PVP SIDDHARTHA INSTITUTE OF TECHNOLOGY, KANURU, VIJAYAWADA-7

DEPARTMENT OF E.C.E.

ANALOG COMMUNICATIONS
LAB MANUAL

Department of Electronics & Communication engineering
Prasad V.Potluri Siddhartha Institute of Technology
Affiliated to JNTU Kakinada,
Approved by AICTE, New Delhi Accredited By NBA,
ISO9001:2008 Certified Institute
(Sponsored by: Siddhartha Academy of General & Technical Education)
Kanuru, Vijayawada -520007.

ANALOG COMMUNICATIONS LAB—SYLLABUS

List of Experiments [twelve experiments to be done]
[a).Hardware, b). Matlab Simulink, c). MATLAB Communication tool box]

A. Amplitude Modulation – Mod. & Demod
B. AM-DSB SC- Mod & Demod.
C. Spectrum Analysis of Modulated signal using Spectrum Analyzer
D. Diode Detector
E. Pre – emphasis & De-emphasis.
F. Frequency Modulation – Mod & Demod.
G. AGC Circuits.
H. Sampling Theorem.
I. Pulse Amplitude Modulation – Mod. & Demod.
J. PWM, PPM – Mod & Demod.
K. PLL

Equipments & Software required:

Software:

i. Computer Systems with latest specifications
ii. Connected in LAN (Optional)
iii. Operating system (Windows ZP)
iv. Simulations software (Simulink & MATLAB)

Equipment:

1. RPS – 0-30V
2. CRO – 0-20MHz
3. Function Generators – 0-1MHz
4. Components
5. Multimeters
6. Spectrum Analyzer

AMPLITUDE MODULATION & DEMODULATION

Aim:

1. To generate amplitude modulated wave and determine the percentage modulation.
2. To Demodulate the modulated wave using envelope detector.

Apparatus Required:

Name of the Component/Equipment	Specifications/Range	Quantity
Transistor (BC 107)	Ft=300MHz Pd =1W Ic (max)=100mA	1
Diode (0A79)	Max Current 35mA	1
Resistors	1KΩ, 2KΩ, 6.8KΩ, 10KΩ	1 each
Capacitors	0.01µF	1
Inductor	130mH	1
CRO	20MHz	1
Function Generator	1MHz	2
Regulated Power Supply	0-30V, 1A	1

Theory:

Amplitude Modulation is defined as a process in which the amplitude of the carrier wave c (t) is varied linearly with the instantaneous amplitude of the message signal m(t). The standard form of amplitude modulated (AM) wave is defined by

$$s(t) = A_c\left(1 + k_a m(t)\right)\cos(2\pi f_c t)$$

Where K_a is a constant called the amplitude sensitivity of the modulator.

The demodulation circuit is used to recover the message signal from the incoming AM wave at the receiver. An envelope detector is a simple and yet highly effective device that is well suited for the demodulation of AM wave, for which the percentage modulation is less then 100%. Ideally, an envelope detector produces an output signal that follows the envelop of the input signal wave form exactly; hence, the name. Same version of this circuit is used in almost all commercial AM radio receivers.

The Modulation Index is defined as, $m = \frac{(E_{max}\ E_{min})}{(E_{max}\ E_{min})}$

Where E_{max} and E_{min} are the maximum and minimum amplitudes of the modulated wave.

Circuit Diagrams:

For Modulation:

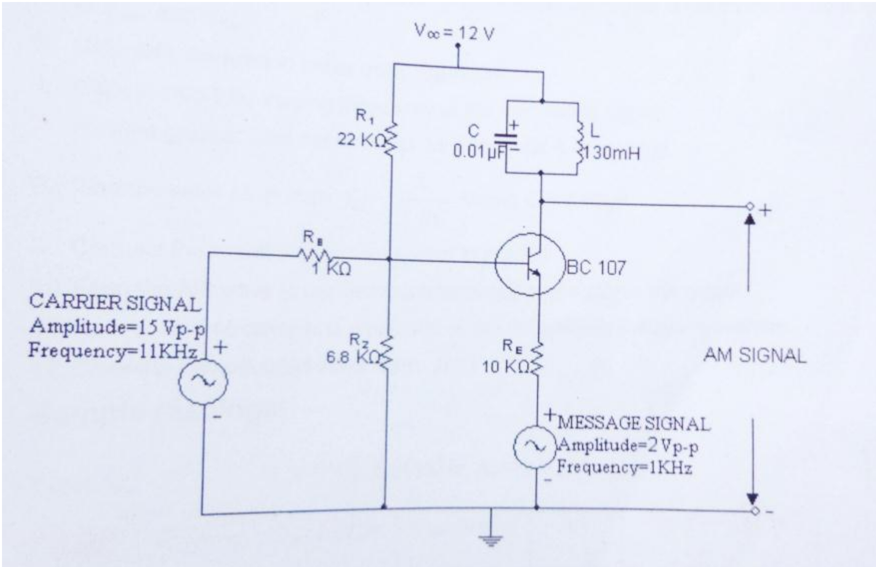


Fig: 1. AM Modulator

For Demodulation:

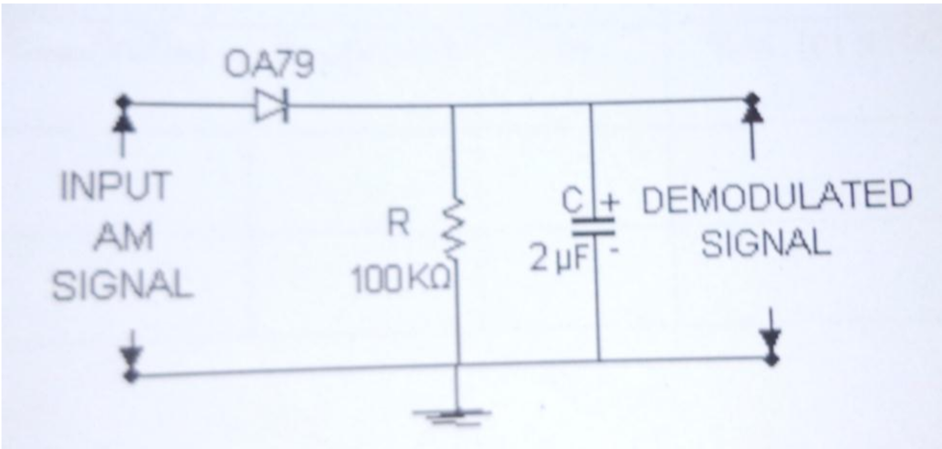


Fig: 2. AM Demodulator

Procedure:

1. The circuit is connected as per the circuit diagram shown in Fig.1.
2. Switch on =12V V_{cc} supply
3. Apply sinusoidal signal of 1KHz frequency and amplitude 2 V_{p-p} as modulating signal, and carrier signal of frequency 11 KHz and amplitude 15 V_{p-p}.

4. Now slowly increase the amplitude of the modulating signal up to 7V and note down values of E_{max} and E_{min}.
5. Calculate modulation index using equation
6. Repeat step 5 by varying frequency of the modulating signal.
7. Plot the graphs: Modulation index vs Amplitude & Frequency
8. Find the value of R from $f_m = \frac{1}{2\pi RC}$ taking C=0.01μF
9. Connect the circuit diagram as shown in Fig.2.
10. Feed the AM wave to the demodulator circuit and observe the output.
11. Note down frequency and amplitude of the demodulated output waveform.
12. Draw the demodulated wave form. m=1.

Sample Readings:

Table1: f_m=1 KHz, f_c=11 KHz, A_c=15V_{p-p}.

S.NO.	V_m (Volts)	E_{max}(Volts)	E_{min}(Volts)	m	%m(mx100)

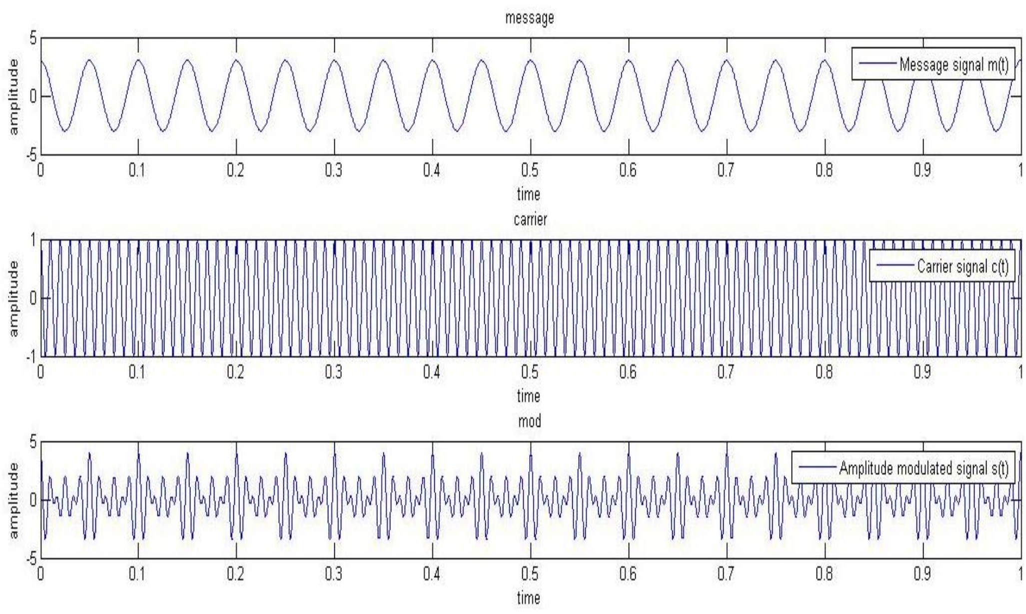
Table 2: A_m=4V_{p-p} , f_c=11KHz, A_c=15V_{p-p}.

S.NO.	f_m(KHz)	E_{max}(Volts)	E_{min}(Volts)	m	%m(mx100)

Precautions:

1. Check the connections before giving the power supply
2. Observations should be done carefully.

Model wave forms:



Result:

DSB-SC MODULATION AND DEMODULATION

Aim: To generate AM-Double Side Band Suppressed Carrier (DSB-SC) signal.

