



**SIDDHARTHA INSTITUTE OF TECHNOLOGY & SCIENCES**

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**SIDDHARTHA INSTITUTE OF TECHNOLOGY & SCIENCES**

DIGITAL COMMUNICATION LAB MANUAL



**DEPARTMENT OF**

**ELECTRONICS AND COMMUNICATION ENGINEERING**



## **LIST OF EXPERIMENTS**

1. PCM Generation and Detection
2. Differential Pulse Code Modulation
3. Delta Modulation
4. Adaptive Delta Modulation
5. Time Division Multiplexing of 2 Band Limited Signals
6. Amplitude Shift Keying Generation and Detection
7. Frequency Shift Keying Generation and Detection
8. Phase Shift Keying Generation and Detection
9. DPSK Generation and Detection
10. QPSK Generation and Detection
11. Study of the spectral characteristics of PAM
12. Study of the spectral characteristics of PWM

## **ADD ON EXPERIMENTS**

1. Companding Using MATLAB
2. Minimum Shift Keying (MSK) Using MATLAB



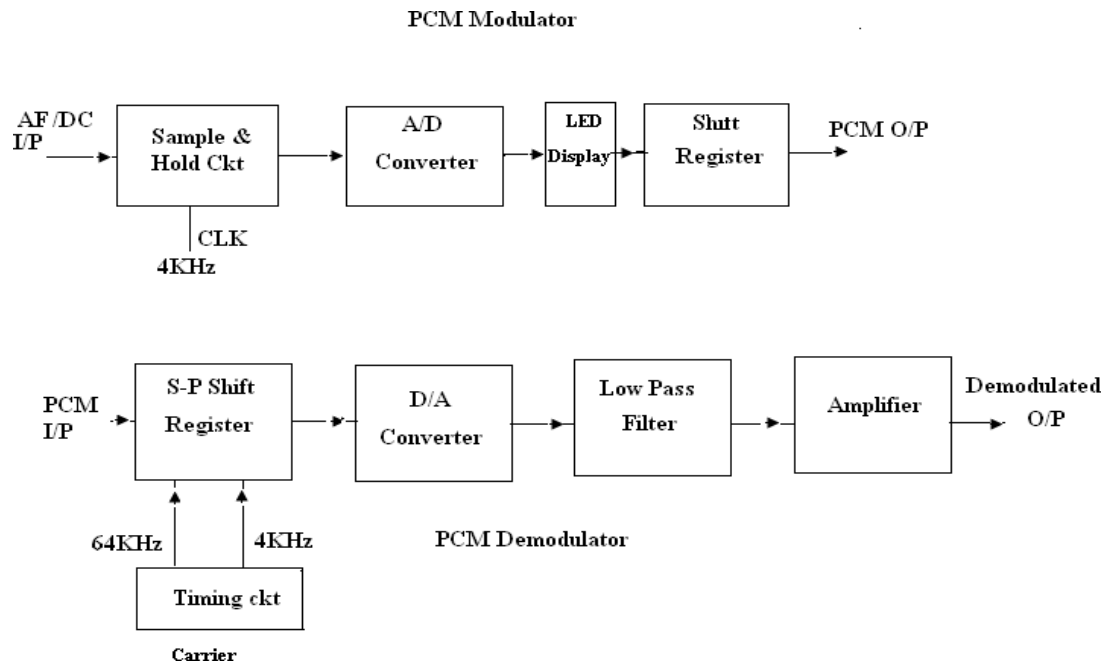
## 1. PCM GENERATION AND DETECTION

**AIM:** To Study & understand the operation of the Pulse code modulation & Demodulation.

### APPARATUS:

1. PCM Modulator trainer
2. PCM Demodulator trainer
3. Storage Oscilloscope/ Dual Trace Oscilloscope
4. Digital multi-meter.
5. Co-axial cables (standard accessories with trainer)
6. Patch chords

### CIRCUIT DIAGRAM:



### THEORY:

**Pulse modulation:** A form of modulation in which a pulse train is used as the carrier. Information is conveyed by modulating some parameter of the pulses with a set of discrete instantaneous



samples of the messages signal. The minimum sampling frequency is the minimum frequency at which the modulating waveform can be sampled to provide the set of discrete values without a significant loss of information.

**PCM:** In pulse code modulation (PCM) only certain discrete values are allowed for the modulating signals. The modulating signal sampled, as in other forms of pulse modulation. But any sample falling within a specified range of values is assigned a discrete value. Each value is assigned a pattern of pulses and the signal transmitted by means of this code. The electronic circuit that produces the coded pulse train from the modulating waveform is termed a coder or encoder. A suitable decoder must be used at the receiver in order to extract the original information from the transmitted pulse train.

### **PROCEDURE:**

1. Study the theory of operation thoroughly.
2. Connect the trainer (Modulator) to the mains and switch on the power supply.
3. Observe the output of the AF generator using CRO; it should be a Sine wave of 200Hz frequency with 3Vpp amplitude.
4. Verify the output of the DC source with multi-meter / scope, output should vary 0 to +5v.
5. Observe the output of the Clock generator using CRO, they should be 64 KHz and 8KHz frequency of square wave with 5Vpp amplitude.
6. Note: These clock signals are internally connected the circuit so no external connections are required.
7. Connect the trainer (De Modulator) to the mains and switch on the power supply.
8. Observe the output of the clock generator using CRO, it should be 64 KHz square wave with 5Vpp amplitude.

### **PCM Operation (with DC input)**

#### **Modulation:**

8. Set DC source to some value say 1 V with the help of multi-meter and connect it to the A/D converter input and observe the output LED's.
9. Note down the digital code i.e. output of the A/D converter and compare with the theoretical value



Theoretical value can be obtained by:

A/D input voltage

$$\frac{\text{A/D input voltage}}{\text{1 LSB value}} = X_{(10)} = Y_{(2)}$$

1 LSB value

Where , 1 LSB value =  $V_{\text{ref}} / 2^n$ , Since  $V_{\text{ref}} = 5\text{V}$  and  $n = 8$

$$1 \text{ LSB Value} = 0.01953$$

**Example:**

A/D input voltage = 1 V

$$= 51.2_{(10)}$$

$$= 00110011_{(2)}$$

So digital output is 00110011

10. Keep CRO in dual mode. Connect one channel to 8KHz signal ( which is connected to the shift register) and another channel to the PCM out put
11. Observe the PCM output with respect to the 8 KHz signal and sketch the waveforms. Compare them with the given waveforms

Note: From this wave form you can observe that the LSB bit enters the output first.

**Demodulation:**

12. Connect PCM signal to the demodulators (S-P Shift register) from the PCM modulator (AET-68M) with help of coaxial cable (supplied with the trainer)
13. Connect clock signal (64 KHz) from the transmitter to the receiver using coaxial cable.
14. Connect transmitter clock to the timing circuit
15. Observe and note down the S-P shift register output data and compare it with the transmitted data (i.e. output A/D converter at transmitter). It will be noticed that the output of the S-P shift register is following the A/D converter output in the modulator. Observe D/A converter output (demodulated output) using multi-meter /scope and compare it with the original signal and you can observe that there is no loss in information in process of conversion and transmission.
16. Similarly you can try for different values of modulating signal voltage.



**Sample work sheet:**

1. Modulating signal : 1V
  2. A/D output (theoretical) : 00 11 00 11<sub>(2)</sub>
  3. A/D output (practical) : 00 11 00 11<sub>(2)</sub>
  4. S-P output : 00 11 00 11<sub>(2)</sub>
  5. D/A Converter output: : 1V
- PCM Operation (with AC input)**

**Modulation:**

17. Connect AC signal of 2V<sub>PP</sub> amplitude to Sample & Hold circuit.
18. Keep the CRO in dual mode. Connect one channel to the AF signal and another channel to the sample & hold output. Observe and sketch the sample & hold output.
19. Connect the sample and hold output to the A/D converter and observe the PCM output using storage oscilloscope/ DTO
20. Observe PCM output by varying AF signal voltage.

**Demodulation:**

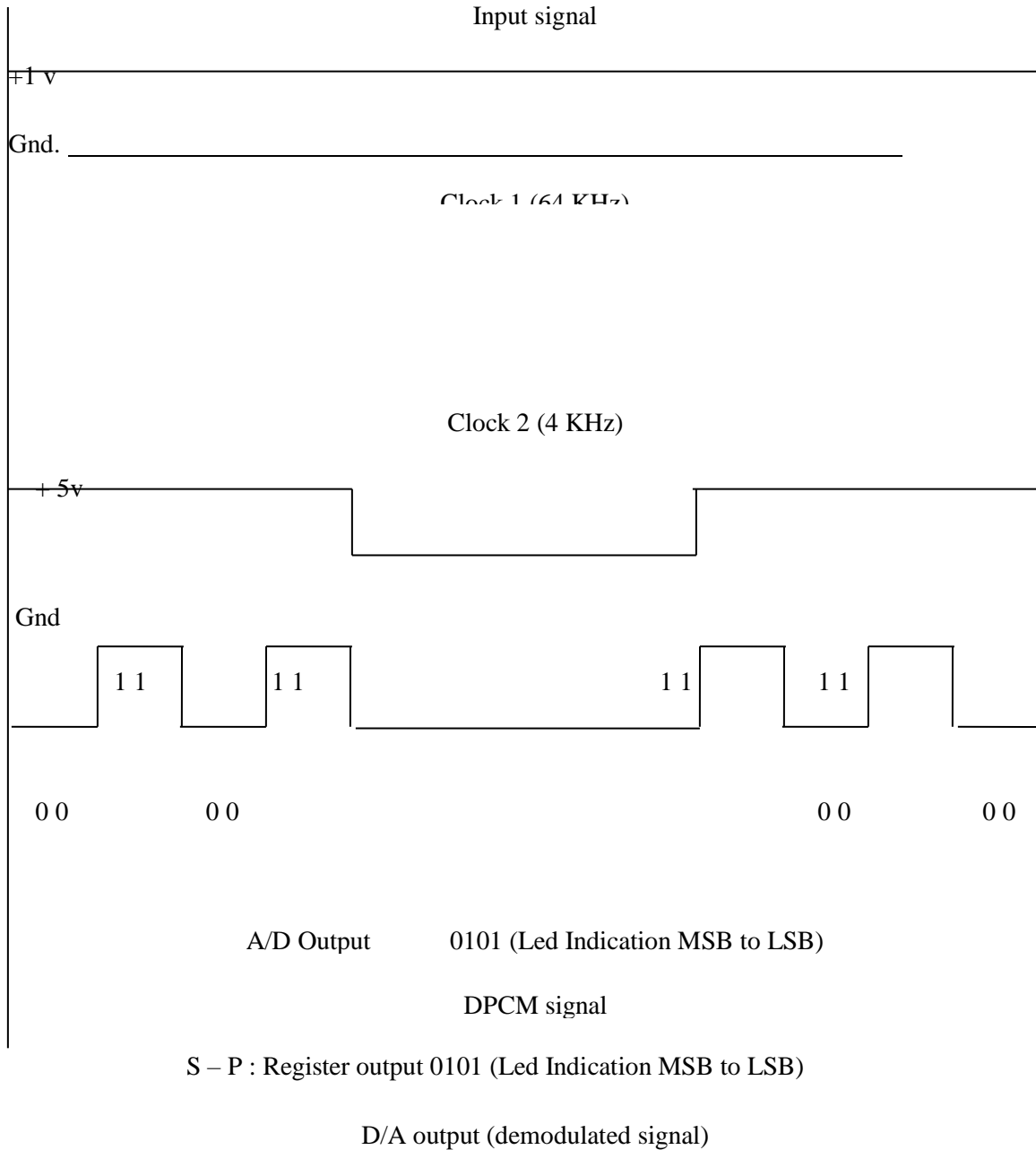
21. Connect PCM signal to the demodulator input (S-P shift register) from the PCM modulator with the help of coaxial cable (supplied with the trainer)
22. Connect clock signal (64KHz) from the transmitter to the receiver using coaxial cable
23. Connect transmitter clock to the timing circuit.
24. Keep CRO in dual mode. Connect CH 1 input to the sample and hold output and CH 2 input of the D/A converter output.
25. Observe and sketch the D/A output.
26. Connect D/A output to the LPF input.
27. Observe output of the LPF/Amplifier and compare it with the original modulating signal.
28. From above observation you can verify that there is no loss in information (modulating signal) in conversion and transmission process.
29. Disconnect clock from transmitter and connect to local oscillator (i.e. clock generator output from De-Modulator) with remaining setup as it is. Observe D/A output and compare it with the previous result. This signal is little bit distorted in shape. This is because lack of synchronization between clock at transmitter and clock at receiver.



Note: You can take modulating signals from external sources. Maximum amplitude should not exceed 4V in case of DC and 3V<sub>PP</sub> in case of AC (AF) signals.

**EXPECTED WAVEFORMS:**

PCM wave forms / timing diagram of DC input





**RESULT:**

**VIVA QUESTIONS:**

1. Mention the major stages to generate a PCM signal?
2. Define sampling?
3. Define Quantization?
4. Define Quantization error?
5. Define Encoding with respect to PCM?
6. Define Synchronization?
7. Mention the applications of PCM?
8. What are the Band width requirements of PCM?
9. What is the role of A/D converter in PCM?
10. Define S/N ration for Uniform Quantization?





## 2. DIFFERENTIAL PULSE CODE MODULATION AND DEMODULATION

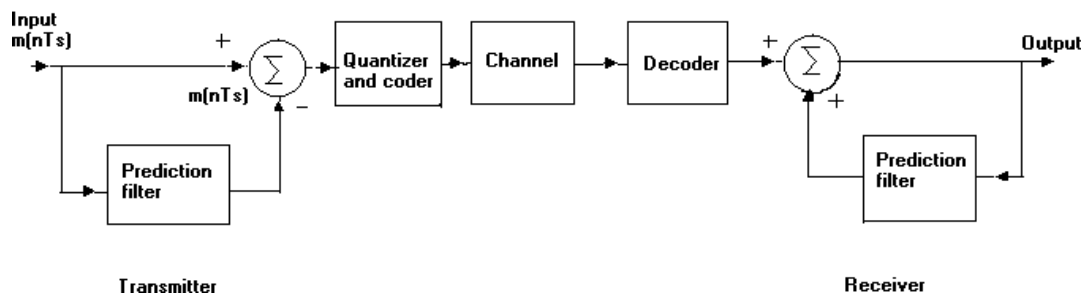
**AIM:** To Study & understand the operation of the DPCM

**APPARATUS:**

1. DPCM Modulator trainer
2. DPCM Demodulator trainer
3. Storage Oscilloscope
4. Digital Multi-meter.
5. 2 No's of co- axial cables (standard accessories with trainer)
6. Patch chords

**BLOCK DIAGRAM:**

Block diagram of DPCM



**THEORY:**

Differential PCM is quite similar to ordinary PCM. However, each word in this system indicates the difference in amplitude, positive or negative, between this sample and the previous sample. Thus the relative value of each sample is indicated rather than, the absolute value as in normal PCM. This unique system consists of

**I. DPCM Modulator**

1. Regulated power supply
2. Audio Frequency signal generator



3. Prediction Filter
4. Sample & Hold circuit
5. A/D Converter
6. Parallel –Serial Shift register
7. Clock generator / Timing circuit
8. DC source

## **II. DPCM Demodulator**

1. Regulated Power Supply
2. Serial-Parallel Shift registers.
3. D/A converter.
4. Clock generator
5. Timing circuit
6. Prediction filter
7. Passive low pass filter

### **PROCEDURE:**

1. Study the theory of operation thoroughly.
2. Connect the trainer (Modulator) to the mains and switch on the power supply.
3. Observe the output of the AF generator using CRO, it should be Sine wave of 400 Hz frequency with 3V pp amplitude.
4. Verify the output of the DC source with multi-meter/scope; output should vary 0 to +290mV.
5. Observe the output of the Clock generator using CRO, they should be 64 KHz and 8 KHz frequency of square with 5 Vpp amplitude.
6. Connect the trainer (De Modulator) to the mains and switch on the power supply.
7. Observe the output of the Clock generator using CRO; it should be 64 KHz square wave with amplitude of 5 pp.

