Name: ______________________________

Class: ______________________________

# 11 - Frequency modulation

# Experiment 11 – Frequency modulation

**Preliminary discussion**
A disadvantage of the AM, DSBSC and SSB communication systems is that they are susceptible to picking up electrical noise in the transmission medium (the *channel*). This is because noise changes the amplitude of the transmitted signal and the demodulators of these systems are designed to respond to amplitude variations.

As its name implies, frequency modulation (FM) uses a message's amplitude to vary the frequency of a carrier instead of its amplitude. This means that the FM demodulator is designed to look for changes in frequency instead. As such, it is less affected by amplitude variations and so FM is less susceptible to noise. This makes FM a better communications system in this regard.

There are several methods of generating FM signals but they all basically involve an oscillator with an electrically adjustable frequency. The oscillator uses an input voltage to affect the frequency of its output. Typically, when the input is 0V, the oscillator outputs a signal at its *rest* frequency (also commonly called the *free-running* or *centre* frequency). If the applied voltage varies above or below 0V, the oscillator's output frequency deviates above and below the rest frequency. Moreover, the amount of deviation is affected by the amplitude of the input voltage. That is, the bigger the input voltage, the greater the deviation.

Figure 1 below shows a bipolar squarewave message signal and an unmodulated carrier. It also shows the result of frequency modulating the carrier with the message.

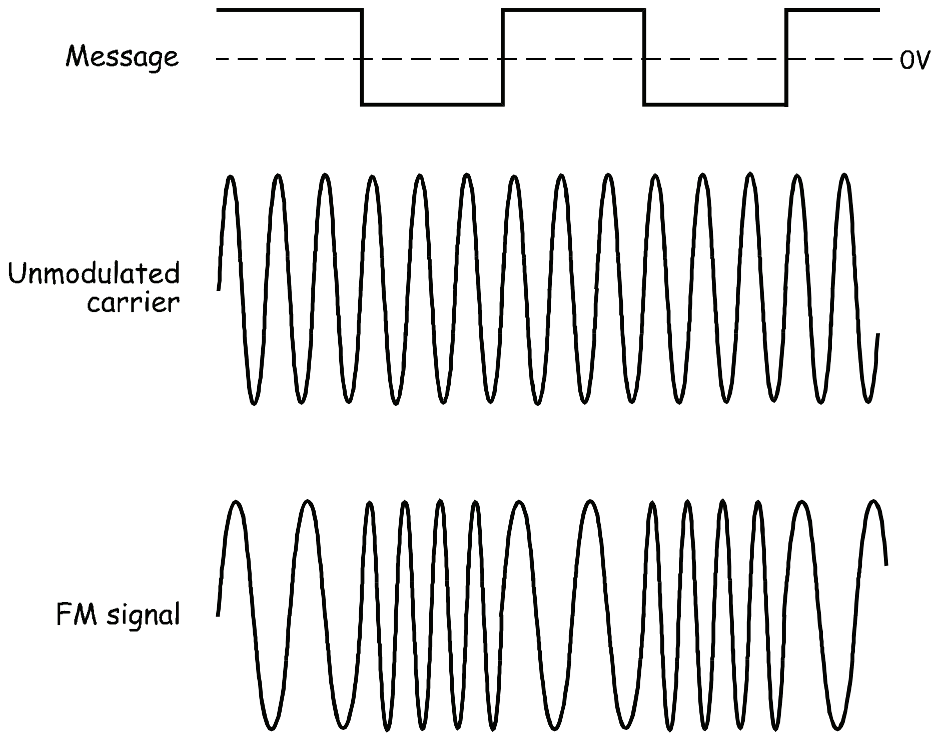



**Figure 1**

There are a few things to notice about the FM signal. First, its envelopes are flat – recall that FM doesn't vary the carrier's amplitude. Second, its period (and hence its frequency) changes when the amplitude of the message changes. Third, as the message alternates above and below 0V, the signal's frequency goes above and below the carrier's frequency. (Note: It's equally possible to design an FM modulator to cause the frequency to change in the opposite direction to the change in the message's polarity.)

Before discussing FM any further, an important point must be made here. A squarewave message has been used in this discussion to help you visualise how an FM carrier responds to its message. In so doing, Figure 1 suggests that the resulting FM signal consists of only two sinewaves (one at a frequency above the carrier and one below). However, this isn't the case. For reasons best left to your instructor to explain, the spectral composition of the FM signal in Figure 1 is much more complex than implied.

This highlights one of the important differences between FM and the modulation schemes discussed earlier. The mathematical model of an FM signal predicts that even for a simple sinusoidal message, the result is a signal that potentially contains many sinewaves. In contrast, for the same sinusoidal message, an AM signal would consist of three sinewaves, a DSBSC signal would consist of two and an SSBSC signal would consist of only one. This doesn't automatically mean that the bandwidth of FM signals is wider than AM, DSBSC and SSBSC signals (for the same message signal). However, in the practical implementation of FM communications, it usually is.

There's another important difference between FM and the modulation schemes discussed earlier. The power in AM, DSBSC and SSBSC signals varies depending on their modulation index. This occurs because the carrier's RMS voltage is fixed but the RMS sideband voltages are proportional to the signals' modulation index. This is not true of FM. The RMS voltage of the carrier and sidebands varies up and down as the modulation index changes such that the square of their voltages always equal the square of the unmodulated carrier's RMS voltage. That being the case, the power in FM signals is constant.

Finally, when reading about the operation of an FM modulator you may have recognised that there is a module on the Emona DATEx that operates in the same way - the VCO output of the function generator. In fact a voltage-controlled oscillator is sometimes used for FM modulation (though there are other methods with advantages over the VCO).

**The experiment**

For this experiment you'll generate a real FM signal using the VCO module on the Emona DATEx. First you'll set up the VCO module to output an unmodulated carrier at a known frequency. Then you'll observe the effect of frequency modulating its output with a squarewave then speech. You'll then use the NI ELVIS II Dynamic Signal Analyzer to observe the spectral composition of an FM signal in the frequency domain and examine the distribution of power between its carrier and sidebands for different levels of modulation.

It should take you about 40 minutes to complete this experiment.

**Instructions for ELVIS II only are in red, Instructions for ELVIS III only are in blue, unless otherwise said , the remaining instructions can be done for both.**

**Equipment**

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona DATEx experimental add-in module
- Two BNC to 2mm banana-plug leads
- Assorted 2mm banana-plug patch leads

**Procedure**

**Part A – Frequency modulating a squarewave**

1. Ensure that the NI ELVIS II power switch at the back of the unit is off.

2. Carefully plug the Emona DATEx experimental add-in module into the NI ELVIS II.

3. Set the *Control Mode* switch on the DATEx module (top right corner) to *PC Control*.

4. Connect the NI ELVIS II to the PC using the USB cable.

   **Note:** This may already have been done for you.

5. Turn on the NI ELVIS II power switch at the rear of the unit then turn on its *Prototyping Board Power* switch at the top right corner near the power indicator.

6. Turn on the PC and let it boot-up.

7. Launch the NI ELVISmx software.

**for ELVIS II only**

8. Launch and run the NI ELVIS II Function Generator VI.

9. Adjust the function generator using its soft controls for an output with the following specifications:

   - Waveshape: Sine
   - Frequency: 20kHz
   - Amplitude: 4Vpp
   - DC Offset: 0V
   - Modulation type: FM

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

**ELVIS II set-up is on the left and ELVIS III set-up setup is on the right**

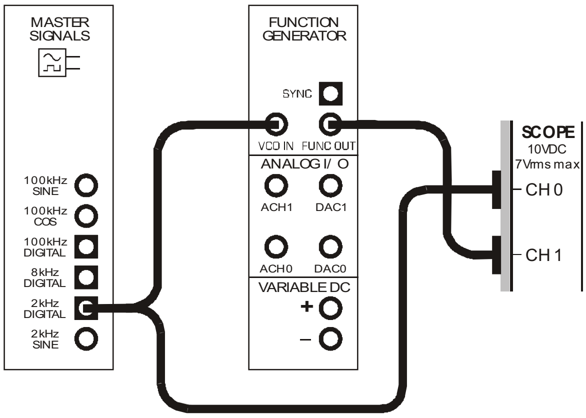



figure 2a : ELVIS II set-up

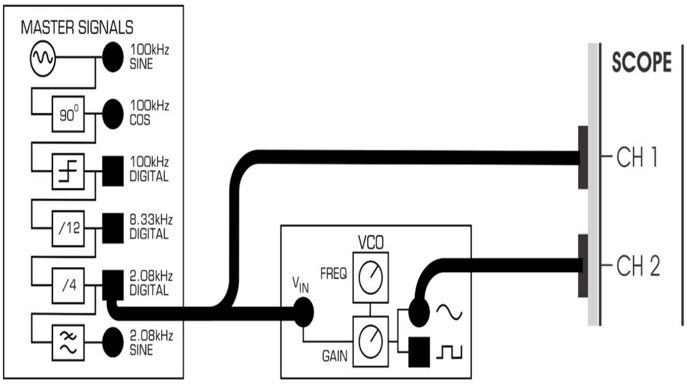



figure 2b : ELVIS III set-up

**Figure 2**

This set-up can be represented by the block diagram in Figure 3 below. The Master Signals module is used to provide a 2kHz squarewave message signal and the VCO is the FM modulator with a 20kHz carrier.

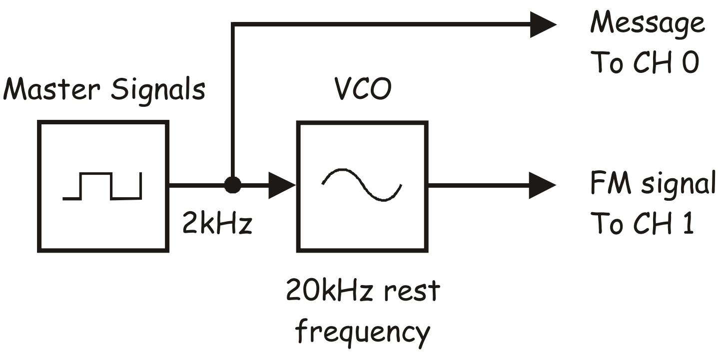



**Figure 3**

## for ELVIS III only

**7.** **Set the VCO module's GAIN to minimum (fully anti-clockwise) and then set the FREQ control to give an output sinusoid of about 20kHz. This has a period of 50us, so you can easily fine tune it in the time domain.**

**8.** **Slowly increase the GAIN to maximum (fully clockwise).**

11. Launch and run the NI ELVIS II Oscilloscope VI.

12. Set up the scope per the procedure in Experiment 1 with the following changes:

    - *Timebase* control to the *100μs/div* position instead of *500μs/div*
    - *Trigger Level* to the *2.5V* position instead of *0V*

13. Activate the scope's Channel 1 input to view the FM signal on the VCO's output as well as the message signal.

**Question 1**
Why does the frequency of the carrier change?

Ask the instructor to check
your work before continuing.

**Part B – Generating an FM signal using speech**
So far, this experiment has generated an FM signal using a squarewave for the message. However, the message in commercial communications systems is much more likely to be speech and music. The next part of the experiment lets you see what an FM signal looks like when modulated by speech.

14. Return the scope's *Trigger Level* control to *0V*.

15. Disconnect the plugs to the Master Signals module's *2kHz SINE* output.

16. Connect them to the Speech module's output as shown in Figure 4 below.

**ELVIS II set-up is on the left and ELVIS III set-up setup is on the right**

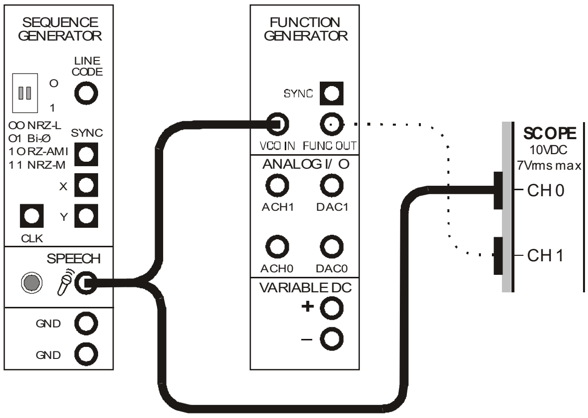



figure 4a : ELVIS II set-up

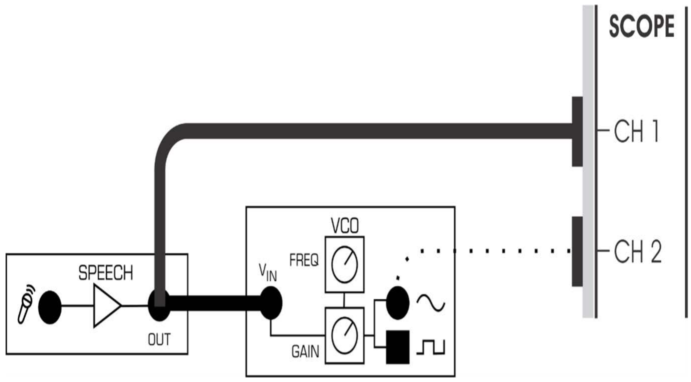



figure 4b : ELVIS III set-up

**Figure 4**

17. Set the scope's *Timebase* control to the *200μs/div* position.

18. Hum and talk into the microphone while watching the scope's display.

Ask the instructor to check
your work before continuing.

**Part C – Power in an FM signal**

As mentioned earlier, the power in an FM signal is constant regardless of its level of modulation. This part of the experiment lets you see this for yourself.

19. Launch the DATEx soft front-panel (SFP) and check that you have soft control over the DATEx board.

20. Locate the Amplifier module on the DATEx SFP and turn soft *Gain* control fully anti-clockwise.

**for ELVIS III only: keep the previous set-up, change the input to GND instead of speech signal**

**for ELVIS II only**

- 21. Completely dismantle the previous set-up.

- 22. Connect the set-up shown in Figure 5 below.

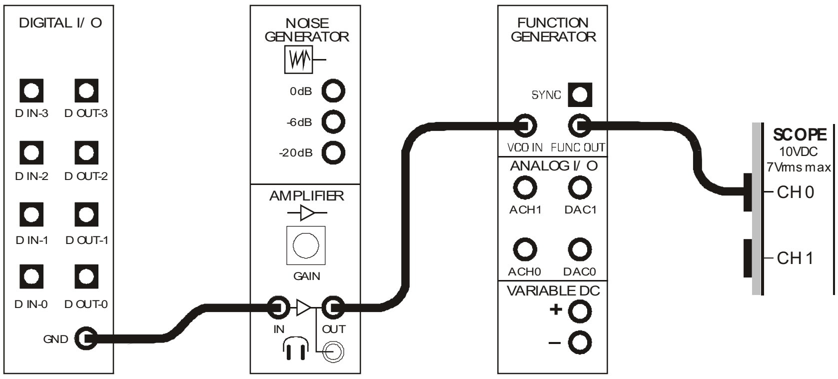



**Figure 5**

This set-up can be represented by the block diagram in Figure 6 on the next page. With the VCO's input connected to ground, its output is a single sinewave at 20kHz.

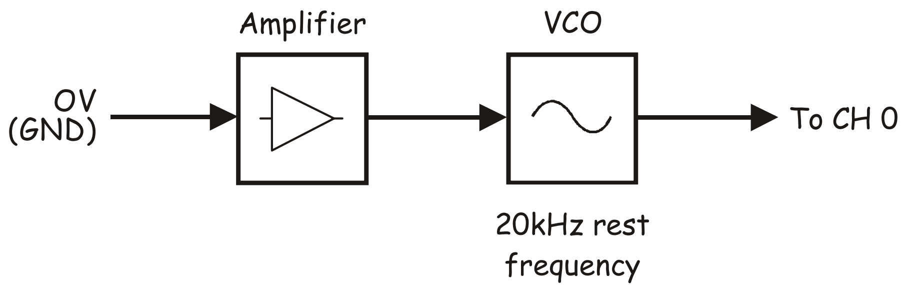



**Figure 6**

23. Use the scope to check that the VCO's output is a 20kHz sinewave.

24. Close the scope's VI.

25. Launch and run the NI ELVIS II Dynamic Signal Analyzer VI. **(FFT mode fore ELVIS III)**

26. Adjust the signal analyzer's controls as follows:

**Input Settings**

- *Source Channel* to *SCOPE CH 0* **(CH 1)**
- Voltage Range to ±10V

**FFT Settings**

- *Frequency Span* to *60,000*
- *Resolution* to *400*
- *Window* to *7 Term B-Harris*

**Averaging**

- *Mode* to *RMS*
- *Weighting* to *Exponential*
- *# of Averages* to *3*

**Trigger Settings**

- *Type* to *Edge*

**Frequency Display**

- *Units* to *Linear*
- *Mode* to *RMS*
- *Scale* to *Auto*

**Cursor settings**

- *Cursors On* box unchecked (for now)

27. Once done, one significant sinewave should be displayed.

**Note: It's important at this point to double-check that the signal analyzer's Frequency Display *Units* option is set to *Linear*.**

**(cursors are available in ELVIS II only), for ELVIS III , try to estimate the values**

28. Activate the signal analyzer's cursors by checking the *Cursors On* box.

29. Use the scope's *C1* cursor to measure the frequency of the sinewave and verify that it's the VCO's rest frequency (that is, 20kHz).

    **Note:** Recall that cursor measurements of frequency and voltage are difference values between *C1* and *C2*. However, when cursor *C2* is moved to the extreme left side of the display, its frequency and voltage is zero so the cursor measurements become absolute values for *C1*.

30. To the left of the cursor's frequency measurement readout is the measurement of the signal's RMS voltage. Record this in Table 1 below.

31. Square and record this voltage.

**for ELVIS III, the values on the graph are in dBV , to covert dBV to volts :**
**Volts = 10^(dBV/20)**

**Table 1**

| Unmodulated Carrier $V_{RMS}$ | Unmodulated Carrier $V_{RMS}^2$ |
|---|---|
| | |

Why square the signal's RMS voltage? To answer this question, remember that we're investigating the power in an FM signal but signal analyzers (and most other test equipment) can't

measure power. However, one of the power equations ( $P = \frac{V_{RMS}^2}{R}$ ) tells us that power and the square of a signal's RMS voltage (that is, $V_{RMS}^2$ ) are proportional values. That being the case, we can investigate power in an FM signal indirectly by investigating the square of the signal's RMS voltage because whatever is true of one must also be true of the other (regardless of *R*).

32. Disconnect the plug to the *GND* socket and modify the set-up as shown in Figure 7 below.

**ELVIS II set-up is on the left and ELVIS III set-up setup is on the right**

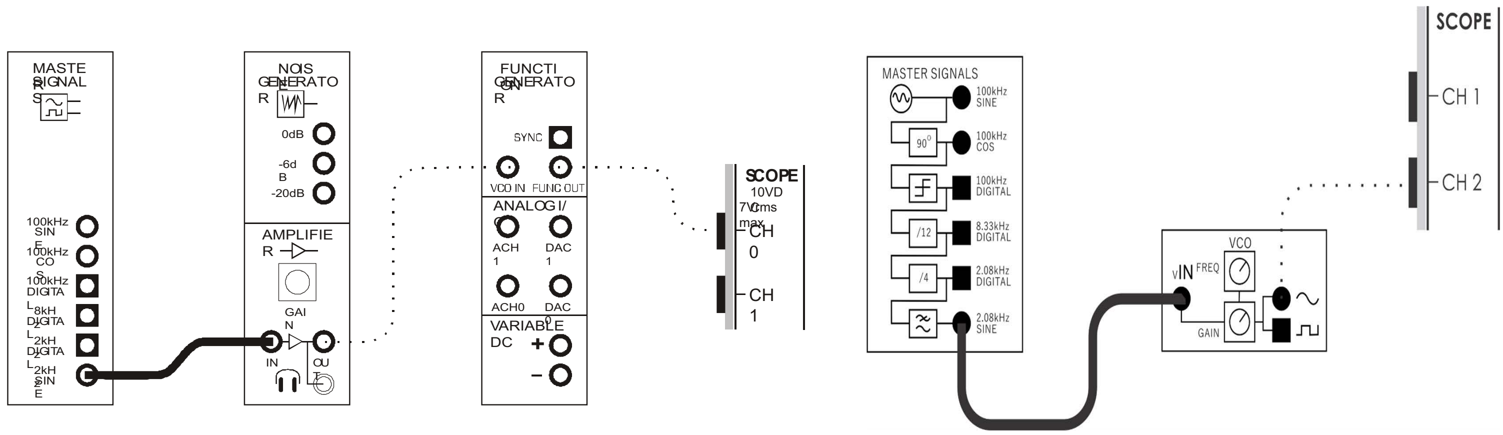



**figure 7a : ELVIS II set-up**

**figure 7b : ELVIS III set-up**

**Figure 7**

This set-up can be represented by the block diagram in Figure 8 below. Importantly, as the Amplifier module's minimum gain isn't zero, the carrier will now be frequency modulated by a low level message signal. This means that the signal analyzer's display will show about four sidebands. As these sidebands are small relative to the carrier, they can be better observed by temporarily setting the analyzer's *Units* option to *dB* instead of *Linear*.