Apparatus Required:

Name of the Component/Equipment	Specifications /Range	Quantity
IC 1496	Wide Frequency response up to 100MHz Internal power dissipation-500mW(MAX)	1
Resistors	6.8KΩ 10KΩ, 3.9KΩ 1KΩ, 51KΩ	1 2 each 3 each
Capacitors	0.1µF	4
Variable Resistor (Linear Pot)	0-50KΩ	1
CRO	100MHz	1
Function Generator	1MHz	2
Regulated Power Supply	0-30V, 1A	1

Theory:

Balanced modulator is used for generating DSB-SC signal. A balanced modulator consists of two standard amplitude modulators arranged in a balanced configuration so as to suppress the carrier wave. The two modulators are identical except the reversal of sign of the modulating signal applied to them.

Circuit Diagram:

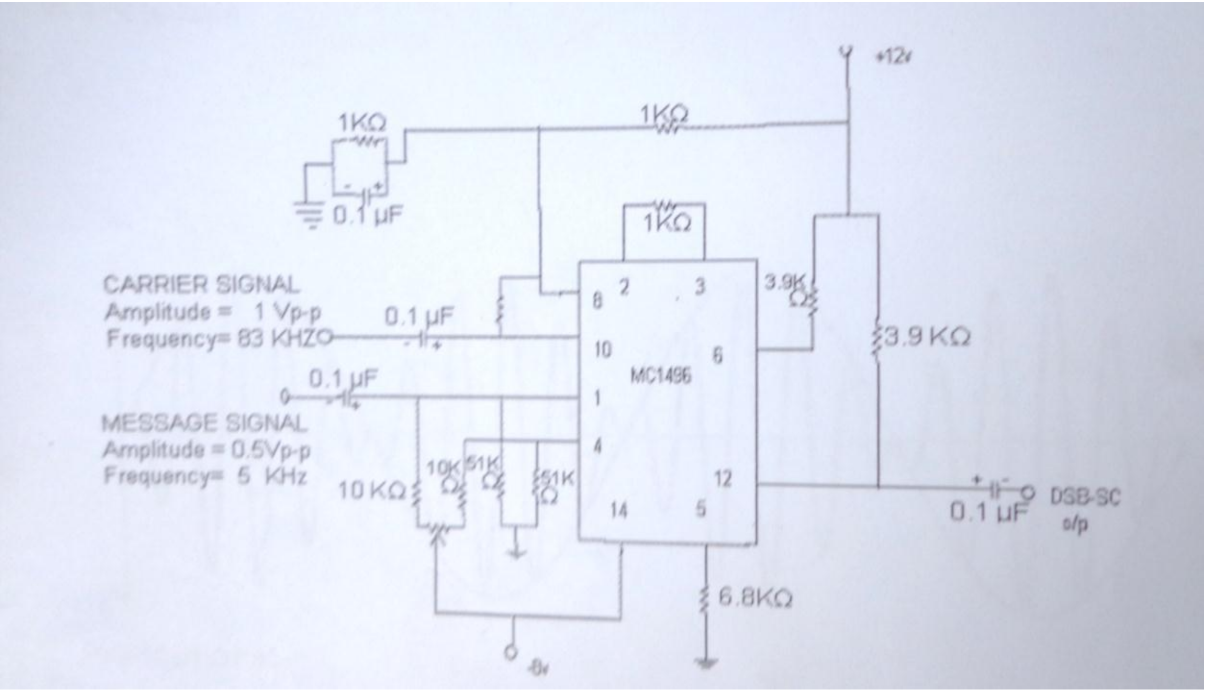


Fig: 1. Balanced Modulator Circuit

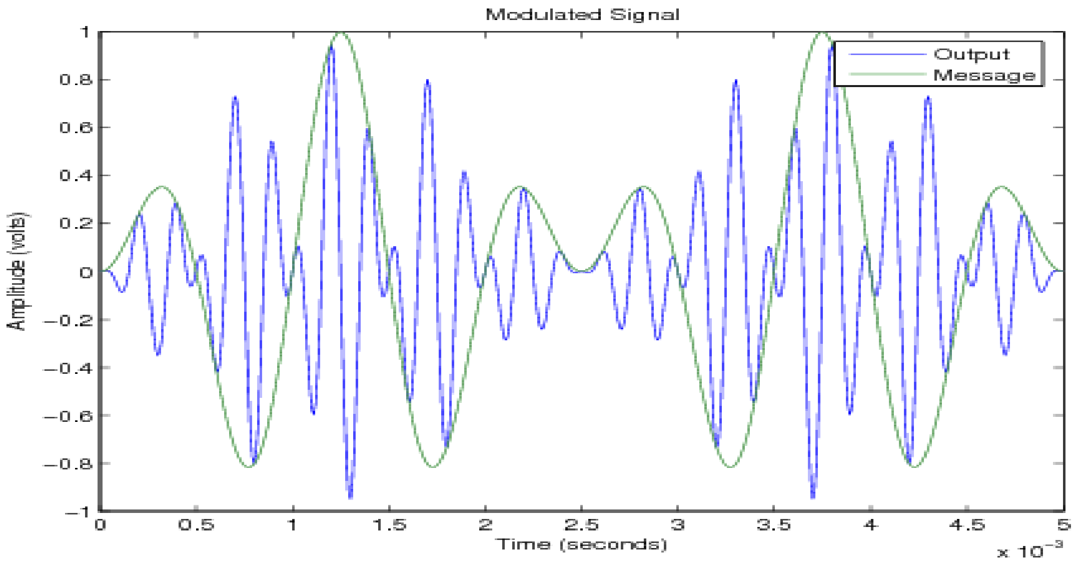
Procedure:

1. Connect the circuit diagram as shown in Fig.1.
2. An Carrier signal of 1 V_{p-p} amplitude and frequency of 83 KHz is applied as carrier to pin no.10
3. An AF signal of 0.5 V_{p-p} amplitude and frequency of 5KHz is given as message signal to pin no.1
4. Observe the DSB-SC waveform at pin no.12.

Sample Readings:

Signal	Amplitude (Volts)	Frequency(HZ)
Message Signal	0.5V	5KHz
Carrier Signal	1V	83.3KHz
DSB-SC Signal	1.92 V_{p-p}	-----------

Wave Forms:



Precautions:

1. Check the connections before giving the supply
2. Observations should be done carefully.

Observe:

Phase reversal in DSB-SC Signal is occurring at the zero crossing of modulating signal.

Result:

FREQUENCY MODULATION AND DEMODULATION

Aim: 1.To generate frequency modulated signal and determine the modulation index and bandwidth for various values of amplitude and frequency of modulating signal, 2. To demodulate a Frequency Modulated signal using FM detector.

Apparatus required:

Name of the Component/ Equipment	Specifications/Range	Quantity
IC 566	Operating Voltage- Max-24 Volts Operating current- Max 12.5 mA	1
IC 8038	Power dissipation – 750 mW Supply voltage-±18V or 36V total	1
IC 565	Power dissipation- 1400mW Supply voltage - ±12V	1
Resistors	15KΩ, 10KΩ, 1.8KΩ, 39KΩ, 560Ω	1,2,1 2,2
Capacitors	470pF, 0.1μF, 100pF, 0.001μF	2,1 1,1 each
CRO	100MHz	1
Function generator	1MHz	2
Regulated Power Supply	0-30V, 1A	1

Theory:

The process, in which the frequency of the carrier is varied in accordance with the instantaneous amplitude of the; modulating signal, is called 'Frequency Modulation'. The FM signal is expressed as: $S(t) = A_c \cos(2\pi f_c t + \beta \sin(2\pi f_m t))$ Where A_c is amplitude the carrier signal, f_c is the carrier frequency f_m is the modulation index of the FM wave.

Procedure: Modulation:

1. The circuit is connected as per the circuit diagram shown in Fig.2 (Fig.1 For IC 566)
2. Without giving modulating signal observe the carrier signal at pin no.2 (at pin no.3 for IC 566). Measure amplitude and frequency of the carrier signal. To obtain carrier signal of desired frequency, find value of R from f=1/ (2πRC) taking C=100pF.
3. Apply the sinusoidal modulating signal of frequency 4 KHz and amplitude $3V_{p-p}$ at pin no. 7. (pin no. 5 for IC566)
   Now slowly increase the amplitude of modulating signal and measure f_{min} and maximum frequency deviation Δf at each step. Evaluate the modulating index (m_f=β) using $\Delta f/f_m$ where $\Delta f=|f_c - f_{min}|$. Calculate Band width. $BW=2(\beta+1)\ f_m=2(\Delta f+ f_m)$
4. Repeat step 4 by varying frequency of the modulating signal.

Demodulation:

1. Connections are made as per circuit diagram shown in Fig.3.
2. Check the functioning of PLL (IC 565) by giving square wave to input and observing the output.
3. Frequency of input signal is varied till input and output are locked.

4. Now modulated signal is fed as input and observe the demodulated signal (output) on CRO.
5. Draw the demodulated wave form.