### **DPCM Operation (with DC input):**

#### **Modulation:**

8. Keep CRO in dual mode. Connect one channel to 8 KHz signal (one which is connected to the Shift register) and another channel to the DPCM output.



9. Observe the DPCM output with respect to the 8 KHz signal and sketch the waveform.
10. Note: From this waveform you can observe that the LSB bit enters the output first.
11. Set DC source to some value say 1 V with the help of multi-meter and connect it to the A/D converter input and observe the output LED's.
12. Note down the digital code i.e. output of the A/D converter and compare with the theoretical value  
Theoretical value can be obtained by:

A/D input voltage

$$\text{_____} = X_{(10)} = Y_{(2)}$$

1 LSB value

Where

$$1 \text{ LSB value} = V_{\text{ref}} / 2^n$$

Since  $V_{\text{ref}} = 290\text{mV}$  and  $n = 4$

$$1 \text{ LSB Value} = 18.125\text{mV}$$

#### **Demodulation**

1. Connect DPCM signal to the demodulator (S-P register) from the DPCM modulator with the help of coaxial cable (supplied with the trainer).
2. Connect clock signal (64 KHz) from the transmitter to the receiver using coaxial cable.
3. Connect transmitter clock to the timing circuit.
4. Observe and note down the S-P shift register output data and compare it with the transmitted data (i.e. output A/D converter at transmitter) notice that the output of the S-P shift register is following the A/D converter output in the modulator.
5. Observe D/A converter output (demodulated output) using multi-meter/scope and compare it with the original signal and can observe that there is no loss in information in process of conversion and transmission.

#### **DPCM Operation (with AC input):**

##### **Modulation:**

6. Connect AC signal of  $3V_{\text{PP}}$  amplitude to positive terminal of the summer circuit.



Note: The output of the prediction filter is connected to the negative terminal of the summer circuit and can observe the waveforms at the test points provided on the board.

7. The output of the summer is internally connected to the sample and hold circuit
8. Keep CRO in dual mode. Connect one channel to the AF signal and another channel to the Sample and Hold output. Observe and sketch the sample & hold output
9. Connect the Sample and Hold output to the A/D converter and observe the DPCM output using oscilloscope.
10. Observe DPCM output by varying AF signal voltage.

**Demodulation:**

11. Connect DPCM signal to the demodulator input (S-P shift register) from the DPCM modulator with the help of coaxial cable (supplied with trainer).
12. Connect clock signal (64 KHz) from the transmitter to the receiver using coaxial cable.
13. Connect transmitter clock to the timing circuit.
14. Keep CRO in dual mode. Connect one channel to the sample & hold output and another channel to the D/A converter output.
15. Observe and sketch the D/A output
16. Connect D/A output to the LPF input and observe the output of the LPF.
17. Observe the wave form at the output of the summer circuit.
18. Disconnect clock from transmitter and connect to the local oscillator (i.e., clock generator output from De Modulator) with remaining setup as it is. Observe D/A output and compare it with the previous result. This signal is little bit distorted in shape. This is because lack of synchronization between clock at transmitter and clock at receiver.



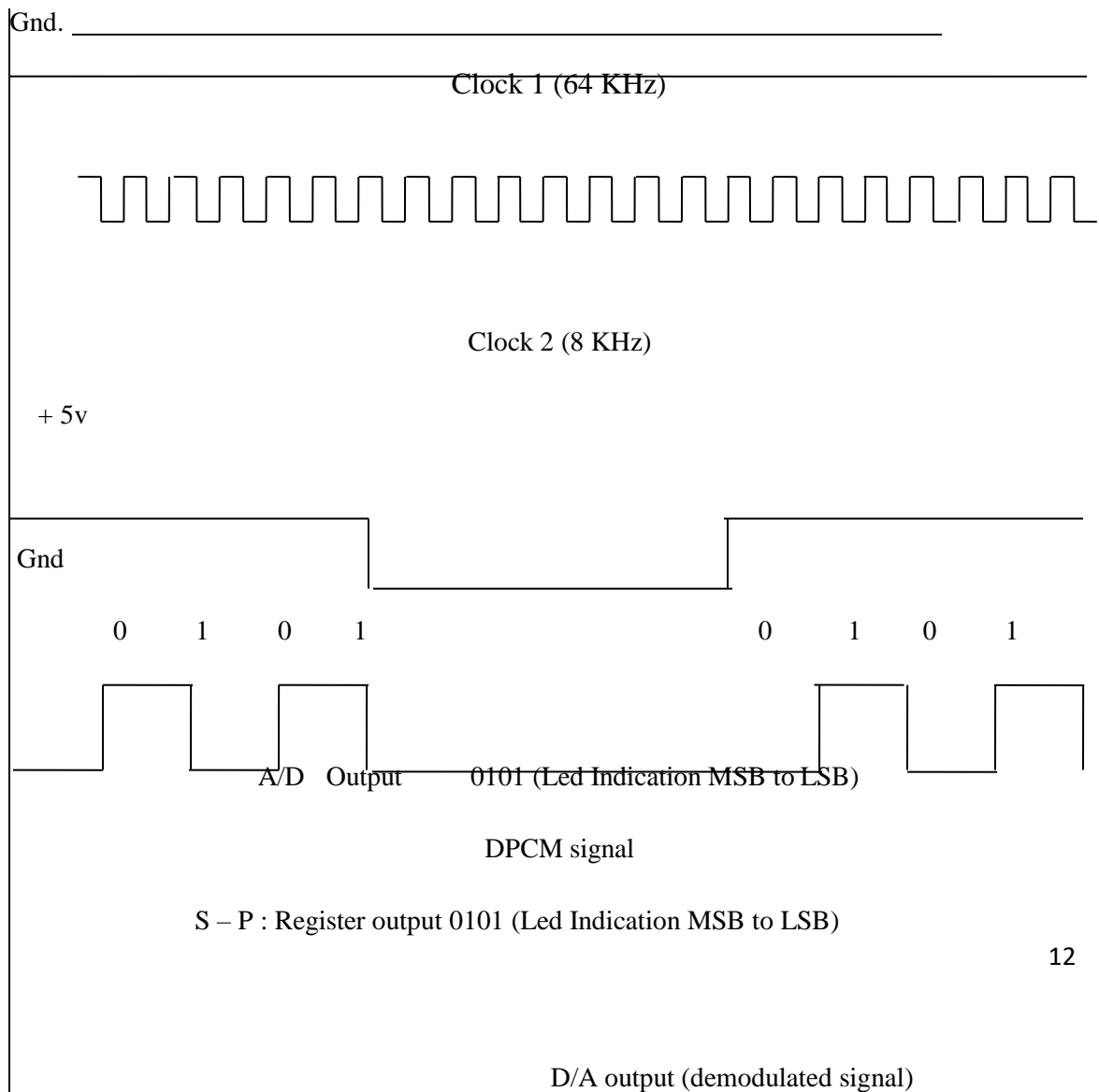
**EXPECTED WAVEFORMS:**

Draw the wave forms for the given DC input, corresponding binary data wave form, and for AC input draw sample and hold waveform then D/A converter o/p and then reconstructed AC signal

DPCM way form / timing diagram DC input

190mV

Input signal





**RESULT:**

**VIVA QUESTIONS:**

1. Define differential Pulse Code Modulation?
2. Mention the difference between PCM and DPCM?
3. Mention the advantages DPCM?
4. Mention the disadvantages of DPCM?
5. Define Synchronization?
6. Define S/N ratio with respect to DPCM?
7. Mention the applications of DPCM?
8. What is the role of predication filter in DPCM?
9. Compare DPCM with Delta Modulation?
10. Draw the output Encoded sequence for DPCM?



### **3. DELTA MODULATION**

**AIM:** To study the Delta modulation process by comparing the present signal with the previous signal of the given Modulating signal.

**APPARATUS:**

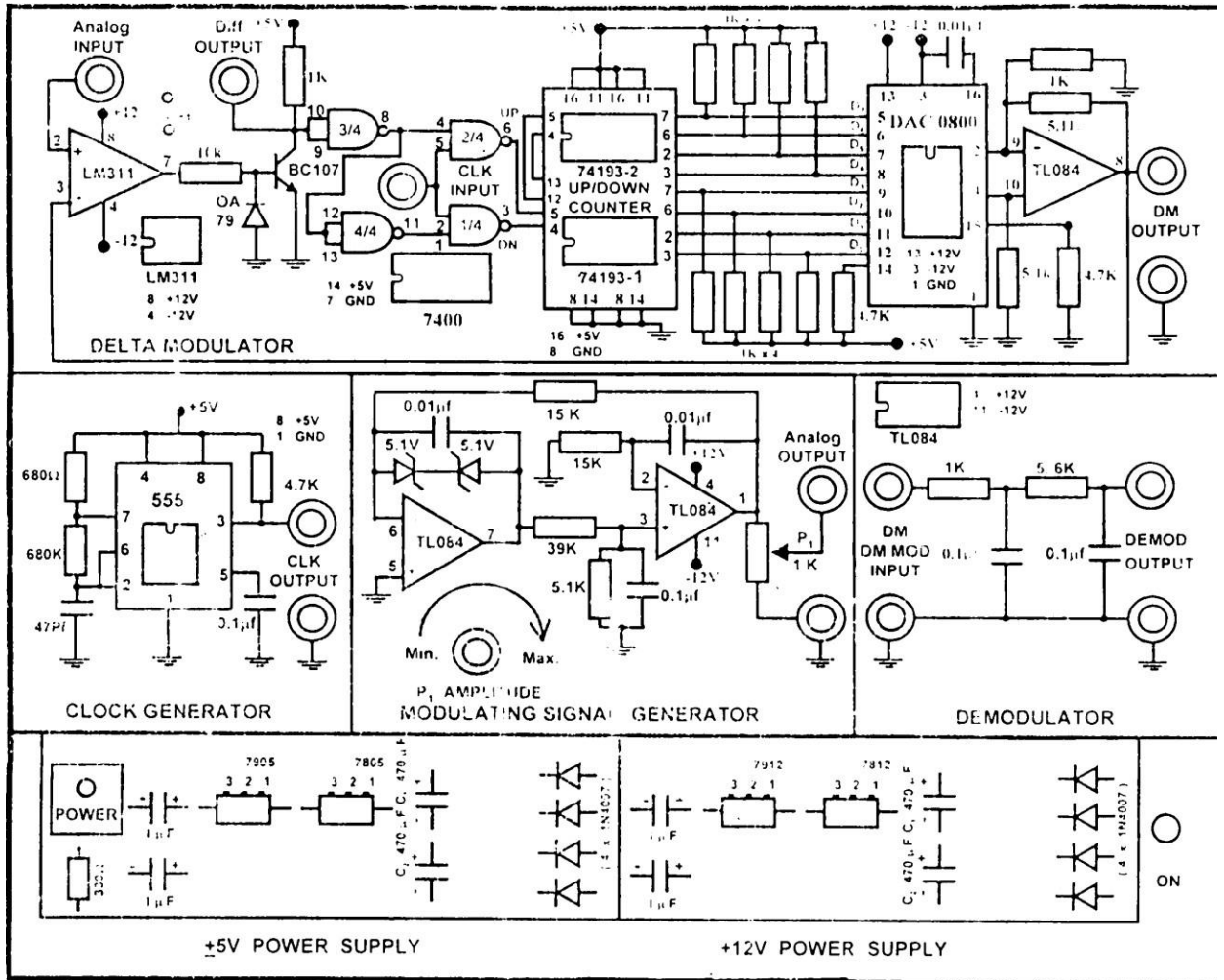
1. Trainer Kit of Delta Modulation & Demodulation.
2. CRO
3. Function Generator
4. Patch cords, Probes.

**PROCEDURE:**

1. Switch ON the experimental board
2. Connect Clock Signal to the Delta Modulator circuit.
3. Connect Modulating Signal to the Modulating signal input of the Delta Modulator and observe the same on channel 1 of a Dual Trace Oscilloscope.
4. Observe the Delta Modulator output on channel II.
5. Observe Slope Over Load noise by increasing the amplitude of Modulating signal and also observe granular noise.
6. Connect this Delta Modulator output to the Demodulator
7. Also connect the clock signal to the demodulator.
8. Observe the demodulator output with and without RF filter on CRO



CIRCUIT DIAGRAM







## **WAVE FORMS**



**RESULT:**

**VIVA QUESTIONS:**

1. What are the advantages of Delta modulator?
2. What are the disadvantages of delta modulator?
3. How to overcome slope overload distortion?
4. How to overcome Granular or ideal noise?
5. What are the differences between PCM & DM?
6. Define about slope over load distortion?
7. What is the other name of Granular noise?
8. What is meant by staircase approximation?
9. What are the disadvantages of Delta modulator?
10. Write the equation for error at present sample?

