Experiment 16 - Frequency Shift Keying

Preliminary discussion

Frequency division multiplexing (FDM) allows a channel to be shared among a set of users. Recall that this is achieved by superimposing the message onto a carrier signal inside the user's allocated portion of the radio-frequency spectrum. Recall also that any of the analog modulation schemes can be used to transmit digital data in this way. When frequency modulation (FM) is used it is known as *binary frequency shift keying* (BFSK or more commonly just FSK).

One of the reasons for using FSK is to take advantage of the relative noise immunity that FM enjoys over AM. Recall that noise manifests itself as variations in the transmitted signal's amplitude. These variations can be removed by FM/FSK receivers (by a circuit called a *limiter*) without adversely affecting the recovered message.

Figure 1 below shows what an FSK signal looks like time-coincident with the digital signal that has been used to generate it.

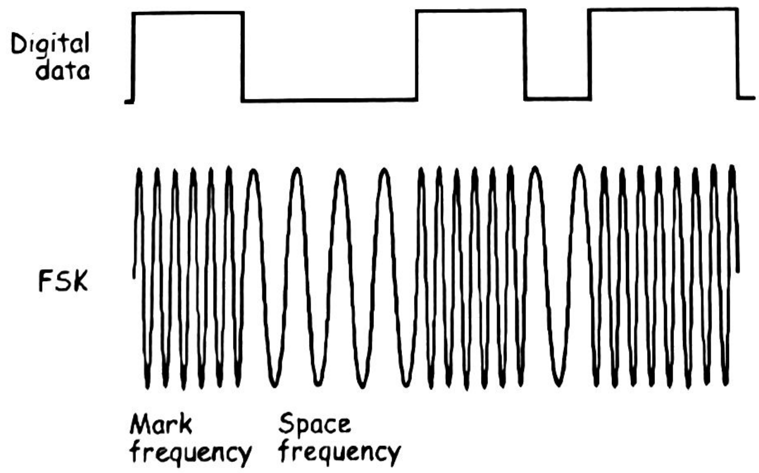

Figure 1

Notice that the FSK signal switches between two frequencies. The frequency of the signal that corresponds with logic-0s in the digital data (called the *space frequency*) is usually lower than the modulator's nominal carrier frequency. The frequency of the signal that corresponds with logic-1s in the digital data (called the *mark frequency*) is usually higher than the modulator's nominal carrier frequency. The modulator doesn't output a signal at the carrier frequency, hence the reference here to it as being the "nominal" carrier frequency.

FSK generation can be handled by conventional FM modulator circuits and the *voltage-controlled oscillator* (VCO) is commonly used. Similarly, FSK demodulation can be handled by conventional FM demodulators such as the *zero crossing detector* (refer to the preliminary discussion of Experiment 10 for an explanation of this circuit's operation) and the *phase-locked loop*. Alternatively, if the FSK signal is passed through a sufficiently selective filter, the two sinewaves that make it up can be individually picked out. Considered on their own, each signal is an ASK signal and so the data can be recovered by passing either one of them through an envelope detector (refer to the preliminary discussion of Experiment 6 for an explanation of the envelope detector's operation).

The experiment

In this experiment you'll use the Emona Telecoms-Trainer 101 to implement the VCO method of generating an FSK signal. Digital data for the message is modelled by the Sequence Generator module. You'll then recover the data by using a filter to pick-out one of the sinewaves in the FSK signal and demodulate it using an envelope detector. Finally, you'll observe the demodulated FSK signal's distortion and use a comparator to restore the data.

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

Equipment

- Emona Telecoms-Trainer 101 (plus power-pack)
- Dual channel 20MHz oscilloscope
- three Emona Telecoms-Trainer 101 oscilloscope leads
- assorted Emona Telecoms-Trainer 101 patch leads

Procedure

Part A - Generating an FSK signal

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

2. Set up the scope per the instructions in Experiment 1.

3. Set the scope's *Trigger Source* control to the *EXT* position.

4. Set the scope's *Trigger Source Coupling* control to the *HF REJ* position.

5. Set the scope's Channel 1 and Channel 2 *Input Coupling* controls to the *DC* position.

6. Locate the VCO module and set its *Gain* control to about half its travel.

7. Set the VCO module's *Frequency Adjust* control to about a quarter of its travel (about the position of the number 9 on a clock face).

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

9. Locate the Sequence Generator module and set its dip-switches to 00.

   Tip: To do this, push both switches up.

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

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

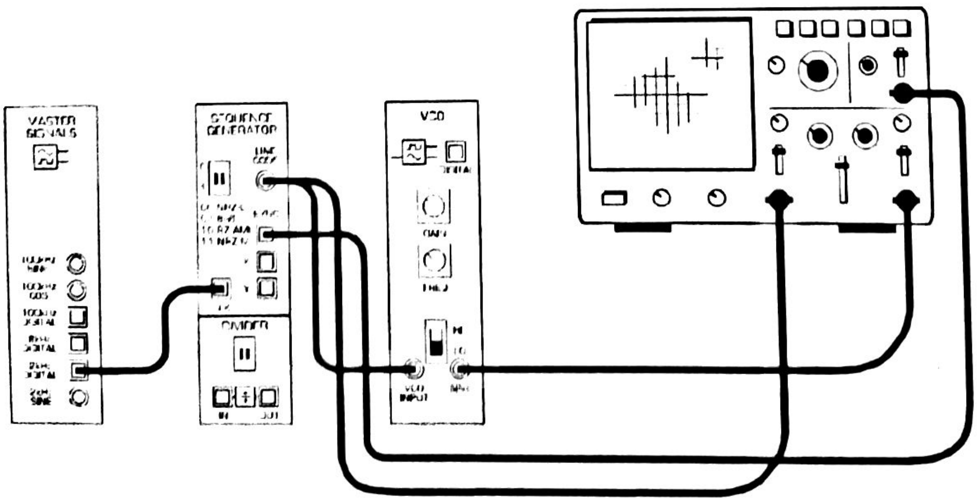

Figure 2

The set-up in Figure 2 can be represented by the block diagram in Figure 3 below. The Sequence Generator module is used to model a digital signal and its SYNC output is used to trigger the scope to provide a stable display. The VCO module is used to generate the FSK signal.

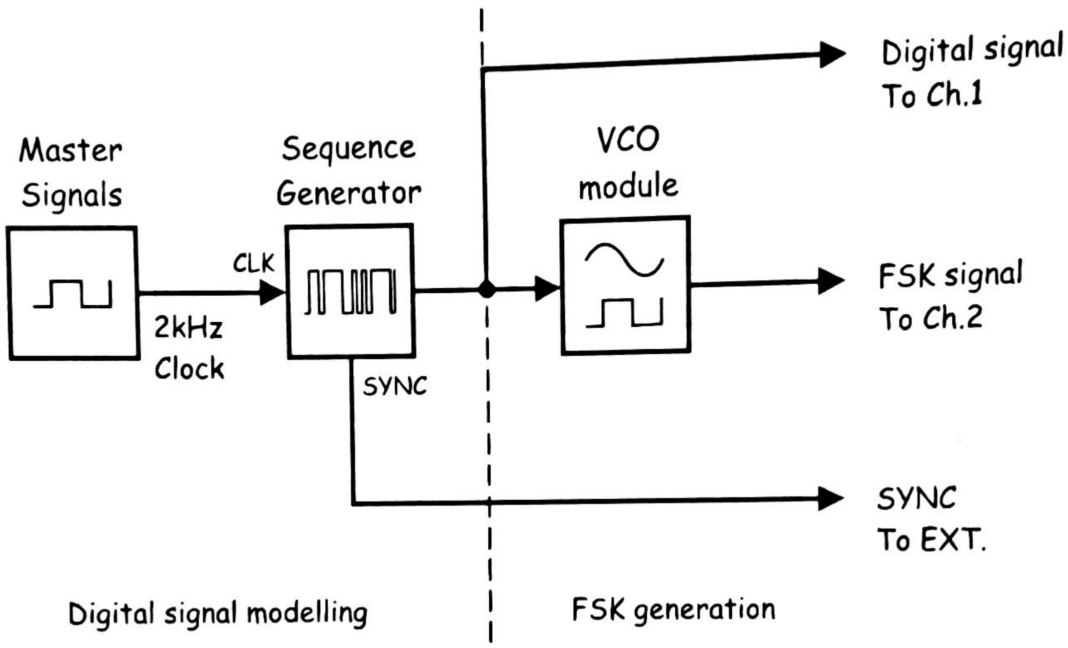

Figure 3

11. Set the scope's *Timebase* control to the *0.5ms/div* position.

12. Set the scope's *Mode* control to the *DUAL* position to view the Sequence Generator module's output and the FSK signal out of the Voltage Controlled Oscillator module.

13. Compare the signals.

    Note: If the sinewaves in the FSK signal roll too much, turn the VCO module's *Frequency Adjust* control a little left or right to stabilise it.

Question 1
What's the name for the VCO output frequency that corresponds with logic-1s in the digital data? **Tip:** If you're not sure, see the preliminary discussion.

Question 2
What's the name for the VCO output frequency that corresponds with logic-0s in the digital data?

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Question 3
Based on your observations of the FSK signal, which of the two is the higher frequency? Explain your answer.

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Ask the instructor to check your work before continuing.

Part B - Demodulating an FSK signal using filtering and an envelope detector
As FSK is really just FM (with a digital message instead of speech or music), it can be recovered using any of the FM demodulation schemes. However, as the FSK signal switches back and forth between just two frequencies we can use a method of demodulating it that cannot be used to demodulate speech encoded FM signals. The next part of the experiment lets you do this.

14. Turn the VCO module's *Frequency Adjust* control to about the position of the number 2 on a clock face.

15. Locate the Tuneable LPF module and turn its *Cut-off Frequency Adjust* control fully clockwise.

16. Turn the Tuneable LPF's *Gain* control fully clockwise.

17. Modify the set-up as shown in Figure 4 on the next page.

    Note: Remember that the dotted lines show leads already in place. Also, the left most modules have been cut-off to fit the drawing on the page.

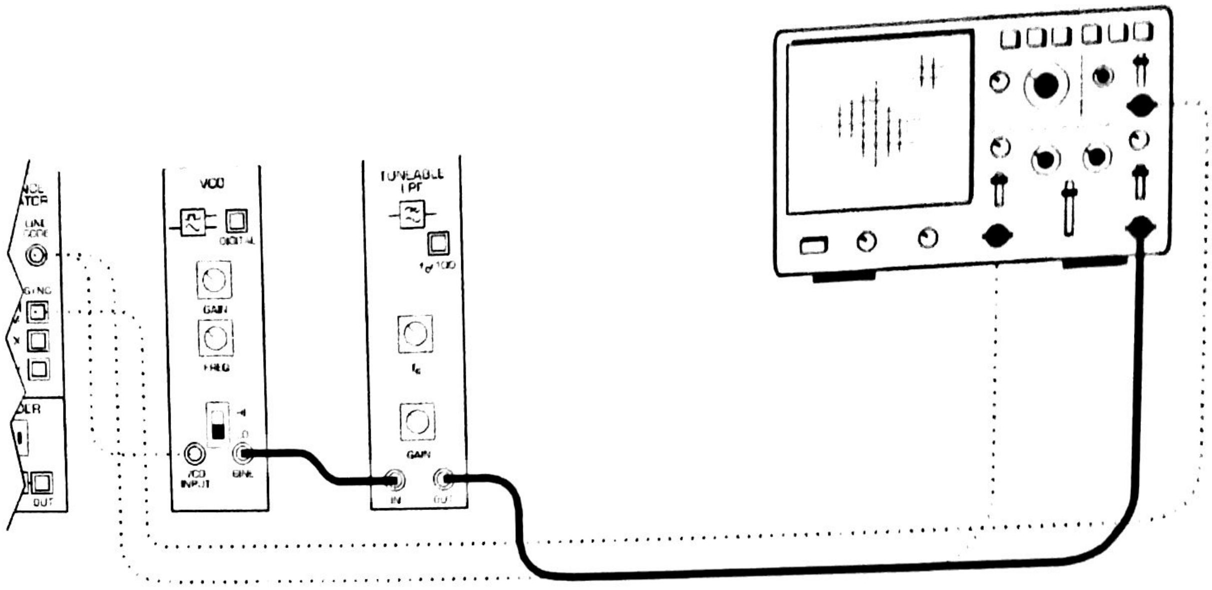

Figure 4

The FSK generation and demodulation parts of the set-up can be represented by the block diagram in Figure 5 below. The Low-pass filter module is used to pick out one of the FSK signal's two sinewaves and the RECTIFIER and BASEBAND LPF combination form the envelope detector to complete the FSK signal's demodulation.

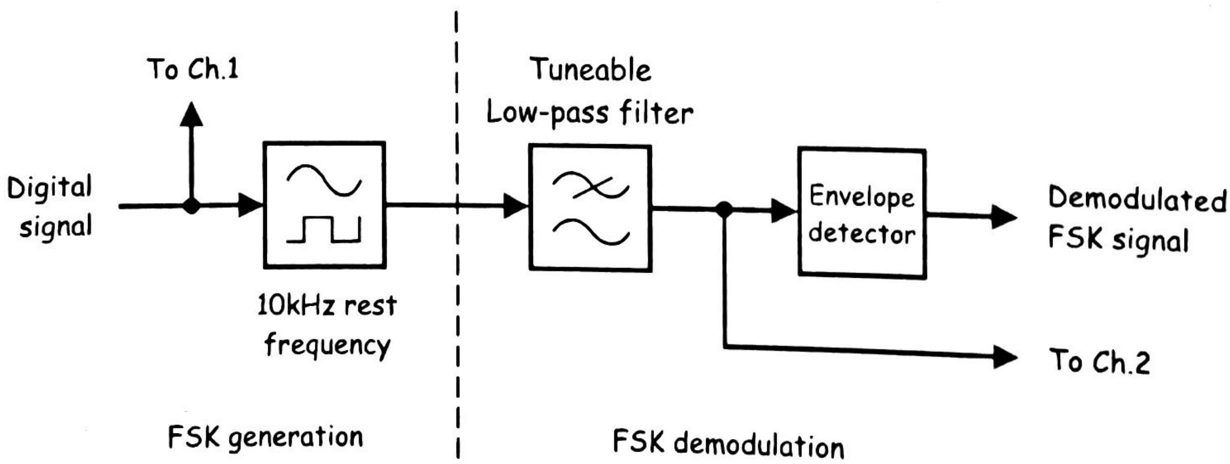

Figure 5

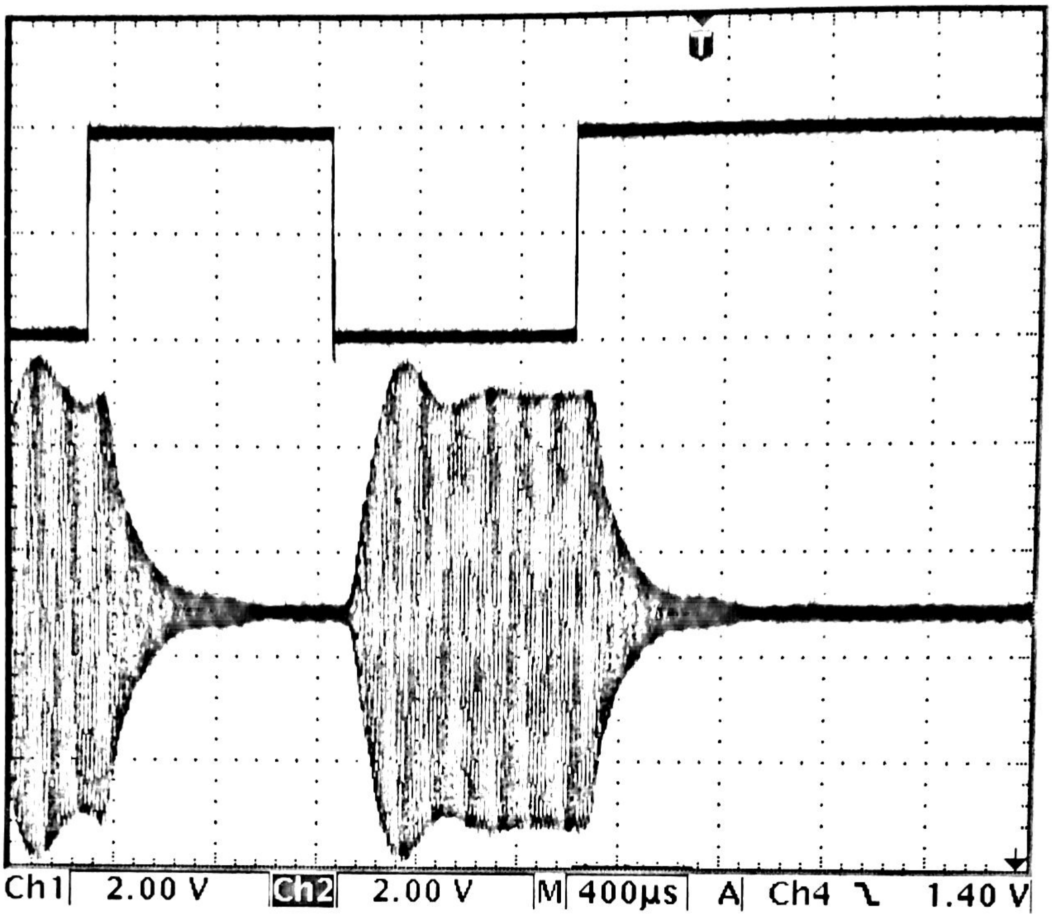

Figure 6

18. Turn the Tuneable LPF's *Cut-off Frequency Adjust* control slowly from fully clockwise until the higher frequency component of the FSK signal becomes equal to zero, as shown in Figure 6.

19. Compare the digital signal and the filter's output.These should be visible as Ch.1 and Ch.2 on the scope display.

Question 4
Which of the FSK signal's two sinewaves is the filter picking out?

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Question 5
What does the filtered FSK signal look like?

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Ask the instructor to check your work before continuing.

20. Modify the setup as shown in Figure 7 to include the envelope detector.

21. Connect the scope's Channel 2 input to the envelope detector's output as shown in Figure 6 below.

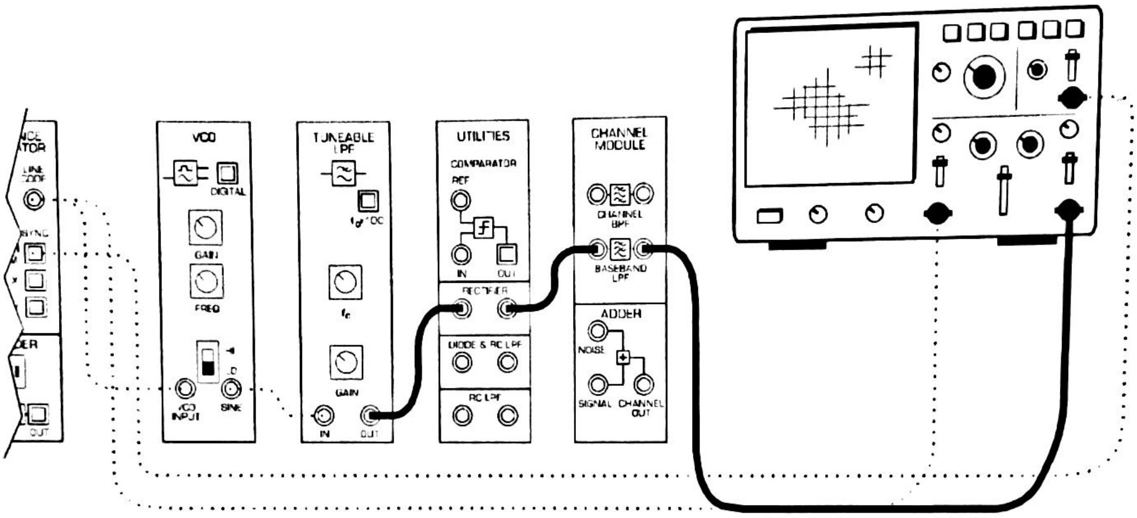

Figure 7

22. Compare the original digital signal with the recovered digital signal.

Question 6
What can be used to "clean-up" the recovered digital signal?

Ask the instructor to check your work before continuing.

Envelope Detection:
The envelope detector used in this experiment differs from the more simple DIODE & RC LPF used in the earlier AM experiment. In this experiment we use a combination of the RECTIFIER followed by the BASEBAND LPF. As FSK uses digital data, a filter which is more responsive to the digital data stream is needed. You can read about the BASEBAND LPF module's characteristics in the User Manual.

Part C - Restoring the recovered data using a comparator

Experiment 14 shows that the comparator is a useful circuit for restoring distorted digital signals. The next part of the experiment lets you use a comparator to clean-up the demodulated FSK signal.

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

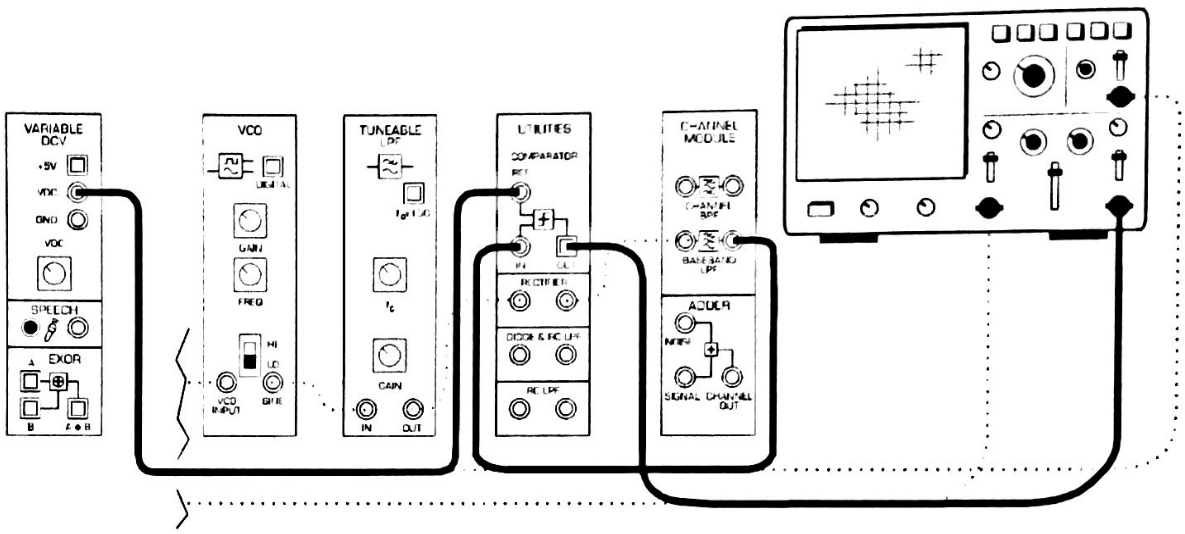

Figure 8

The FSK generation, demodulation and digital signal restoration parts of the set-up can be represented by the block diagram in Figure 9 below.

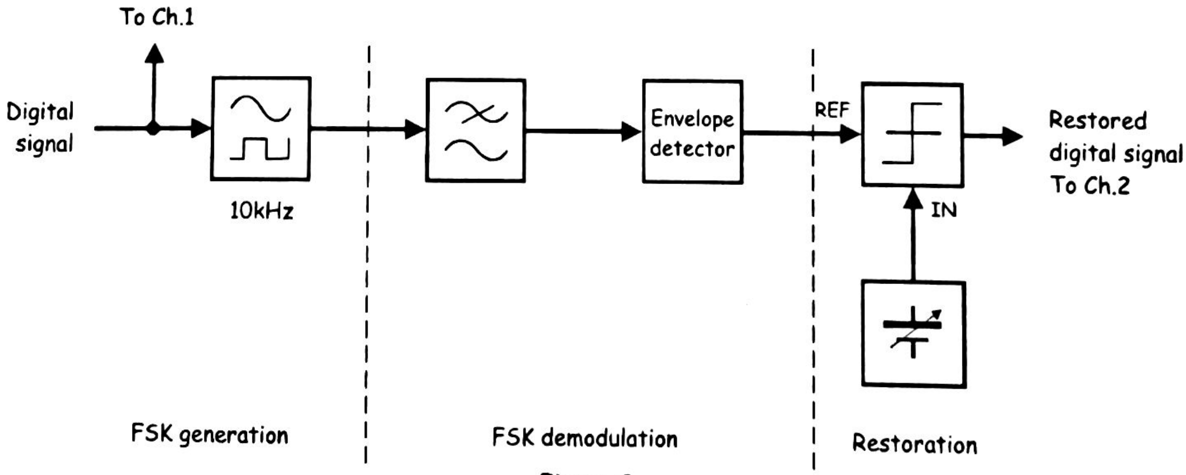

Figure 9

24. Note the amplitude of the filtered signal into the COMPARATOR. It varies from about 0 volts to a maximum level.

25. Set the Variable DCV module's Variable DC voltage output to a level which is half of the level noted in step 24 above. This signal is setting the threshold voltage of the COMPARATOR.

26. Compare the original digital signal and the recovered digital signal out of teh COMPARATOR. If they're not the same vary the Variable DCV module's Variable DC control slightly until they are.

Question 7
How does the comparator turn the slow rising voltages of the recovered digital signal into sharp transitions?

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Ask the instructor to check your work before finishing.