Circuit Diagram:

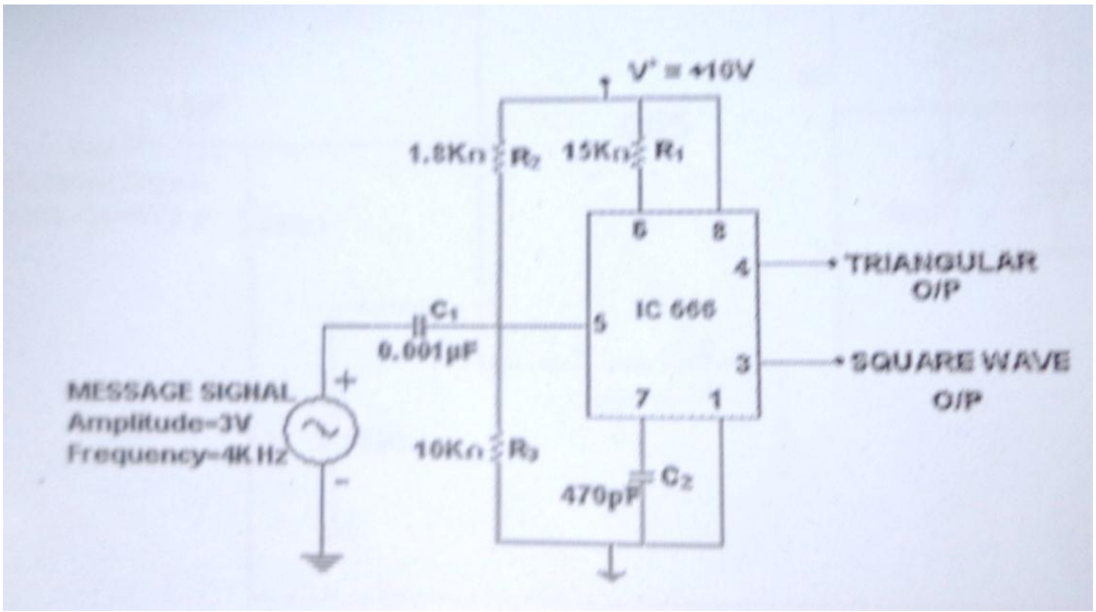


Fig: 1. FM Modulator Using IC 566

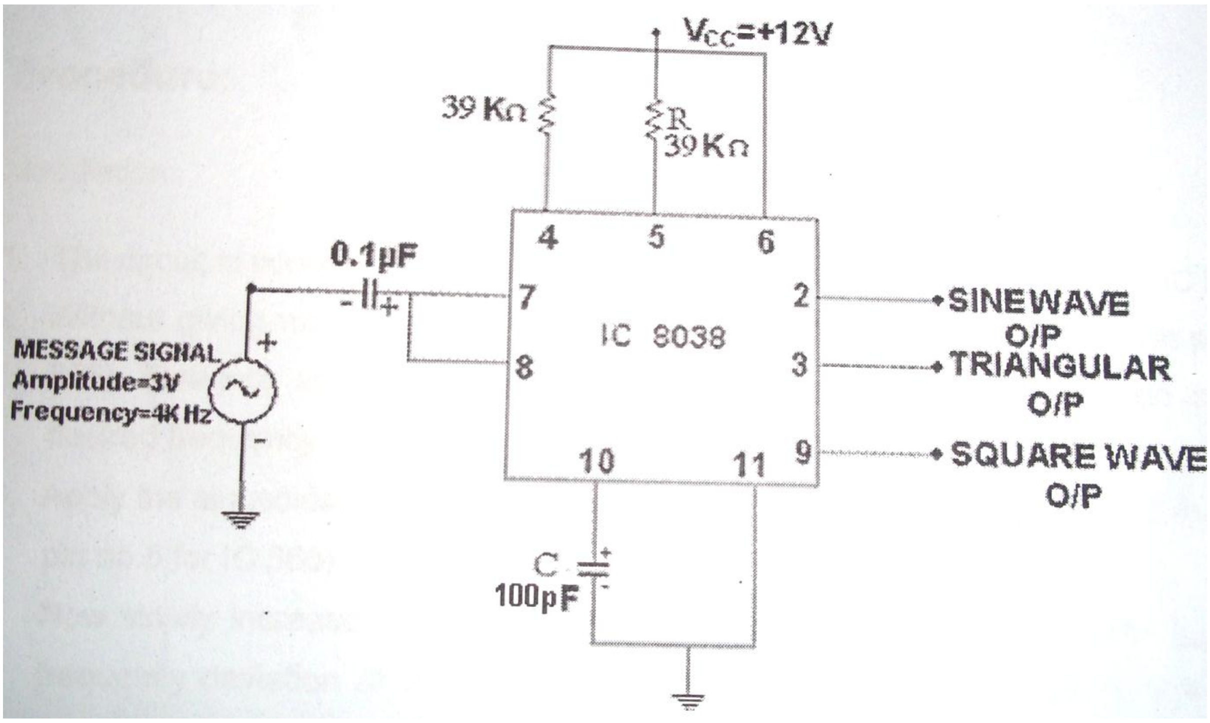


Fig: 2. FM Modulator Circuit using 8038

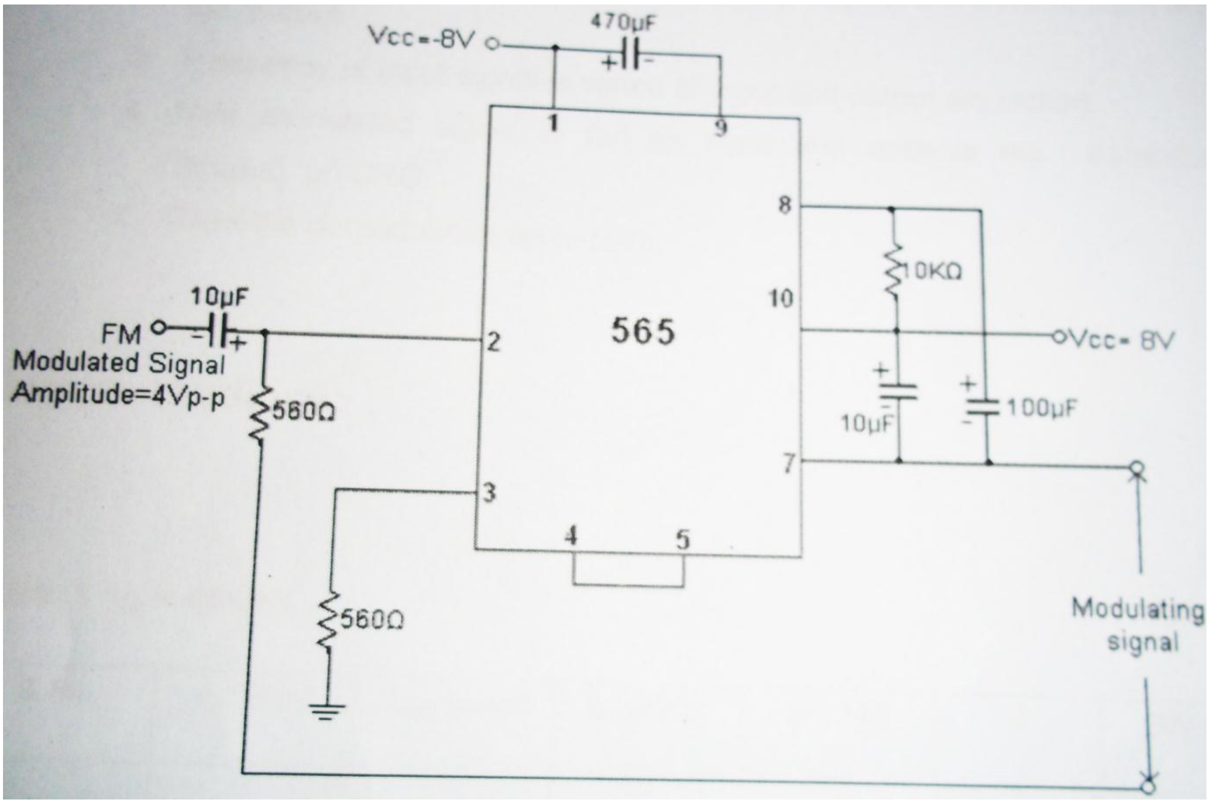


Fig: 3. FM Demodulator Circuit

Sample Readings:

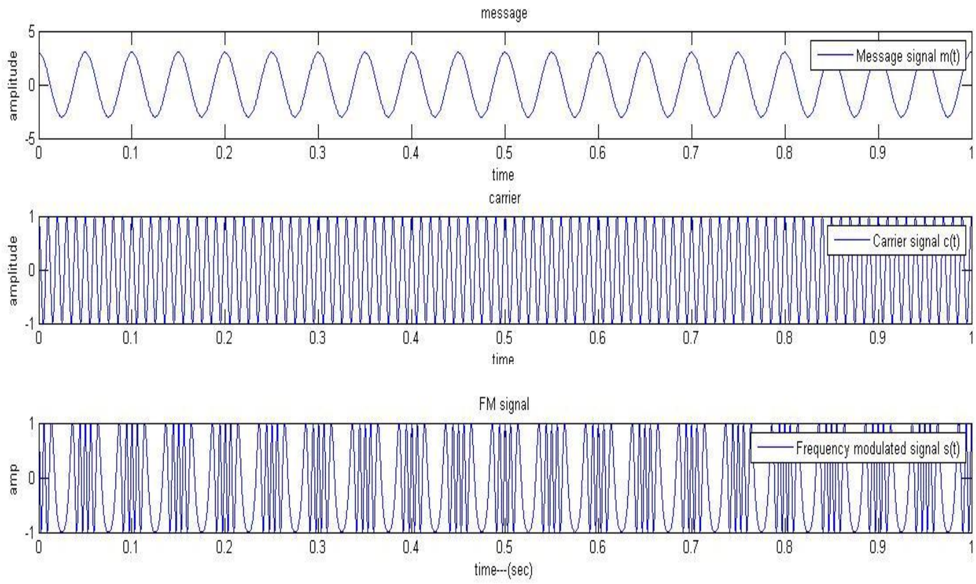
Table: 1 F_c=45 KHz

S.NO.	f_m (KHz)	T_{max}(µsec)	f_{min} (KHZ)	Δf (KHz)	β	BW(KHz)

Table: 2 f_m=4 KHz, f_c=45 KHz

S.NO.	A_m (Volts)	T(µsec)	f_{min} (KHz)	Δf (KHz)	β	BW(KHz)

Wave Forms:



Precautions:

1. Check the connections before giving the power supply.
2. Observations should be done carefully.

Result:

PRE-EMPHASIS & DE-EMPHASIS

Aim: 1. To Observe the effects of pre-emphasis on given input signal.
2. To observe the effects of De-emphasis on given input signal.