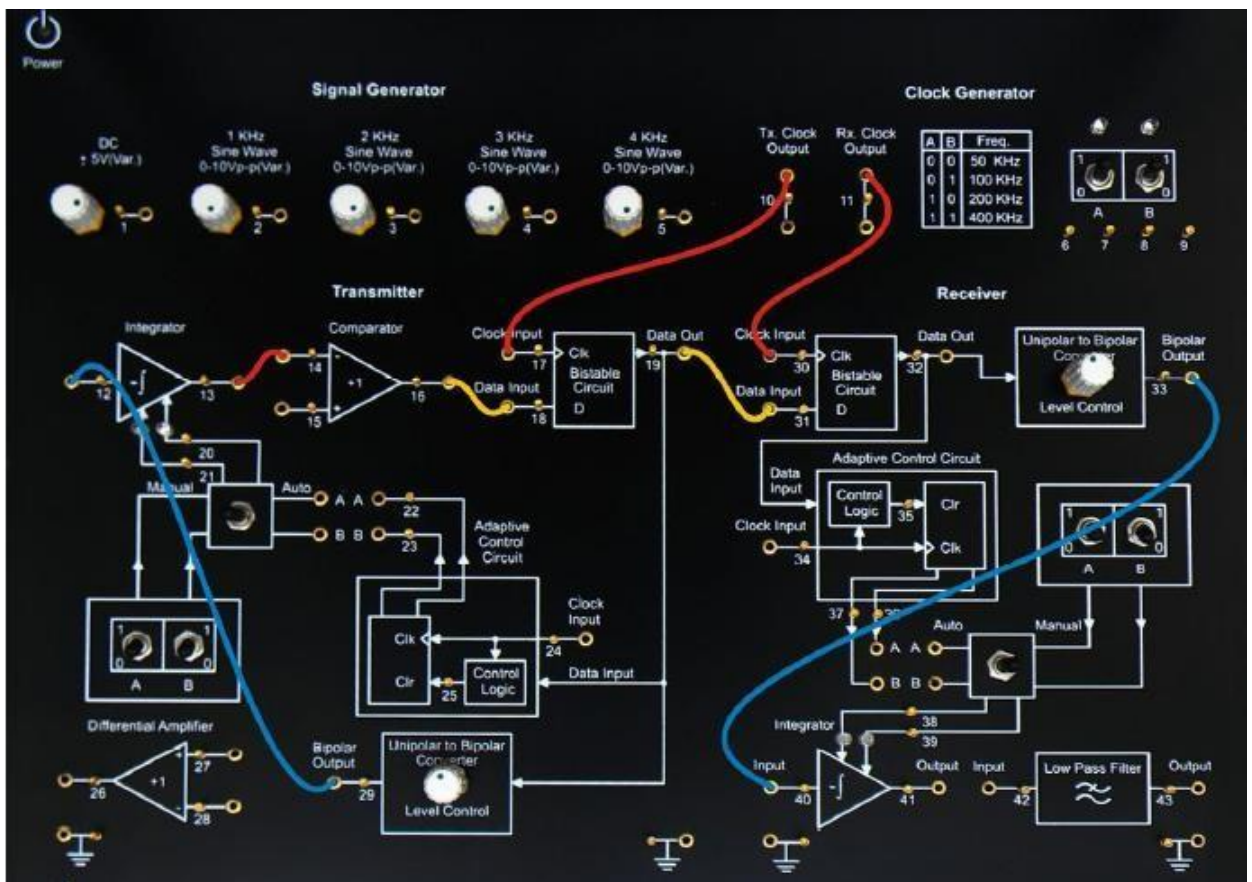
## 4. ADAPTIVE DELTA MODULATION

**AIM:** To Study & understand the operation of the Adaptive Delta modulator.

**APPARATUS:**

1. ADM Modulator trainer
2. ADM Demodulator trainer
3. Storage Oscilloscope
4. Patch chords

**BLOCK DIAGRAM:**



**Fig: Adaptive Delta Modulator and Demodulator**



**PROCEDURE:**

1. Connect the main supply cord to the trainer kit.
2. Keep the switch into AUTO mode in both Transmitter and Receiver.
3. Connect the switches A to A and B to B in both Transmitter and Receiver.
4. Apply the input signal of 1 KHz or 2 KHz or 3 KHz or 4 KHz of sine wave of voltage 0-10 V to the Comparator (TP-15).

**Modulation:**

5. Connect the Bi-polar output (TP-29) to the integrator (TP-12).
6. Apply integrator output (TP-13) to the Comparator (TP-14).
7. Apply the required clock signal from TP-10 to Bi-stable multi vibrator (TP-17) as well as Adaption control circuit (TP-24).
8. Connect the comparator output (TP-16) to the data input (TP-18).
9. Switch ON the supply of trainer kit and oscilloscope.
10. Observe the Data output at TP-19. Compare ADM output with approximated signal (TP-14). And also observe output with respect to approximated signal.
11. Draw the wave forms of input signal, clock signal, approximated signal and ADM output.

**Demodulation:**

12. Apply the ADM output to demodulator data input (TP-31).
13. Receiver clock pulse will be given to TP-30 and TP-34.
14. Connect the output of Bi-polar output to the integrator input and give its output to the LPF.
15. Observe the demodulated output at the LPF.
16. Draw the demodulated output and compare with input.
17. Also observe the Slope Over load Noise by applying the external signal with high amplitude (more than 20V) from function generator.

**WAVEFORMS:**



**RESULT:**

**VIVA QUESTIONS:**

1. What is adaptive delta modulation?
2. What is the drawback of delta modulation?
3. What is the effect of frequency on adaptive delta modulation?
4. What is advantage of adaptive delta modulation?
5. Why integrator is required for adaptive modulation?
6. Write short notes on Companding.
7. Write the formulae for  $\mu$ -law and A-law companding.



## **5. TIME DIVISION MULTIPLEXER AND DE-MULTIPLEXER**

**AIM:** To study time division multiplexing and de-multiplexing.

### **APPARATUS:**

1. Time division multiplexer and de-multiplexer trainer kits.
2. Coaxial cable.
3. Patch cords.

### **PROCEDURE:**

#### **MULTIPLEXER:**

1. Observe the AF generator-1 output and note down the amplitude and frequency.
2. Observe the AF generator-2 output and note down the amplitude and frequency.
3. Connect the AF generator and 2 outputs to CH1 and CH2 of TDM multiplexer.
4. Observe and connect the clock generator output to the control input of the TDM multiplexer (it acts like selection line for MUX).
5. Observe the TDM output in storage oscilloscope.

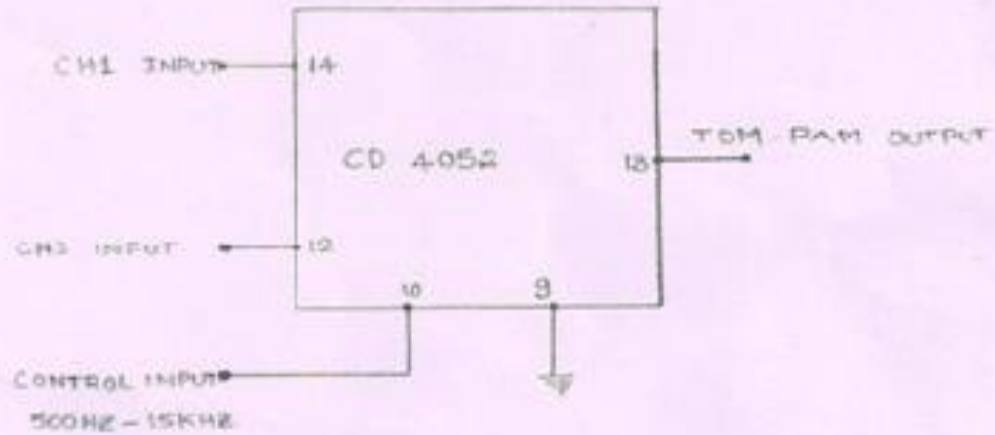
#### **DEMULTIPLEXER:**

6. Using coaxial cable connect the TDM de-multiplexer.
7. Connect the clock generator output in de-multiplexer trainer to the control input of the TDM de-multiplexer.
8. Observe the de-multiplexed signals at CH1 and CH2.
9. Connected the CH1 and CH2 outputs to low pass filter and amplifier and note down the outputs.

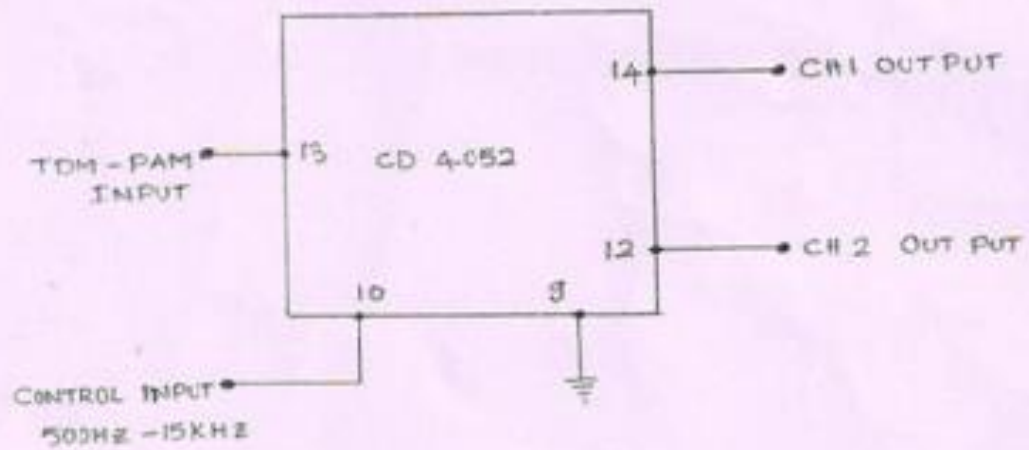


**CIRCUIT DIAGRAM:**

**MULTIPLEXER:**

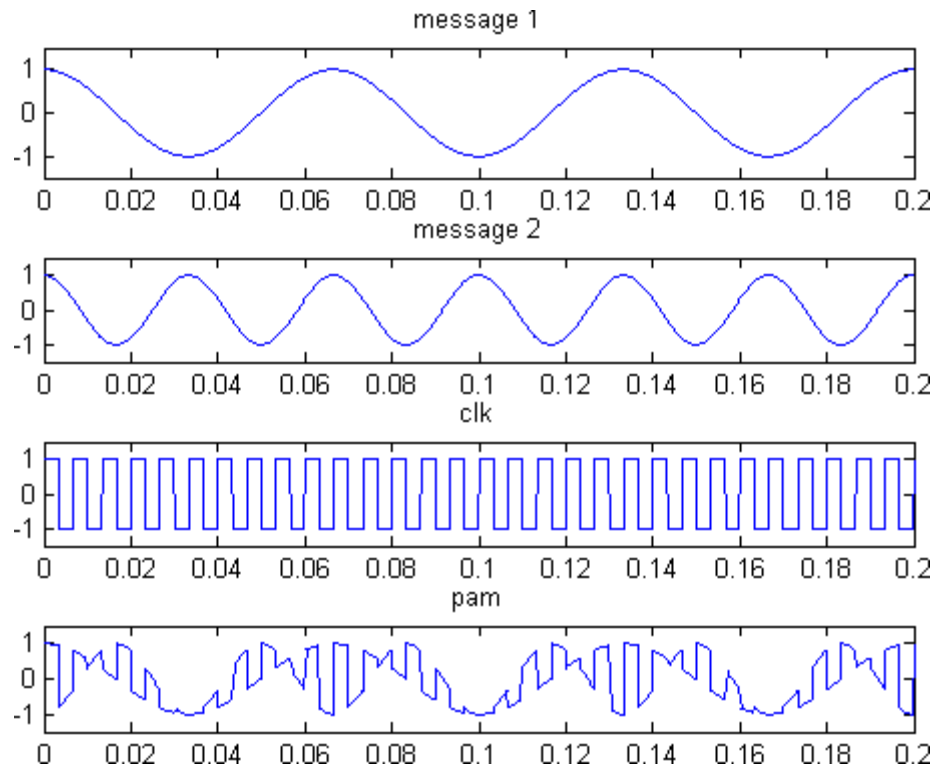


**DEMULTIPLEXER:**





**EXPECTED WAVEFORMS:**



**RESULT:**

**VIVA QUESTIONS:**

1. What is meant by multiplexing technique and what are the different types of Multiplexers?
2. Briefly explain about TDM&FDM?
3. What is the transmission band width of a PAM/TDM signal?
4. Define crosstalk effect in PAM/TDM system?
5. What are the advantages of TDM system?
6. What are major differences between TDM&FDM?
7. Give the value of  $T_s$  in TDM system?
8. What are the applications of TDM system and give some example?
9. What is meant by signal overlapping?
10. Which type of modulation technique will be used in TDM?





## **6. ASK MODULATION AND DEMODULATION**

**AIM:** To Study the process of Amplitude shift keying modulation & Demodulation and Study various data formatting modulation and Demodulation Techniques.

### **APPARATUS:**

1. ASK Modulation & Demodulation Trainer kit
2. C.R.O. 30 MHZ Dual Channel
3. Patch cords

### **PROCEDURE:**

#### **Modulation:**

1. Connect the sine wave 500 KHz from the carrier generator to the carrier input of the modulator.
2. And also connect the Data clock D1 i.e., modulation signal to the modulation input.
3. Switch ON the power supply.
4. Observe the output.
5. By varying the gain pot P3 observe the ASK output.
6. Adjusting the carrier offset and modulation offset we can observe the ASK output.
7. By changing the carrier signal 1MHz and different data clocks D2, D3, D4 observe the output.

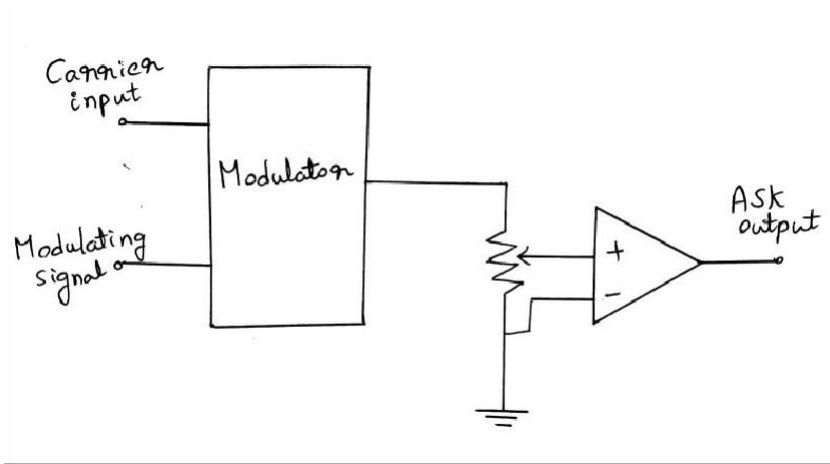
#### **Demodulation:**

1. Connect ASK output to the rectifier input and observe the waveform.
2. Now connect rectifier output to the low pass filter input and observe the output.
3. Connect LPF output to the data squaring circuit input and observe the demodulation output waveform.
4. By changing the different data clocks and observe the demodulation output.

