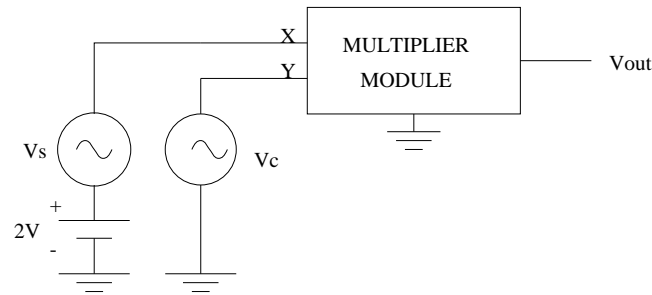
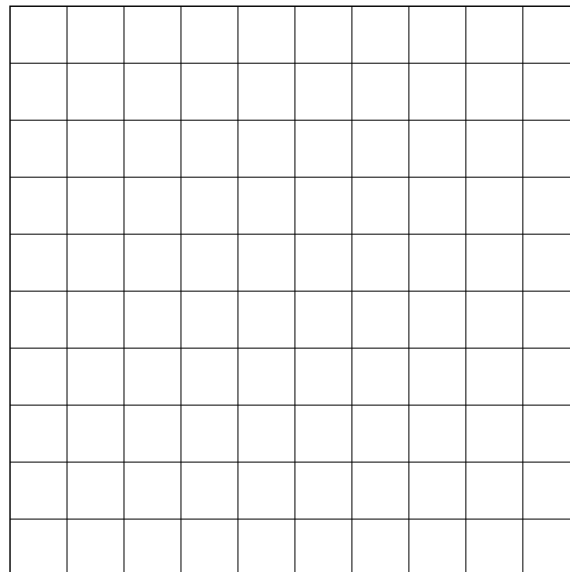
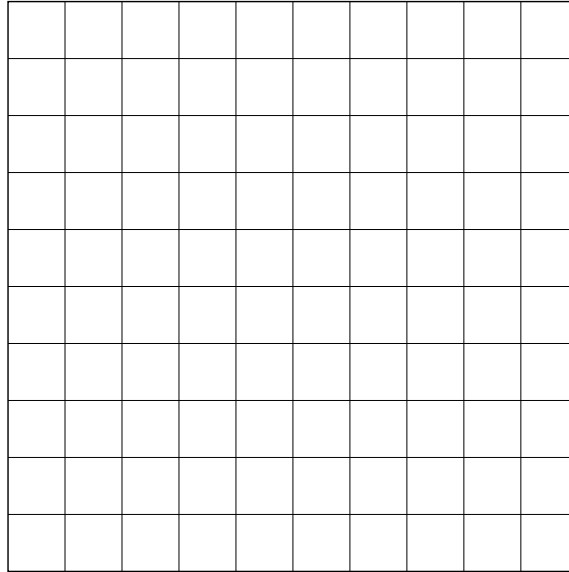


Figure (2)

2. Use the oscilloscope to display the signal @ the x-input. Measure the modulation index (m). Use Graph (1) to plot the AM-signal display.
3. Use the oscilloscope in the XY-mode [the display is known as the trapezoidal display of modulation, whereby the AM signal is shown versus the modulating signal]. This trapezoidal display provides an alternative method to measure the modulation index (m). How would you determine (m) from the trapezoidal display? Use Graph (2) to plot the trapezoidal display of modulation.



Graph (1)



Graph (2)

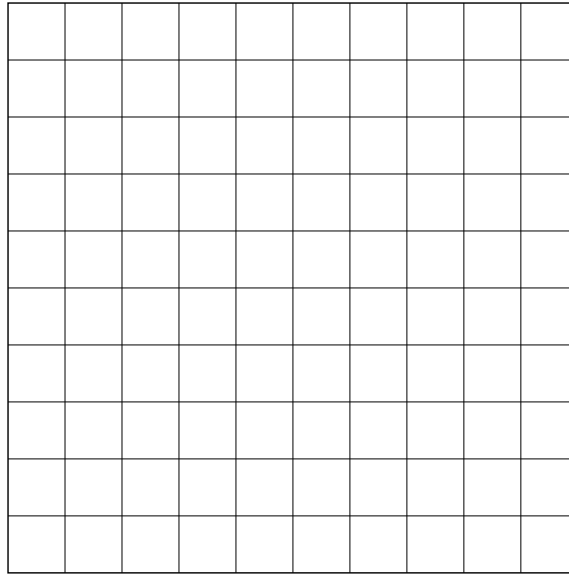
4. Use the spectrum analyzer to display the frequency contents of  $V_{out}$ . Use Graph (3) to plot the spectrum. Measure the rms voltages of the carrier ( $V_c$ ), and upper & lower-sideband components ( $V_{usb}$  &  $V_{lsb}$ ). Determine the modulation index (m), and the percentage of total power in both sidebands ( $P_{sb}$  %) and in the carrier ( $P_c$  %). Record your results in table (1).
5. Measure the carrier and the sideband components in dB. How would you now calculate the modulation index from the measurements?

[You now have FOUR different methods to measure the modulation index (m). Record in table (1) the value of the percentage modulation (m %) which you think to be the most accurate.]

Table (1)

$V_s$ (p-p) V	4	3	2	1	0.1
$V_c$ (V)					
$V_{lsb}$ (V)					
$V_{usb}$ (V)					
%m					
% $P_c$					
% $P_{sb}$					

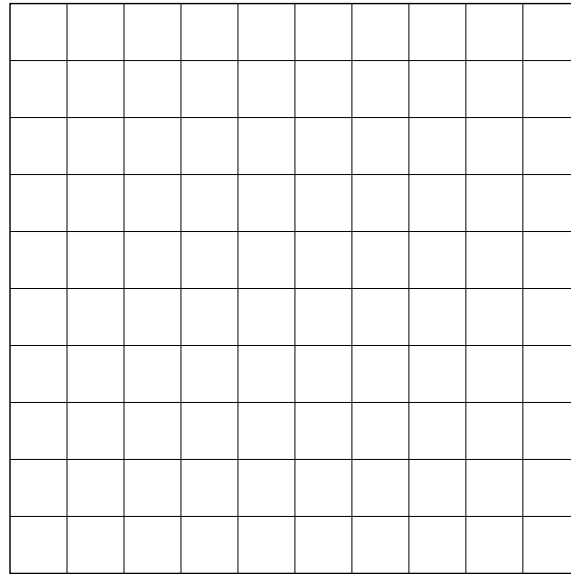
6. Adjust the (peak-peak) value ( $V_s$ ) of the 1 kHz-modulating sinusoid to each of the settings in table (1), and repeat all the above measurements. Use Graph(4) to plot the percentage of the total power in both sidebands ( $P_{sb}$  %) and in the carrier ( $P_c$  %) versus the percentage modulation.



Graph (4)

### B Envelope Detection

7. Connect the precision half-wave rectifier circuit shown in Fig(1). Apply a 6V (p-p) sinusoid @ 100Hz to the input of the circuit ( $V_i$ ); display  $V_i$  &  $V_o$  on the oscilloscope.
- Set the oscilloscope in the XY - mode to display the voltage transfer characteristics ( $V_o$  versus  $V_i$ ) of the circuit; Use Graph (5) to plot this display.



Graph (5)

8. Connect the circuit shown in Fig(3). Apply a 10V (p-p) sinusoid @ 25 kHz to Y-input of the multiplier module; apply a 2V (p-p) @ 150 Hz [with a +2V dc offset] to the X-input. Use the YA- channel of the oscilloscope to display the modulating signal.
9. Use the YB-channel to display, in sequence, the voltage waveforms at nodes K, L & M in Fig(3); adjust the cut-off frequency of the LPF so that the waveform at the node M becomes a replica of the modulating signal, except for a slight phase shift. Sketch all the displayed waveforms in the space above each corresponding node in Fig(3).