Apparatus Required:

Name of the Component/Equipment	Specifications/Range	Quantity
Transistor(BC107)	f_t =300MHz P_d=1W I_c (max)=100mA	1
Resistors	10KΩ, 7.5KΩ, 6.8KΩ	1 each
Capacitors	10nF,0.1µF	1, 2
CRO	20MHz	1
Function Generator	1Mhz	1
Regulated Power Supply	0-30V, 1A	1

Theory:

The noise has a effect on the higher modulating frequencies than on the lower ones. Thus, if the higher frequencies where artificially boosted at the transmitter and correspondingly cut at the receiver, an improvement in noise immunity could be expected, thereby increasing the SNR ratio. This boosting of the higher modulating frequencies at the transmitted is known as pre-emphasis and the compensation at the receiver is called de-emphasis.

Circuit Diagrams:

For Pre-emphasis:

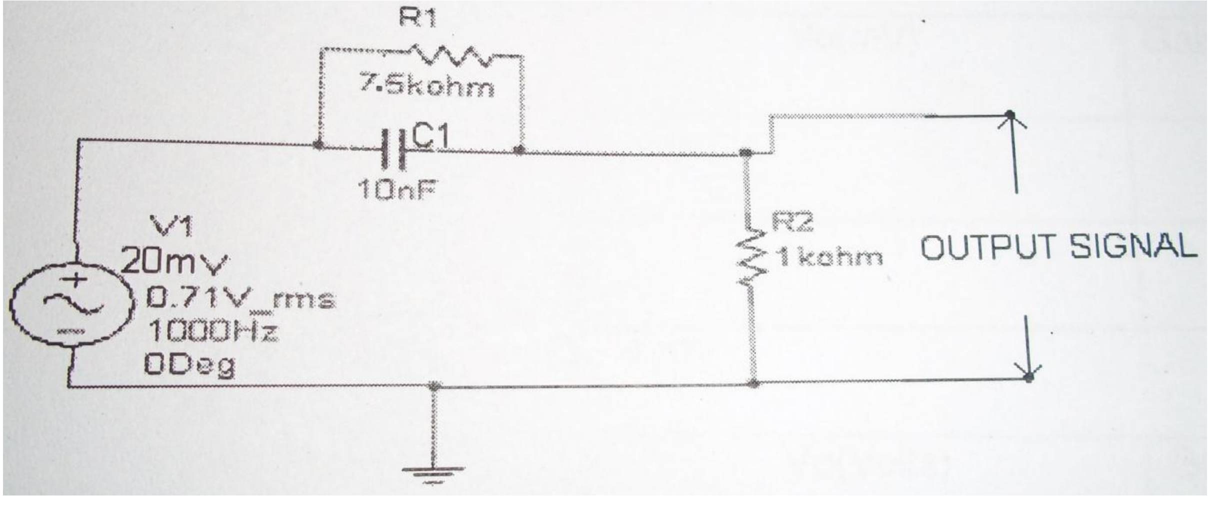


Fig: 1. Pre-emphasis circuit

For De-emphasis:

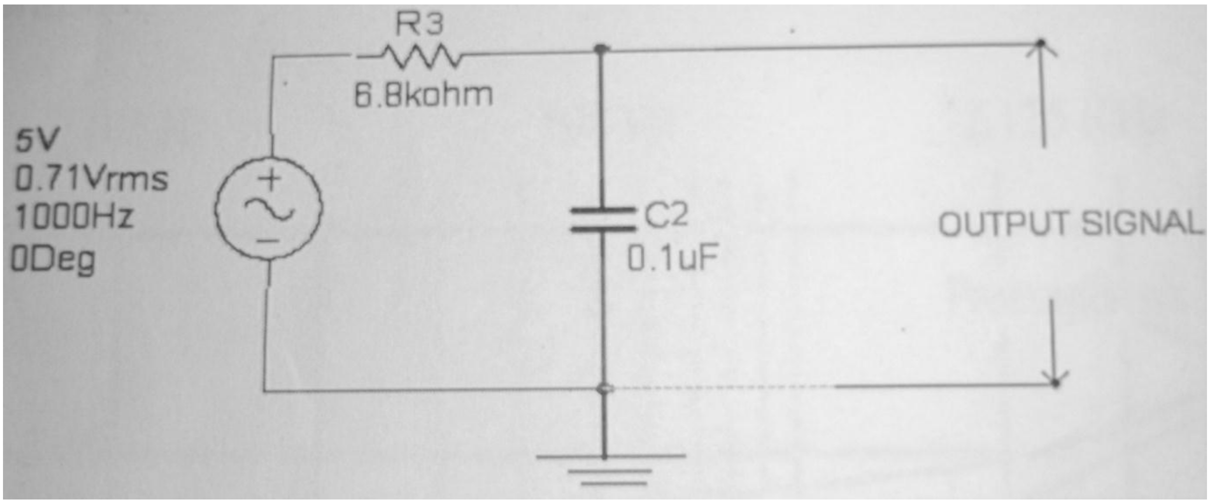


Fig: 2. De-emphasis Circuit

Procedure:

1. Connect the circuit as per circuit diagram as shown in Fig.1.
2. Apply the sinusoidal signal of amplitude 20mV as input signal to pre emphasis circuit.
3. Then bty increasing the input signal frequency from 500Hz to 20KHz, observe the output voltage (V_o) and calculate gain ($20\log(V_o/V_i)$).
4. Plot the graph between gain Vs frequency.
5. Repeat above steps 2 to 4 for de-emphasis circuit (shown in Fig: 2.) by applying the sinusoidal signal of 5V as input signal.

Sample Readings:

Table: 1: **Pre-emphasis**

V_i=20mV

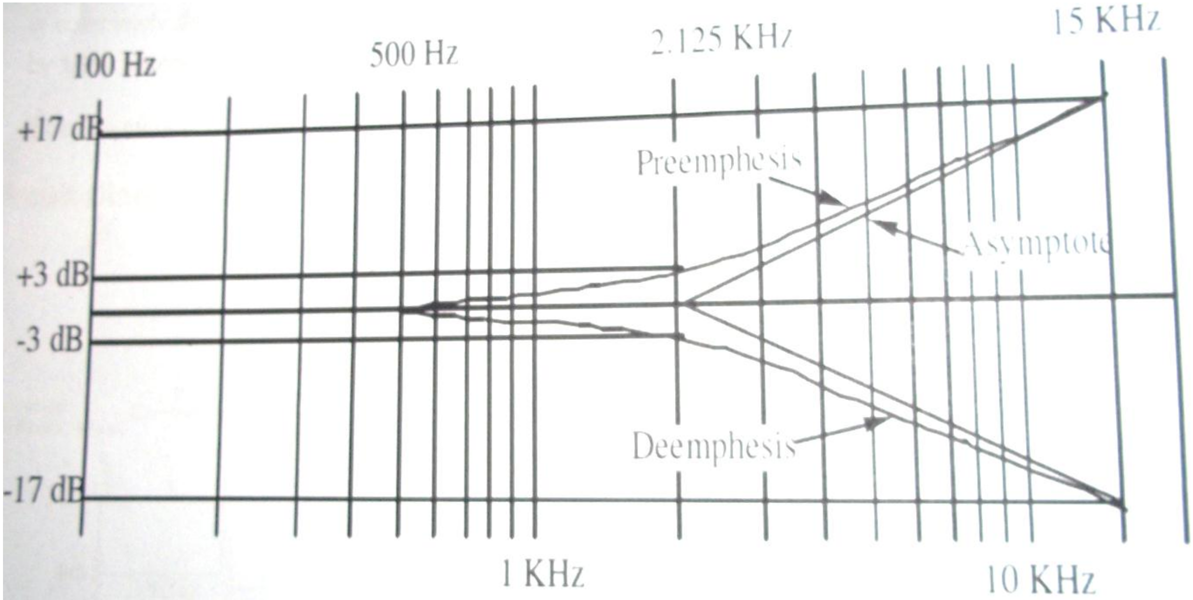
Frequency (KHz)	V_o (mV)	Gain in dB($20\log(V_o/V_i)$)

Table: 2: **De-emphasis**

V_i=5V

Frequency (KHz)	V_o (Volts)	Gain in dB($20\log(V_o/V_i)$)

Graphs:



Precautions:

1. Check the connections before giving the power supply.
2. Observations should be done carefully.

Result:

SAMPLING THEOREM VERIFICATION

Aim: To verify the sampling theorem.

Apparatus:

1. Sampling theorem verification trainer kit

2. Function Generator (1MHz)

3. Dual Trace Oscilloscope (20MHz)

Theory:

The analog signal can be converted to a discrete time signal by a process called sampling. The sampling theorem for a band lilmited signal of finite energy can be stated as, "A band limited signal of finite energy, which has no frequency component higher than W Hz is completely described by specifying the valules of the signal at instants of time separated by 1/2W seconds."

It can be recovered from knowledge of samples taken at the rate of 2W per second.

