Name: ______________________

Class: ______________________

13 - PCM decoding

Experiment 13 - PCM decoding

Preliminary discussion

The previous experiment introduced you to the basics of pulse code modulation (PCM) which you'll recall is a system for converting message signals to a continuous serial stream of binary numbers (*encoding*). Recovering the message from the serial stream of binary numbers is called *decoding*.

At its simplest, decoding involves:

- Identifying each new frame in the data stream.
- Extracting the binary numbers from each frame.
- Generating a voltage that is proportional to the binary number.
- Holding the voltage on the output until the next frame has been decoded (forming a pulse amplitude modulation (PAM) version of the original message signal).
- Reconstructing the message by passing the PAM signal through a low-pass filter.

The PCM decoder's clock frequency is crucial to the correct operation of simple decoding systems. If it's not the same frequency as the encoder's clock, some of the transmitted bits are read twice while others are completely missed. This results in some of the transmitted numbers being incorrectly interpreted, which in turn causes the PCM decoder to output an incorrect voltage. The error is audible if it occurs often enough. Some decoders manage this issue by being able to "self-clock".

There is another issue crucial to PCM decoding. The decoder must be able to detect the beginning of each frame. If this isn't done correctly, every number is incorrectly interpreted. The synchronising of the frames can be managed in one of two ways. The PCM encoder can generate a special *frame synchronisation* signal that can be used by the decoder though this has the disadvantage of needing an additional signal to be sent. Alternatively, a frame synchronisation code can be embedded in the serial data stream that is used by the decoder to work out when the frame starts.

A little information about the TIMS PCM Decoder module
Like the PCM Encoder module on the Emona Telecoms-Trainer 101, the PCM Decoder module works with 8-bit binary numbers. For 00000000 the PCM Decoder module outputs -2V and for 11111111 it outputs +2V. For numbers in between, the output is a proportional voltage between ±2V. For example, the number 10000000 is half way between 00000000 and 11111111 and so for this input the module outputs 0V (which is half way between +2V and -2V).

The PCM Decoder module is not self-clocking and so it needs a digital signal on the *CLK* input to operate. Importantly, for the PCM Decoder module to correctly decode PCM data generated by the PCM Encoder module, it must have the same clock signal. In other words, the decoder's clock must be "stolen" from the encoder.

Similarly, the PCM Decoder module cannot self-detect the beginning of each new frame and so it must have a frame synchronisation signal on its *FS* input to do this.

The experiment
In this experiment you'll use the Emona Telecoms-Trainer 101 to convert a sinewave and speech to a PCM data stream then convert it to a PAM signal using the PCM Decoder module. For this to work correctly, the decoder's clock and frame synchronisation signal are simply "stolen" the PCM Encoder module. You'll then recover the message using the Tuneable Low-pass filter module.

It should take you about 45 minutes to complete this experiment.

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 PCM encoder
To experiment with PCM decoding you need PCM data. The first part of the experiment gets you to set up a PCM encoder.

1. Gather a set of the equipment listed on the previous page.

2. 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.

3. Locate the PCM Encoder module and set its *Mode* switch to the *PCM* position.

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

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

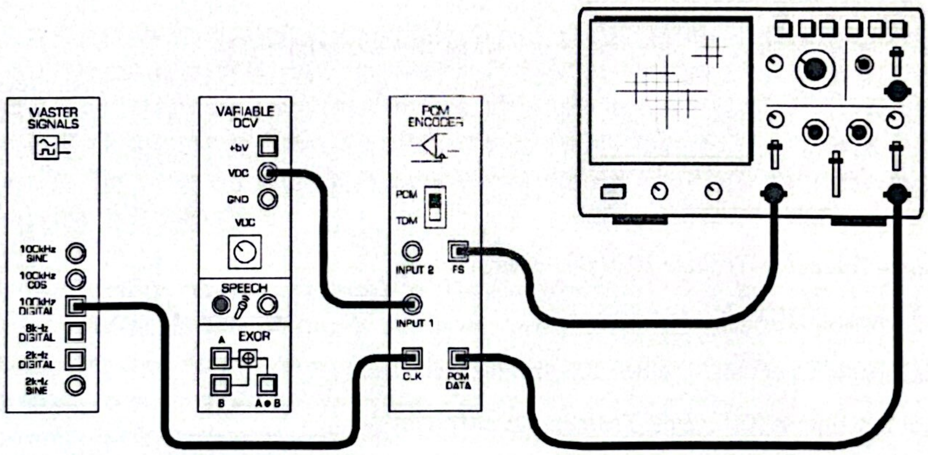

Figure 1

This set-up can be represented by the block diagram in Figure 2 on the next page. The PCM Encoder module is clocked by the Master Signals module's *100kHz DIGITAL* output. Its analog input is the Variable DC module's *VDC* output.

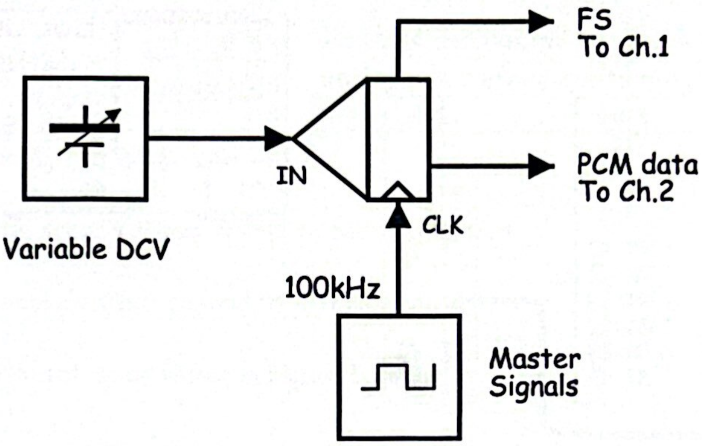

Figure 2

5. Set the scope's *Slope* control to the "-" position.

6. Adjust the scope's *Timebase* control to view one pulse of the PCM Encoder module's *FS* output.

   Tip: The *10μs/div* setting is probably the best to use.

7. Set the Variable DCV module's *Variable DC* control to about the middle of its travel.

8. Set the scope's *Mode* control to the *DUAL* position to view the PCM Encoder module's *PCM DATA* output as well as its *FS* output.

9. Vary the Variable DCV module's *Variable DC* control left and right.

If your set-up is working correctly, this last step should cause the number on PCM Encoder module's *PCM DATA* output to go down and up. If it does, carry on to the next step. If not, check your wiring or ask the instructor for help.

10. Disconnect the plug to the Variable DCV module's *VDC* output.

11. Locate the VCO module and turn its *Frequency Adjust* control fully anti-clockwise.

12. Set the VCO module's *Range* control to the *LO* position.

13. Modify the set-up as shown in Figure 3 on the next page.

    Remember: Dotted lines show leads already in place.

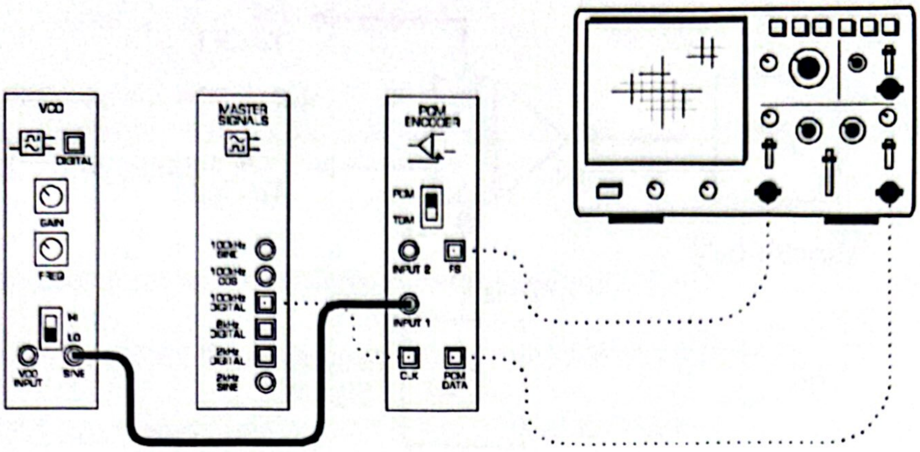

Figure 3

This set-up can be represented by the block diagram in Figure 4 below. Notice that the PCM Encoder module's input is now the VCO module's *SINE* output.

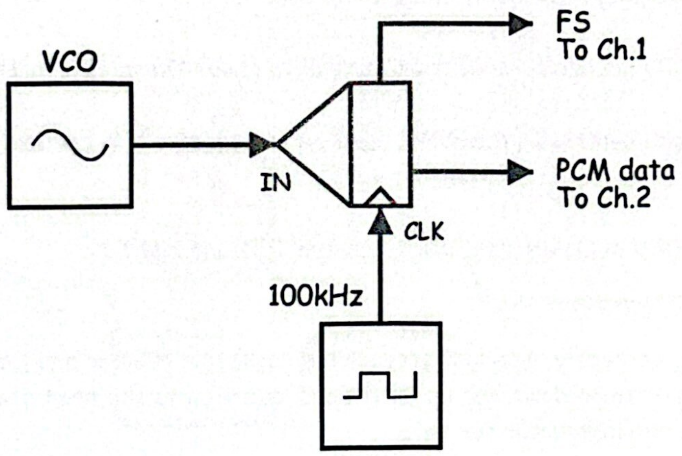

Figure 4

As the PCM Encoder module's input is a sinewave, the module's input voltage is continuously changing. This means that you should notice the *PCM DATA* output changing continuously also.

Ask the instructor to check your work before continuing.

Part B - Decoding the PCM data

14. Return the scope's *Slope* control to the "+" position.

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

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

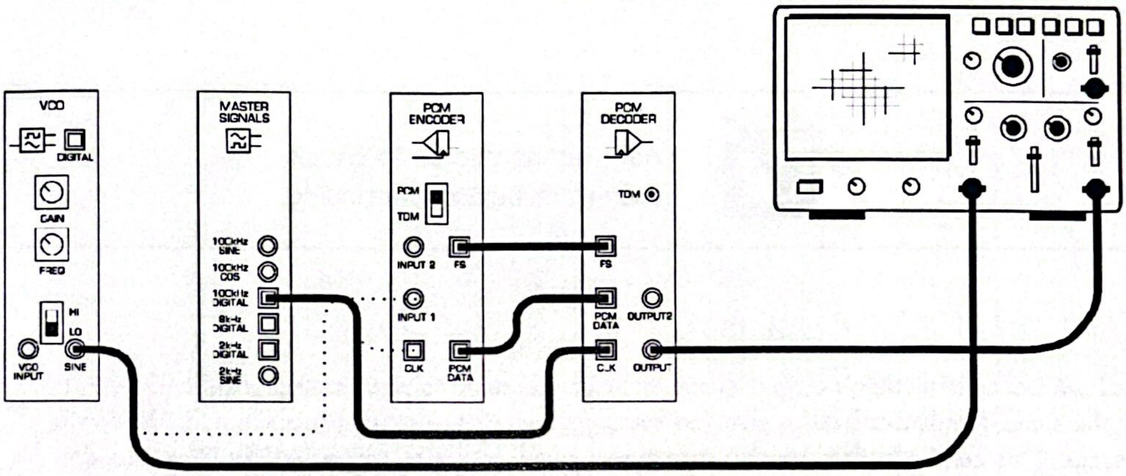

Figure 5

The entire set-up can be represented by the block diagram in Figure 6 below. Notice that the decoder's clock and frame synchronisation information are "stolen" from the encoder.

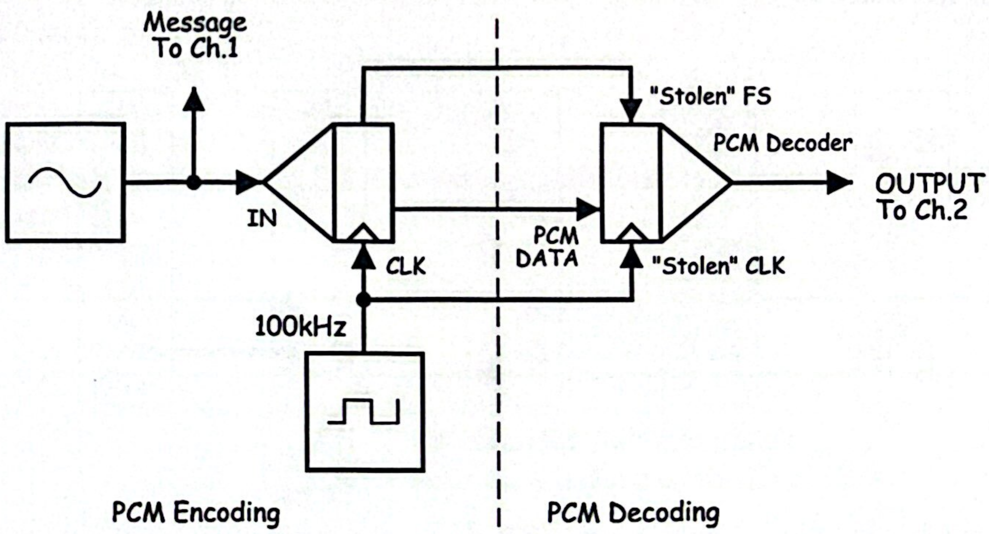

Figure 6

17. Adjust the scope's *Timebase* control to view two or so cycles of the message.

18. Set the scope's Mode control to the *DUAL* position to view the PCM Decoder module's output as well as the message signal.

Question 1
What does the PCM Decoder's "stepped" output tell you about the type of signal that it is? **Tip:** If you're not sure, see the preliminary discussion for this experiment or for Experiment 11.

Ask the instructor to check your work before continuing.

The PCM Decoder module's output signal looks very similar to the message. However, they're not the same. Remember that a sampled message contains many sinewaves in addition to the message. This can be better appreciated if you compare the message and the PCM Decoder module's output by listening to them.

19. Add the Buffer module to the set-up as shown in Figure 7 below leaving the scope's connections as they are.

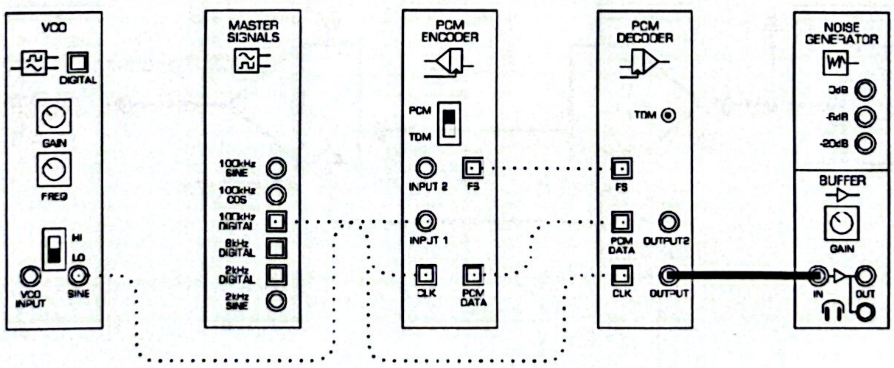

Figure 7

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

21. Without wearing the headphones, plug them into the Buffer module's headphone socket.

22. Put the headphones on.

23. Turn the Buffer module's *Gain* control clockwise until you can comfortably hear the PCM Decoder module's output.

24. Disconnect the Buffer module's lead where it plugs to the PCM Decoder module's output.

25. Modify the set-up as shown in Figure 8 below, again leaving the scope's connections as they are.

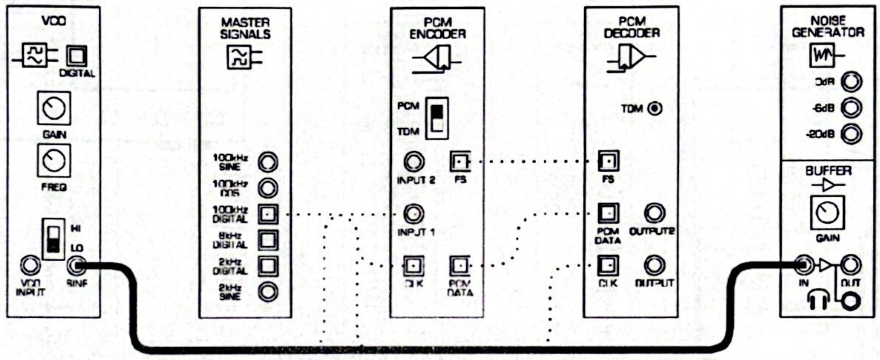

Figure 8

26. Compare the sound of the two signals. You should notice that they're similar but clearly different.

Question 2
What must be done to the PCM Decoder module's output to reconstruct the message properly?

Ask the instructor to check your work before continuing.

Part C - Encoding and decoding speech

So far, this experiment has encoded and decoded a sinewave for the message. The next part of the experiment lets you do the same with speech.

27. Completely remove the Buffer module from the set-up while leaving the rest of the leads in place.

28. Disconnect the plugs to the VCO module's *SINE* output.

29. Modify the set-up as shown in Figure 9 below.

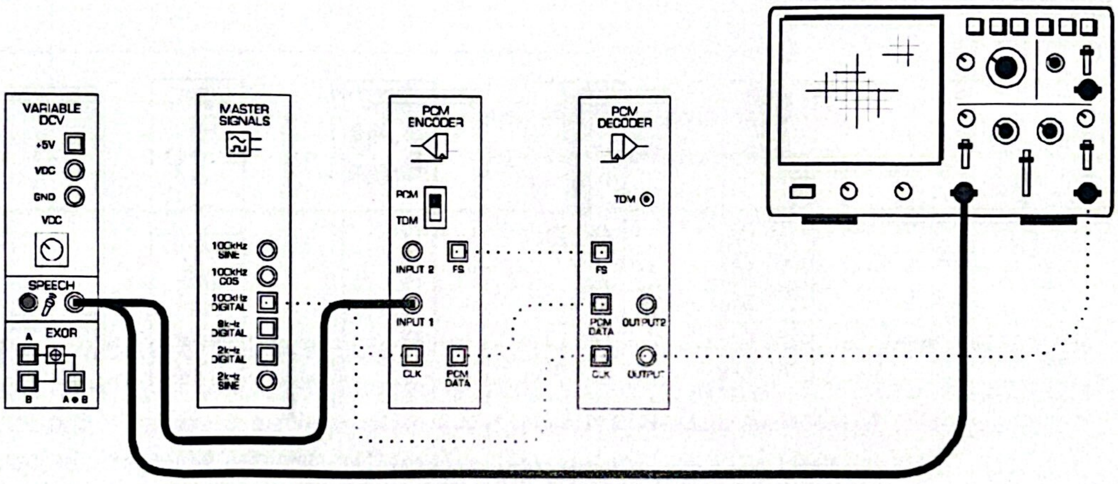

Figure 9

30. Talk, sing or hum while watching the scope's display.

Ask the instructor to check your work before continuing.

Part D - Recovering the message

As mentioned earlier, the message can be reconstructed from the PCM Decoder module's output signal using a low-pass filter. This part of the experiment lets you do this.

31. Locate the Tuneable Low-pass Filter module and set its *Gain* control to about the middle of its travel.

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

33. Disconnect the plugs to the Speech module's output.

34. Modify the set-up as shown in Figure 10 below.

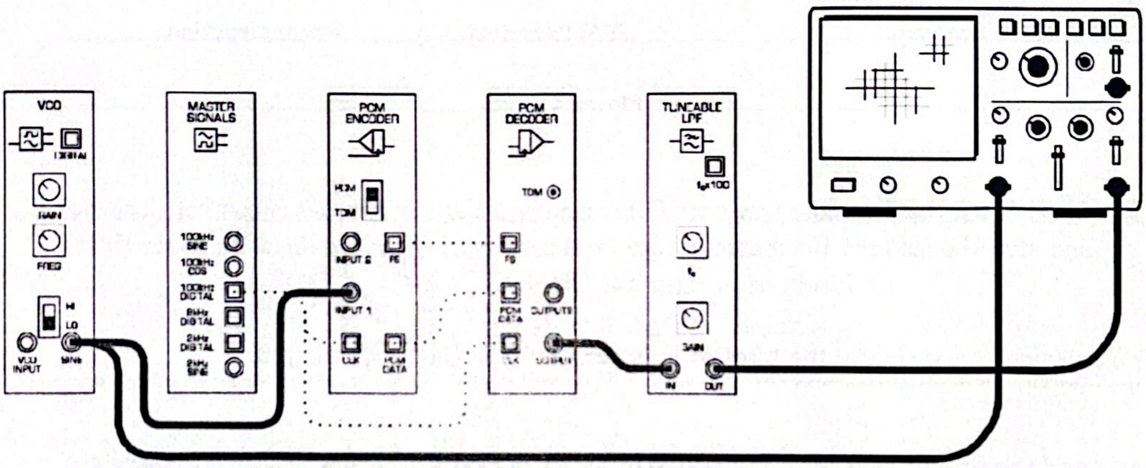

Figure 10

The entire set-up can be represented by the block diagram in Figure 11 below. The Tuneable Low-pass Filter module is used to reconstruct the original message from the PCM Decoder module's PAM output.

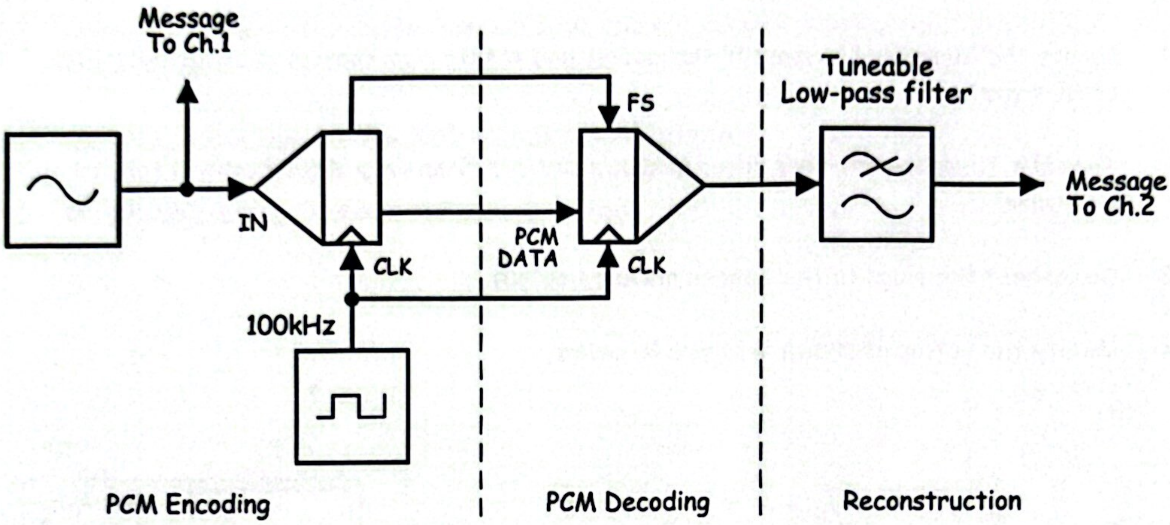

Figure 11

35. Slowly turn the Tuneable Low-pass Filter module's *Cut-off Frequency* control clockwise and stop the moment the message signal has been reconstructed (ignoring phase shift).

The two signals are clearly the same so let's see what your hearing tells you.

36. Add the Buffer module to the set-up as shown in Figure 12 below leaving the scope's connections as they are.

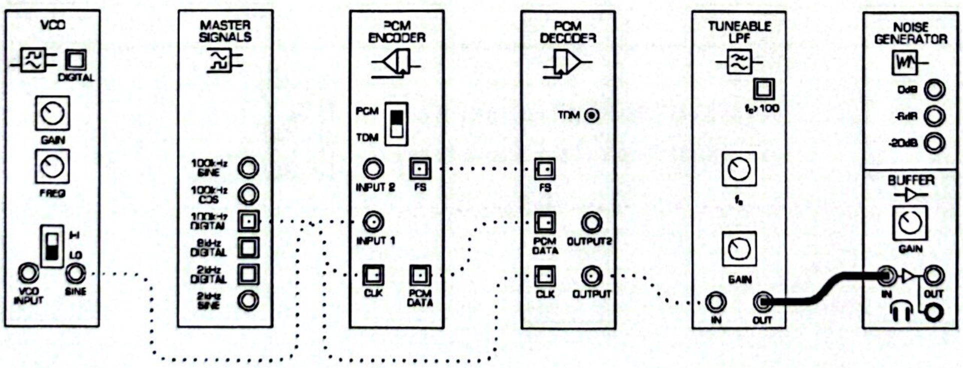

Figure 12

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

38. Put the headphones on.

39. Turn the Buffer module's *Gain* control clockwise until you can comfortably hear the Tuneable Low-pass Filter module's output.

40. Disconnect the Buffer module's lead where it plugs to the PCM Decoder module's output and connect it to the VCO module's output (like you did when wiring Figure 8).

41. Compare the sound of the two signals. You should find that they're very similar.

Question 3
Even though the two signals look and sound the same, why isn't the reconstructed message a perfect copy of the original message? **Tip:** If you're not sure, see the preliminary discussion for Experiment 12.

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Ask the instructor to check your work before finishing.

