Daffodil International University
Department of Electrical and Electronic Engineering
EEE 316: Communications Engineering Laboratory

EXPERIMENT NO: 02

NAME OF THE EXPERIMENT: Study of AM demodulation

Objective and Theory

If you've completed Experiment 1 then you've seen what happens when you use a 2 kHz sinewave to amplitude modulate a carrier to produce an AM signal. Importantly, you would have seen a key characteristic of an AM signal - its envelopes are the same shape as the message (though the lower envelope is inverted).

Recovering the original message from a modulated carrier is called demodulation and this is the main purpose of communications and telecommunications receivers. The circuit that is widely used to demodulate AM signals is called an envelope detector. The block diagram of an envelope detector is shown in Figure 1 below.

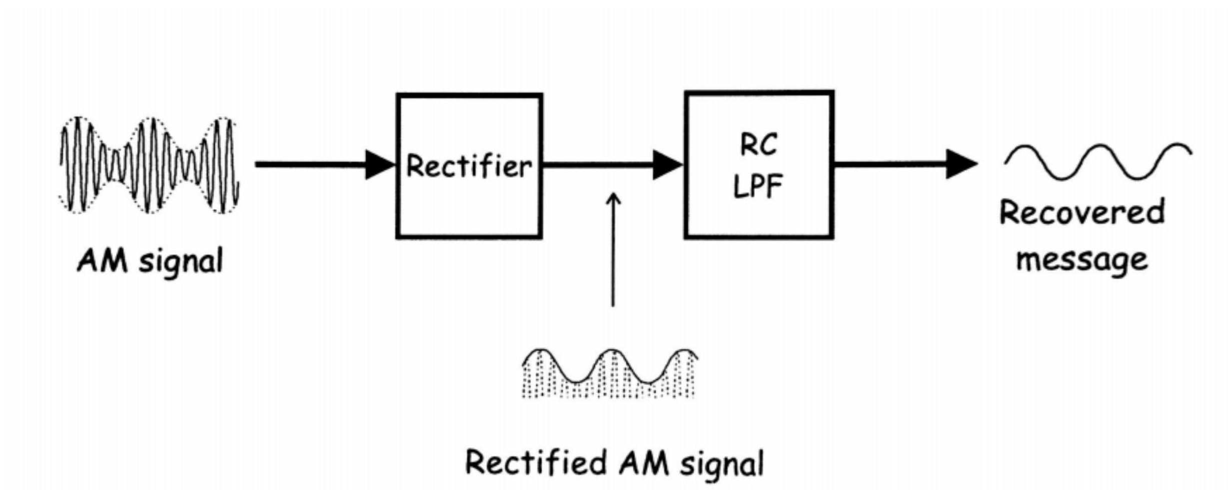

Figure: 01

As you can see, the rectifier stage chops the AM signal in half letting only one of its envelopes through (the upper envelope in this case but the lower envelope is just as good). This signal is fed to an RC LPF which tracks the peaks of its input. When the input to the RC LPF is a rectified AM signal, it tracks the signal's envelope. Importantly, as the envelope is the same shape as the message, the RC LPF's output voltage is also the same shape as the message and so the AM signal is demodulated.

A limitation of envelope detector shown in Figure 1 is that it cannot accurately recover the message from over-modulated AM signals. To explain, recall that when an AM carrier is over- modulated the signal's envelope is no-longer the same shape as the original message. Instead the envelope is distorted and so, by definition, this means that the envelope detector must ' produce a distorted version of the message.

The experiment

In this experiment you'll use the Emona Telecoms- Trainer 101 to generate an AM signal by implementing its mathematical model. Then you'll set-up an envelope detector using the Rectifier and RC LPF on the trainer's Utilities module.

Once done, you'll connect the AM signal to the envelope detector's input and compare the demodulated output to the original message and the AM signal's envelope. You'll also observe the effect that an over-modulated AM signal has on the envelope detector's output.