Circuit Diagram:

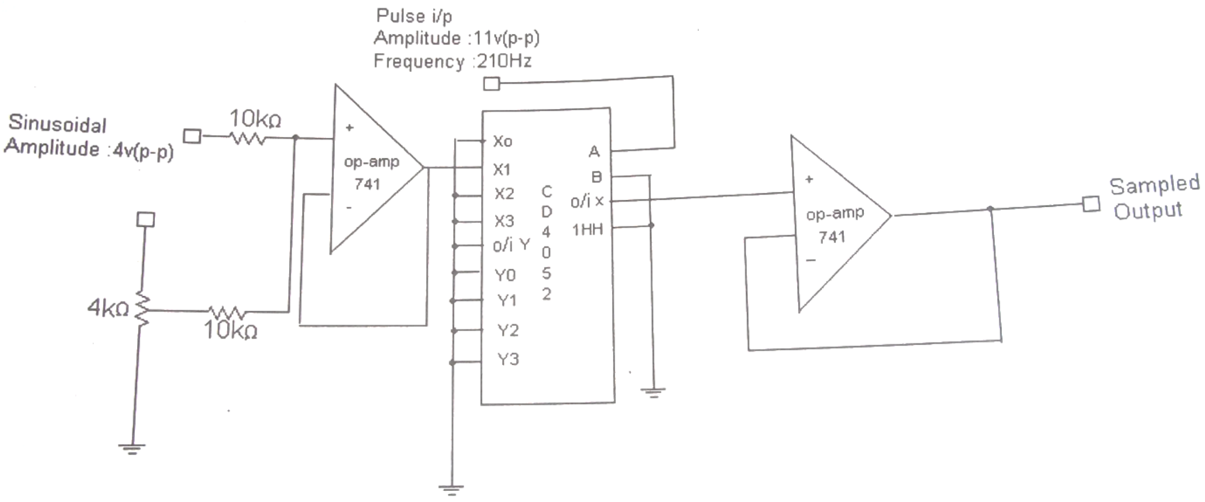


Fig: 1 Sampling Circuit

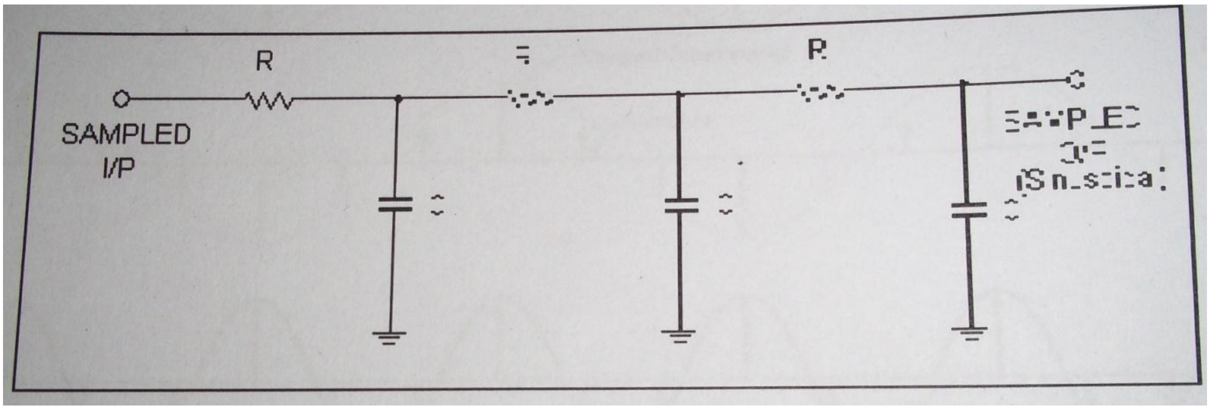
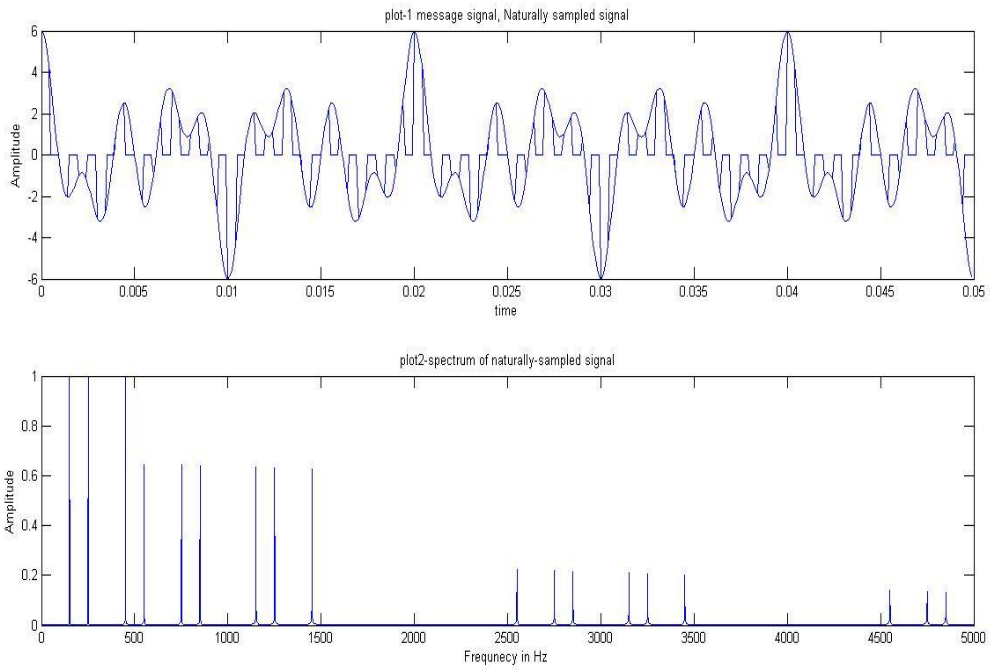


Fig: 2 Reconstructing Circuit

Procedure:

1. The circuit is connected as per the circuit diagram shown in the fig1.
2. Switch on the power supply and set at +11V and -11V.
3. Apply the sinusoidal signal of approximately 4V (p-p) at 105Hz frequency and pulse signal of 11V(p-p) with frequency between 100Hz and 4KHz.
4. Connect the sampling circuit output and AF signal to the two inputs of oscilloscope.
5. Initially set the potentiometer to minimum level andsampling frequency to 200Hz and observe the output on the CRO. Now by adjusting the potentiometer, vary the amplitude of modulating signal and observe the output of smplling circuit. Note thet the amplitude of the sampling pulses will be varying in accordance with the amplitude of the modulating signal.
6. Design the reconstructing circit. Depending on sampling frequency, R & C values are calculated using the relations $F_s = 1/T_s$, T_s=RC. Choosing an appropriate value for C, R can be found using the relation R= T_s/C.
7. Connect the sampling circuit output to the reconstructing circuit shown in Fig:2.
8. Observe the output of the reconstructing circuit (AF signal) for different sampling frequencies. The original AF signal would appear only when the sampling frequency is 200Hz or more.

Model Wave forms:



Result:

PULSE AMPLITUDE MODULATION & DEMODULATION

Aim: To generate the Pulse Amplitude modulated and demodulated signals.

Apparatus required:

Name of the Apparatus	Specifications/Range	Quantity
Resistors	1KΩ, 10KΩ, 100KΩ, 5.8KΩ, 2.2KΩ	Each one
Transistor	BC107	2
Capacitor	10µF, 0.001µF	Each one
CRO	30MHz	1
Function Generator	1MHz	1
Regulated Power Supply	0-30V, 1A	1
CRO Probes	--	1

Theory:

PAM is the simplest form of data modulation. The amplitude of uniformly spaced pulses is varied in proportion to the corresponding sample values of a continuous message m (t).

A PAM waveform consists of a sequence of flat-topped pulses. The amplitude of each pulse corresponds to the value of the message signal x (t) at the leading edge of the pulse.

The pulse amplitude modulation is the process in which the amplitudes of regularity spaced rectangular pulses vary with the instantaneous sample values of a continuous message signal in a one-one fashion. A Pam wave is represented mathematically as,

$$S(t) = \sum[1 + k_a x(nT_s)]P(1 - nT_s)$$

Where

x (nT_s)➔represent the n^{th} sample of the message signal x(t)

K➔is the sampling period.

K_a ➔a constant called amplitude sensitivity

P (t)➔denotes a pulse

PAM is of two types: 1. Double polarity PAM ➔ this is the PAM wave of only either negative (or) Positive pulses. In this the fixed dc level is added to the signal to ensure single polarity signal. It is represented as

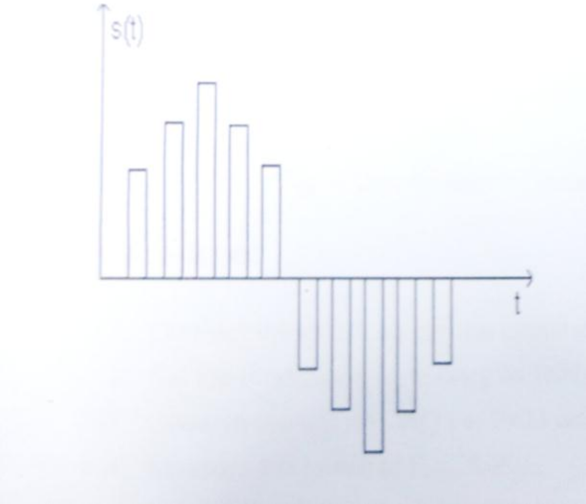


Fig: 1 Bipolar PAM signal

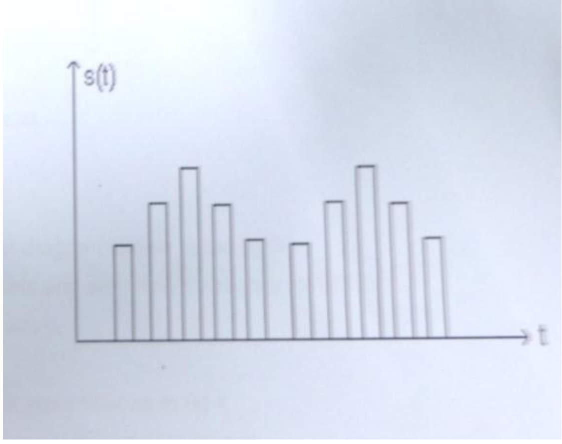


Fig: 2.Single Polarity PAM

Circuit Diagram:

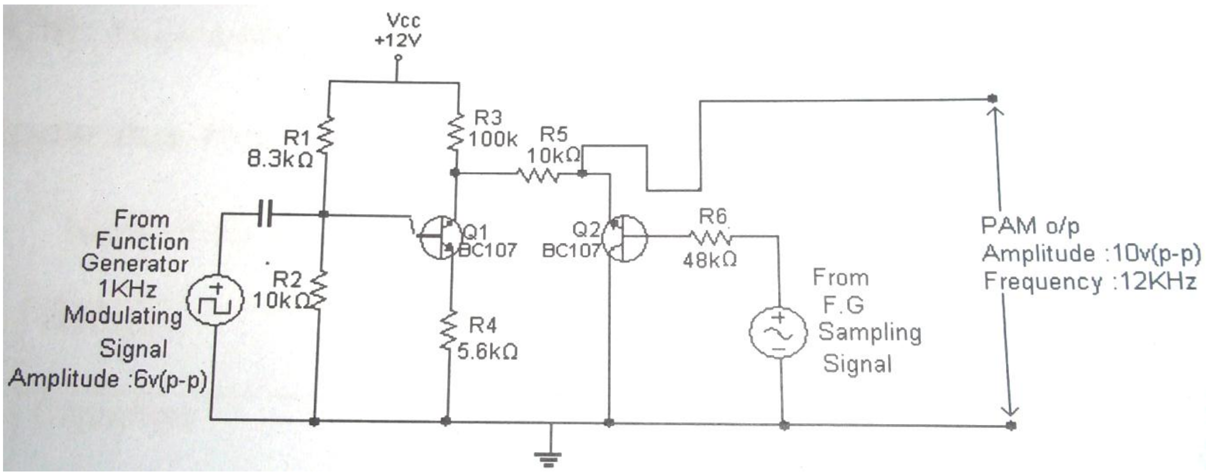


Fig: 3. Pulse Amplitude Modulation Circuit

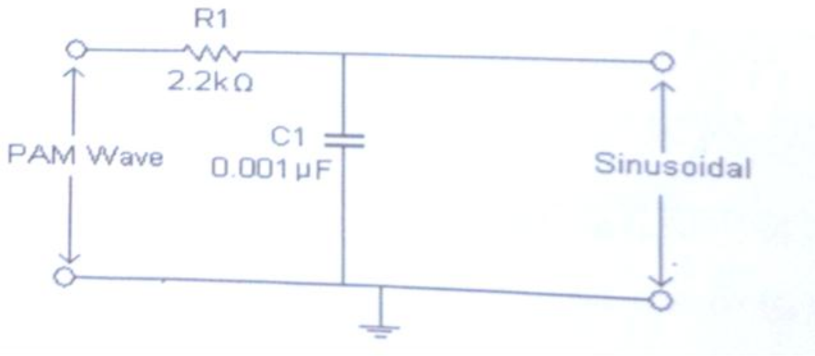


Fig: 4. Demodulation Circuit

Procedure:

1. Connect the circuit as per the circuit diagram shown in the fig 3
2. Set the modulating frequency to 1KHz and sampling frequency to 12KHz.
3. Observe the o/p on CRO i.e. PAM wave.
4. Measure the levels of E_{max} & E_{min}
5. Feed the modulated wave to the low pass filter as in fig 4.
6. The output observed on CRO will be the demodulated wave.
7. Note down the amplitude (p-p) and time period of the demodulated wave. Vary the amplitude and frequency of modulating signal. Observe and note down the changes in output.
8. Plot the wave forms on graph sheet.

Result:

PULSE WIDTH MODULATION AND DEMODULATION

Aim: To generate the pulse width modulated and demodulated signals.

Apparatus required:

Name of the Apparatus	Specifications/Range	Quantity
Resistors	1.2KΩ, 1.5KΩ, 8.2KΩ	1,1,2
Capacitors	0.01μF, 1μF	2,2
Diode	0A79	1
CRO	0-30MHz	1
Function Generator	1MHz	1
RPS	0-30V, 1A	1
IC555	Operating temperature: SE555-55ºC to 125ºC NE 555 0º to 70ºC Supply Voltage : +5V to +18V Timing : μsec to Hours Sink current: 200mA Temperature stability: 50 PPM/ºC Change in temp or 0-005%/ºC	1
CRO Probes	--	1

Theory:

Pulse Time Modulation is also known as Pulse Width Modulation or Pulse Length Modulation. In PWM, the samples of the message signal are used to vary the duration of the individual pulses. Width may be varied by varying the time of occurrence of leading edge, the trailing edge or both edges of the pulse in accordance with modulating wave. It is also called pulse Duration Modulation.

Circuit Diagram:

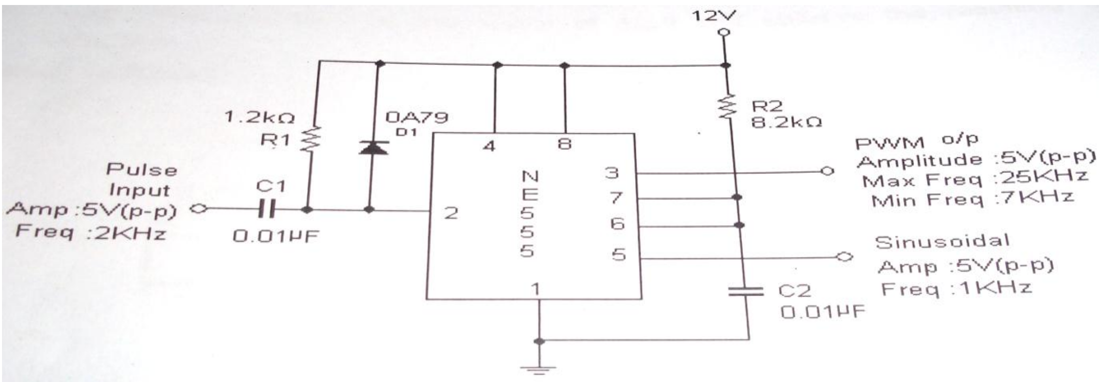


Fig: 1 Pulse Width Modulation Circuit

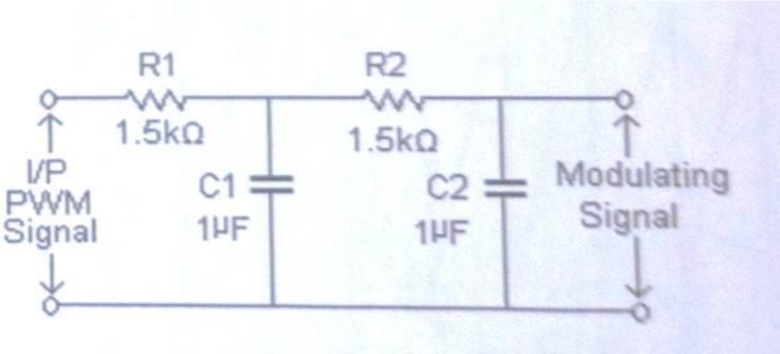


Fig: 2 Demodulation Circuit

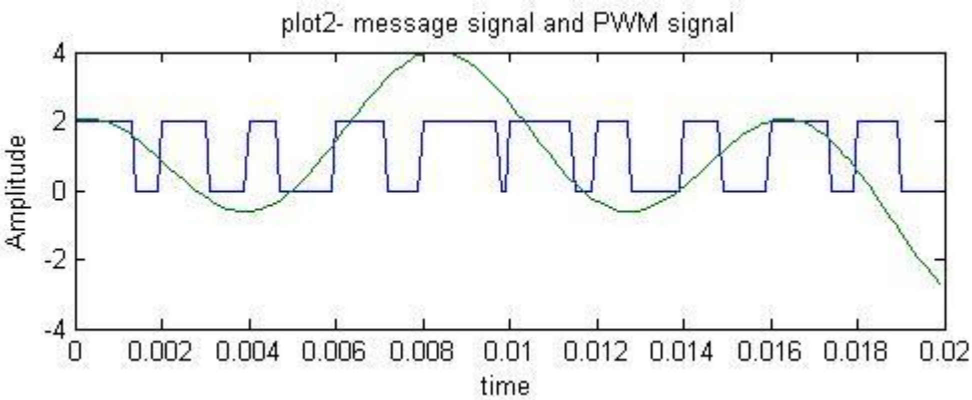
Procedure:

1. Connect the circuit as per circuit diagram shown in fig 1.
2. Apply a trigger signal (Pulse wave) of frequency 2 KHz with amplitude of 5V (p-p).
3. Observe the sample signal at the pin3.
4. Apply the ac signal at the pin 5 and vary the amplitude.
5. Note that as the control voltage is varied output pulse width is also varied.
6. Observe that the pulse width increases during positive slope condition & decreases under negative slope condition. Pulse width will be maximum at the +ve peak and minimum at the –ve peak of sinusoidal waveform. Record the observations.
7. Feed PWM waveform to the circuit of Fig: 2 and observe the resulting demodulated waveform.

Observations:

S.NO.	Control Voltage(V_{p-p})	Output pulse width (msec)

Wave forms:



Result:

PULSE POSITION MODULATION & DEMODULATION

Aim: To generate pulse position modulation and demodulation signals and to study the effect of amplitude of the modulating signal on output.

Apparatus required:

Name of the apparatus	Specifications/Range	Quantity
Resistors	3.9KΩ, 3KΩ, 10KΩ, 680KΩ	Each one
Capacitors	0.01µF, 60µF	2,1
Function Generator	1MHz	1
RPS	0-30V, 1A	1
CRO	0-30MHz	1
IC555	Operating temperature: SE 555 0^o to 70^oC Supply Voltage : +5V to +18V Timing : µSec to Hours Sink Current : 200mA Temperature stability : 50ppm/^oC Change in temperature or 0-005%/^oC.	1
CRO Probes	--	1

Theory:

In Pulse Position Modulation, both the pulse amplitude and pulse duration are held constant but the position of the pulse is varied in proportional to the sampled values of the message signal. Pulse time modulation is a class of signaling techniques that encodes the sample values of an analog signal on to the time axis of a digital signal and it is analogous to angle modulation techniques. The two main types of PTM are PWM and PPM. In PPM the analog sample value determines the position of a narrow pulse relative to the clocking time. In PPM rise time of pulse decides the channel bandwidth. It has low noise interference.

Procedure:

1. Connect the circuit s per circuit diagram as shown in the fig 1.
2. Observe the sample output at pin 3 and observe the position of the pulses on CRO and adjust the amplitude by slightly increasing the power supply. Also observe the frequency of pulse output.
3. Apply the modulating signal, sinusoidal signal of 2 $V_{(p-p)}$ (ac signal) 2V (p-p) to the control pin 5 using function generator.
4. Now by varying the amplitude of the modulating signal, note down the position of the pulses.
5. During the demodulation process, give the PPM signal as input to the demodulated circuit as shown in Fig: 2.
6. Observe the O/P on CRO.
7. Plot the waveform.