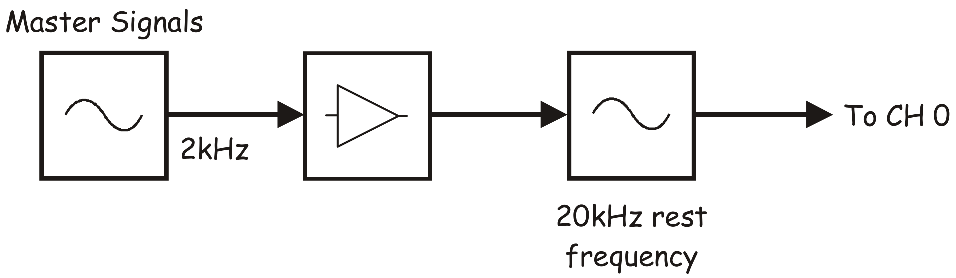



**Figure 8**

33. If you haven't already done so, return the analyzer's *Units* option to *Linear*.

**Use the VCO module's Gain control**

34. Use the Amplifier module's soft *Gain* control to adjust the modulation of the FM signal slightly until only five sinewaves are clearly visible in the signal's spectrum.

35. Use the cursor to measure the RMS voltage of these sinewaves and record them in Table 2 on the next page.

36. Square and record the voltages.

37. Add and record the squared voltages.

**Table 2**

| Sinewave | $V_{RMS}$ | $V_{RMS}^2$ |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| | **Total** | |

## Use the VCO module's Gain control

38. Use the Amplifier module's soft *Gain* control to increase the modulation of the FM signal until the carrier drops to zero for the first time.

39. Repeat Steps 35 and 37 for the six most significant sinewaves in the signal recording your measurements in Table 3 below.

**Table 3**

| Sinewave | $V_{RMS}$ | $V_{RMS}^2$ |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| | **Total** | |

**Question 2**
How do the totals in Tables 2 and 3 compare with each other and the value in Table 1?

**Question 3**
What do these measurements help to prove? Explain your answer.

Ask the instructor to check
your work before continuing.

**Part D – Bandwidth of an FM signal**

The spectral composition of an FM signal can be complex and consist of many sidebands. Usually, many of them are relatively small in size and so an engineering decision must be made about how many of them to include as part of the signal's bandwidth. There are several standards in this regard and a common one involves including all sidebands that are equal to or greater than 1% of the unmodulated carrier's power (or $V_{RMS}^2$). This part of the experiment lets you use this criterion to measure FM signal bandwidth.

40. Use the signal analyzer's *C1* cursor to identify the lowest frequency sinewave in the FM signal with a $V_{RMS}^2$ equal to or greater than 1% of the value in Table 1.

    **Note:** You have to do this by measuring the RMS voltage of the smallest sinewaves and square the value until you find the first one with a $V_{RMS}^2$ equal to or greater than 1% of the value in Table 1.

41. Use the signal analyzer's *C2* cursor to identify the highest frequency sinewave in the FM signal with a voltage equal to or greater than 1% of the value in Table 1.

42. The signal analyzer's *df (Hz)* reading is a measurement of the difference in frequency between its cursors. Following Steps 40 and 41, this reading is the FM signal's bandwidth. Record this value in Table 4 below.

**Table 4**

| FM signal's bandwidth |
|---|
| |

**Question 4**

Calculate the bandwidth of a 20kHz carrier amplitude modulated by a 2kHz sinewave.

**Question 5**

How does the FM signal's bandwidth compare to an AM signal's bandwidth for the same inputs?

Ask the instructor to check your work before continuing.

43. Increase the Amplifier module's gain until the cursor on its soft *Gain* control points to the 9 o'clock position. **until the carrier drops to zero for the first time**

44. Repeat steps 40 to 42 recording your measurement in Table 5 below.

**Table 5**

| FM signal's bandwidth |
|---|
| |

**Question 6**
What is the relationship between the message signal's amplitude and the FM signal's bandwidth?

Ask the instructor to check your work before finishing.

Name: ______________________

Class: ______________________

# 12 - FM demodulation

# Experiment 12 – FM demodulation

**Preliminary discussion**

There are as many methods of demodulating an FM signal as there are of generating one. Examples include: the *slope detector*, the *Foster-Seeley discriminator,* the *ratio detector*, the *phase-locked loop* (PLL), the *quadrature FM demodulator* and the *zero-crossing detector*. It's possible to implement several of these methods using the Emona DATEx but, for an introduction to the principles of FM demodulation, the zero-crossing detector is used here.

**The zero-crossing detector**

The zero-crossing detector is a simple yet effective means of recovering the message from FM signals. Its block diagram is shown in Figure 1 below.

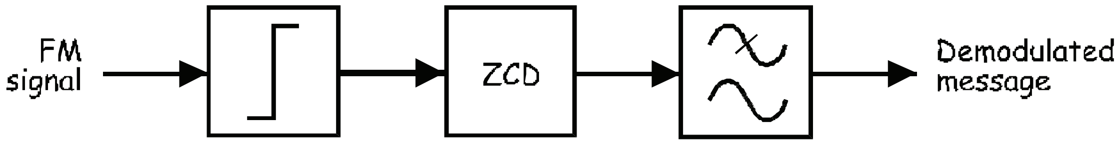



**Figure 1**

The received FM signal is first passed through a comparator to clip it heavily, effectively converting it to a squarewave. This allows the signal to be used as a trigger signal for the zero-crossing detector circuit (ZCD).

The ZCD generates a pulse of fixed duration every time the squared-up FM signal crosses zero volts (either on the positive or the negative transition but not both). Given the squared-up FM signal is continuously crossing zero, the ZCD effectively converts the squarewave to a rectangular wave with a fixed *mark* time.

When the FM signal's frequency changes (in response to the message), so does the rectangular wave's frequency. Importantly though, as the rectangular wave's mark is fixed, changing its frequency is achieved by changing the duration of the space and hence the signal's mark/space ratio (or *duty cycle*). This is shown in Figure 2 on the next page using an FM signal that only switches between two frequencies (because it has been generated by a squarewave for the message).

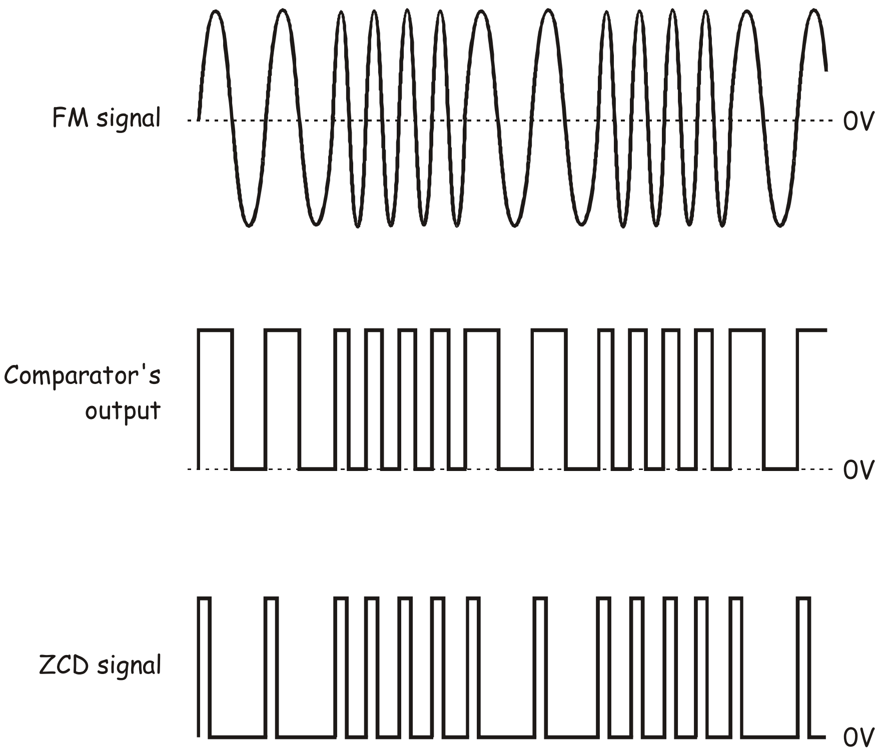



**Figure 2**

Recall from the theory of complex waveforms, pulse trains are actually made up of sinewaves and, in the case of Figure 2 above, a DC voltage. The size of the DC voltage is affected by the pulse train's duty cycle. The greater its duty cycle, the greater the DC voltage.

That being the case, when the FM signal in Figure 2 above switches between the two frequencies, the DC voltage that makes up the rectangular wave out of the ZCD changes between two values. In others words, the DC component of the rectangular wave is a copy of the squarewave that produced the FM signal in the first place. Recovering this copy is a relatively simple matter of picking out the changing DC voltage using a low-pass filter.

Importantly, this demodulation technique works equally well when the message is a sinewave or speech.

**The experiment**

For this experiment you'll use the Emona DATEx to generate an FM signal using a VCO. Then you'll set-up a zero-crossing detector and verify its operation for variations in the message's amplitude.

It should take you about 50 minutes to complete this experiment.

**Equipment**

- Personal computer with appropriate software installed
- NI ELVIS II plus USB cable and power pack
- Emona DATEx experimental add-in module
- Two BNC to 2mm banana-plug leads
- Assorted 2mm banana-plug patch leads
- One set of headphones (stereo)

**Procedure**

**Part A – Setting up the FM modulator**
To experiment with FM demodulation you need an FM signal. The first part of the experiment gets you to set one up. To make viewing the signals around the demodulator possible, we'll start with a DC voltage for the message.

1. Ensure that the NI ELVIS II power switch at the back of the unit is off.

2. Carefully plug the Emona DATEx experimental add-in module into the NI ELVIS II.

3. Set the *Control Mode* switch on the DATEx module (top right corner) to *PC Control*.

4. Connect the NI ELVIS II to the PC using the USB cable.

   **Note:** This may already have been done for you.

5. Turn on the NI ELVIS II power switch at the rear of the unit then turn on its *Prototyping Board Power* switch at the top right corner near the power indicator.

6. Turn on the PC and let it boot-up.

7. Launch the NI ELVISmx software.

**for ELVIS II only**

- 8. Launch and run the NI ELVIS II Function Generator VI.

- 9. Adjust the function generator for an output with the following specifications:
   - Waveshape: Sine
   - Frequency: 15kHz
   - Amplitude: 4Vpp
   - DC Offset: 0V
   - Modulation type: FM

**Use the ELVIS III Function Generator output Channel 2 to create a DC voltage of about 1V by loading the Custom waveform file "ECB_positive1V_DC.csv".**

10. Check that the function generator's *Signal Route* option (near the bottom right-hand corner of the VI is set to *Prototyping Board*.

    **Important note:** There is the potential for a hardware conflict when using the scope's external triggering input (*TRIG*) at the same time as the function generator. This is because the connector for the *TRIG* input doubles as an output for the function generator when its *Signal Route* option is set to *FGEN BNC*. To avoid hardware conflicts always set the *Signal Route* to *Prototyping Board*.

11. Launch and run the NI ELVIS II Variable Power Supplies VI.

12. Turn the Variable Power Supplies negative output soft *Voltage* control fully anti-clockwise to output 0V.

13. Connect the set-up shown in Figure 3 below.

**ELVIS II set-up is on the left and ELVIS III set-up setup is on the right**

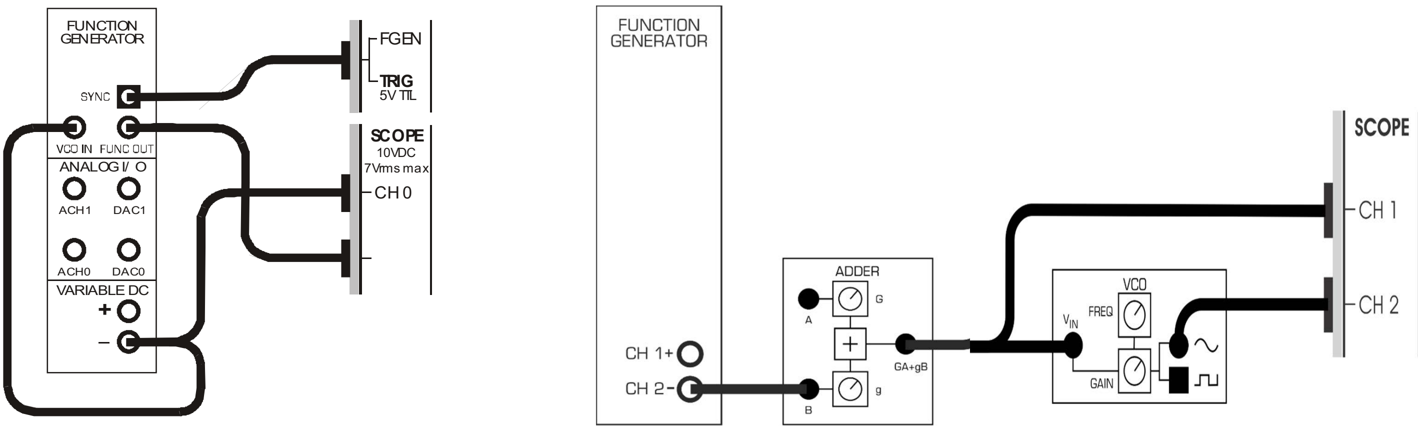



figure 3a : ELVIS II set-up

figure 3b : ELVIS III set-up

**Figure 3**

This set-up can be represented by the block diagram in Figure 4 on the next page. The negative output of the Variable DC Power Supplies is being used to provide a simple DC message and the VCO implements the FM modulator with a carrier frequency of 15kHz.

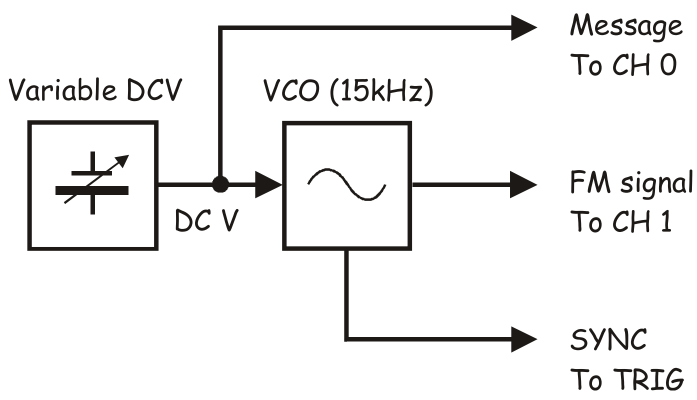



**Figure 4**

14. Launch and run the NI ELVIS II Oscilloscope VI.

15. Set up the scope per the procedure in Experiment 1 with the following changes:

- *Scale* control for Channel 0 to *2V/div* instead of *1V/div*
- *Trigger Type* control to *Digital* instead of *Edge*
- *Coupling* controls for both channels to *DC* instead of *AC*

16. Activate the scope's Channel 1 input to view the FM signal on the VCO's output as well as the DC message signal.

17. Set the scope's *Timebase* control to view two or so cycles of the VCO output.

18. Vary the Variable Power Supplies negative output soft *Voltage* control and check that the VCO's output frequency changes accordingly.

Ask the instructor to check
your work before continuing.

**Part B – Setting up the zero-crossing detector**

19. Launch the DATEx soft front-panel (SFP) and check that you have soft control over the DATEx board.

20. Locate the Twin Pulse Generator module on the DATEx SFP and turn its soft *Width* control fully anti-clockwise.

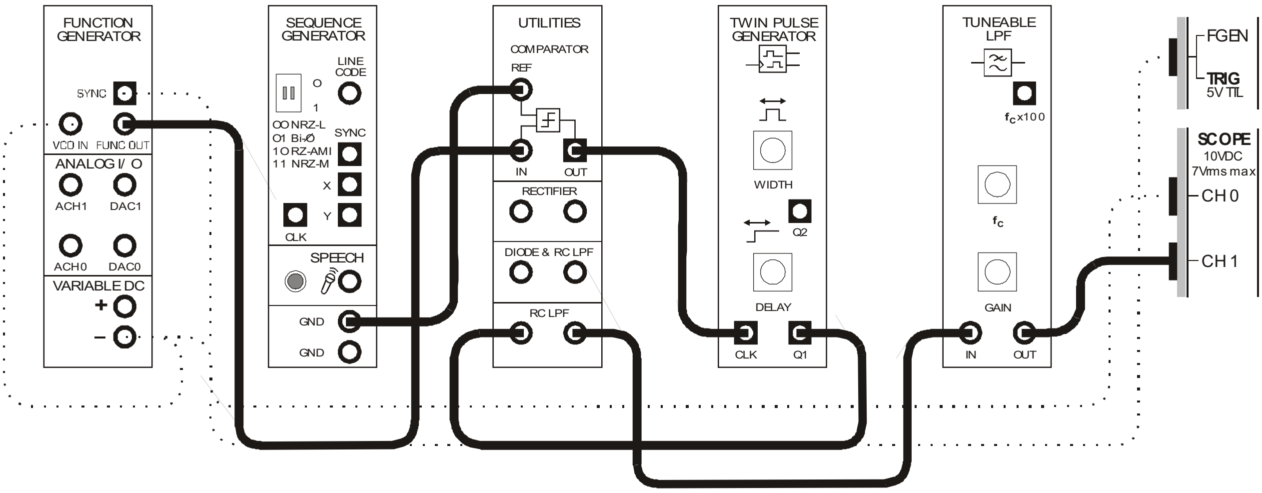
21. Set the Twin Pulse Generator module's soft *Delay* control fully anti-clockwise.

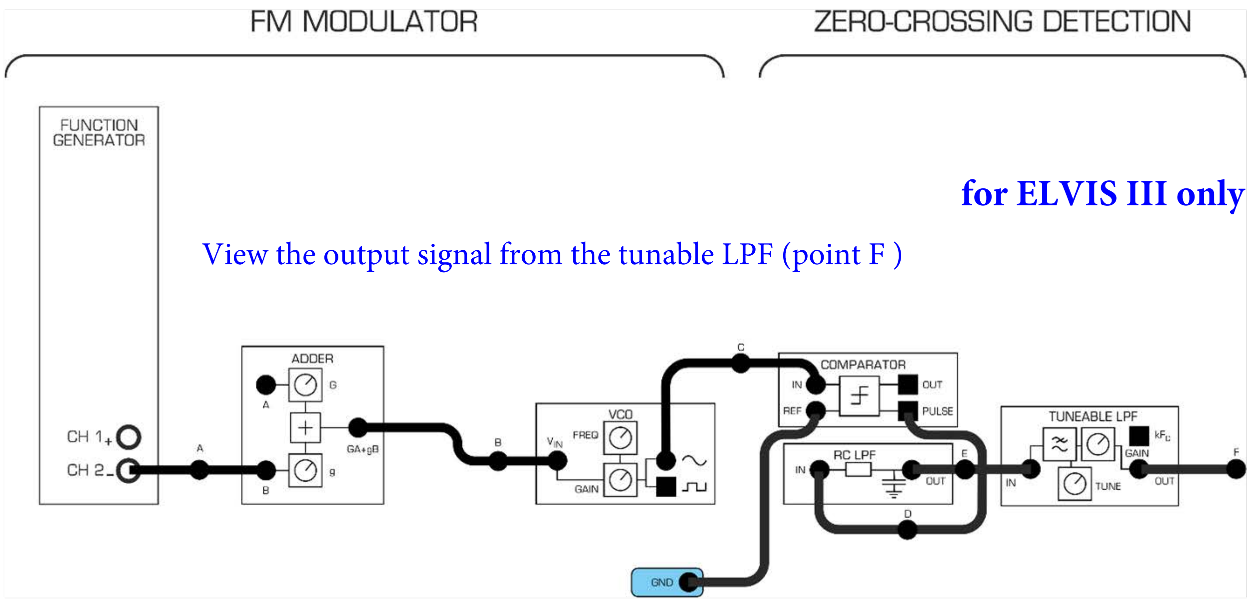
22. Locate the Tuneable Low-pass Filter module on the DATEx SFP and turn its soft *Gain* control fully clockwise.

23. Turn the Tuneable Low-pass Filter module's soft *Cut-off Frequency Adjust* control fully clockwise.

24. Modify the set-up as shown in Figure 5 below.

**for ELVIS II only**




The additions to the set-up can be represented by the block diagram in Figure 6 on the next page. The comparator on the Utilities module is used to clip the FM signal, effectively turning it into a squarewave. The positive edge-triggered Twin Pulse Generator module is used to implement the zero-crossing detector. To complete the FM demodulator, the RC Low-pass Filter module and Tuneable Low-pass Filter module combination is used to pick-out the changing DC component of the Twin Pulse Generator module's output.

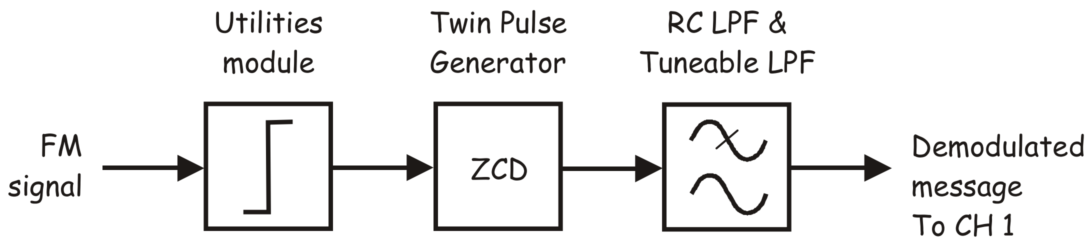



**Figure 6**

**Note:** The RC LPF and Tuneable LPF modules are used in combination because the Tuneable LPF is a clocked "switched capacitor" filter which uses internal sampling technology. These types of filters are subject to *aliasing* (a concept that is covered in later experiments) which can cause problems in sampled systems. To avoid such problems, we use the RC LPF as an *anti-aliasing* pre-filter for the Tuneable LPF. If time permits, explore this part of the experiment without the RC LPF.

The entire set-up can be represented by the block diagram in Figure 7 below.

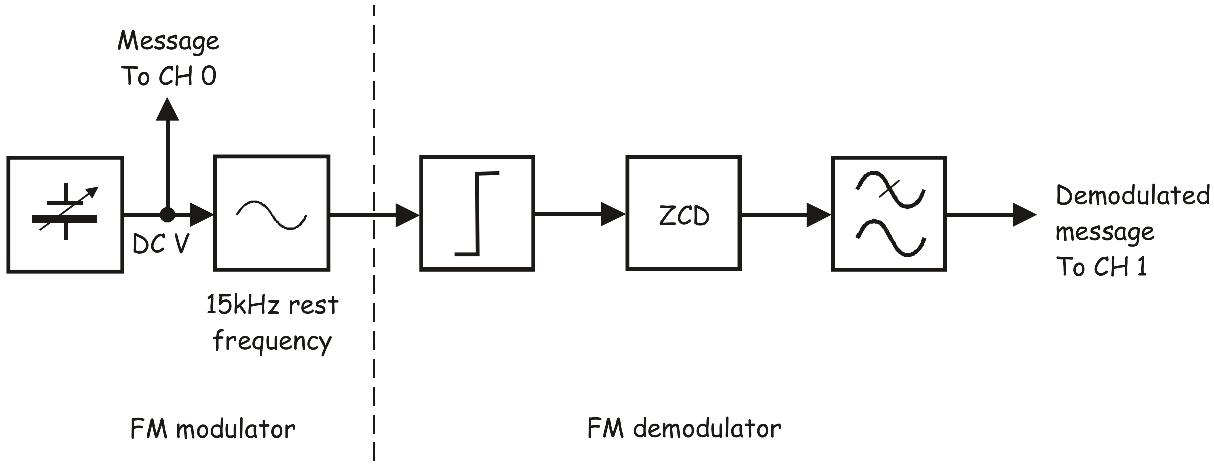



**Figure 7**

You will now tune the Tuneable Low-pass Filter to isolate the DC component of the ZCD for the voltage range of the input signal we plan to use.

25. Set the Variable Power Supplies negative output to -2V.

26. Set the scope's Channel 1 *Scale* control to the *100mv/div* position.

    **Note:** You should now see a 430mVp-p sinewave with a DC offset of approximately 230mV. This is the filtered pulse train out of the ZCD.

27. Slowly turn the Tuneable Low-pass Filter module's soft *Cut-off Frequency Adjust* control anti-clockwise until the sine wave becomes a DC voltage. Stop the moment this happens.

    **Note 1:** You have now eliminated all non-DC components from the signal. That said, the filter will still allow the message signal to pass.

    **Note 2:** Don't change the Tuneable Low-pass Filter module's soft *Cut-off Frequency Adjust* control setting for the rest of the experiment unless instructed to.

ADDERs GAIN

28. Vary the Variable Power Supplies negative output between 0V and a maximum of -2V.

    **Note 1:** As you do, you should notice that the DC voltage out of the Tuneable Low-pass Filter module varies as well.

    **Note 2:** If this doesn't happen, check that the scope's Channel 1 *Coupling* control is set to the DC position.

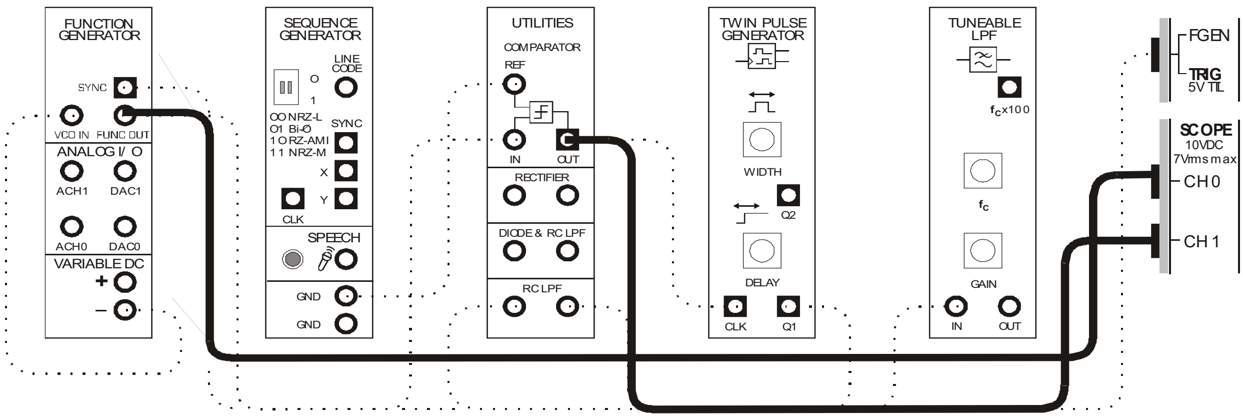
Ask the instructor to check your work before continuing.

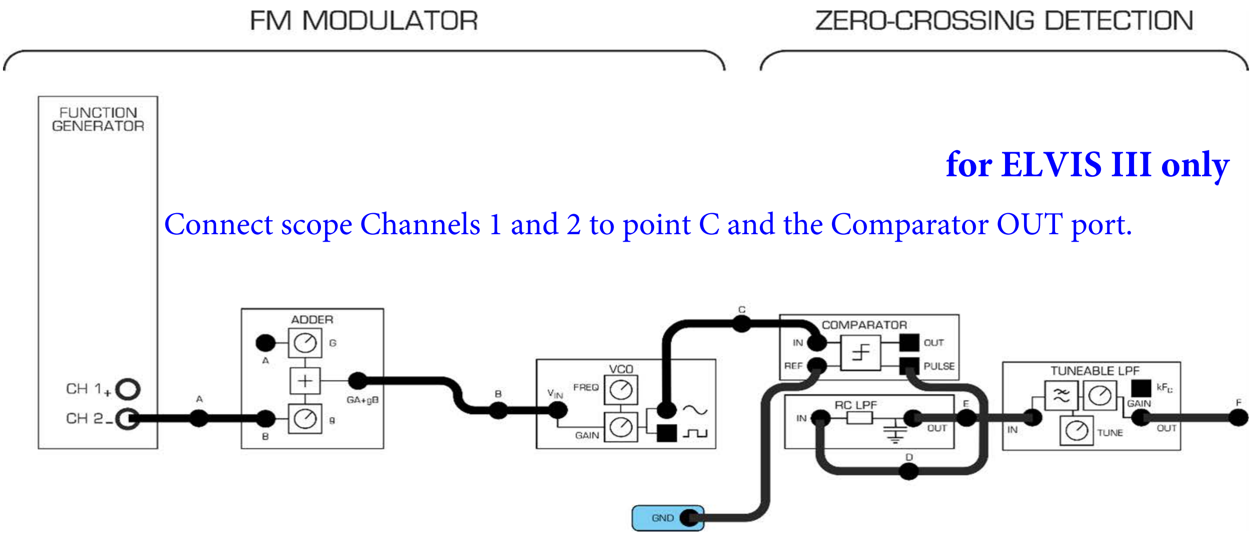
**Part C – Investigating the operation of the zero-crossing detector**

The next part of the experiment lets you verify the operation of the zero-crossing detector.

29. Rearrange the scope's connections to the set-up as shown in Figure 8 below.

**for ELVIS II only**




**for ELVIS III only**

Connect scope Channels 1 and 2 to point C and the Comparator OUT port.

The new scope connections can be shown using the block diagram in Figure 9 below.

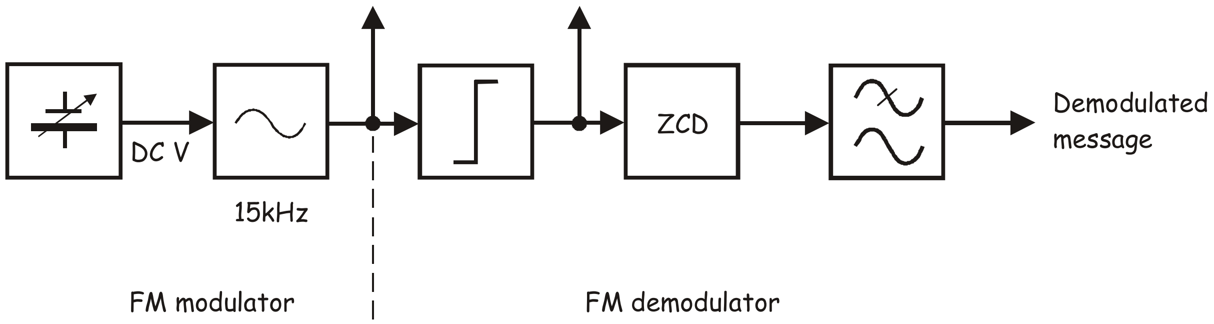



**Figure 9**

ADDER GAIN

30. Vary the Variable Power Supplies negative output in small steps using the up and down arrow buttons on the VI.

**Note:** This will cause small but noticeable changes in the FM signal's frequency.

31. As you vary the FM signal's frequency, pay close attention to the mark-space ratio (that is, the duty cycle) of the Comparator's output.

**Tip:** You may find it helpful to adjust the scope's *Vertical Position* controls to separate the signals on the display.

**Question 1**

Does the mark-space ratio of the signal on the Comparator's output change?

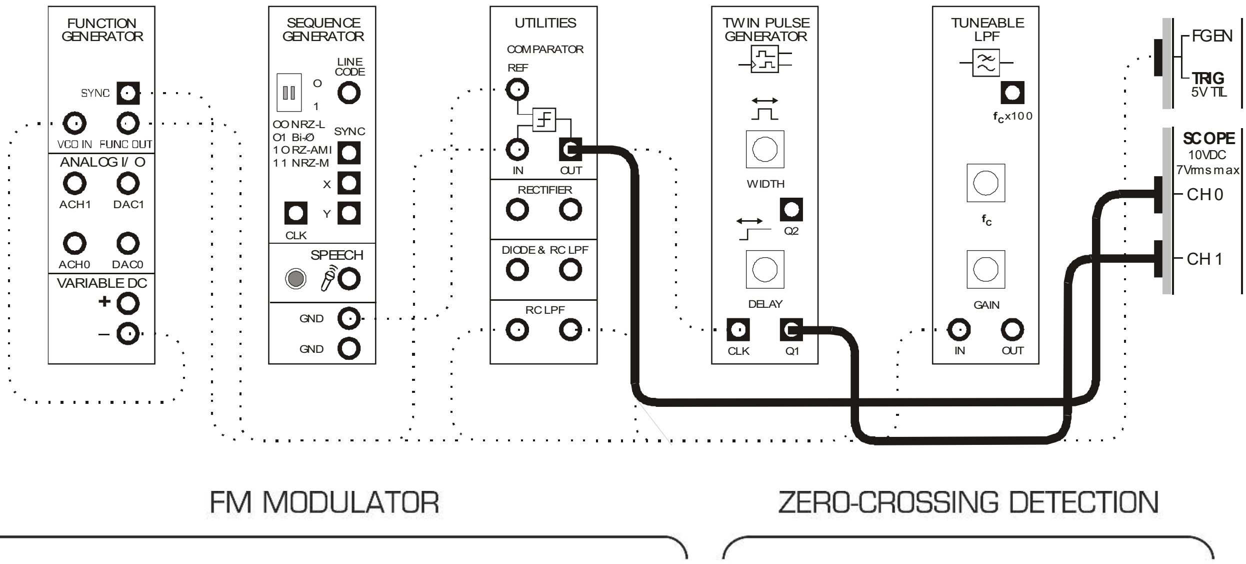
**Question 2**

What does this tell us about the DC component of the comparator's output?

Ask the instructor to check your work before continuing.

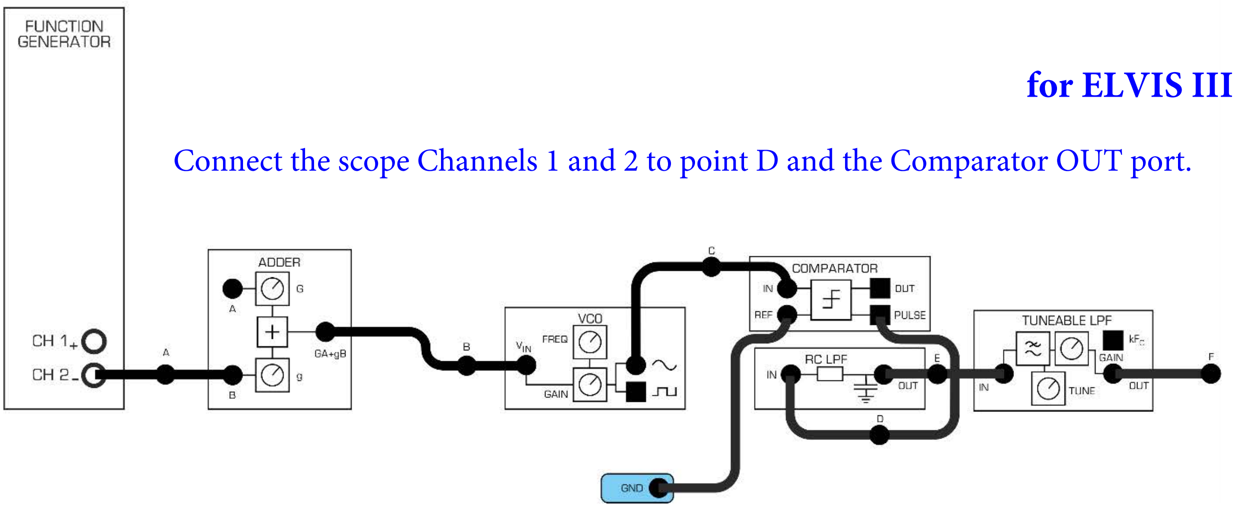
32. Rearrange the scope's connections to the set-up as shown in Figure 10 below.

**for ELVIS II only**




**for ELVIS III only**

Connect the scope Channels 1 and 2 to point D and the Comparator OUT port.




The new scope connections can be shown using the block diagram in Figure 11 below.

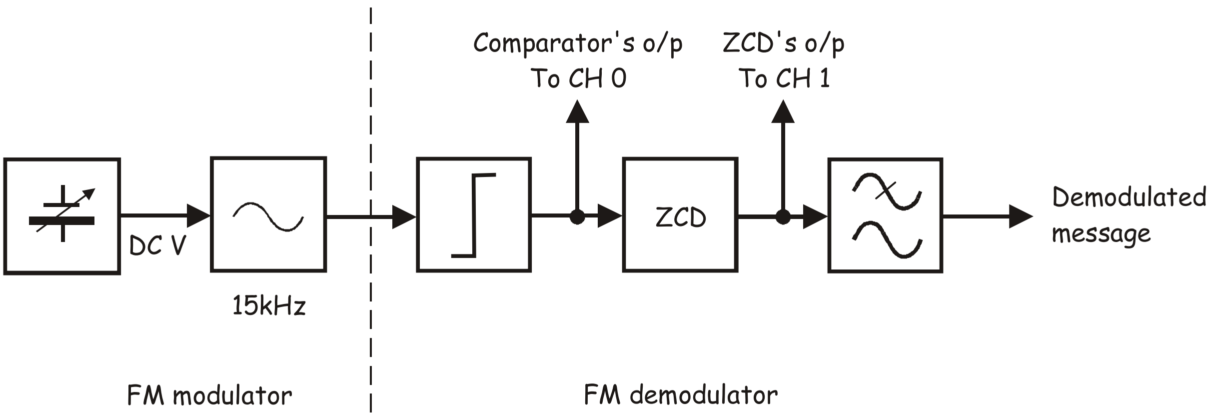



**Figure 11**

ADDER GAIN

33. Vary the Variable Power Supplies negative output in small steps again to model an FM signal's changing frequency.

34. As you perform the step above, note how the frequency of the two signals changes.

35. Turn on the scope's cursors.

36. Use the scope's cursors to measure the width of the ZCD output's mark and space for different DC input voltages.

    **Note:** The time difference between the two cursors is displayed directly above the Channel 0 & 1 measurements and is denoted as *dT*.

    **Tip:** You may find it helpful to turn the scope's Channel 0 off as you do this and set its *Timebase* control to *10μs/div* when measuring the mark's width.

**Question 3**
As the FM signal changes frequency so does the ZCD's output. What aspect of the ZCD's output signal changes to achieve this?

☐ Neither the signal's mark nor space

☐ Only the signal's mark

☐ Only the signal's space

☐ Both the signal's mark and space

**Question 4**
What does this tell us about the DC component of the comparator's output?

________________________________________

________________________________________

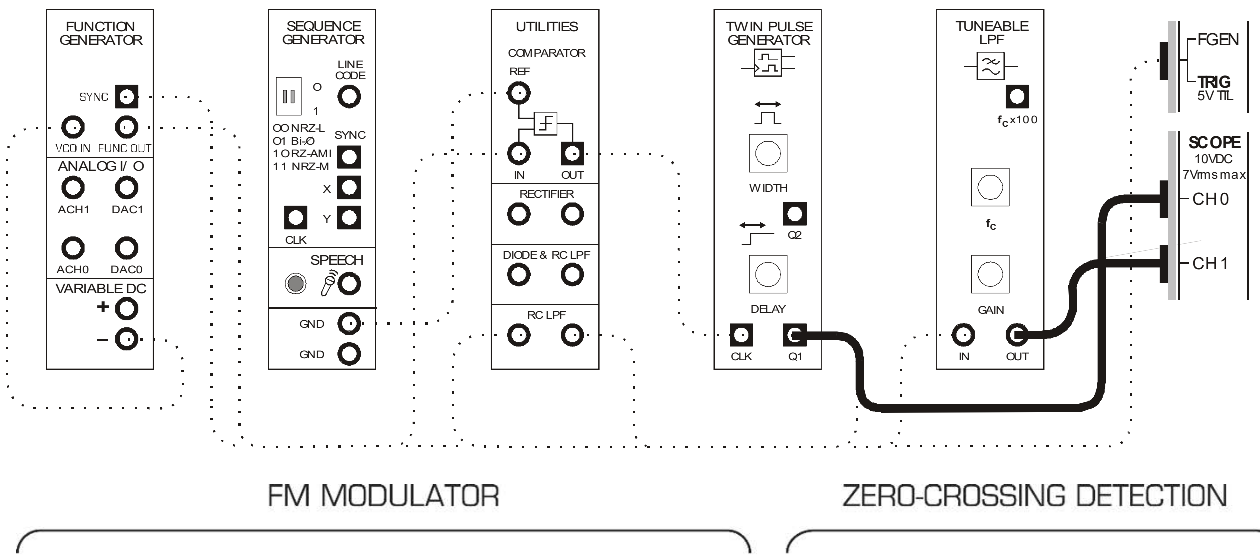
Ask the instructor to check
your work before continuing.

The next part of the experiment lets you verify your answer to the previous question.

37. If you deactivated the scope's Channel 0 then reactivate it and return its *Timebase* control to *50μs/div*.

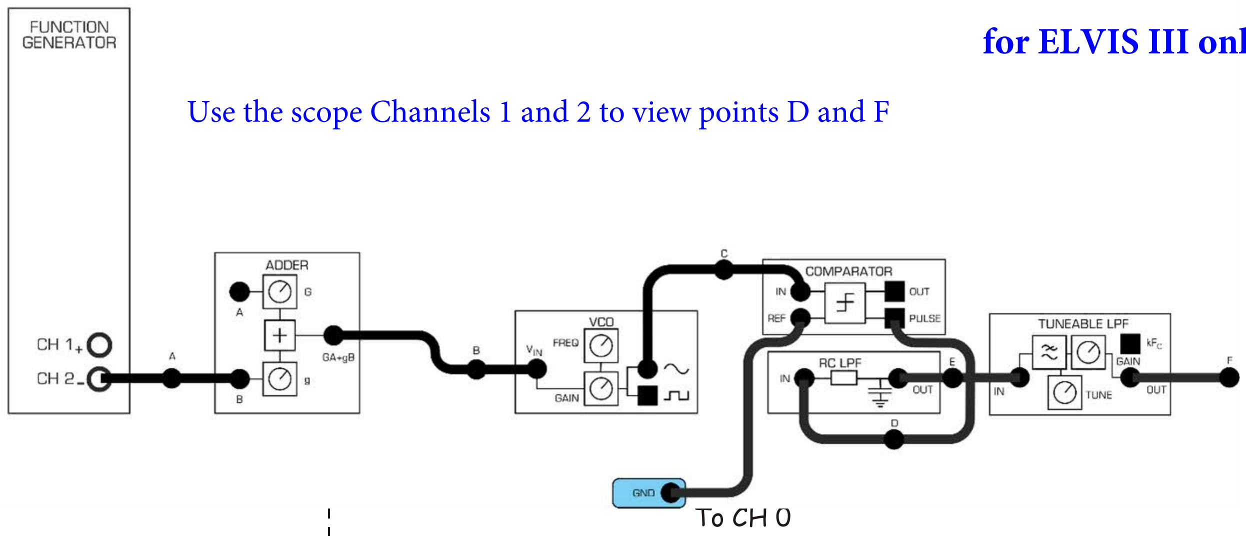
38. Rearrange the scope's connections to the set-up as shown in Figure 12 below.

**for ELVIS II only**




**for ELVIS III only**

Use the scope Channels 1 and 2 to view points D and F



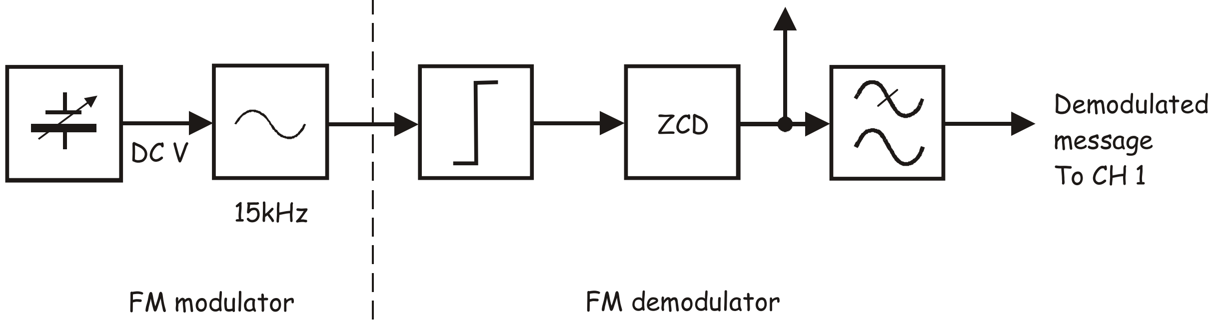




**Figure 13**

39. If you've adjusted the scope's Channel 1 *Vertical Position* control, re-zero it.

40. Vary the Variable Power Supplies negative output in small steps again to model an FM signal's changing frequency.

41. As you perform the step above, compare the outputs from the Twin Pulse Generator module (the ZCD) and the Tuneable Low-pass Filter module.

**Question 5**
Why does the Tuneable Low-pass Filter module's DC output go up as the mark-space ratio of the ZCD's output goes up?

________________________________________

________________________________________

**Question 6**
If the original message is a sinewave instead of a variable DC voltage, what would you expect to see out of the Tuneable Low-pass Filter module?

________________________________________

________________________________________

Ask the instructor to check
your work before continuing.

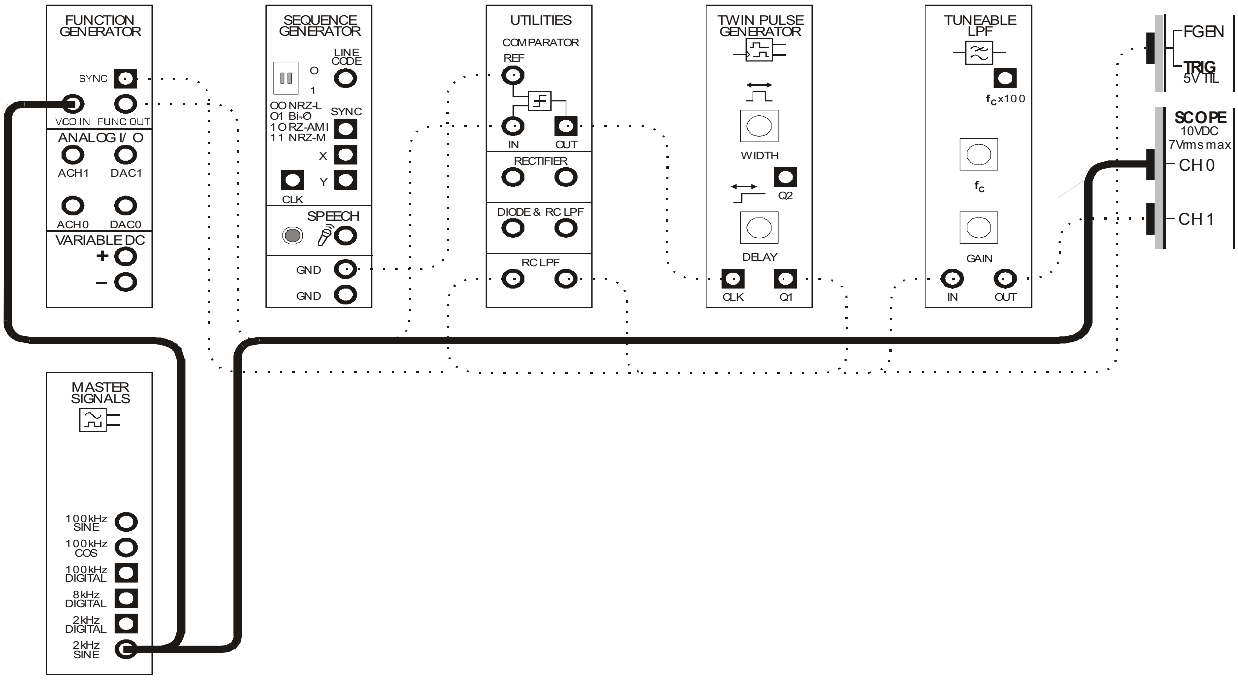
**Part D – Transmitting and recovering a sinewave using FM**

This experiment has set up an FM communication system to "transmit" a message that is a DC voltage. The next part of the experiment lets you use the set-up to modulate, transmit and demodulate a test signal (a sinewave).

42. If it's not already, turn the Tuneable Low-pass Filter module's soft *Gain* control fully clockwise.

43. Modify the set-up as shown in Figure 14 below.

for ELVIS II only




for ELVIS III only

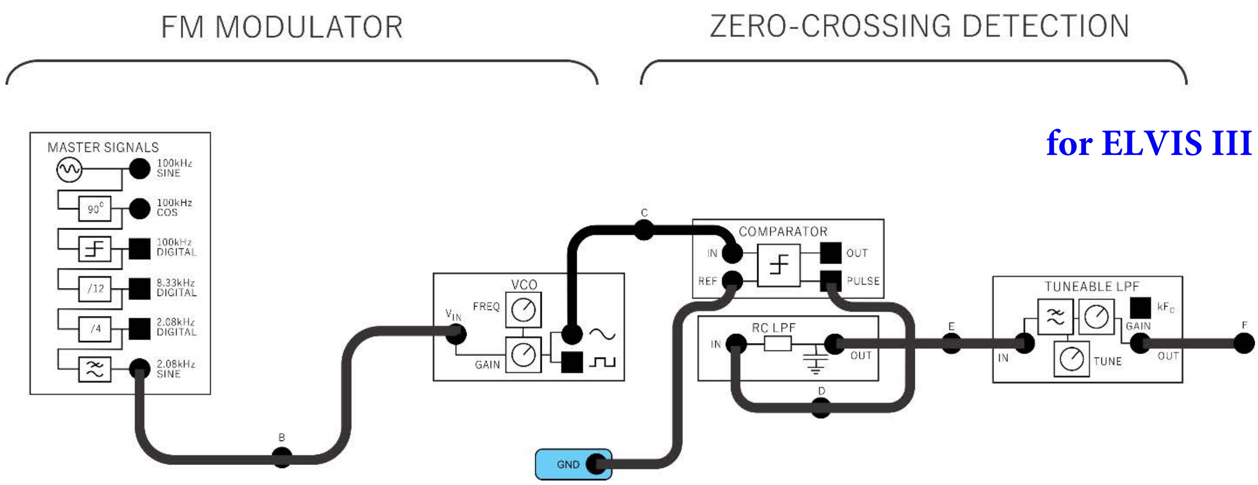



**Figure 14**

This modification to the FM modulator can be shown using the block diagram in Figure 15 on the next page. Notice that the message is now provided by the Master Signals module's *2kHz SINE* output.

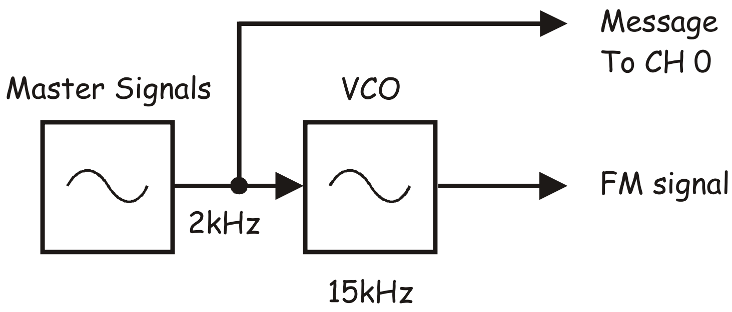



**Figure 15**

44. Make the following adjustments to the scope's controls:

- *Scale* control for Channel 0 to *2V/div* and to *100mV/div* for Channel 1
- *Input Coupling* control for both channels to *AC*
- *Trigger Type* to *Edge*
- *Trigger Source* to *CH 0*
- *Timebase* control to *200μs/div*

45. Use the *TAB* and arrow keys to turn the Tuneable Low-pass Filter module's soft *Cut-off Frequency Adjust* control slightly anti-clockwise to fine tune the filter's cut-off frequency.

**Note:** You will already be viewing the demodulated 2kHz message sinewave with an amplitude of approximately 250mVp-p.

**Question 7**
What does the FM modulator's output signal tell you about the ZCD signal's duty cycle?

Ask the instructor to check your work before continuing.

**Part E – Transmitting and recovering speech using FM**

The next part of the experiment lets you use the set-up to modulate, transmit and demodulate speech.

46. Disconnect the plugs to the Master Signals module's *2kHz SINE* output.

47. Modify the set-up as shown in Figure 16 below.

for ELVIS II only

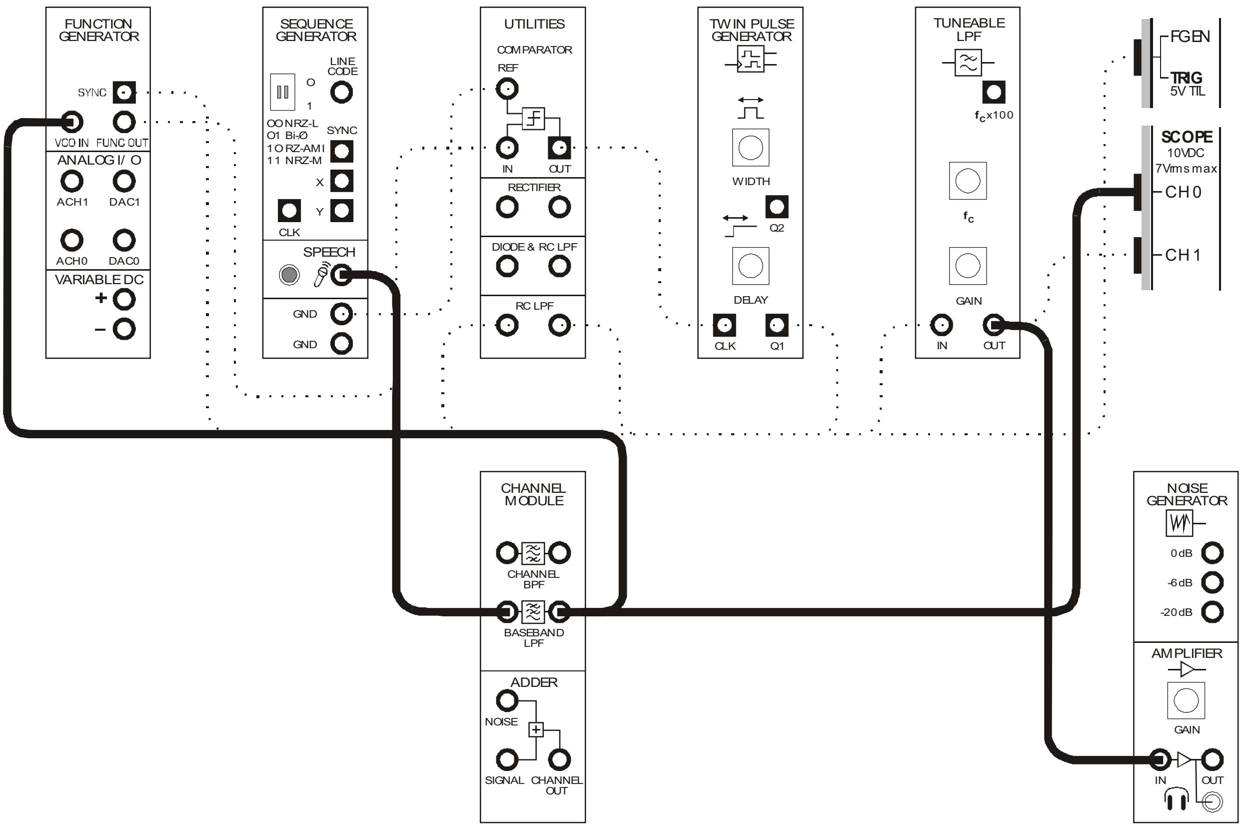



**Figure 16**

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

49. Locate the Amplifier module on the DATEx SFP and turn its soft *Gain* control fully anti-clockwise.

For ELVIS III :modifying the previous set-up, replace the sinewave input signals with a Speech signal from the microphone module and the output to Amplifier & Headphone . Continue to view the input message at point B, as well as the output at point F

50. Without wearing the headphones, plug them into the Amplifier module's headphone socket.

51. Put the headphones on.

52. As you perform the next step, set the Amplifier module's soft *Gain* control to a comfortable sound level.

53. Hum and talk into the microphone while watching the scope's display and listening on the headphones.

60. Once you have completed viewing the signal with the scope, stop the scope and start the NI ELVIS II Dynamic Signal Analyzer to view the spectrum of the frequency modulated speech. Set the DSA frequency setting to 40kHz. Try whistling into the microphone. This will help you to see the difference between single tones and speech during modulation.

Ask the instructor to check your work before finishing.

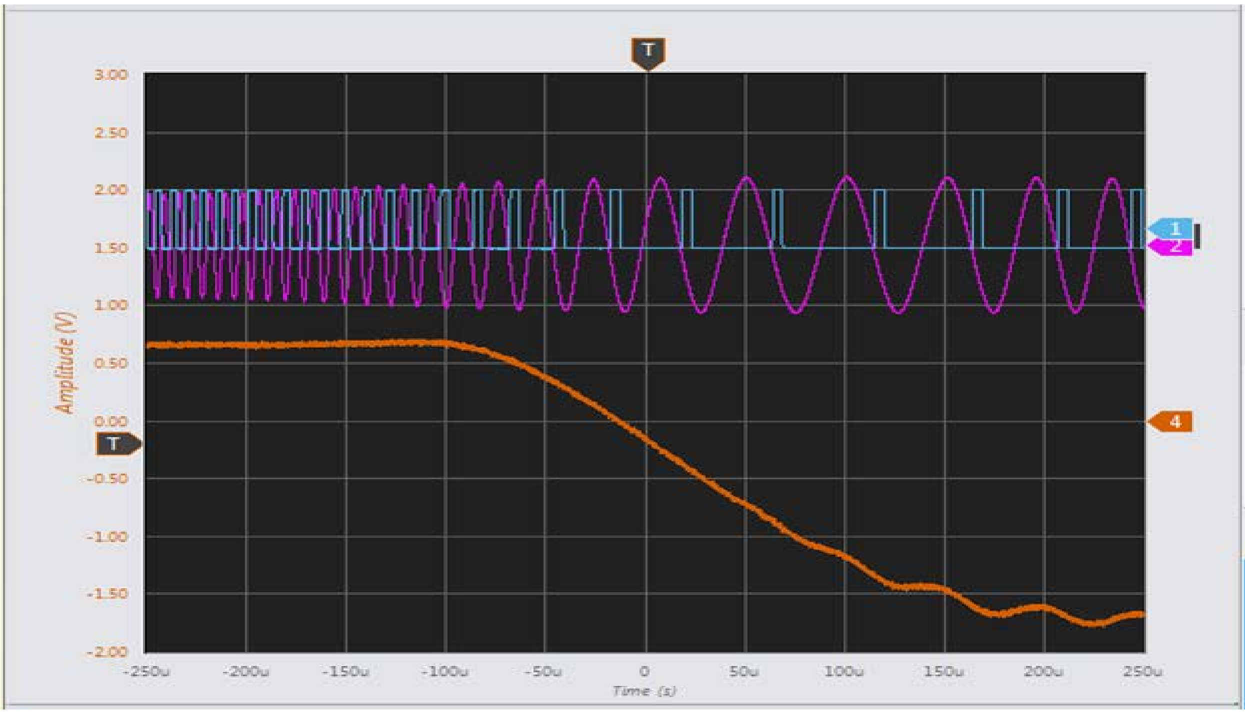



Figure 17: Example signals for FM, ZCD and demodulated output