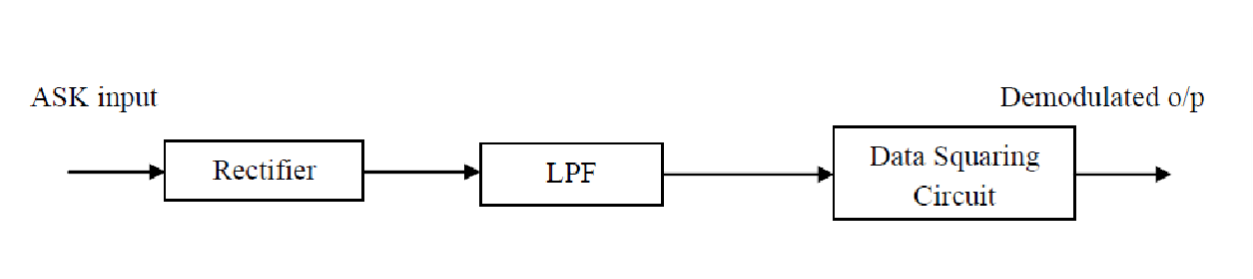


**BLOCK DIAGRAM:**

**MODULATOR:**

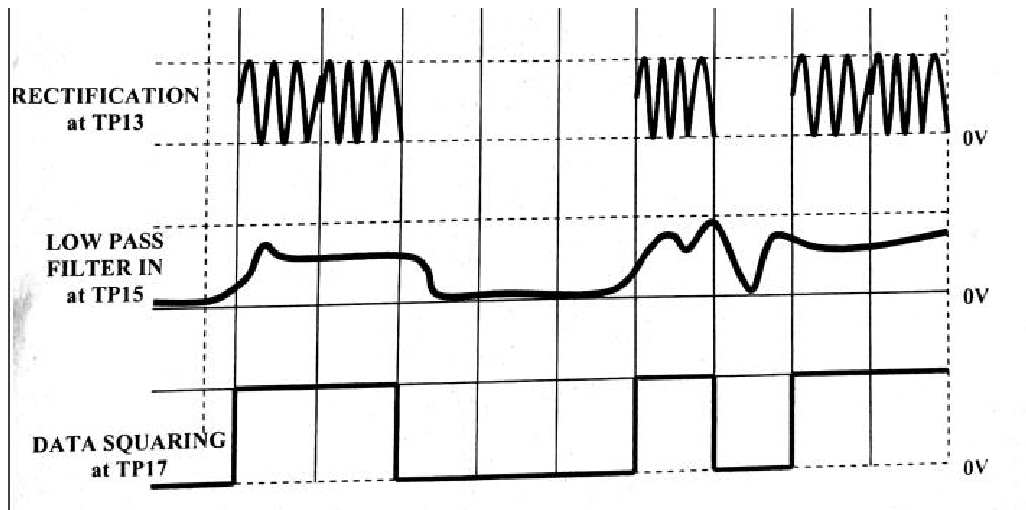
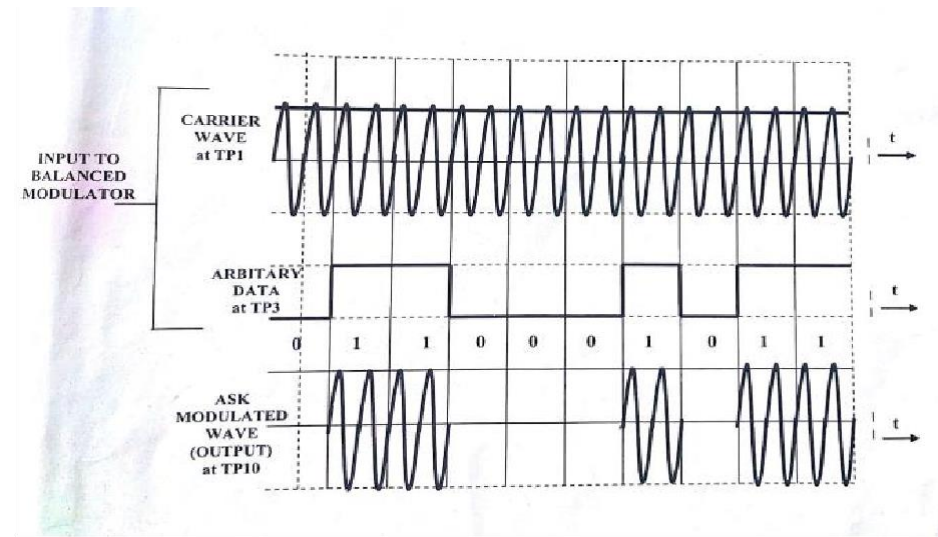


**DEMODULATOR:**





**EXPECTED  
GRAPHS:**



**RESULT:**



**VIVA QUESTIONS:**

- a. Define Amplitude shift keying?
- b. What is the bandwidth of ASK?
- c. What are the advantages of ASK?
- d. What are the disadvantages of ASK?
- e. Give the applications of ASK?
- f. Draw a ASK signal for an input bit sequence of 100111

## 7.FREQUENCY SHIFT KEYING GENERATION AND DETECTION

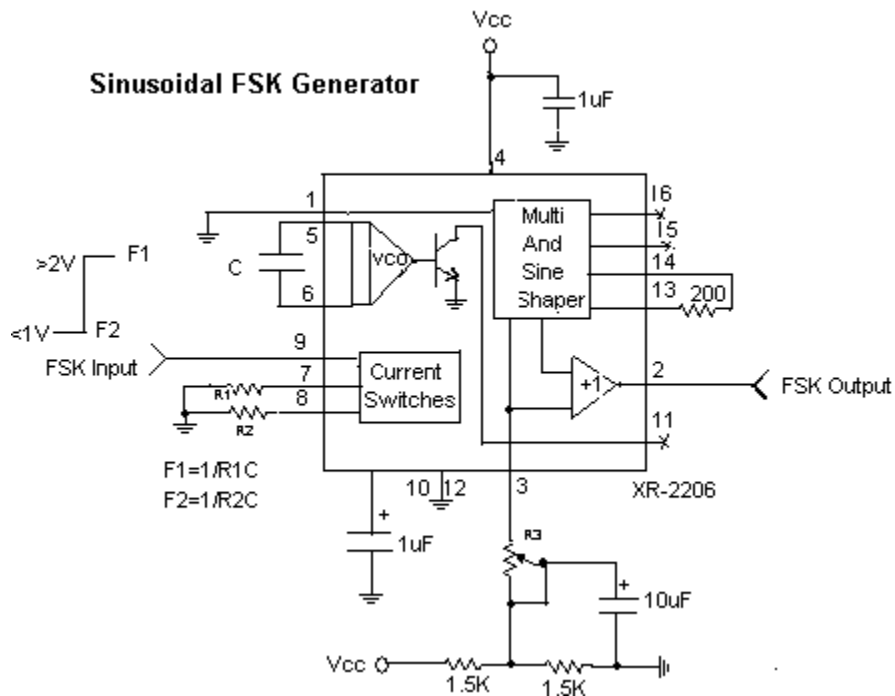
**AIM:** Study the operation of FSK modulation & Demodulation and to plot the Frequency Shift Keying waveforms for binary data at different frequencies.

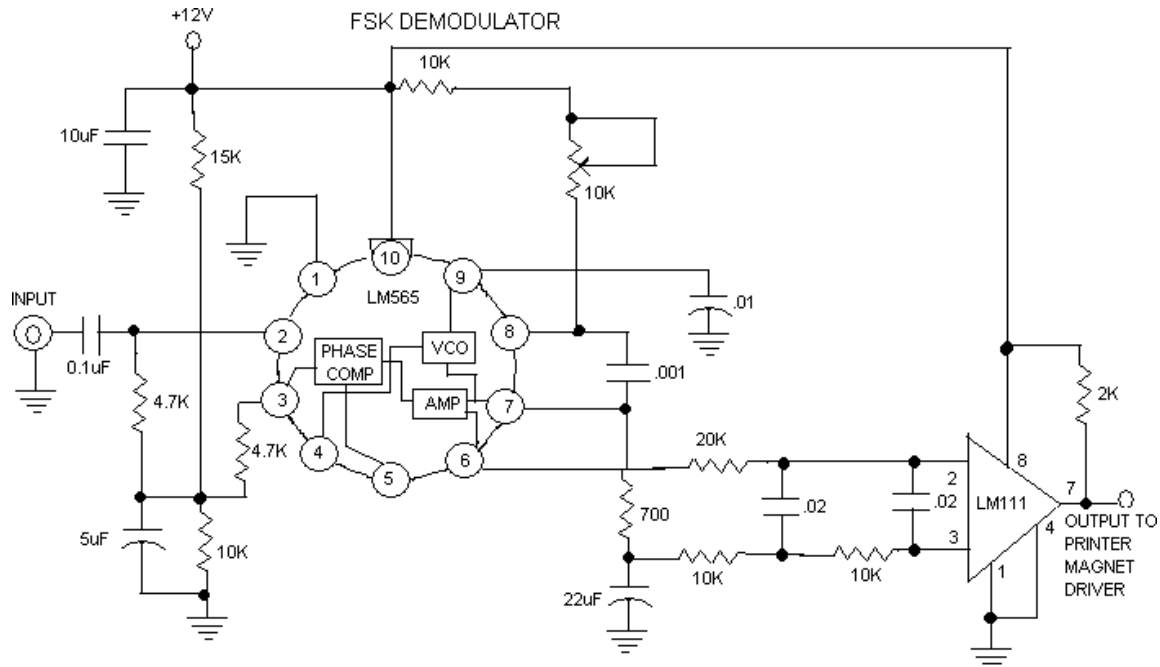
**APPARATUS:** 1. Frequency Shift Keying kit

2. Dual trace C.R.O (30MHz)

3. Digital frequency counter & DMM

**CIRCUIT DIAGRAM:**





### **THEORY:**

Frequency shift keying (FSK) is a modulation / Data transmitting technique in which carrier frequency is shifted between two distinct fixed frequencies to represent logic 1 and logic 0. The low carrier frequency represents a digital 0 (space) and higher carrier frequency is a 1 (mark). FSK system has a wide range of applications in low speed digital data transmission systems. Waveforms are shown in figure. FSK modulating & demodulating circuitry can be developed in number of ways; familiar VCO and PLL circuits are used in this trainer.

### **FSK Modulator:**

Figure 1 shows the FSK modulator using IC XR 2206, IC XR 2206 is a VCO based monolithic function generator capable of producing Sine, Square, Triangle signals with AM and FM facility. In this trainer XR2206 is used generate FSK signal. Mark (Logic 1) and space (Logic 0) frequencies can be independently adjusted by the choice of timing potentiometers F) & F!. The output is phase continuous during transitions. The keying signal i.e. data signal is applied to pin 9.

**FSK Demodulator:**

Figure 2 shows FSK Demodulator is a combination of PLL (LM565) and comparator (Op-amp). The frequency changing signal at the input to the PLL drives the phase detector to result in rapid change in the error voltage, which is applied to the input of the comparator. At the space frequency, the error voltage out of the phase detector is below the comparison voltage of the comparator. The comparator is a non inverting circuit, so its output level is also low. As the phase detector input frequency shifts low ( to the mark frequency), the error voltage steps to a high level, passing through the comparison level, causing the comparator output voltage between its two output levels in manner that duplicates the data signal input to the XR2206 modulator.

The free running frequency of the PLL (no input signal) is set midway between the mark and space frequencies. A space at 2025 HZ and mark at 2225 Hz will have a free running VCO frequency of 21125Hz.

**PROCEDURE:**

1. Study the theory of operation.
2. Connect the trainer to mains and switch on the power supply.
3. Measure the output voltage of the regulated power supply i.e +12V with the help of digital multi-meter.
4. Verify the operation of the logic source using digital multi-meter. Output should be zero volts in logic 0 position and 12V in logic 1 position.
5. Observe the output of the data signal using oscilloscope. It should be a square wave of 20Hz to 180Hz @ 10Vpp. Select 125Hz for getting proper demodulated output. (For frequency variation potentiometer is provided).

**FSK Modulation:**

6. Connect output of the logic source to data input of the FSK modulator.



7. Set logic source switch in 0 positions.
8. Connect FSK modulator output to oscilloscope as well as frequency counter.
9. Set the output frequency of the FSK modulator as per your desire( say 2KHz) with the help of control F0 which represents logic 0
10. Set logic source switch in 1 position.
11. Set the output frequency of the FSK modulator as per your desire (say 2.5 KHz) with the help of control F1 which represents logic 1.  
Note: we have chosen F0 as 2 KHz and F1 as 2.5 KHz for ease of operation in fact you may set any value.
12. Now connect data input of the FSK modulator to the output of the data signal generator.
13. Keep CRO in dual mode connect CH1 input of the oscilloscope to the input of the FSK modulator and CH2 input to the output of the FSK modulator.
14. Observe the FSK signal for different data signal frequencies and plot them. By this we can observe that the carrier frequency shifting between two predetermined frequencies as per the data signal i.e. 2 KHz when data signal is 0 and 2.5KHz when data input is 1 in this case.
15. Compare these plotted wave forms with the theoretically drawn in figure.

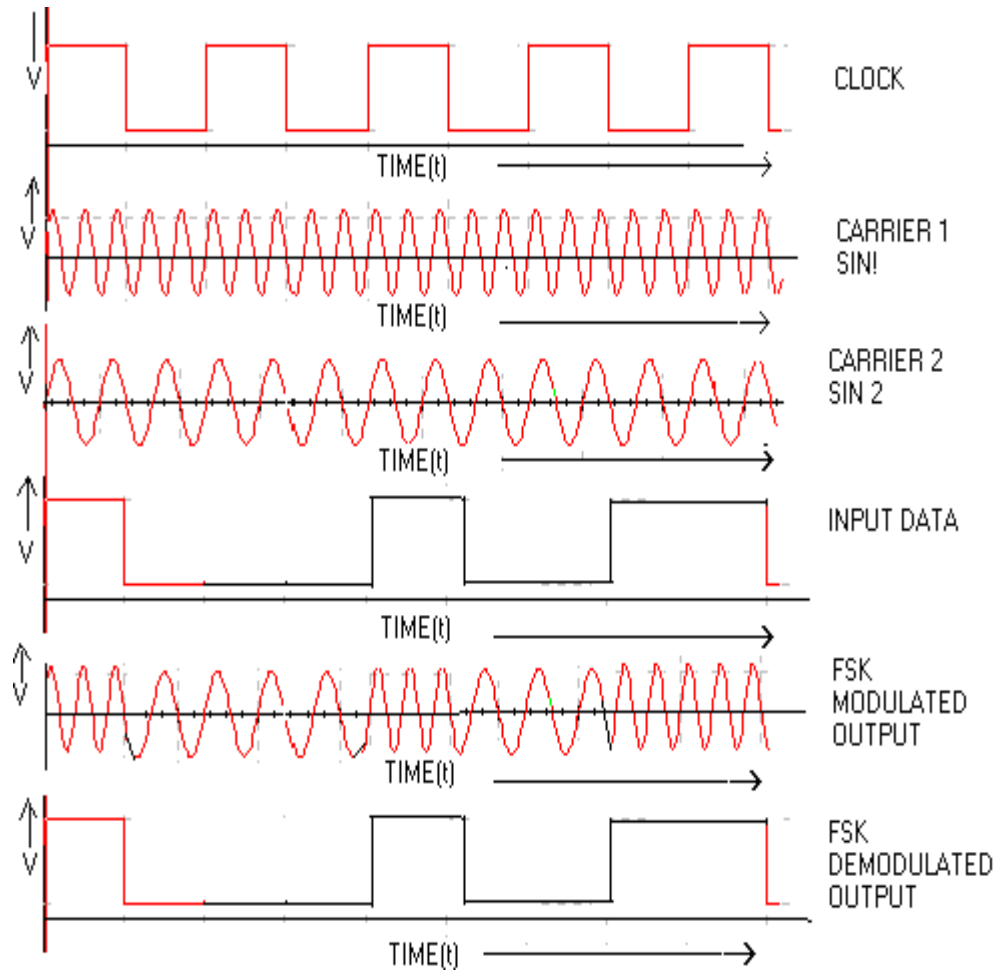
**FSK Demodulation:**

16. Now connect the FSK modulator output to the FSK input of the demodulator.
17. Connect CH1 input of the Oscilloscope to the data signal at modulator and CH2 input to the output of the FSK demodulator (keep CRO in dual mode)
18. Observe and plot the output of the FSK demodulator for different frequencies of data signal. Compare the original data signal and demodulated signal; by this we can observe that there is no loss in process of FSK modulation and demodulation.