Circuit Diagram:

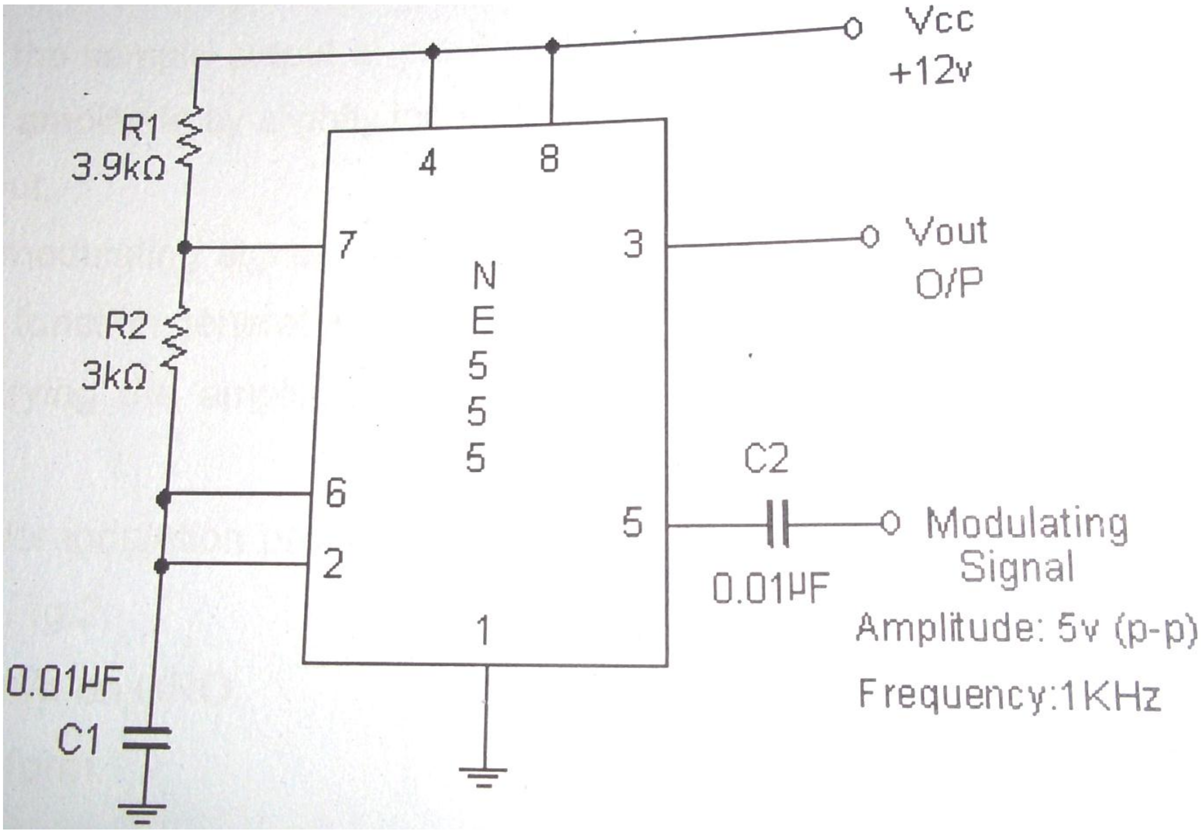


Fig: 1 Pulse Position Modulation Circuit

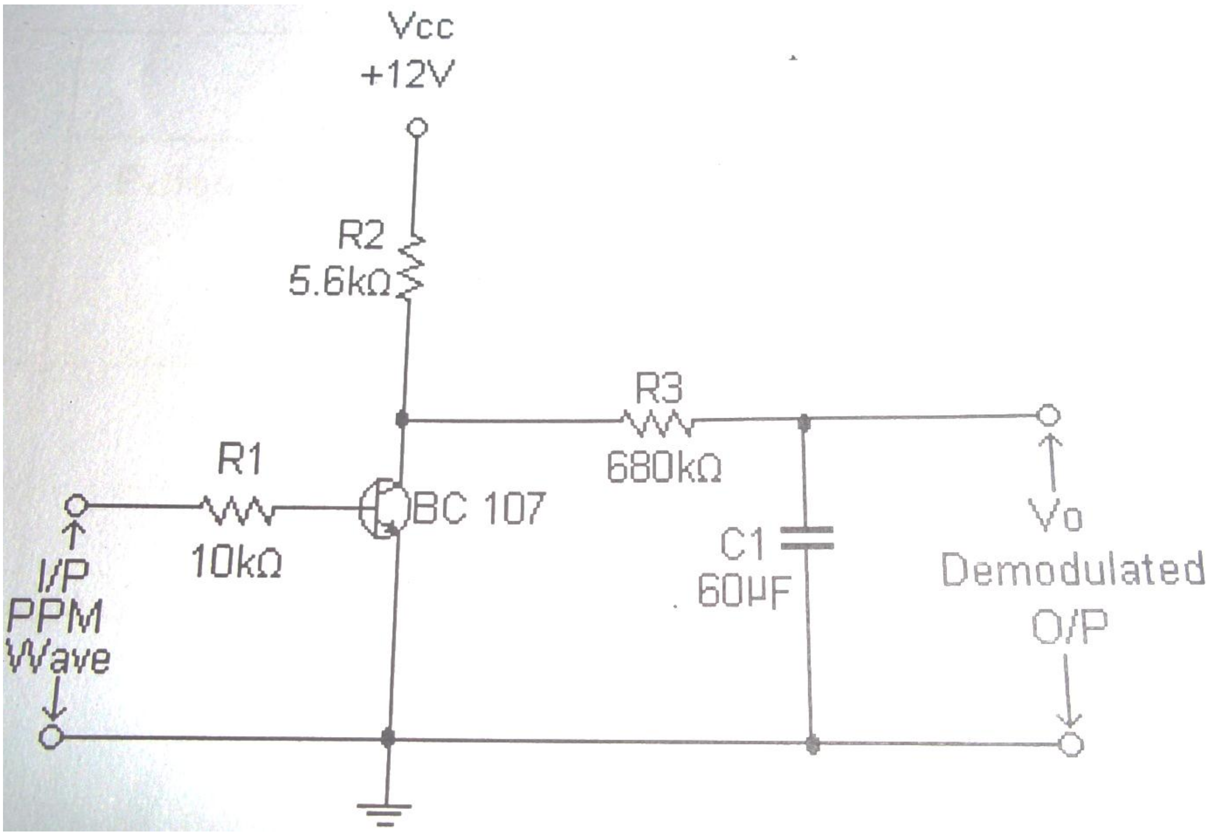


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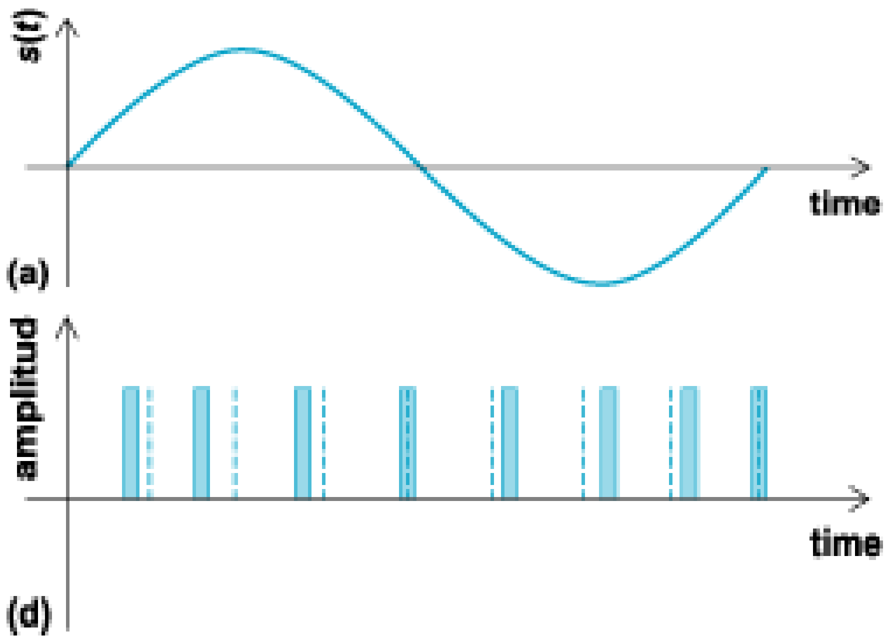
Fig: 2 Demodulation Circuit

Observations:

Modulating signal Amplitude $V_{(p-p)}$	Time Period(ms)		Total Time Period (ms)
	Pulse width ON (ms)	Pulse width OFF (ms)	

Wave Forms:



Result:

SSB MODULATION AND DEMODULATION

Aim: To generate the SSB modulated wave.

Apparatus Required:

Name of the Component/Equipment	Specifications	Quantity
SSB System trainer board	--	1
CRO	30MHz	1

Theory:

An SSB signal is produced by passing the DSB signal through a highly selective band pass filter. This filter selects either the upper or the lower sideband. Hence transmission bandwidth can be cut by half if one sideband is entirely suppressed. This leads to single sideband modulation (SSB). In SSB modulation bandwidth saving is accompanied by a considerable increase in equipment complexity.