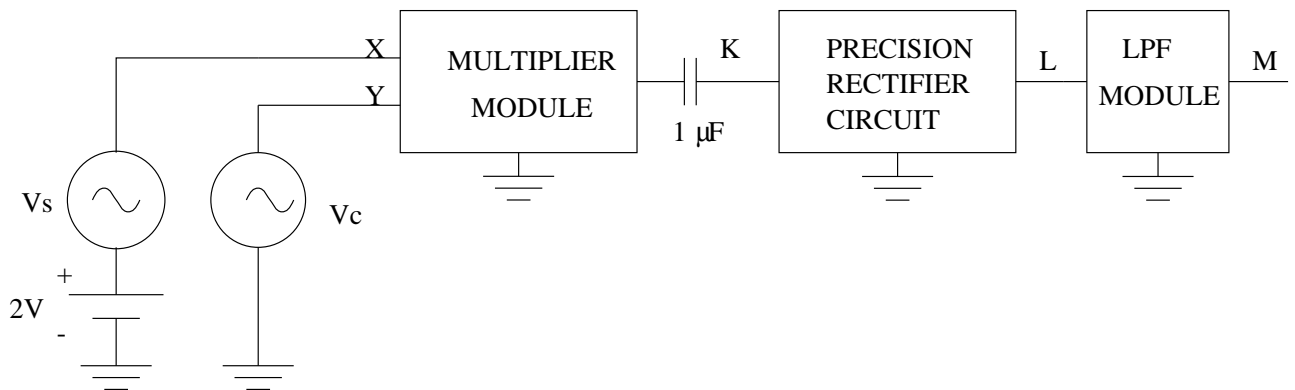
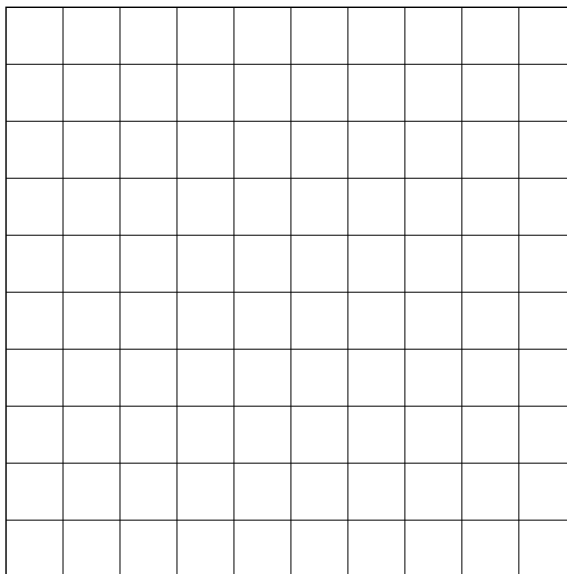
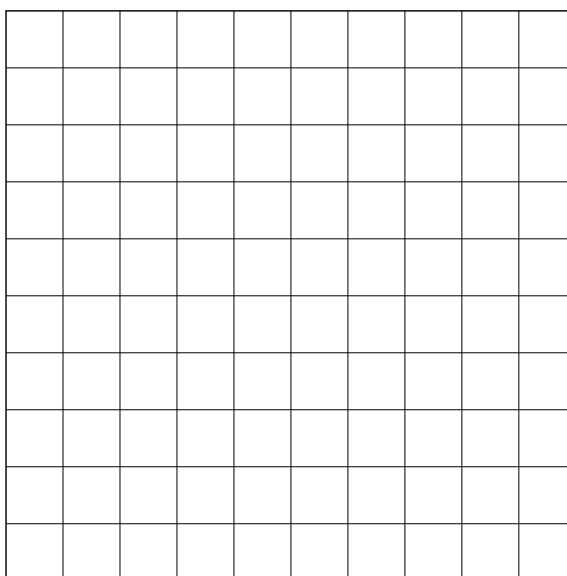


Figure (3)

10. Connect YB back to node K, and YA to node M. How does the signal at the output of the LPF compare with the envelop of the AM signal?
11. Gradually increase the peak-peak value of the modulating signal ( $V_s$ ), and observe the oscilloscope's displays. Use Graphs (6 & 7) to plot the AM signal and the envelope-detected output @ node M, when the percentage modulation exceeds 100%.



Graph (6)



Graph (7)

5. Comments and Conclusions:

1. Which method would you use to measure the modulation index of an AM signal with a very low percentage modulation? Explain why.
2. Commercial AM radio sets utilize a much simpler envelope detector circuit than that shown in Fig(1). Draw the circuit diagram of a cheaper and simpler envelope detector. What order of magnitude of AM-signal levels would be needed for the circuit to operate properly?
3. The AM Broadcast station technical standards specify that the % modulation be maintained @ 85 - 95%; comment on any possible disadvantages [based on your experimental results] that will occur by ignoring this specification.