Finally, if time permits, you'll demodulate the AM signal by multiplying it with a local carrier instead of using an envelope detector.

It should take you about 1hour to complete Parts A to D of this experiment and another 20 minutes to complete Part E.

Equipment

• Emona Telecoms- Trainer 101 (plus power-pack)

• Dual channel 20MHz oscilloscope

• Two Emona Telecoms- Trainer 101 oscilloscope leads

• Assorted Emona Telecoms- Trainer 101 patch leads

• One set of headphones (stereo)

Procedure

Part A - Setting up the AM modulator

To experiment with AM demodulation you need an AM signal. The first part of the experiment gets you to set one up.

1. Gather a set of the equipment listed above.

2. Set up the scope per the instructions in Experiment 1. Ensure that :
   - The Trigger Source control is set to the CHJ (or INT) position.
   - The Mode control is set to the CHJ position.

3. Set the scope's Channel l Input Coupling control to the DC position.

4. Locate the Adder module and turn its G and g controls fully anti-clockwise.

5. Locate the Variable DCV module and turn its DC Voltage control almost fully anti-clockwise.

6. Connect the set-up shown in Figure 2 below.

Note: Insert the black plugs of the oscilloscope leads into a ground (GND) socket.

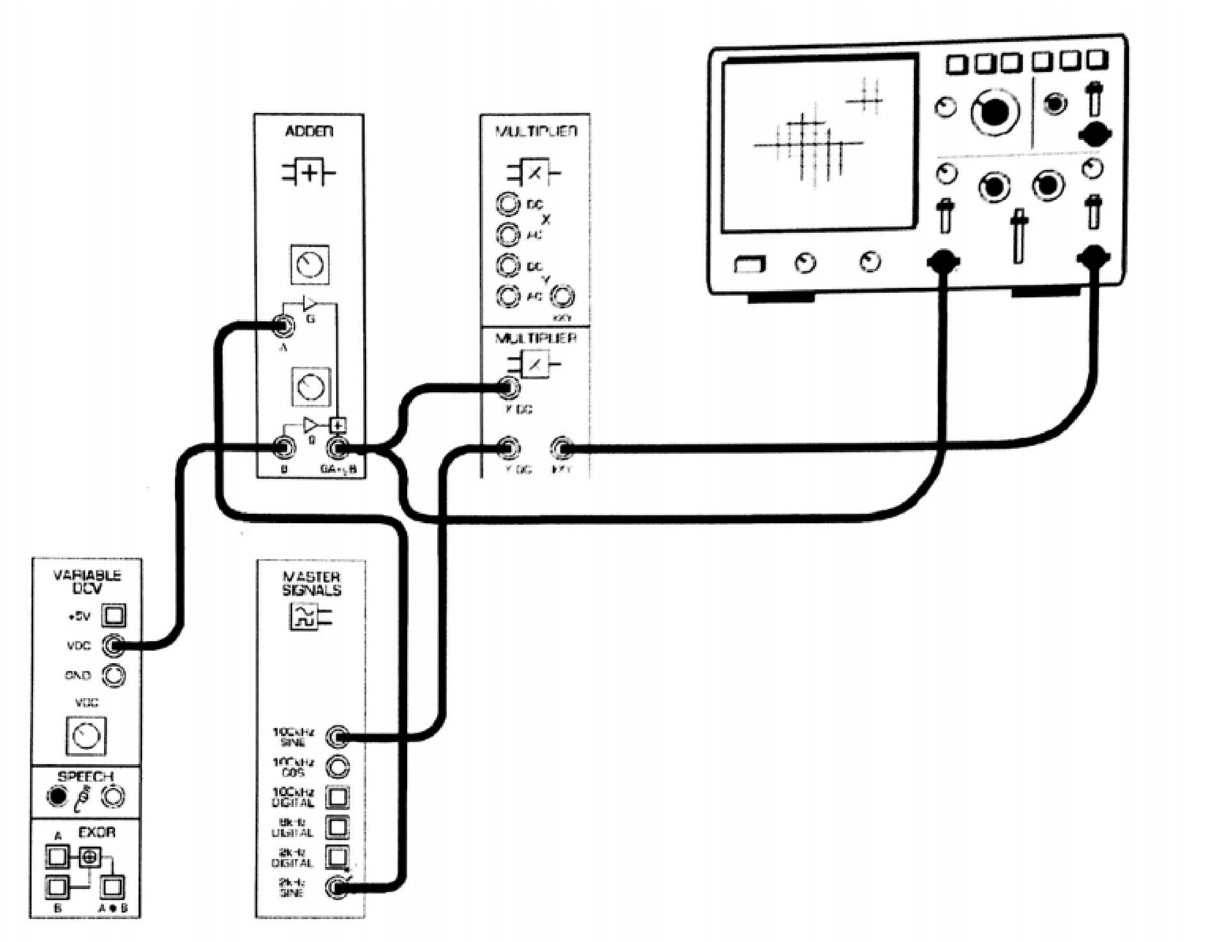

Figure: 02

This set-up can be represented by the block diagram in Figure 3 below. It generates a 100 kHz carrier that is amplitude modulated by a 2 kHz sinewave message.

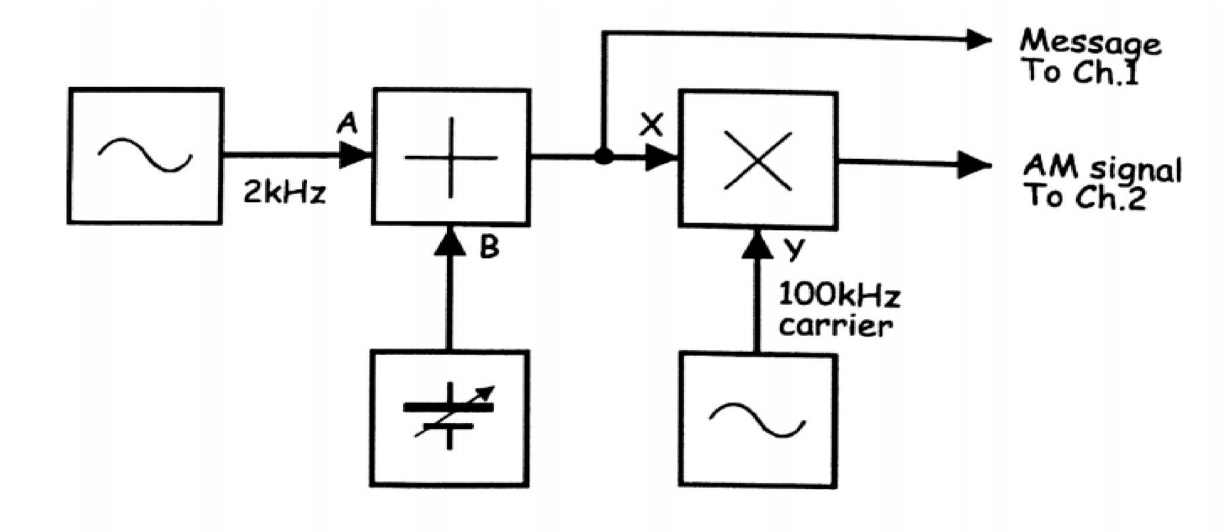

Figure: 03

Note: Although the scope is now displaying the Adder module's output, it'll just be a straight line because the output is 0V.

7. Use the scope's Channel 1 Vertical Position control to move the trace so that it lines up with the horizontal line in the middle of the scope's screen.

8. While watching the Adder module's output on the scope, turn its g control until the DC level is 1V.

Tip: It is probably most convenient to do this with the scope's Ch-1 Vertical Attenuation control on the 0.5V/div setting.

9. While watching the Adder module's output on the scope, turn i.ts G control to obtain a 1Vp-p sinewave.

Tip: You may need to adjust the scope's Timebase control to view two or so cycles of the signal.

10. Set the scope's Mode control to the DUAL position to view the AM signal out of the Multiplier module as well as the message signal.

11. Measure the AM signal's depth of modulation.

Tip: If you're not sure how to do this, see Experiment 1.

If you've connected the set-up and adjusted the controls correctly, the AM signal has a depth of modulation of about 0.5.

Part B - Recovering the message using an envelope detector

12. Modify the set-up as shown in Figure 4 below.

Remember: Dotted lines show leads already in place.

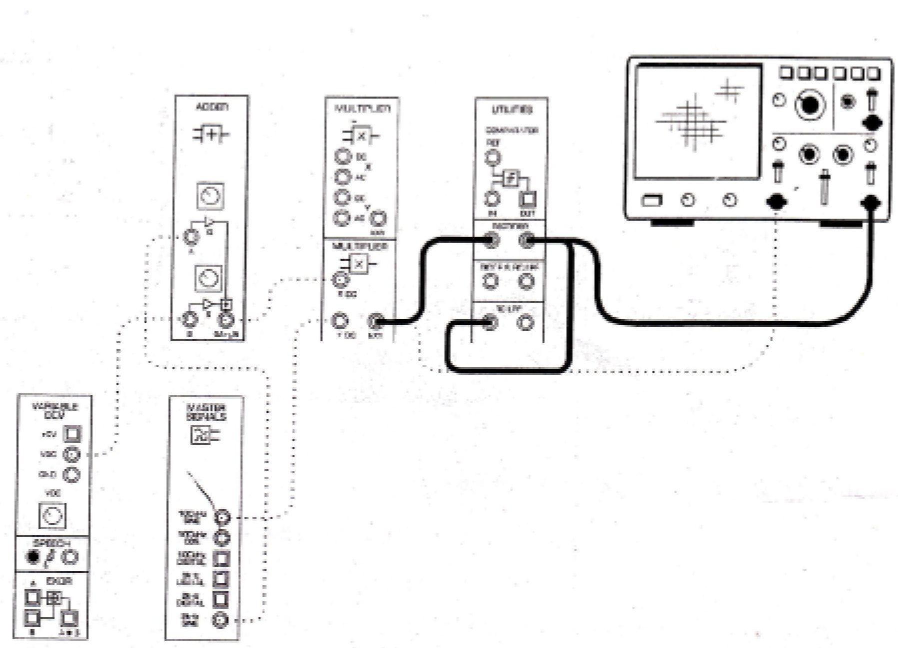

Figure: 04

The additions to the set-up in Figure 4 can be represented by the block diagram in Figure 5 below. As you can see, it's the envelope detector explained in the preliminary discussion.

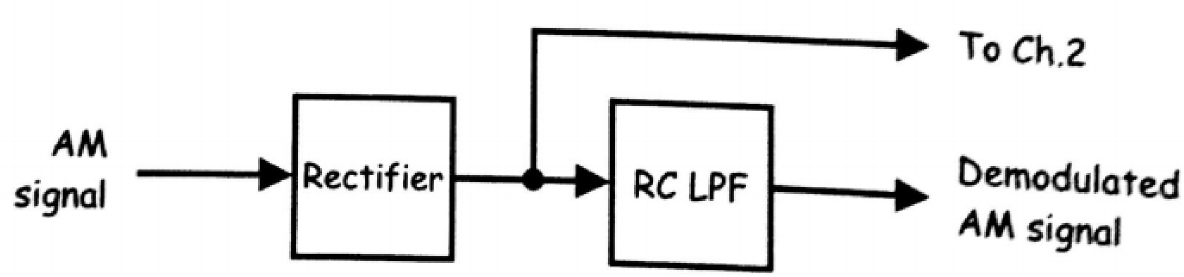

Figure: 05

13. Draw the two waveforms to scale.

14. Disconnect the scope's Channel 2 input from the rectifier's output and connect it to the RC LPF's output instead.

15. Draw the demodulated AM signal to scale.

Question 1

What is the relationship between the original message signal and the recovered message?

Part C- Investigating the message's amplitude on the recovered message

16. Vary the message signal's amplitude up and down a little (by turning the Adder module’s G control left and right a little) while watching the demodulated signal.

Question 2

What is the relationship between the amplitude of the two message signals?

17. Slowly increase the message signal's amplitude to maximum while watching the demodulated signal.

Question 3

What do you think causes the heavy distortion of the demodulated signal? **Tip**: If you're not sure, connect the scopes Channel 1 input to the AM modulator's output and set its Trigger Source control to the CH2 position.

Question 4

Why does over-modulation cause the distortion?

Part D- Transmitting and recovering speech using AM

This experiment has set up an AM communication system to "transmit" a message that is a 2 kHz sinewave. The next part of the experiment lets you use the set-up to modulate, transmit, demodulate and listen to speech.

18. If you moved the scope's Channel l input to help you answer Question 4, reconnect it to the Adder module's output and return the scope's Trigger Source control to the CH1 position.

19. Adjust the message signal's amplitude back to l V p-p (by turning the Adder module's G control anti-clockwise).

20. Modify the set-up as shown in Figure 6 below.

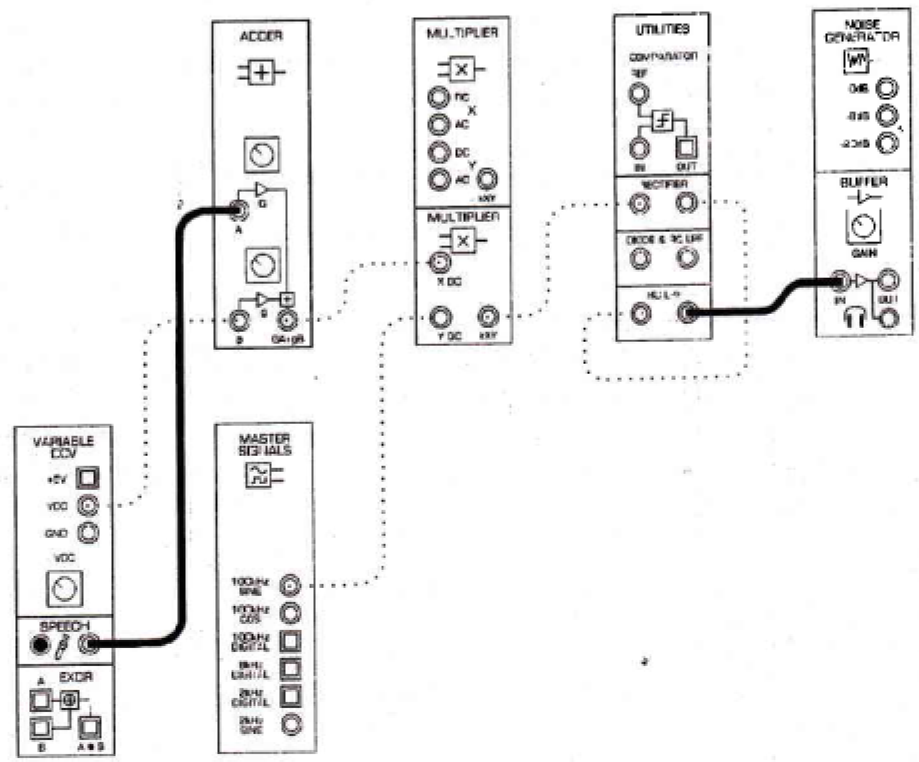

Figure: 06

21. Set the scope's Timebase control to the 2ms/div position.

22. Turn the Buffer module's Gain control fully anti-clockwise.

23. Without wearing the headphones, plug them into the Buffer module’s headphone socket.

24. Put the headphones on.

25. As you perform the next step, set the Buffer module's sound level.

26. Talk, sing or hum while watching the scope's display and listening on the headphones.

Part E - The mathematics of AM demodulation

AM demodulation can be understood mathematically because it uses multiplication to reproduce the original message. To explain recall that when two pure sinewaves are multiplied together (a mathematical process that necessarily involves some trigonometry that is not shown here) the result gives two completely new sinewaves:

- One with a frequency equal to the sum of the two signals' frequencies
- One with a frequency equal to the difference between the two signals’ frequencies

The envelope detector works because the rectifier is a device that multiplies all signals on its one input with each other. Ordinarily, this is a nuisance but not for applications like AM demodulation. Recall that an AM signal consists of a carrier .the carrier plus the message and the carrier minus the message. So, when an AM signal is connected to a rectifier's input, mathematically the rectifier's cross multiplication of all of its sinewaves looks like:

$$Rectifier's\ output = carrier \times (carrier + message) \times (carrier - message)$$

If the message signal used to generate the AM signal is a simple sinewave then, when the equation above is solved, the rectifier outputs six sinewaves at the following frequencies.

- Carrier + (carrier + message)
- Carrier + (carrier - message)
- (carrier + message) + (carrier - message)
- Carrier - (carrier + message) which simplifies to just the message
- Carrier - (carrier - message) which also simplifies to just the message
- (carrier + message) - (carrier - message)

To make this a little more meaningful, let's do an example with numbers. The AM modulator that you set up at the beginning of this experiment uses a 100 kHz carrier and a 2 kHz message (with a DC component). So, the resulting AM signal consists of three sinewaves: one at 100 kHz, another at 102 kHz and a third at 98 kHz. Table 1 below shows what happens when these sinewaves are cross-multiplied by the rectifier.

Table 1	100 kHz×102 kHz	100 kHz×98 kHz	98 kHz×102 kHz
Sum	202 kHz	198 kHz	200 kHz
Difference	2 kHz	2 kHz	4 kHz

Notice that two of the sinewaves are at the message frequency. In other words, the message has been recovered! And, as the two messages are in phase, they simply add together to make a single bigger message.

Importantly, we don't want the other non-message sinewaves so, to reject them but keep the message, the rectifier's output is sent to a low-pass filter (which explains why a low-pass filter can double as a peak detector). Ideally, the filter's output will only consist of the message signal. The chances of this can be improved by making the carrier's frequency much higher than the highest frequency in the message. This in turn makes the frequency of the "summed" signals much higher and easier for the low-pass filter to reject.

[As an aside, the 4 kHz sinewave that was generated would pass through the low-pass filter as well and be present on its output along with the 2 kHz signal. This is inconvenient as it is a signal that was not present in the original message. Luckily, as the signal was generated by multiplying the sidebands, its amplitude is much lower than the recovered message and can be ignored.]

An almost identical mathematical process can be modelled using the Emona Telecoms- Trainer l0l's Multiplier module. However, instead of multiplying the AM signal's sinewaves with each other (the Multiplier module doesn't do this), it must be multiplied with on additional pure 100 kHz sinewave. The next part of this experiment lets you demodulate an AM signal this way.

27. Modify the set-up to return it to just an AM modulator with a 2 kHz sinewave for the message as shown in Figure 7 below.

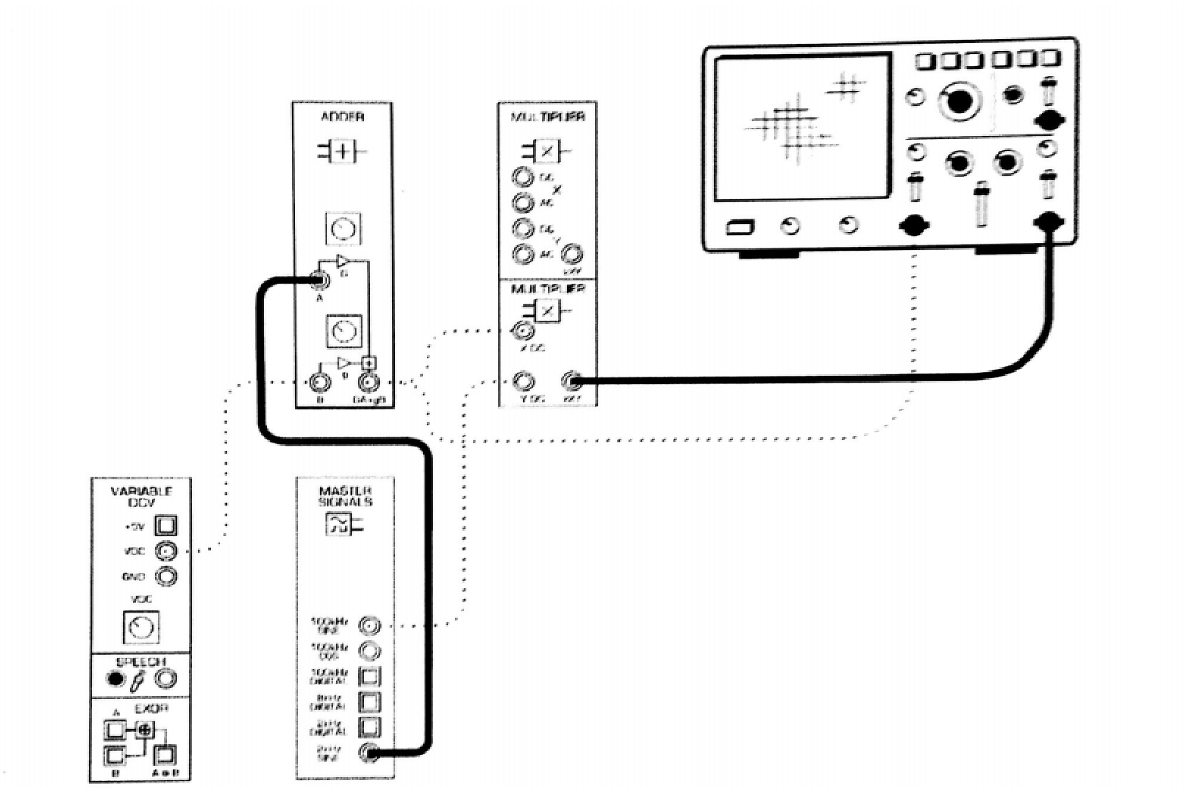

Figure: 07

28. Check that the message signal's amplitude is l V p-p. If not, adjust the Adder module's G control until it is.

Tip: You'll need to return the scope's Timebase control to its earlier setting if you've not done so already.

29. Modify the set-up as shown in Figure 8 below.

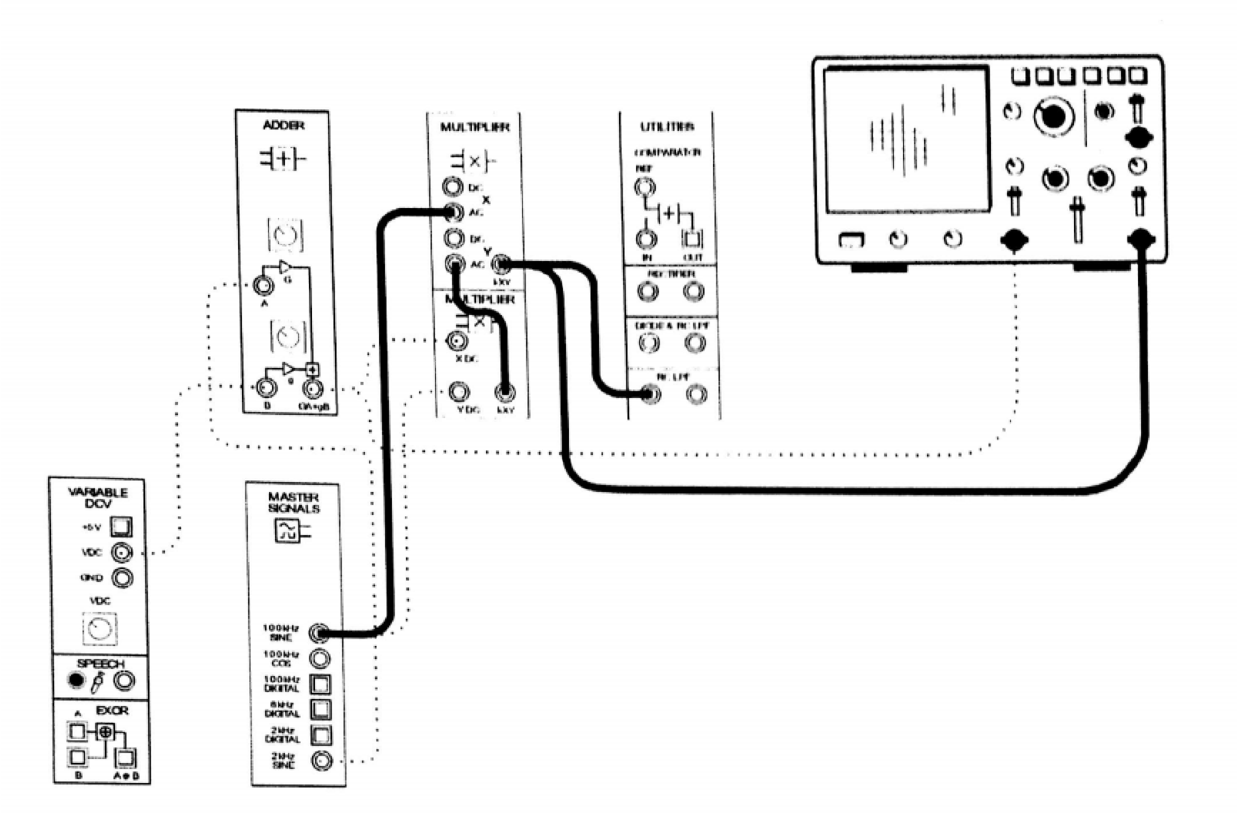

Figure: 08

The additions to the set-up can be represented by the block diagram in Figure 9 below. The Multiplier module models the mathematical basis of AM demodulation and the RC Low-pass filter on the Utilities module picks out the message while rejecting the other sinewaves generated.

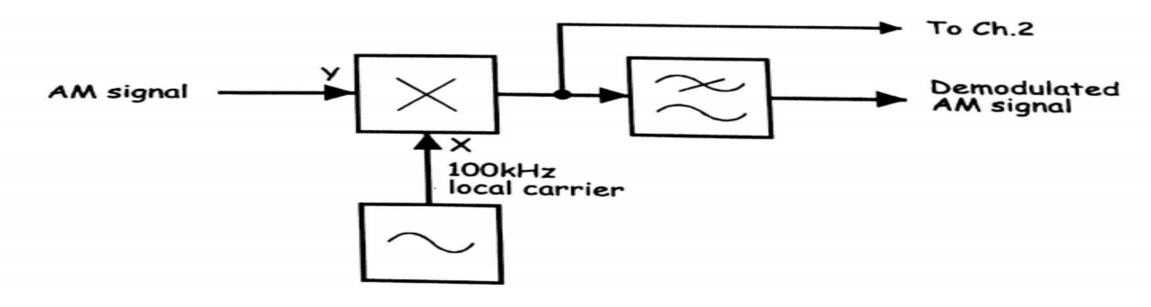

Figure: 09

30. Compare the Multiplier module's output with the rectifier's output that you drew earlier (see page 6-7).

Question 5

Given the AM signal (Which consists of 100 kHz, 102 kHz and 98 kHz sinewaves) is being multiplied by a 100 kHz sinewaves:

A) How many sinewaves are present in the Multiplier module's output?

B) What are their frequencies?

31. Disconnect the scope's Channel 2 input from the Multiplier module's output and connect it to the RC LPF's output instead.

32. Compare the RC LPF's output with the message and the output RC LPF's that you drew earlier.