Circuit Diagram:

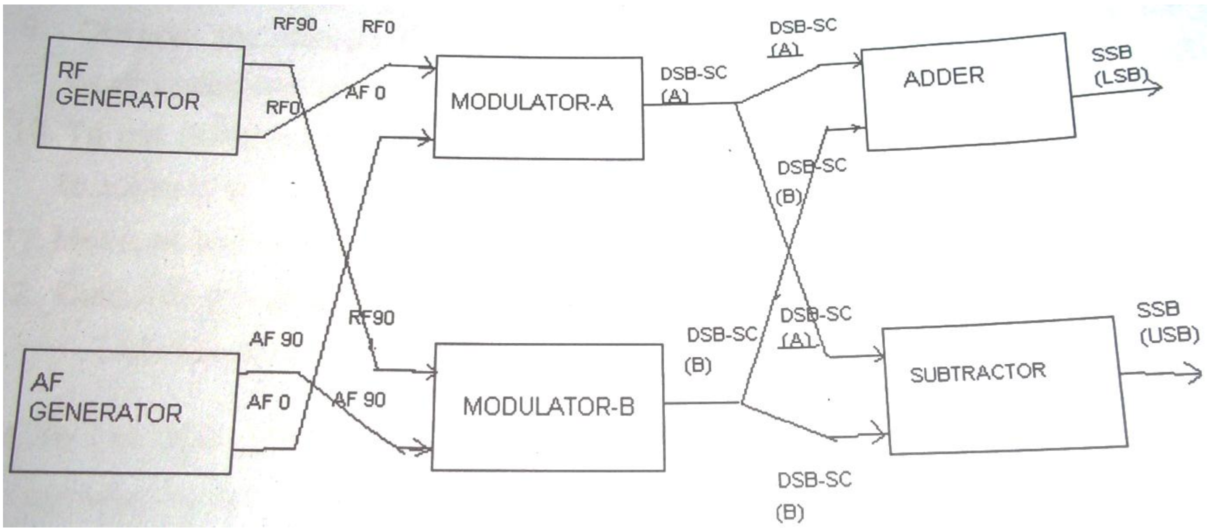


Fig: 1 Single Side Band System

Procedure:

1. Switch ON the trainer and measure the output of the regulated power supply i.e. $\pm$12V and 8V
2. Observe the output of the RF generator using CRO. There are 2 outputs from the RF generator, one is direct output and another is 90° out of phase with the direct output. The output frequency is 100 KHz and the amplitude is $\geq$ 0.2V_{pp}. (Potentiometers are provided to vary the output amplitude).
3. Observe the output of the AF generator, using CRO. There are 2 outputs from the AF generator, one is direct output and another is 90° out of phase with the direct output. A switch is provided to select the required frequency (2 KHz, 4 KHz or 6 KHz). AGC potentiometer is provided to adjust the gain of the oscillator (or to set the output to

good shape). The oscillator output has amplitude 10V_{pp}. This amplitude can be varied suing the potentiometers provided.

4. Measure and record the RF signal frequency using frequency counter. (Or CRO).
5. Set the amplitudes of the RF signals to 0.1 V_{pp} and connect direct signal to one balanced modulator and 90° phase shift signal to another balanced modulator.
6. Select the required frequency (2 KHz, 4 KHz or 6 KHz) of the AF generator with the help of switch and adjust the AGC potentiometer until the output amplitude is 10 V_{pp} (when amplitude controls are in maximum condition).
7. Measure and record the AF signal frequency using frequency counter (or CRO).
8. Set the AF signal amplitudes to 8 $V_{p\text{-}p}$ using amplitude control and connect to the balanced modulators.
9. Observe the outputs of both the balanced modulators simultaneously using Dual trace oscilloscope and adjust the balance control until desired output wave forms (DSB-SC).
10. To get SSB lower side band signal, connect balanced modulator output (DSB-SC) signals to Subtractor.
11. Measure and record the SSB signal frequency.
12. Calculate theoretical frequency of SSB (LSB) and compare it with the practical value. LSB frequency = RF frequency – AF frequency
13. To get SSB upper side band signal, connect the output of the balanced modulator to the summer circuit.
14. Measure and record the SSB upper side band signal frequency.
15. Calculate theoretical value of the SSB (USB) frequency and compare it with practical value. USB frequency = RF frequency + AF frequency.

Sample Readings:

Signal	Amplitude (Volts)	Frequency(KHz)
Message signal	2	1
Carrier signal	2	100
SSB (LSB)	0.5	98.54
SSB(USB)	0.42	101.4

Wave forms:

Precautions:

1. Check the connections before giving the power supply
2. Observations should be done careful.

Result:

PHASE LOCKED LOOP

Aim: To measure the phase detection and measurement using phase locked loop and to find out the lock-in-range.

Apparatus:

1. Experimental kit of Phase Locked Loop

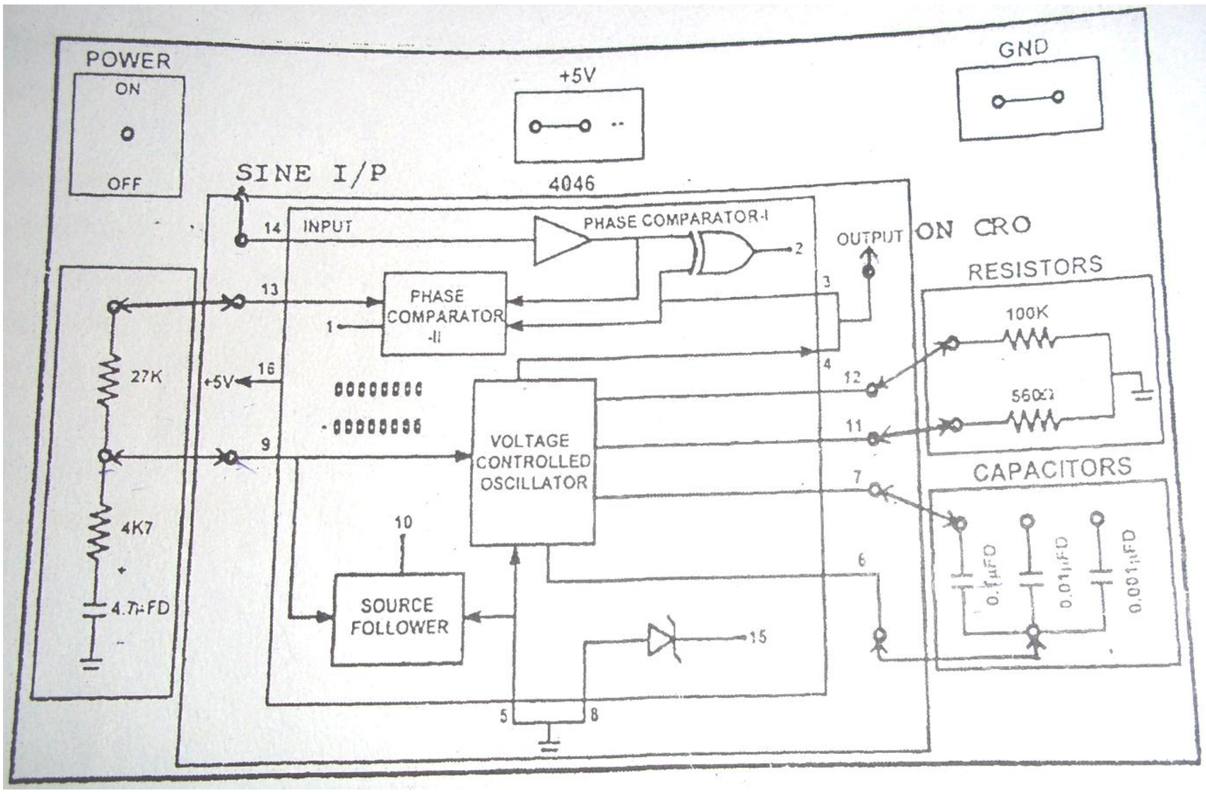
2. 20 MHz Dual Trace Oscilloscope

3. Patch Chords & CRO Probes

Circuit Diagram:

Wiring Diagram

PHASE DETECTION & MEASUREMENT USING PLL



↔ indicates the patching connections

Procedure:

1. Set the Oscilloscope for the following settings: Channel 1-1V/division, Time base: 0.5ms/division
2. Patch the circuit as shown in the wiring diagram and apply power to the trainer. Adjust the output of the oscillator (sine wave) to approximately. 1 KHz, and the peak

to peak voltage to 6 volts (i.e., 6 vertical divisions). Now connect the oscilloscope to pins 3 and 4 of the 4046 device. The output frequency of the phase locked loop should be the same as the input.

3. Set the Oscilloscope time base to 2ms/division. Now, with a piece of wire, connect pin 9 of the 4046 integrated circuit to ground. Record the resultant output frequency of the phase locked loop.
    a. F_L----------------------------------Hz
    b. This output frequency is the lower range of the VCO, which is determined by the 0.1µF capacitor connected between pins 6 and 7, and the 100K ohms resistor connected between pin 12 and ground.
4. Set the Oscilloscope time base to 0.2ms/division. Now with the same wire, connect pin 9 to the +5 volts supply. Observe an output frequency that is higher than the one measured in Step 3. Record this frequency.
    a. F_H=--Hz
    b. This output frequency is upper range of VCO, which determined by the 0.1µF capacitor connected between pins 6 and 7, and the 560 ohms resistor connected between pin 11 and ground.
5. Now remove the connection between pin 9 and the +5 volt supply. Again measure an output frequency that is the same as the frequency of the function generator (approximately 1 KHz).
6. Now slowly increase the frequency of the function generator. Observe that the output frequency also increases. In fact, the output frequency follows the changes of the input frequency to confirm this.
7. While watching the output frequency of the phase locked loop, continue to slowly increase the input frequency and stop when the output frequency does not continue to increase. Measure the input frequency and record the result.
    a. F_{in}(H)=---Hz

    It is find that this frequency is about the same as the frequency which is measured in step 4, the upper range of the VCO. The phase licked loop then follows input frequency changes for frequencies below this upper range.
8. Set the oscilloscope time base to 2ms/division. Now decrease the input frequency while observing the oscilloscope. At some point the output frequency will remain constant. Measure the input frequency and record the result.

    F_{in}(L)=---Hz

    It should find that this frequency is about the same as the frequency which is measured in step 3, the lower range of the VCO. Consequently, the phase locked loop circuit follows changes in the input frequency for any frequency between the lower and upper range of the VCO. Therefore, the loop is locked. The range over which the phase locked loop follows changes in the input frequency is called the lock range.
9. To determine the lock-in-range, subtract the value determined in step 8 from the value in step 7 and record the result.

    Lock-in-range=---Hz

The lock-in-range can be changed by simply changing the value of the capacitor connected to pin 6 and C7. Decreasing the 0.1μF capacitor at pin 6 & 7 to 0.01μF increases the frequency.

Precautions:

1. Do not make any inter connections while power switched ON.
2. Set the function generator frequency in proper range while measuring the higher end and lower end frequencies to find out the lock-in-range correctly.
3. Verify the loose connections before observing the output on CRO.

Result: