Experiment 2 - An introduction to the Telecoms-Trainer 101

Preliminary discussion

As its name implies, the Emona Telecoms-Trainer 101 is used to help people learn about communications and telecommunications principles. It lets you bring to life the block diagrams that fill communications textbooks. A "block diagram" is a simplified representation of a more complex circuit. An example is shown in Figure 1 below.

Block diagrams are used to explain the principle of operation of electronic systems (like a radio transmitter for example) without worrying about how the circuit works. Each block represents a part of the circuit that performs a separate task and is named according to what it does. Examples of common blocks in communications equipment include the *adder*, *filter*, *phase shifter* and so on.

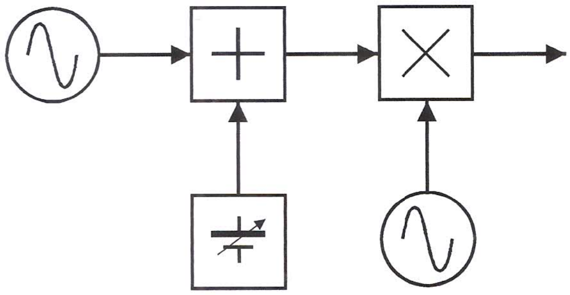

Figure 1

The Emona Telecoms-Trainer 101 has a collection of blocks (called *modules*) that you can put together to implement dozens of communications and telecommunications block diagrams.

The experiment

This experiment is in three stand-alone parts (2-1, 2-2 and 2-3) and each introduces you to one or more of the trainer's analog modules.

It should take you about 1 hour to complete 2.1 of this experiment, about 50 minutes to complete 2.2 and about 1 hour to complete 2.3.

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
- **For 2.1 only** - one set of headphones (stereo)

Some things you need to know for the experiment

This box contains definitions for some electrical terms used in this experiment. Although you've probably seen them before, it's worth taking a minute to read them to check your understanding.

Two signals that are **in phase** with each other are synchronised. That is, they go up and down at the same time.

Two signals that **out of phase** are not synchronised. That is, they are out of step with each other. An example of two signals that are out of phase is shown in Figure 3 below.

Phase difference describes how much two signals are out of phase and is measured in degrees (like degrees in a circle). Signals that are in phase have a phase difference of 0°. Signals that are out of phase have a phase difference > 0° but < 360°.

A **sinewave** is a repetitive signal with the shape shown in Figure 1.

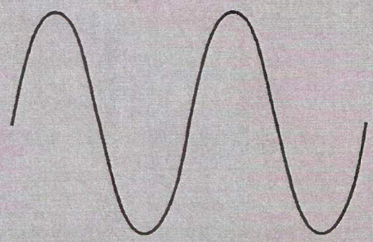

Figure 2

A **cosine wave** is simply a sinewave that is out of phase with another sinewave by exactly 90°. A sinewave and a cosine wave are shown in Figure 3. (They're not marked because, in this case, it doesn't matter which one is which.)

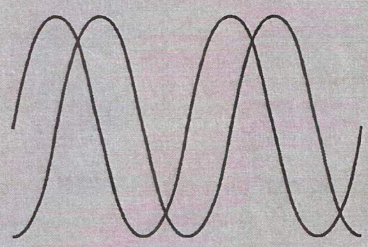

Figure 3

2.1 - The Master Signals, Speech and Buffer modules

The Master Signals module

The Master Signals module is an AC signal generator or *oscillator*. The module has six outputs providing the following:

Analog

- A 2kHz sinewave
- A 100kHz sinewave
- A 100kHz cosine wave

Digital

- A 2.083kHz squarewave
- An 8.33kHz squarewave
- A 100kHz squarewave

Each signal is available on a socket on the module's faceplate that's labelled accordingly.

Procedure

1. Gather a set of the equipment listed on page 2-2.

2. Connect the set-up shown in Figure 1 below.

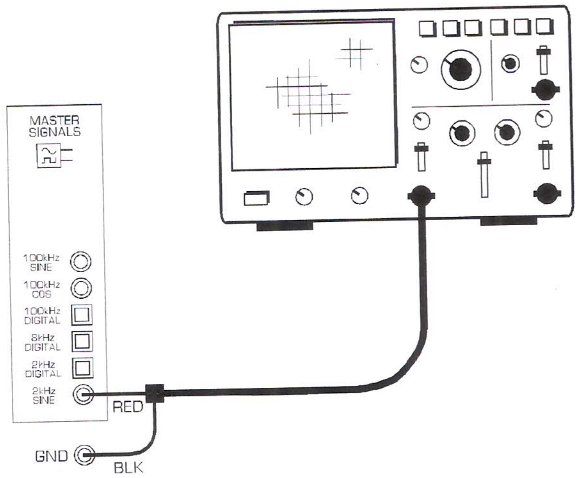

Figure 1

This set-up can be represented by the block diagram in Figure 2 below.

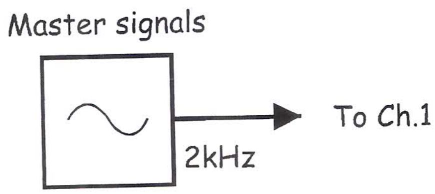

Figure 2

3. Set up the scope per the instructions in Experiment 1. Ensure that:

- the *Trigger Source* control is set to the *CH1* (or *INT*) position.
- the *Mode* control is set to the *CH1* position.

4. Adjust the scope's *Timebase* control to view two or so cycles of the Master Signals module's *2kHz SINE* output.

5. Measure the amplitude (peak-to-peak) of the Master Signals module's *2kHz SINE* output. Record your measurement in Table 1 below.

   Tip: If you're not sure how to measure the signal's amplitude, see Experiment 1 (page 1-6).

6. Measure and record the period of the Master Signals module's *2kHz SINE* output.

   Tip: If you're not sure how to measure the signal's period, see Experiment 1 (page 1-7).

7. Use the period to calculate and record the frequency of the Master Signals module's *2kHz SINE* output.

   Tip: If you're not sure how to calculate the signal's frequency, see Experiment 1 (page 1-8).

8. Repeat Steps 4 to 7 for the Master Signals module's other two analog outputs.

Table 1	Output voltage	Period	Frequency
2kHz SINE			
100kHz COS			
100kHz SINE			

Ask the instructor to check your work before continuing.

It is critical to the operation of several communications and telecommunications systems that there be two (or more) sinewaves that are the same frequency but out of phase with each other. Figure 3 below shows examples of pairs of sinewaves that are out of phase by different amounts.

Figure 3

It's a useful skill in communications and telecommunications to be able to measure the phase difference between signals. The next part of the experiment gives you practise at this by getting you to measure the phase difference between the Master Signals module's *100kHz SINE* and *COSINE* outputs.

9. Connect the set-up shown in Figure 4 below.

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

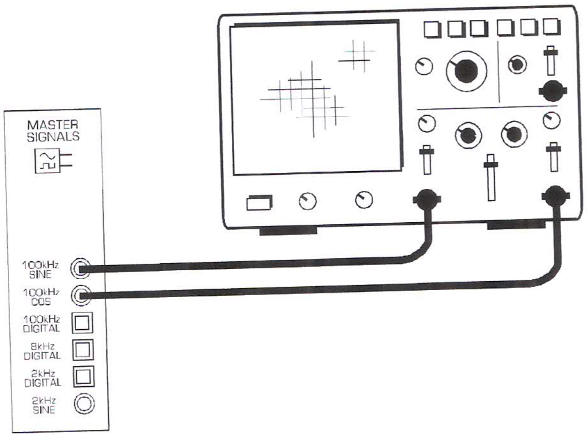

Figure 4

The following procedure can be used whenever you need to measure the phase difference between two signals.

10. Set the scope's *Mode* control to the *Dual* position to view both of the Master Signals module's 100kHz outputs.

11. Adjust the scope's *Timebase* control to view as few **complete** cycles of the two signals as possible.

12. Set the *Input Coupling* controls for both channels to the *GND* position.

13. Use the *Vertical Position* control of both channels to align both traces with the horizontal line in the middle of the scope's display.

14. Set the *Input Coupling* control for Channel 1 to the *AC* position.

15. As accurately as you can, count the number of divisions for one cycle of the signal. Call this dimension the "period".

    Record your measurement here: Period = ______________

16. Set the *Input Coupling* control for Channel 2 to the *AC* position.

17. As accurately as you can, count the number of divisions between the two signals as shown in Figure 5.

    Call this dimension the "difference" and record your measurement here:

    Difference = ______________

    Tip: The sub-divisions on the scope's display are each worth 0.2 of a division.

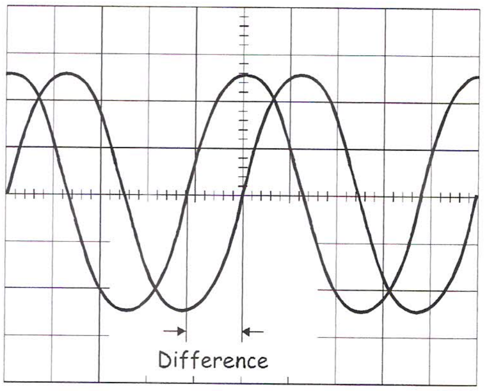

Figure 5

18. Use the equation below to calculate the phase difference between the two signals. Record the answer to your calculation in Table 2 (on the next page).

$$\Phi \; difference = \frac{difference}{period} \times 360^{\circ}$$

Table 2

Φ difference between the SINE and COS outputs	

Question 1
The theoretical phase shift between a sinewave and a cosine wave is 90°. If your measurement isn't exactly 90°, what could explain the difference?

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Ask the instructor to check your work before continuing.

The Speech module

Sinewaves are important to communications. They're used extensively for the *carrier* signal in many communications systems. Sinewaves also make excellent test signals. However, the purpose of most communications equipment is the transmission of speech (among other things) and so it's useful to examine the operation of equipment using signals generated by speech instead of sinewaves. The Emona Telecoms-Trainer 101 allows you to do this using the Speech module.

19. Set the scope's *Mode* control to the *CH1* position.

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

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

    Note: Insert the oscilloscope lead's black plug into a ground (*GND*) socket.

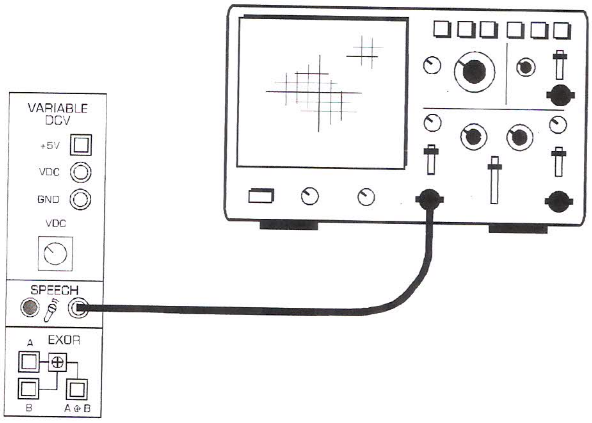

Figure 6

22. Talk into the microphone while watching the scope's display. Be sure to say "one" and "two" several times. Try humming and whistling too.

Ask the instructor to check your work before continuing.

The Buffer module

Amplifiers are used extensively in communications and telecommunications equipment. They're often used to make signals bigger. They're also used as an interface between devices and circuits that can't normally be connected. The Buffer module in the Emona Telecoms-Trainer 101 is an amplifier that can do both.

23. Locate the Buffer module and set its *Gain* control to about the middle of its travel.

24. Connect the set-up shown in Figure 7 below.

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

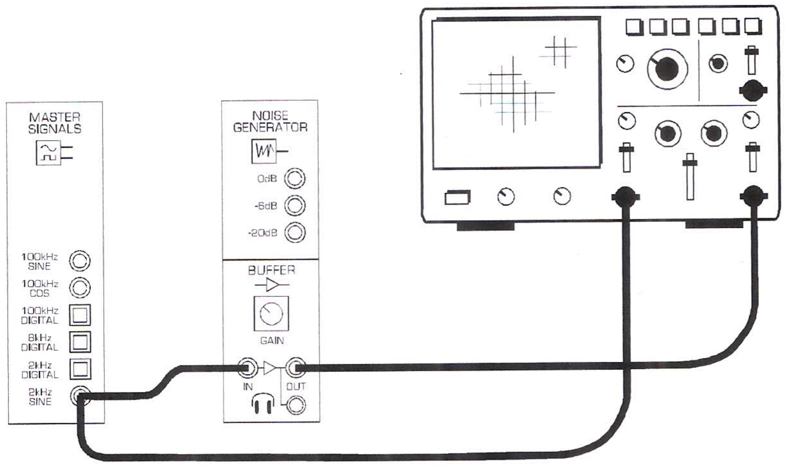

Figure 7

This set-up can be represented by the block diagram in Figure 8 below.

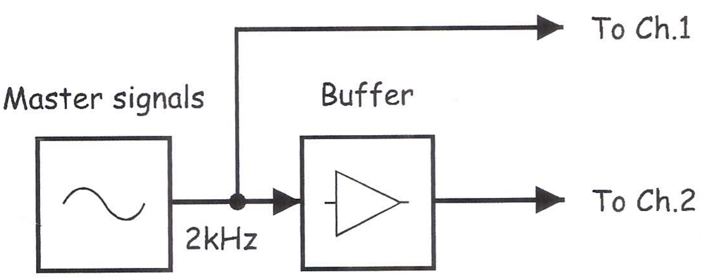

Figure 8

25. Set the scope's *Mode* control to the *DUAL* position.

26. Adjust the scope's *Timebase* control to view two or so cycles of the Buffer module's input.

27. Adjust both of the scope's *Vertical Attenuation* controls to make the signals as big on the display as possible without going off the top and bottom of the screen's grid.

28. Measure the amplitude (peak-to-peak) of the Buffer module's input. Record your measurement in Table 3 below.

    Tip: If you're not sure how to measure the signal's peak-to-peak voltage, see Experiment 1 (page 1-6).

29. Measure and record the amplitude of the Buffer module's output.

Table 3

Input voltage	Output voltage

The measure of how much bigger an amplifier's output is compared to its input is called *gain* (A_V). An amplifier's gain can be expressed as a simple ratio and is calculated using the equation:

$$A_V = \frac{Vout}{Vin}$$

Importantly, if the amplifier's output signal is upside-down compared to its input then a negative sign is usually put in front of the gain figure to highlight this fact.

Question 2
Calculate the Buffer module's gain (on its present gain setting).

The Buffer module's gain is variable. Usefully, it can be set so that the output voltage is smaller than the input voltage. This is not amplification at all. Instead it's a loss or *attenuation*. The next part of the experiment shows how attenuation affects the gain figure.

30. Turn the Buffer module's *Gain* control fully anti-clockwise then turn it clockwise just a little until you can just see a sinewave.

31. Measure the amplitude of the Buffer module's input. Record your measurement in Table 4 below.

32. Measure and record the amplitude of the Buffer module's new output.

    Tip: You'll have to adjust the scope's Channel 2 *Vertical Attenuation* control first.

Table 4

Input voltage	Output voltage
See Table 3	

Question 3
Calculate the Buffer module's new gain.

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Question 4
In terms of the gain figure, what's the difference between gain and attenuation?

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Ask the instructor to check your work before continuing.

Amplifiers work by taking the DC power supply voltage and using it to make a copy of the amplifier's input signal. Obviously then, the DC power supply limits the size of the amplifier's output. If the amplifier is forced to try to output a signal that is bigger than the DC power supply voltages, the tops and bottoms of the signal are chopped off. This type of signal distortion is called *clipping*.

Clipping usually occurs when the amplifier's input signal is too big for the amplifier's gain. When this happens, the amplifier is said to be *overdriven*. It can also occur if the amplifier's gain is too big for the input signal. To demonstrate clipping:

33. Turn the Buffer module's *Gain* control fully clockwise.

Question 5
What do you think the output signal would look like if the buffer's gain was sufficiently large?

Ask the instructor to check your work before continuing.

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

Headphones are low impedance devices - typically around 50Ω. Most electronic circuits are not designed to have such low impedances connected to their output. For this reason, headphones should not be directly connected to the output of most of the modules on the Emona Telecoms-Trainer 101.

However, the Buffer module has been specifically designed to handle low impedances. So, it can act as an interface between the modules' outputs and the headphones to let you listen to signals. The next part of the experiment shows how this is done.