**EXPECTED WAVEFORMS:**



**RESULT:**



**VIVA QUESTIONS:**

1. Define frequency shift keying?
2. What is meant by carrier swing?
3. Define Frequency deviation of FSK?
4. What are the advantages of FSK?
5. Give the differences between FSK & FM?
6. What are the disadvantages of FSK?
7. What is the bandwidth required for coherent FSK?
8. Compare FSK with ASK signaling schemes?
9. Define Binary FSK signal?
10. Draw a FSK signal for an input bit sequence of 10011001?

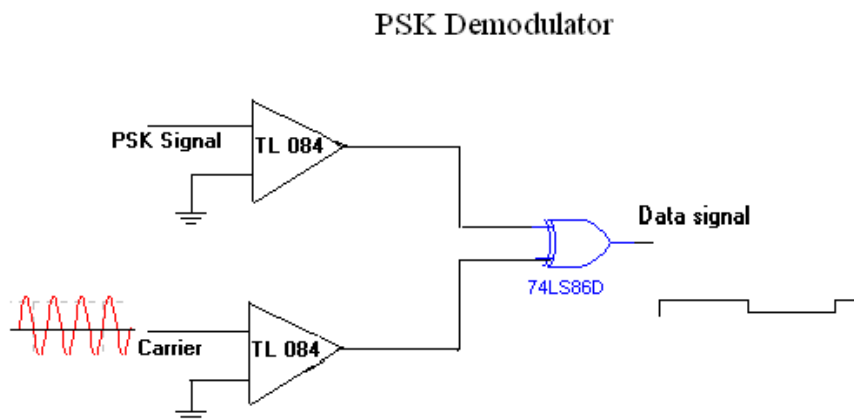
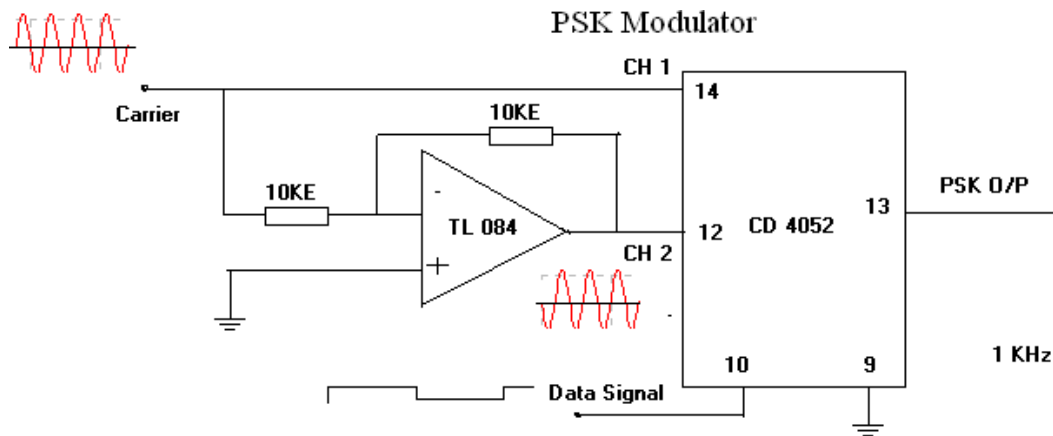
## 8. PHASE SHIFT KEYING GENERATION AND DETECTION

**AIM:** Study the operation of PSK (Binary) Modulation & Demodulation and to plot the PSK wave forms for Binary data at different frequencies.

### APPARATUS:

1. Phase Shift keying trainer-kit
2. Dual trace Oscilloscope
3. Digital multi-meter
4. Patch chords

### BLOCK DIAGRAM:





**THEORY:** Phase Shifting Keying (PSK) is a modulating / Data transmitting technique in which phase of the carrier signal is shifted between two distinct levels. In a simple PSK (i.e Binary PSK) un-shifted carrier  $V \cos W_o t$  is transmitted to indicate a 1 condition , and the carrier shifted by  $180^\circ$  i.e  $-V \cos W_o t$  is transmitted to indicate a 0 condition. Wave forms are shown in Figure PSK Modulating & Demodulating circuitry can be developed in number of ways, one of the simple circuit is used in this trainer.

**PROCEDURE:**

1. Study the theory of operation.
2. Connect the trainer to mains and switch on the power supply.
3. Measure the output of the regulated power supply i.e +5V and -5V with the help of digital multi-meter.
4. Observe the output of the carrier generator using CRO, it should be an 8 KHz Sine with 5 Vpp amplitude.
5. Observe the various data signals (1 KHz, 2 KHz and 4 KHz) using CRO.

**Modulation**

6. Connect carrier signal to carrier input of the PSK Modulator.
7. Connect data signal say 4 KHz from data source to data input of the modulator.
8. Keep CRO in dual mode.
9. Connect CH1 input of the CRO to data signal and CH2 to the output of the PSK modulator
10. Observe the PSK o/p Signal with respect to data signal and plot the wave forms  
Compare the plotted waveforms with given wave forms.

**Demodulation:**

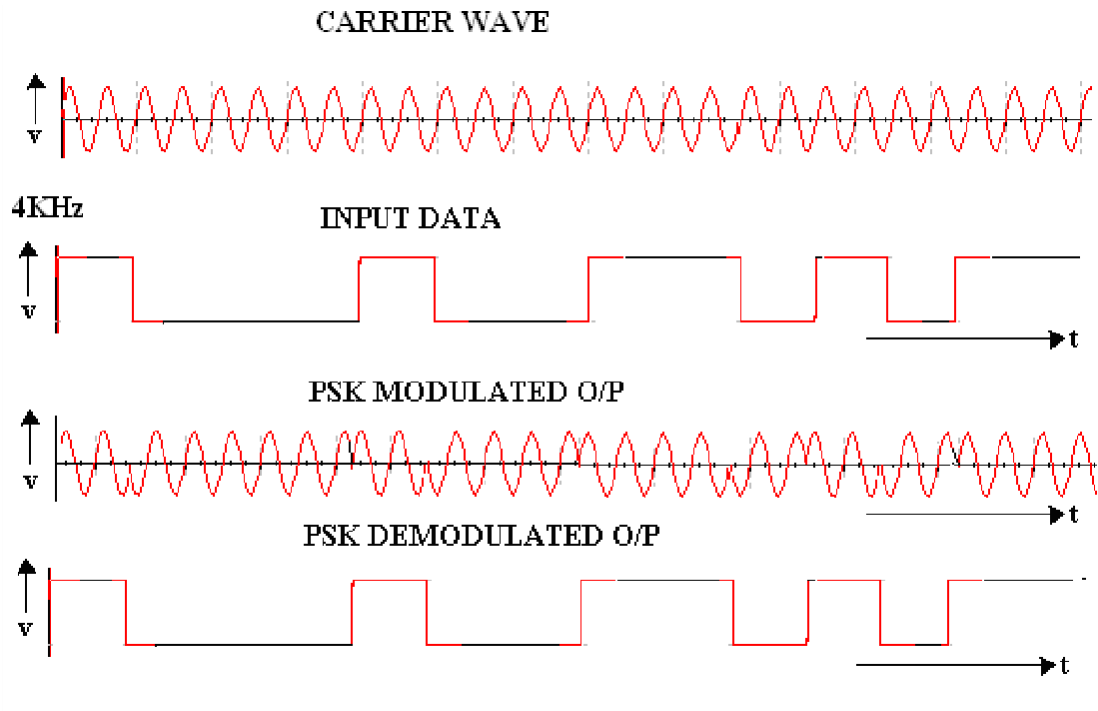
11. Connect the PSK output to the PSK input of the demodulator.
12. Connect carrier to the carrier input of the PSK demodulator  
Note: In actual communication system reference carrier is generated at receiver.
13. Keep CRO in dual mode.
14. Connect CH1 to the data signal (at Modulator) and CH2 to the output of the demodulator.



15. Compare the demodulated signal with original data signal; by this we can notice that there is no loss in modulation and demodulation process.

16. Repeat the steps 7 to 15 with different data signals i.e. 2 KHz and 1 KHz.

**EXPECTED WAVEFORMS:**



**RESULT:**

**VIVA QUESTIONS:**

1. Explain concept of PSK?
2. What is the band width requirement of a DPSK?
3. Explain the operation of DPSK detection?
4. What are the advantages of PSK?
5. What is meant by differential encoding?
6. In Differential encoding technique which type of logic gates are used?
7. Draw the waveforms of PSK?
8. What is the difference between PSK&DPSK?
9. What is the minimum bandwidth required in PSK?
10. Explain the Demodulation scheme of PSK?

## 9. DIFFERENTIAL PHASE SHIFT KEYING

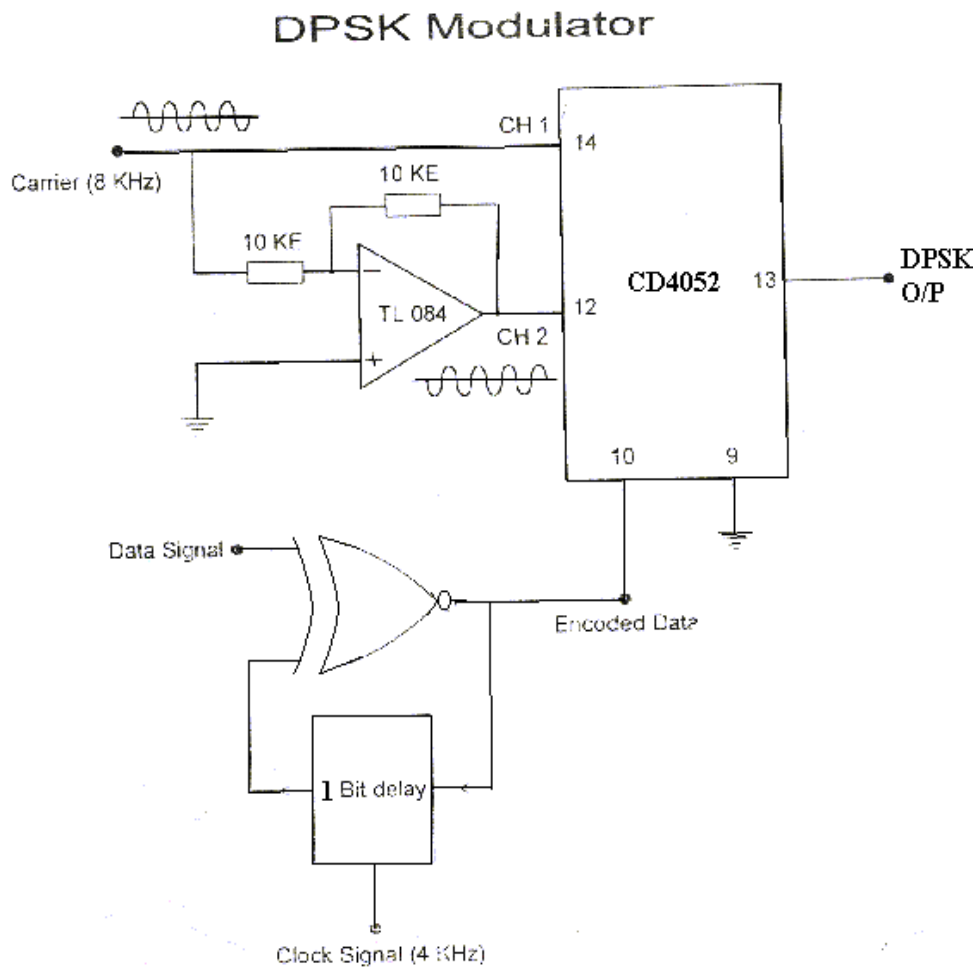
### GENERATION AND DETECTION

**AIM:** Study the characteristics of differential phase shift keying.

**APPARATUS:**

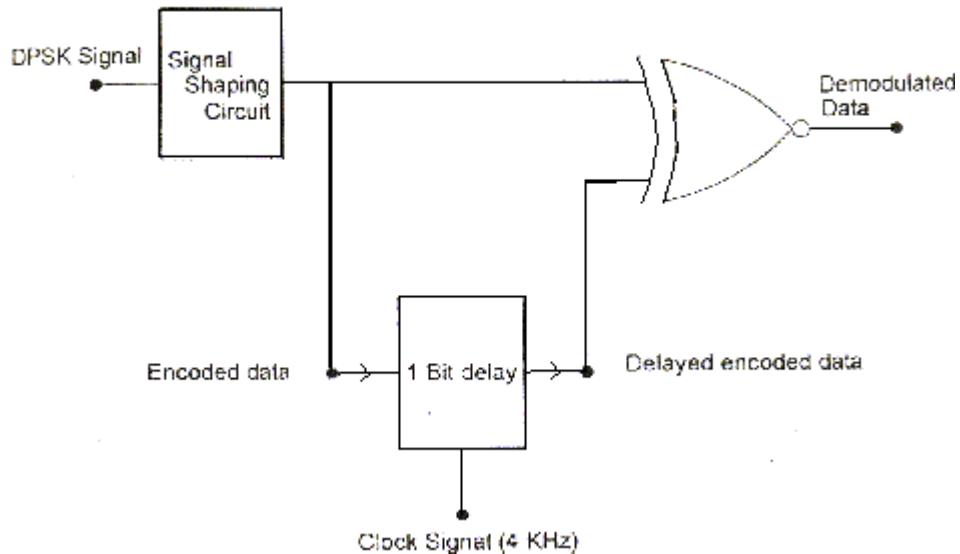
1. Differential Phase Shift Keying Kits
2. C.R.O (20MHz)
3. Digital multi-meter.
4. No's of coaxial cables (standard accessories with trainer)

**BLOCK DIAGRAM:**





### DPSK Demodulator



#### THEORY:

DPSK: Phase Shift Keying requires a local oscillator at the receiver which is accurately synchronized in phase with the un-modulated transmitted carrier, and in practice this can be difficult to achieve. **Differential Phase Shift Keying (DPSK)** over comes the difficult by combining two basic operations at the transmitter (1) differential encoding of the input binary wave and (2) phase shift keying – hence the name differential phase shift keying. In other words DPSK is a non-coherent version of the PSK.

The differential encoding operation performed by the modulator is explained below Let  $b(t)$  be the binary message to be transmitted. An encoded message stream  $b'(t)$  is generated from  $b(t)$  by using a logic circuit The first bit in  $b(t)$  is arbitrary which may be chosen as 1 or 0 . The subsequent bits in  $b(t)$  are determined on the basis of the rule that when  $b'(t)$  is 1  $b(t)$  does not change its value. In the first bit stream, the initial bit (arbitrary) is 1 and in the second bit stream, the initial bit is 0 EX-NOR gate can be used to perform this operation as its output is a 1 when both the input are same, and a 0 when the inputs are different.

$b'(t)$		0	1	1	0	0	
$b(t)$	1	0	0	0	1	0	
Phase		$0^0$	$180^0$	$180^0$	$180^0$	$0^0$	$180^0$



	B(t)		0	1	1	1	0	1
Phase	180 <sup>0</sup>	0 <sup>0</sup>	0 <sup>0</sup>	0 <sup>0</sup>	180 <sup>0</sup>	0 <sup>0</sup>		

Example for Complete DPSK operation (with arbitrary bit as 0):

Message signal (to be transmitted) 0		1	1	0	0		
Encoded data (differential data)		0	1	1	1	0	1
Transmitted signal phase:		180 <sup>0</sup>	0 <sup>0</sup>	0 <sup>0</sup>	0 <sup>0</sup>	180 <sup>0</sup>	0 <sup>0</sup>
Received signal phase:		180 <sup>0</sup>	0 <sup>0</sup>	0 <sup>0</sup>	0 <sup>0</sup>	180 <sup>0</sup>	0 <sup>0</sup>
Encoded data (differential data)			0	1	1	1	0
Message signal (Demodulation)			0	1	1	0	0

DPSK Demodulator:

**DPSK Modulator:** IC CD 4052 is a 4 channel analog multiplexer and is used as an active component in this circuit. One of the control signals of 4052 is grounded so that 4052 will act as a two channel multiplexer and other control is being connected to the binary signal i.e., encoded data. Un- shifted carrier signal is connected directly to CH1 and carrier shifted by 180<sup>0</sup>is connected to CH2. Phase shift network is a unity gain inverting amplifier using Op-Amp (TL084).

When control signal is at high voltage, output of the 4052 is connected to CH1 and un-shifted (or 0 phase) carrier is passed on to output. Similarly when control signal is at zero voltage output of 4052 is connected to CH2 and carrier shifted by 180<sup>0</sup> is passed on to output.

Differential encoder: This consists of 1 bit delay circuit and an X-NOR Gate. 1 bit delay circuit is formed by a D-Latch. Data signal i.e., signal to be transmitted is connected to one of the input of the X-NOR gate and other one being connected to out of the delay circuit. Output of the X-NOR gate and is connected to control input of the multiplexer (IC 4052) and as well as to input of the D-Latch. Output of the X-NOR gate is 1 when both the inputs are same and it is 0 when both the inputs are different.

**DPSK Demodulator:** This consists of 1 bit delay circuit, X-NOR Gate and a signal shaping circuit. Signal shaping circuit consists of Op-amp based zero crossing detector followed by a D-latch. Receiver DPSK signal is converted to square wave with the help of zero crossing and this square wave will pass through the D-Latch. So output of the D-latch is an encoded data. This encoded data is applied to 1 bit delay circuit as well as to one of the inputs of X-NOR gate. And output of the delay circuit is connected to another input of the X-NOR gate. Output of the X-NOR gate is 1 when both the inputs are same and it is 0 when both the inputs are different.





**PROCEDURE:**

**Modulation:**

1. Connect carrier signal to carrier input of the PSK Modulator.
2. Connect data signal from data input of the X-NOR gate.
3. Keep CRO in dual mode.
4. Connect CH1 input of the CRO to data signal and CH2 input to the encoded data (which is nothing but the output of the X-NOR gate)
5. Observe the encoded data with respect to data input. The encoded data will be in a given sequence.
6. Actual data signal : 10101101001010110100
7. Encoded data signal : 01100011011001110010
8. Now connect CH2 input of the CRO to the DPSK output and CH1 input to the encoded data. Observe the input and output waveforms and plot the same.
9. Compare the plotted waveforms with the given waveforms in fig: 1.3
10. Note: Observe and plot the waveforms after perfect triggering. Better to keep the encoded data more than 4 cycles for perfect triggering.

**Modulation:**

6. Connect carrier signal to carrier input of the PSK Modulator.
7. Connect data signal from data input of the X-NOR gate.
8. Keep CRO in dual mode.
9. Connect CH1 input of the CRO to data signal and CH2 input to the encoded data (which is nothing but the output of the X-NOR gate)
10. Observe the encoded data with respect to data input. The encoded data will be in a given sequence.
6. Actual data signal : 10101101001010110100
7. Encoded data signal : 01100011011001110010
11. Now connect CH2 input of the CRO to the DPSK output and CH1 input to the encoded data. Observe the input and output waveforms and plot the same.

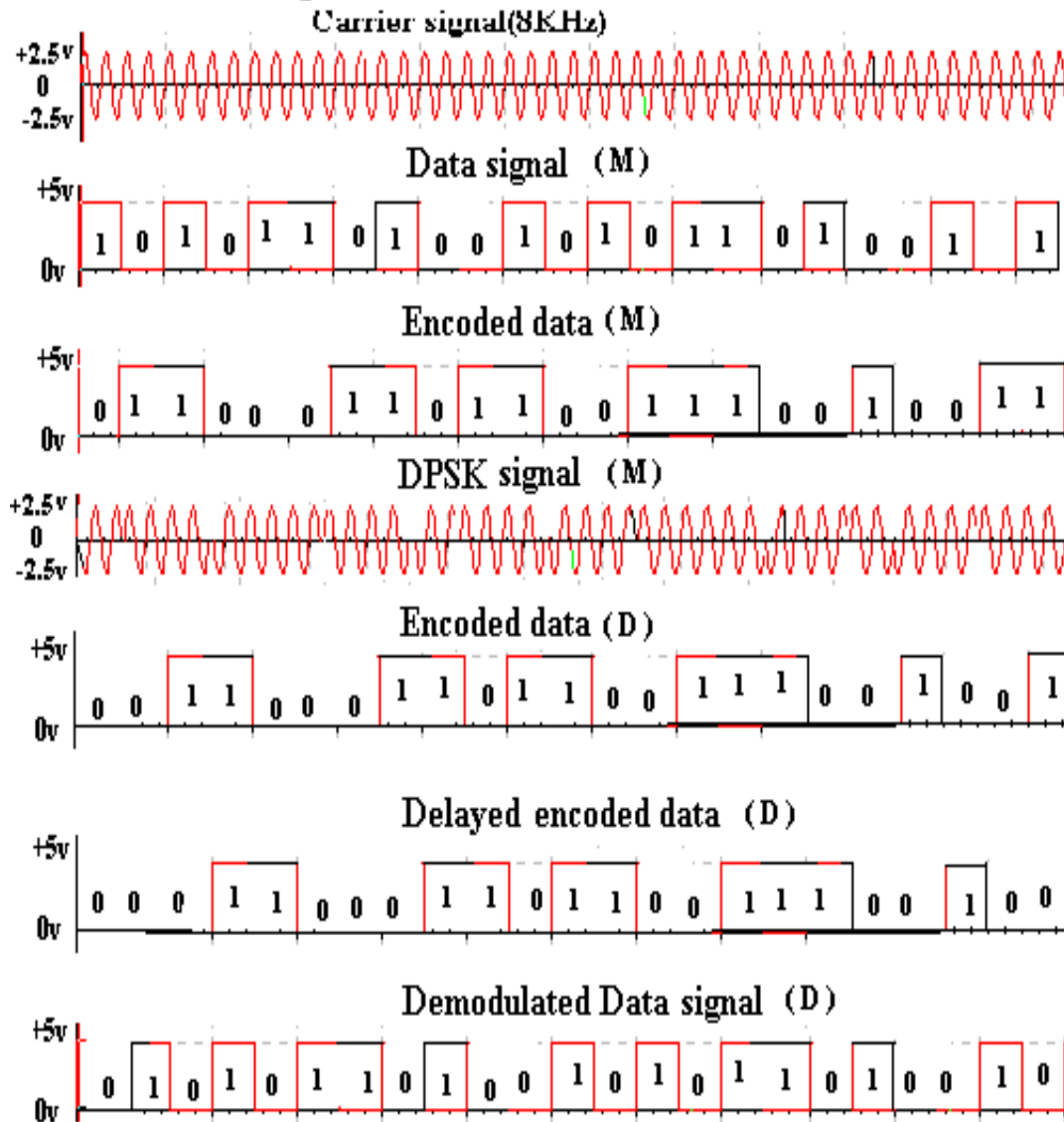


12. Compare the plotted waveforms with the given waveforms in fig: 1.3

Note: Observe and plot the waveforms after perfect triggering. Better to keep the encoded data more than 4 cycles for perfect triggering. clock at demodulator. You can get further perfection in output waveform by adjusting the locally generated clock frequency by varying potentiometer.

**EXPECTED WAVEFORMS:**

**Fig 1:3 DPSK Wave forms**



**RESULT:**



**VIVA  
QUESTIONS:**

1. Define DPSK?
2. Mention the Advantages of DPSK?
3. Mention the Disadvantages of DPSK?
4. Draw the waveforms of DPSK?
5. Compare ASK, PSK, FSK & DPSK?
6. What are the Applications of DPSK?
7. What is the expression for DPSK Error?
8. Why do we need 1-Bit delay in DPSK Modulator & Demodulator?
9. How does DPSK differ from PSK?
10. Is the error rate of DPSK is greater than PSK?



## **10.QPSK Generation and Detection**

**AIM:** To study modulation and demodulation of QPSK and sketch the relevant waveforms.

### **APPARATUS:**

1. QPSK modulation and demodulation trainer.
2. CRO
3. Connecting probes and cords
4. Power supply.

### **PROCEDURE:**

1. Connect and switch on the power supply.
2. QPSK is selected by default and LEDs of corresponding technique will glow.
3. Select the bit pattern using push button i.e. 8 bit or 16 bit or 32 bit or 64 bit. Observe bit pattern on TP-2.
4. Select data rate using push button i.e. 2 KHz or 4 KHz or 8 KHz 16 KHz.

### **Modulation:**

5. Observe the input bit pattern at TP-2 by varying bit pattern using respective push button.
6. Observe the data rate at TP-1 by varying data rate using respective push button.
7. Observe the Two- bit encoding i.e. I-Channel (TP-3) and Q-Channel (TP-4).
8. Observe carrier signal i.e. cosine wave (TP-5) and sine wave (TP-6). Frequency of carrier signal will change with respect to data rate.
9. Observe I-Channel (TP-7) and Q-Channel (TP-8) modulated signal.
10. Observe QPSK modulated signal at TP-9.

### **Demodulation:**

11. Apply the QPSK modulated output to the demodulator input.
12. Observe the multiplied signal of QPSK and carrier signal, cosine at TP-12 and also observe the multiplied signal of QPSK and carrier signal, sine at TP-13.
13. Observe the integrated output at I-channel (TP-14) and Q-channel (TP-15).

14. Observe the comparator output at I-channel (TP-16) and Q-channel (TP-17) i.e. same as at input with delay.
15. Observe the QPSK demodulated output at TP-18.

**BLOCK DIAGRAM:**

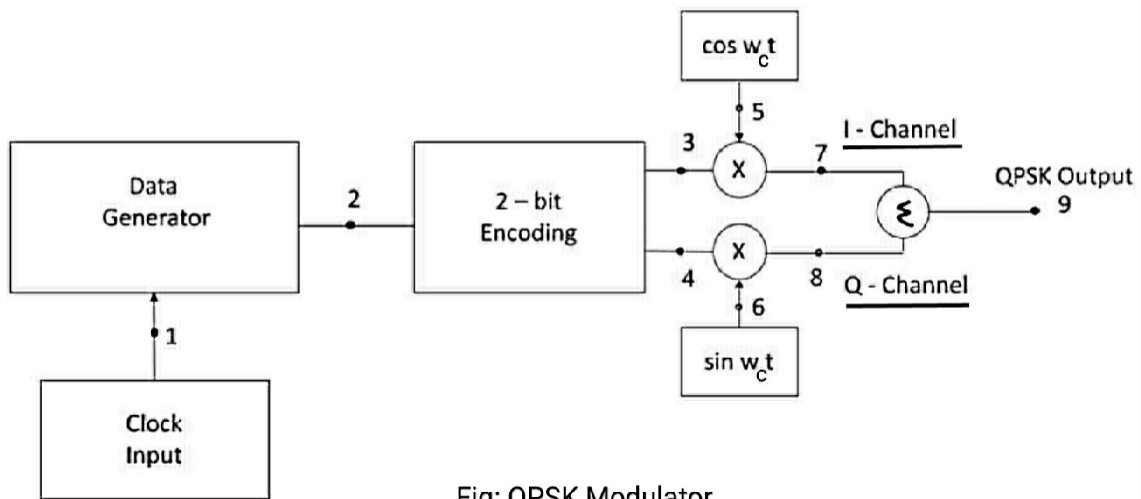


Fig: QPSK Modulator

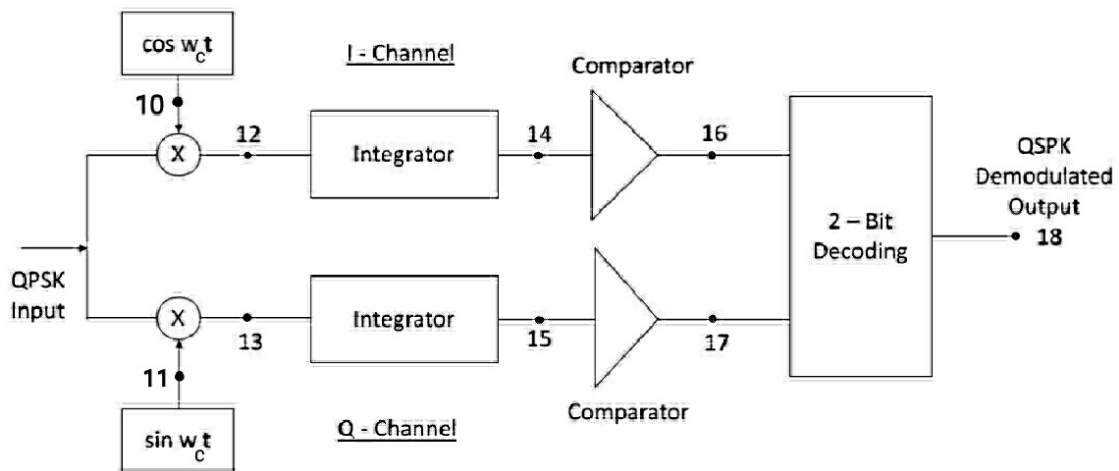


Fig: QPSK Demodulator



**WAVEFORMS**

**RESULT:**



## **11. STUDY OF SPECTRAL CHARACTERISTICS OF PAM**

### **AIM:**

To study the operation of pulse amplitude modulation and to plot spectrum of PAM

### **EQUIPMENT REQUIRED:**

1. Pulse Amplitude modulation trainer kit
2. Dual trace oscilloscope
3. Digital multi-meter
4. Patch cords

### **EXPERIMENTAL PROCEDURE:**

1. As the circuitry is already wired you just have to trace the circuit according to the circuit diagram given above.
2. Connect trainer to mains and switch on the power.
3. Measure the output voltages of regulated power supply circuit i.e.  $\pm 12V$ .
4. Observe the output of AF generator and pulse generator using CRO and note that AF signal is approximately 3V P-P of 400Hz frequency and pulse generator output is pulse train of 10V P-P with frequency between 1 KHz and 6 KHz.

### **MODULATOR:**

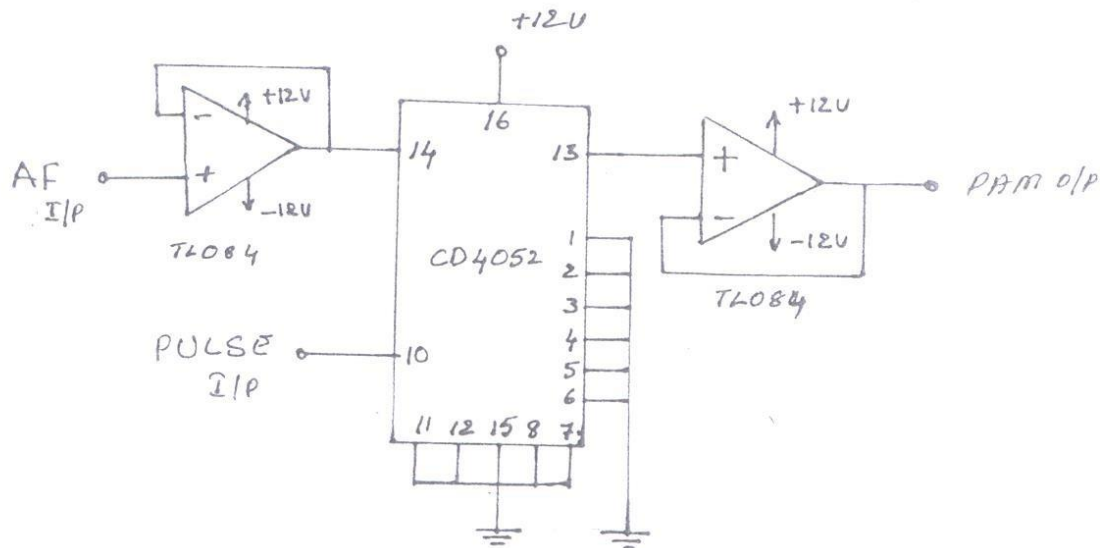
1. Connect pulse output and AF output to the respective inputs of modulator circuit.
2. Connect one of the inputs of oscilloscope to the modulator output and another to AF signal.
3. Initially set the amplitude of the AF generator to minimum level and sampling frequency to 1 KHz (by adjusting the preset provided in pulse generator block). Note down the output of modulator, by varying amplitude of modulating signal observe the modulator output so that you can notice the amplitude of the sampling pulses is varying in accordance with the modulating signal.

### **SPECTRUM:**

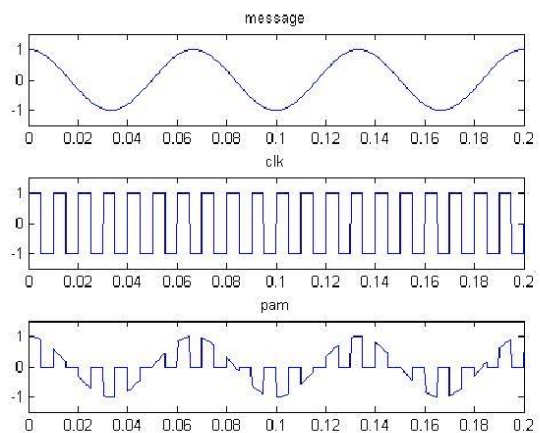
1. Observe the output of PAM with the help of Spectrum analyzer and note down the frequencies.
2. Draw the spectrum.



**PAM MODULATOR CIRCUIT DIAGRAM:**



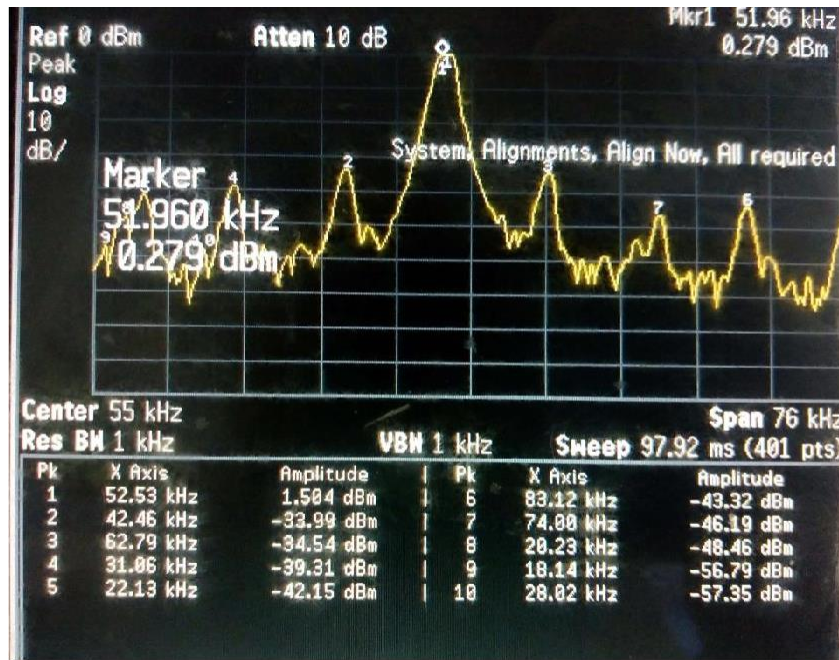
**INPUT & OUTPUT WAVE FORMS:**







### Spectrum of PAM:



### RESULT:

### VIVA QUESTIONS:

1. Define pulse amplitude modulation?
2. What is the circuit used to generate PAM signal?
3. Mention the advantages of PAM?
4. Mention the disadvantages of PAM?
5. Mention the applications of PAM?
6. Compare PPM with PWM and PAM?
7. Mention the IC used to generate PWM.



## **12. STUDY OF SPECTRAL CHARACTERISTICS OF PWM**

**AIM:** To study the operation of pulse width modulation and to plot spectrum of PWM

### **EQUIPMENT:**

1. PWM demonstrator trainer.
2. Dual trace oscilloscope (Storage oscilloscope is desirable).
3. Digital multi-meter.
4. Patch cords.

### **PROCEDURE:**

#### **Observation of PWM with AC input signal:**

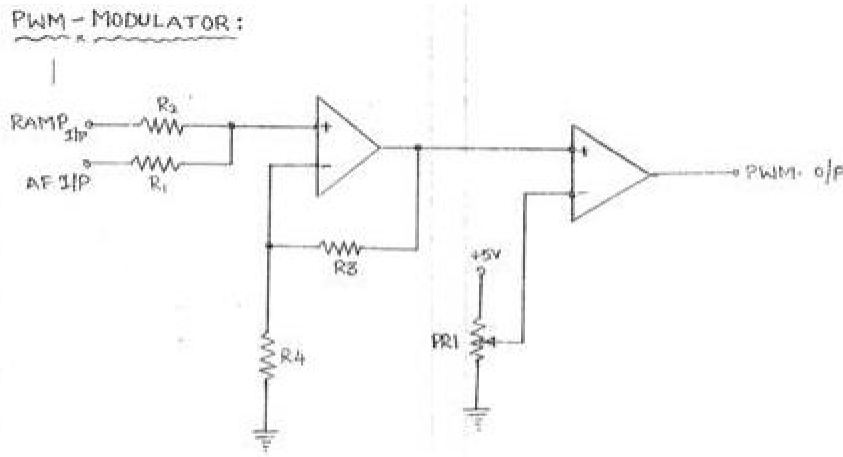
1. Study the circuit operation thoroughly.
2. Switch on the trainer and measure the output voltages of the regulated power supply i.e. +5V and -5V.
3. Observe the output of the AF generator using CRO, note that the output is 5V p-p @ 400 Hz frequency.
4. Observe the output of the control signal generator i.e. ramp and reference pulse using CRO.
5. Now connect AF signal to the modulator and observe output waveform (condition: scope is in dual mode, CH 1 is connected to AF signal and CH 2 is connected to PWM output, trigger source in CH 1, if you are using storage oscilloscope after setting AF input voltage observe output in stop mode).

#### **Procedure to obtain Spectrum:**

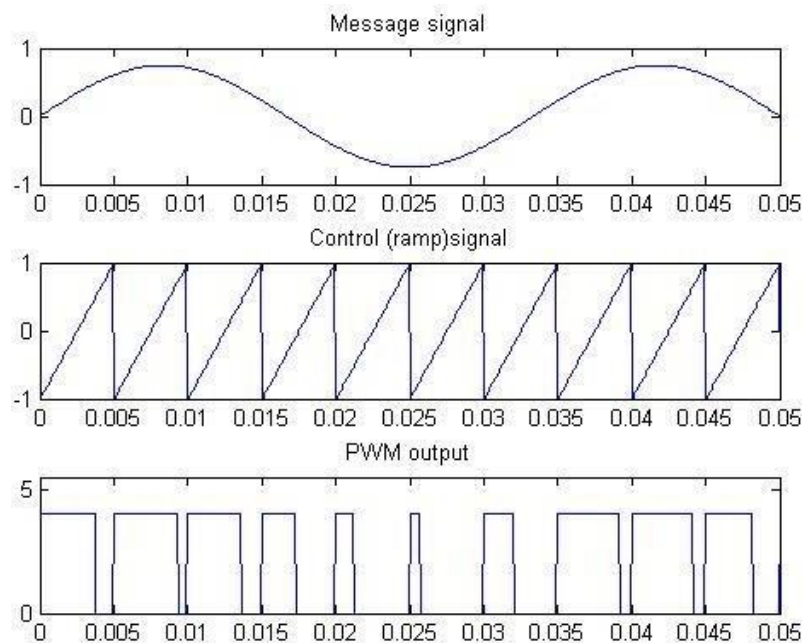
6. Observe the output of PWM with the help of Spectrum analyzer and note down the frequencies of harmonics.
7. Draw the spectrum.



**PWM MODULATOR CIRCUIT DIAGRAM:**

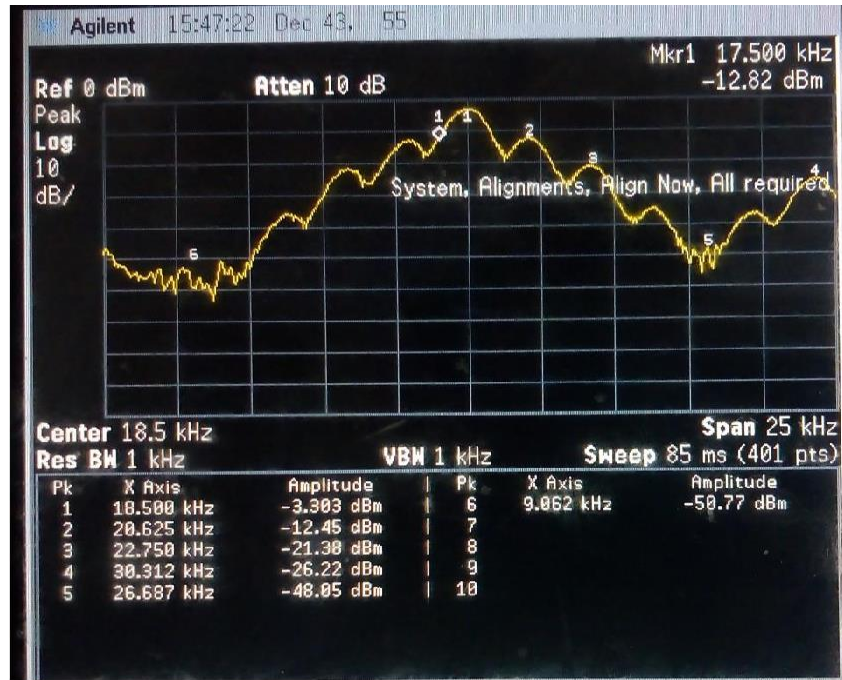


**WAVEFORMS:**





### Spectrum of PWM



### RESULT:

### VIVA QUESTIONS:

1. Define pulse width modulation.
2. What is the circuit used to generate a PWM signal.
3. Mention the advantages of PWM.
4. Mention the disadvantages of PWM.
5. What is the IC used as function generator.
6. Mention the bandwidth requirements of PWM.
7. Mention the applications of PWM.
8. What is the circuit used to demonstrate a PWM signal.
9. Compare PWM with PAM.
10. Mention the IC used to generate PWM.

## **ADD ON EXPERIMENTS**

1. Companding Using MATLAB

2. Minimum Shift Keying (MSK) Using MATLAB

# AMPLITUDE SHIFT KEYING

**Aim:** To generate and demodulate amplitude shift keyed (ASK) signal using MATLAB

## Theory

### Generation of ASK

Amplitude shift keying - ASK - is a modulation process, which imparts to a sinusoid two or more discrete amplitude levels. These are related to the number of levels adopted by the digital message. For a binary message sequence there are two levels, one of which is typically zero. The data rate is a sub-multiple of the carrier frequency. Thus the modulated waveform consists of bursts of a sinusoid. One of the disadvantages of ASK, compared with FSK and PSK, for example, is that it has not got a constant envelope. This makes its processing (eg, power amplification) more difficult, since linearity becomes an important factor. However, it does make for ease of demodulation with an envelope detector.

### Demodulation

ASK signal has a well defined envelope. Thus it is amenable to demodulation by an envelope detector. Some sort of decision-making circuitry is necessary for detecting the message. The signal is recovered by using a correlator and decision making circuitry is used to recover the binary sequence.

### Algorithm

Initialization commands

### ASK modulation

1. Generate carrier signal.
2. Start FOR loop
3. Generate binary data, message signal(on-off form)
4. Generate ASK modulated signal.
5. Plot message signal and ASK modulated signal.
6. End FOR loop.
7. Plot the binary data and carrier.

### ASK demodulation

1. Start FOR loop
2. Perform correlation of ASK signal with carrier to get decision variable
3. Make decision to get demodulated binary data. If  $x > 0$ , choose '1' else choose '0'
4. Plot the demodulated binary data.

## Program

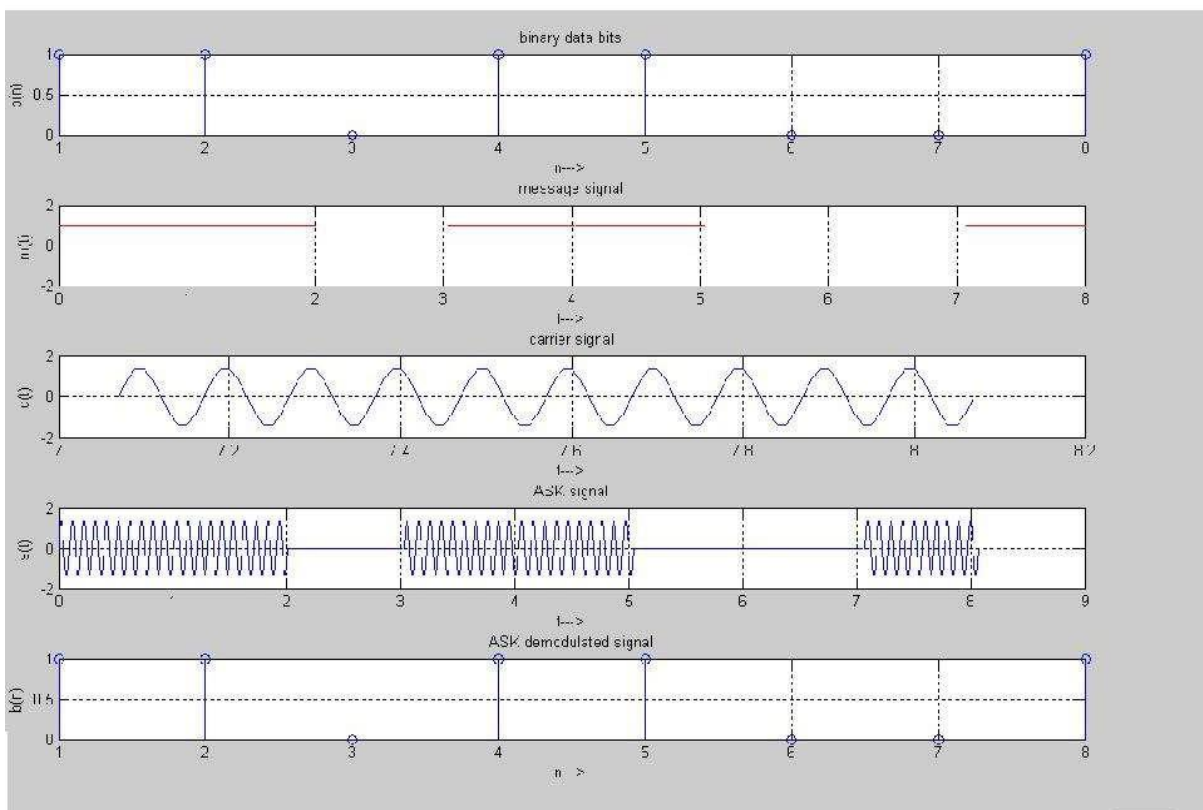
### %ASK Modulation

```
clc;
clear all;
close all;
%GENERATE CARRIER SIGNAL
Tb=1; fc=10;
t=0:Tb/100:1;
c=sqrt(2/Tb)*sin(2*pi*fc*t);
%generate message signal
N=8;
m=rand(1,N);
t1=0;t2=Tb
for i=1:N
t=[t1:.01:t2]
if m(i)>0.5
    m(i)=1;
    m_s=ones(1,length(t));
else
    m(i)=0;
    m_s=zeros(1,length(t));
end
message(i,:)=m_s;
%product of carrier and message
ask_sig(i,:)=c.*m_s;
t1=t1+(Tb+.01);
t2=t2+(Tb+.01);
%plot the message and ASK signal
subplot(5,1,2);axis([0 N -2 2]);
plot(t,message(i,:), 'r');
title('message signal');xlabel('t--->');ylabel('m(t)');
grid on hold on;
subplot(5,1,4);plot(t,ask_sig(i,:));
title('ASK signal');xlabel('t--->');ylabel('s(t)');grid on hold on
end
hold off
%Plot the carrier signal and input binary data
subplot(5,1,3);plot(t,c);
title('carrier signal');xlabel('t--->');ylabel('c(t)');grid on
subplot(5,1,1);stem(m);
title('binary data bits');xlabel('n--->');ylabel('b(n)');grid on
```

## % ASK Demodulation

```
t1=0;t2=Tb
for i=1:N
t=[t1:Tb/100:t2]
%correlator
x=sum(c.*ask_sig(i,:));
%decision device
if x>0
    demod(i)=1;
else
    demod(i)=0;
end
t1=t1+(Tb+.01);
t2=t2+(Tb+.01);
end
%plot demodulated binary data bits
subplot(5,1,5);stem(demod);
title('ASK demodulated signal'); xlabel('n--->');ylabel('b(n)');grid
on
```

## Model Graphs





## PHASESHIFTKEYING

**Aim:** To generate and demodulate phase shift keyed (PSK) signal using MATLAB

### Generation of PSK signal

PSK is a digital modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (the carrier wave). PSK uses a finite number of phases, each assigned a unique pattern of binary digits. Usually, each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. The demodulator, which is designed specifically for the symbol-set used by the modulator, determines the phase of the received signal and maps it back to the symbol it represents, thus recovering the original data.

In a coherent binary PSK system, the pair of signal  $S_1(t)$  and  $S_2(t)$  used to represent binary symbols 1 & 0 are defined by

$$S_1(t) = \sqrt{2E_b/T_b} \cos 2\pi f_c t$$
$$S_2(t) = \sqrt{2E_b/T_b} (2\pi f_c t + \pi) = -\sqrt{2E_b/T_b} \cos 2\pi f_c t \quad \text{where } 0 \leq t < T_b \text{ and}$$

$E_b$  = Transmitted signed energy for bit

The carrier frequency  $f_c = n/T_b$  for some fixed integer  $n$ .

### Algorithm

Initialization commands

### PSK modulation

1. Generate carrier signal.
2. Start FOR loop
3. Generate binary data, message signal in polar form
4. Generate PSK modulated signal.
5. Plot message signal and PSK modulated signal.
6. End FOR loop.
7. Plot the binary data and carrier.

### PSK demodulation

1. Start FOR loop  
Perform correlation of PSK signal with carrier to get decision variable
2. Make decision to get demodulated binary data. If  $x > 0$ , choose '1' else choose '0'
3. Plot the demodulated binary data.

### Program

% PSK modulation

clc;

```

clear all;
close all;
%GENERATE CARRIER SIGNAL
Tb=1;
t=0:Tb/100:Tb;
fc=2;
c=sqrt(2/Tb)*sin(2*pi*fc*t);
%generate message signal
N=8;
m=rand(1,N);
t1=0;t2=Tb
for i=1:N
t=[t1:.01:t2]
if m(i)>0.5
    m(i)=1;
    m_s=ones(1,length(t));
else
    m(i)=0;
    m_s=-1*ones(1,length(t));
end
message(i,:)=m_s;
%product of carrier and message signal
bpsk_sig(i,:)=c.*m_s;
%Plot the message and BPSK modulated signal
subplot(5,1,2);axis([0 N -2 2]);plot(t,message(i),'r');
title('message signal (POLAR form)');xlabel('t--->');ylabel('m(t)');
grid on; hold on;
subplot(5,1,4);plot(t,bpsk_sig(i,:));
title('BPSK signal');xlabel('t--->');ylabel('s(t)');
grid on; hold on;
t1=t1+1.01; t2=t2+1.01;
end
hold off
%plot the input binary data and carrier signal
subplot(5,1,1);stem(m);
title('binary data bits');xlabel('n--->');ylabel('b(n)');
grid on;
subplot(5,1,3);plot(t,c);
title('carrier signal');xlabel('t--->');ylabel('c(t)');
grid on;

```

## % PSK Demodulation

```

t1=0;t2=Tb
for i=1:N
    t=[t1:.01:t2]
%correlator
    x=sum(c.*bpsk_sig(i,:));
%decision device
    if x>0
        demod(i)=1;
    else
        demod(i)=0;
    end
end

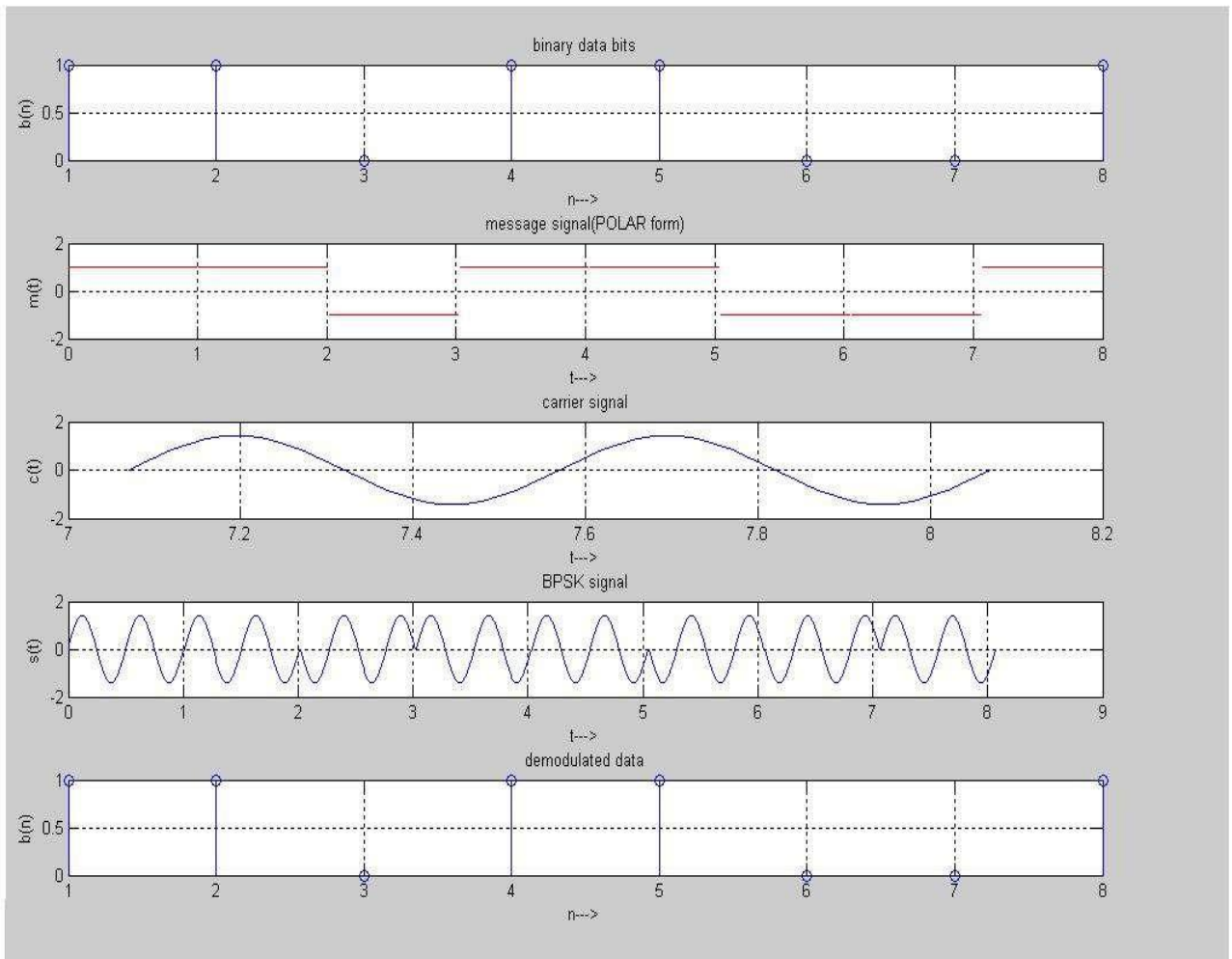
```

```

end
t1=t1+1.01;
t2=t2+1.01;
end
%plot the demodulated data bits
subplot(5,1,5);stem(demod);
title('demodulated data');xlabel('n-->');ylabel('b(n)'); grid on

```

### Modal Graphs



# FREQUENCYSHIFTKEYING

**Aim:** To generate and demodulate frequency shift keyed (FSK) signal using MATLAB

## Theory Generation of

### FSK

Frequency- shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes of a carrier wave. The simplest FSK is binary FSK (BFSK). BFSK uses a pair of discrete frequencies to transmit binary (0s and 1s) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency.

In binary FSK system, symbol 1 & 0 are distinguished from each other by transmitting one of the two sinusoidal waves that differ in frequency by a fixed amount.

$$S_i(t) = \sqrt{2E/T_b} \cos 2\pi f_i t \quad 0 \leq t \leq T_b$$

0 elsewhere Where  $i=1, 2$  &

$E_b$ =Transmitted energy/bit

Transmitted freq=  $f_i = (nc+i)/T_b$ , and  $n = \text{constant (integer)}$ ,  $T_b = \text{bit interval}$  Symbol 1 is represented by  $S_1(t)$

Symbol 0 is represented by  $S_0(t)$

### Algorithm Initialization

commands **FSK**

### modulation

1. Generate two carriers signal.
2. Start FOR loop
3. Generate binary data, message signal and inverted message signal
4. Multiply carrier 1 with message signal and carrier 2 with inverted message signal
5. Perform addition to get the FSK modulated signal
6. Plot message signal and FSK modulated signal.
7. End FOR loop.
8. Plot the binary data and carriers.

### FSK demodulation

1. Start FOR loop
2. Perform correlation of FSK modulated signal with carrier 1 and carrier 2 to get two decision variables  $x_1$  and  $x_2$ .

3. Make decision on  $x = x_1 - x_2$  to get demodulated binary data. If  $x > 0$ , choose '1' else choose '0'.
4. Plot the demodulated binary data.

### Program

#### % FSK Modulation

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clc; clear
all; close
all;
%GENERATE CARRIER SIGNAL
Tb=1; fc1=2;fc2=5;
t=0:(Tb/100):Tb;
c1=sqrt(2/Tb)*sin(2*pi*fc1*t);
c2=sqrt(2/Tb)*sin(2*pi*fc2*t);
%generate message signal
N=8;
m=rand(1,N);
t1=0;t2=Tb for
i=1:N
    t=[t1:(Tb/100):t2]
    if m(i)>0.5
        m(i)=1;
        m_s=ones(1,length(t));
        invm_s=zeros(1,length(t));
    else
        m(i)=0;
        m_s=zeros(1,length(t));
        invm_s=ones(1,length(t));
    end
    message(i,:)=m_s;
%Multiplier
    fsk_sig1(i,:)=c1.*m_s;
    fsk_sig2(i,:)=c2.*invm_s;
    fsk=fsk_sig1+fsk_sig2;
%plotting the message signal and the modulated signal
subplot(3,2,2);axis([0 N -2 2]);plot(t,message(i,:), 'r'); title('message
signal');xlabel('t---->');ylabel('m(t)');grid on;hold on;
subplot(3,2,5);plot(t,fsk(i,:));
title('FSK signal');xlabel('t---->');ylabel('s(t)');grid on;hold on;
t1=t1+(Tb+.01); t2=t2+(Tb+.01); end

hold off
%Plotting binary data bits and carrier signal
subplot(3,2,1);stem(m);
title('binary data');xlabel('n ---->');
ylabel('b(n)');grid on;
subplot(3,2,3);plot(t,c1);
title('carrier signal-1');xlabel('t---->');ylabel('c1(t)');grid on;
subplot(3,2,4);plot(t,c2);

```

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title('carrier signal-2');xlabel('t---->');ylabel('c2(t)');grid on;

% FSK Demodulation

t1=0;t2=Tb
for i=1:N
    t=[t1:(Tb/100):t2]
%correlator
    x1=sum(c1.*fsk_sig1(i,:));
    x2=sum(c2.*fsk_sig2(i,:));
    x=x1-x2;
%decision device
    if x>0
        demod(i)=1;
    else
        demod(i)=0; end
    t1=t1+(Tb+.01);
    t2=t2+(Tb+.01);
end
%Plotting the demodulated data bits
    subplot(3,2,6);stem(demod);
title(' demodulated data');xlabel('n---->');ylabel('b(n)'); grid on;

```

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