QMP 7.1 D/F

Channabasaveshwara Institute of Technology

(Affiliated to VTU, Belagavi & Approved by AICTE, NewDelhi)

(**NAAC Accredited & ISO 9001:2015 Certified Institution)**

NH 206 (B.H. Road), Gubbi, Tumkur – 572 216.Karnataka.

Department of Electronics & Communication Engineering

COMMUNICATION LAB

18ECL67

B.E - VI Semester

Lab Manual 2022-23

Name:____

USN:____

Batch:______________________Section:_______________

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Department of Electronics and Communication Engineering

Communication Lab

March2023

Preparedby:

SANJEEVAKUMAR HARIHAR
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Reviewed by:

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Professor & Head,
Dept. of ECE

VISION OF THE INSTITUTE

"To create centres of excellence in education and to serve the society by enhancing the quality of life through value based professional leadership"

MISSION STATEMENT OF THE INSTITUTE

- **To provide high quality technical and professionally relevant education in a diverse learningenvironment.**
- **To provide the values that prepare students to lead their lives with personal integrity, professional ethics and civic responsibility in a globalsociety.**
- **To prepare the next generation of skilled professionals to successfully compete in the diverse globalmarket.**
- **To promote a campus environment that welcomes and honors women and men of all races, creeds and cultures, values and intellectual curiosity, pursuit of knowledge and academic integrity andfreedom.**
- **To offer a wide variety of off-campus education and training programmes to individuals andgroups.**
- **To stimulate collaborative efforts with industry, universities, government and professionalsocieties.**
- **Tofacilitatepublicunderstandingoftechnicalissuesandachieveexcellencein the operations of the institute.**

QUALITY POLICY OF THE INSTITUTE

Our organization delights customers (students, parents and society) by providing value added quality education to meet the national and international requirements. We also provide necessary steps to train the students for placement and continue to improve our methods of education to the students through effectivequality management system, quality policy and quality objectives.

VISION OF THE DEPARTMENT

"To create globally competent Electronics and Communication Engineering professionals with ethical and moral values for the betterment of the society"

MISSION OF THE DEPARTMENT

- **To impart quality technical education in the field of electronics andcommunication engineering to meet over the current/future global industryrequirements.**
- **To create the centres of excellence in the field of electronics and communication in collaboration with industry anduniversities**
- **To nurture the technical/professional/engineering and entrepreneurial skillsfor overall self and societalupliftment**
- **To orient the student community towards the higher education, research and developmentactivities**
- **To provide a platform for equipping the students with necessary skills through co-curricular and extra-curricularevents.**
- **To have Industrial collaboration for strengthening the Teaching-Learning Process/Academics**
- **To associate with industries for training the faculty on the latest technologies through continuous educationprogrammes.**

PROGRAM EDUCATIONAL OBJECTIVES

PEO1 : Provide technical solutions to real world problems in the areas of electronics and communication by developing suitable systems.

PEO2 : Pursue engineering career in Industry and/or pursue higher education an Research.

PEO3 : Acquire and follow best professional and ethical practices in Industry and Society.

PEO4 : Communicate effectively and have the ability to work in team and to lead the Team

PROGRAM SPECIFIC OBJECTIVES

PSO1: Specify, design, build and test analog and digital systems for signal processing including multimedia applications, using suitable components or simulation tools.

PSO2: Understand and architect wired and wireless analog and digital communication systems as per specifications and determine their performance.

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DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

SYLLABUS

Communication LAB

Subject Code: 18ECL67	IA Marks: 40
No. of Practical Hrs/Week: 02(Tutorial)+02(Laboratory)	Exam Hours: 03
Total no. of Practical Hrs.: 42	Exam Marks: 60

PART-A: Following Experiments No. 1 to 5 has to be performed using discrete components.

1. Amplitude Modulation and Demodulation: 1)standard AM, 2)DSBSC (LM741 and LF398 ICs can be used)
2. Frequency Modulation and Demodulation (IC 8038/2206 can beused)
3. Pulse sampling, Flat top sampling and reconstruction.
4. Time Division Multiplexing and Demultiplexing of twobandlimited signals.
5. FSK and PSK generation anddetection.
6. Measurement of frequency, guide wavelength, power, VSWRand attenuation in microwave testbench.
7. Measurement of directivity and gain of microstrip dipole andYagi antennas.
8. Determinationof
   a. Coupling and isolation characteristics of microstripdirectional coupler.
   b. Resonance characteristics of microstrip ring resonatorand computation of dielectric constant of thesubstrate.
   c. Power division and isolation of microstrip powerdivider.

PART-B: Simulation Experiments using SCILAB/MATLAB/Simulink or LabView

9. Simulate NRZ, RZ, half-sinusoid and raised cosine pulses and generate eye diagram for binary polarsignaling.
10. SimulatethePulsecodemodulationanddemodulationsystemand display thewaveforms.
11. Computation of the Probability of bit error for coherent binary ASKS,FSK and PSK for an AWGN channel and compare them with their performance curves.
12. Simulate Digital modulation schemes 1) DPSK transmitter and receiver 2)DPSK transmitter and receiver .Plot the signals andits constellationdiagram.

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Department of Electronics and Communication Engineering

Communication Lab Course Objective's and CourseOutcome's

OBJECTIVES

The main objectives of this lab are,

- Design and demonstrate the Analog modulationtechniques
- Design and demonstrate the digital modulationtechniques
- Demonstrate and measure the wave propagation in microstrip antennas Characteristics of microstrip devices and measurement of its parameters
- Model an optical communication system and study itscharacteristics
- Simulate the digital communication concepts and compute and displayvarious parameters along withplots/figures

OUTCOMES

After completing this course the student could be able to,

- ✓ Design and test the analog modulation and digital modulation circuits/systems and display the waveforms.
- ✓ Determine the characteristics and response of microwave devices andoptical waveguide.
- ✓ Determine the characteristics of microstripantennas and devices and compute the parameters associated withit.
- ✓ Simulate the digital modulation schemes with the display of waveformsand computation of performanceparameters

ProgramOutcomes(PO)

PO-1:Engineeringknowledge: EngineeringKnowledge:Applytheknowledgeofmathematics,science, engineering fundamentals, and an engineering specialization to the solution of complexengineeringproblems.

PO-2: Problem analysis: Problem analysis: Identify, formulate, research literature, and analyse complexengineering problems reaching substantiated conclusions using first principles of mathematics, naturalsciences,andengineeringsciences.

PO-3: Design/development of solutions: Design/development of solutions: Design solutions forcomplex engineering problems and design system components or processes that meet the specifiedneeds with appropriate consideration for the public health and safety, and the cultural, societal, andenvironmentalconsiderations.

PO-4: Conduct investigation of complex problems: Use research-based knowledge and researchmethodsincluding designofexperiments, analysisandinterpretationofdata,andsynthesisoftheinformationtoprovidevalidconclusions.

PO-5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modernengineering and IT tools including prediction and modelling to complex engineering activities with anunderstandingofthelimitations.

PO-6: The engineering and society: Apply reasoning informed by the contextual knowledge to assesssocietal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to theprofessionalengineeringpractice.

PO-7: Environment and sustainability: Understand the impact of the professional engineeringsolutions in societal and environmental contexts, and demonstrate the knowledge of need forsustainabledevelopment.

PO-8: Ethics: Apply ethica lprinciples and commit to professional ethics and responsibilities and norms of the engineering practice.

PO-9: Individual&teamwork: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO-10: Communication: Communicate effectively on complex engineering activities with theengineering community and with society at large, such as, being able to comprehend and writeeffective reports and design documentation, make effective presentations, and give and receiveclear instructions.

PO-11:Projectmanagementandfinance: Demonstrateknowledgeandunderstandingoftheengineering and management principles and apply these to one‘s own work, as a member and leader ina team,tomanageprojectsandinmultidisciplinary environments.

PO-12: Life- long learning: Recognize the need for, and have the preparation and ability to engage inindependentandlife-longlearninginthebroadestcontextoftechnologicalchange.

P**rogramme Specific Outcomes(PSO)**

PSO1:Specify,design,buildandtestanaloganddigitalsystemsforsignalprocessingincludingmulti mediaapplications,usingsuitablecomponentsorSimulationtools.

PSO2:Understandandarchitect wiredandwireless analoganddigitalCommunicationsystemsas perspecifications anddeterminetheirperformance.

‘INSTRUCTIONS TO THE CANDIDATES’

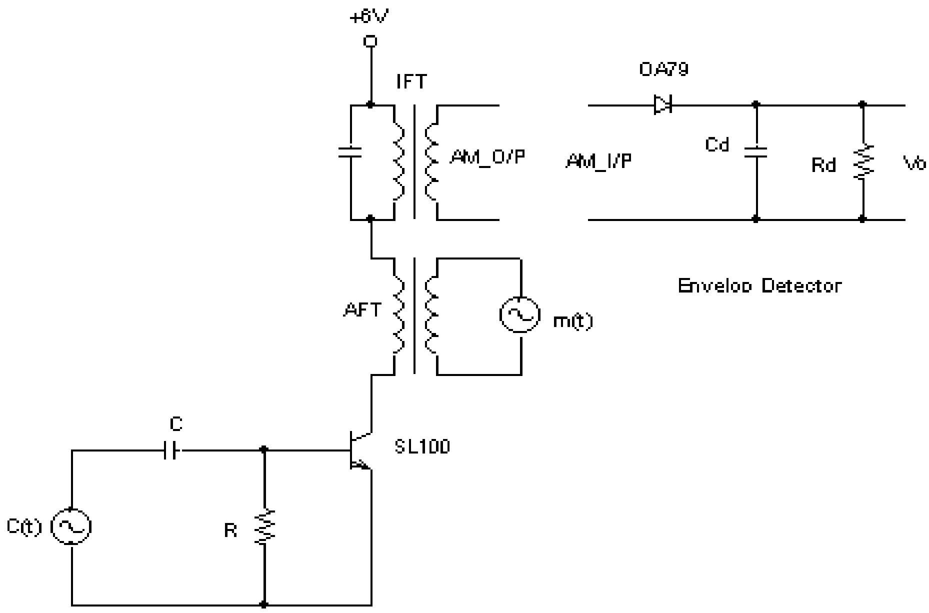
- Student should come with thorough preparation for the experiment to be conducted.
- Student should take prior permission from the concerned faculty before availing theleave.
- Student should come with proper dress code and to be present on time in thelaboratory.
- Student will not be permitted to attend the laboratory unless they bring the practical record fully completed in all respects pertaining to the experiment conducted in the previousclass.
- Student will not be permitted to attend the laboratory unless they bring the observation book fully completed in all respects pertaining to the experiment to be conducted in presentclass.
- Experiment should be started conducting only after the staff-in-charge has checked the circuitdiagram.
- All the calculations should be made in the observation book. Specimen calculations for one set of readings have to be shown in the practical record.
- Wherever graphs to be drawn, A-4 size graphs only should be used and the same should be firmly attached in the practicalrecord.
- Practical record and observation book should be neatlymaintained.
- Student should obtain the signature of the staff-in-charge in the observation book after completing eachexperiment.
- Theory related to each experiment should be written in the practical record before procedure in your own words with appropriatereferences.

CONTENTS

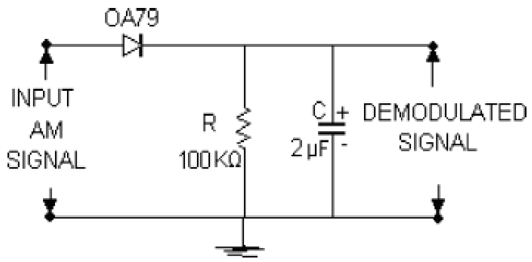
INDEX PAGE

Sl. No	Name of the Experiment	Date			Manual Marks (Max . 20)	Record Marks (Max. 10)	Signature (Student)	Signature (Faculty)
		Conduction	Repetition	Submission of Record				
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
Average								

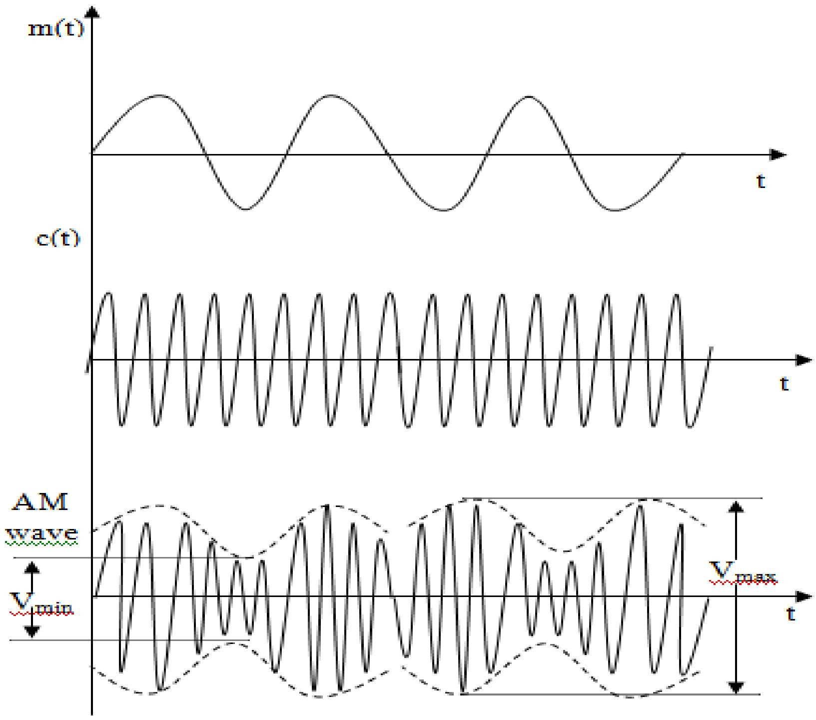
Circuit Diagram- For AM Modulation:



For Demodulation:



Waveform: (a) Standard AM



ExperimentNo.1 **Date:___/___/______**

AMPLITUDE MODULATION

A. Standard AM generation and demodulation using LM 741 & LF398 ICs

Aim: To conduct an experiment to generate AM signal and to demodulate the AM signal.
Apparatus Required:

Sl.No.	Particulars	Range	Quantity
1.	Transistor	SL100	01
2.	Resistors & Capacitors	As per design	-
3.	Diode	OA79	01
4.	IFT, AFT	-	01 each
5.	Probes	-	03 set

Procedure:

1. Check the components/Equipemnts for their working condition.
2. Connetions are made as shown in the circuit diagram.
3. By switching off the modulating signal, find the tuned frequency of IFT by varing frequency of c(t).
4. Keeping the carrier frequency at the tuned frequency of the IFT switch on the modulating signal and observe the AM signal.
5. Find the modulation index m, the amplitude of the carrier signal V_c and the amplitude of the message signal V_m by recording the V_{max} and V_{min}. (V_{max} and V_{min} should be measured from both AM signal and Trapezoidal waveform.)
6. Repeat the above step by varying the amplitude of modulating signal. Plot a graph of V_m Vs %m.
7. Connect the envelop detector circuit and observe the demodulated siganl.

Note: To obtain the Trapezoidal waveform, feed the modulating signal to channel (i) and AM wave to channel (ii), press X-Y knob.

Design :

Specification : f IFT = 455 kHz

RC >> T where T = 1 / f_{IFT}

Let RC = 100 T

Assume C = 0.01 μf then R = 21.97 kΩ

Envelop Detector :

1/fm > Rd Cd > 1/fc Let Rd Cd = 100 / fc

assume Cd = 0.001 μf, then Rd = 200 kΩ

Tabular Column :

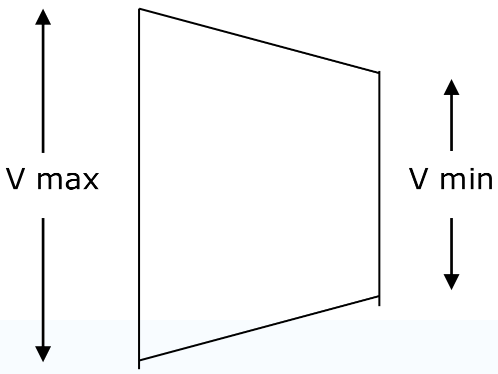
Modulation :

Sl. No.	V max in Volt	V min in Volt	$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$	$V_m = \frac{V_{max} - V_{min}}{2}$ in Volt	$V_c = \frac{V_{max} + V_{min}}{2}$ in Volt

Demodulation :

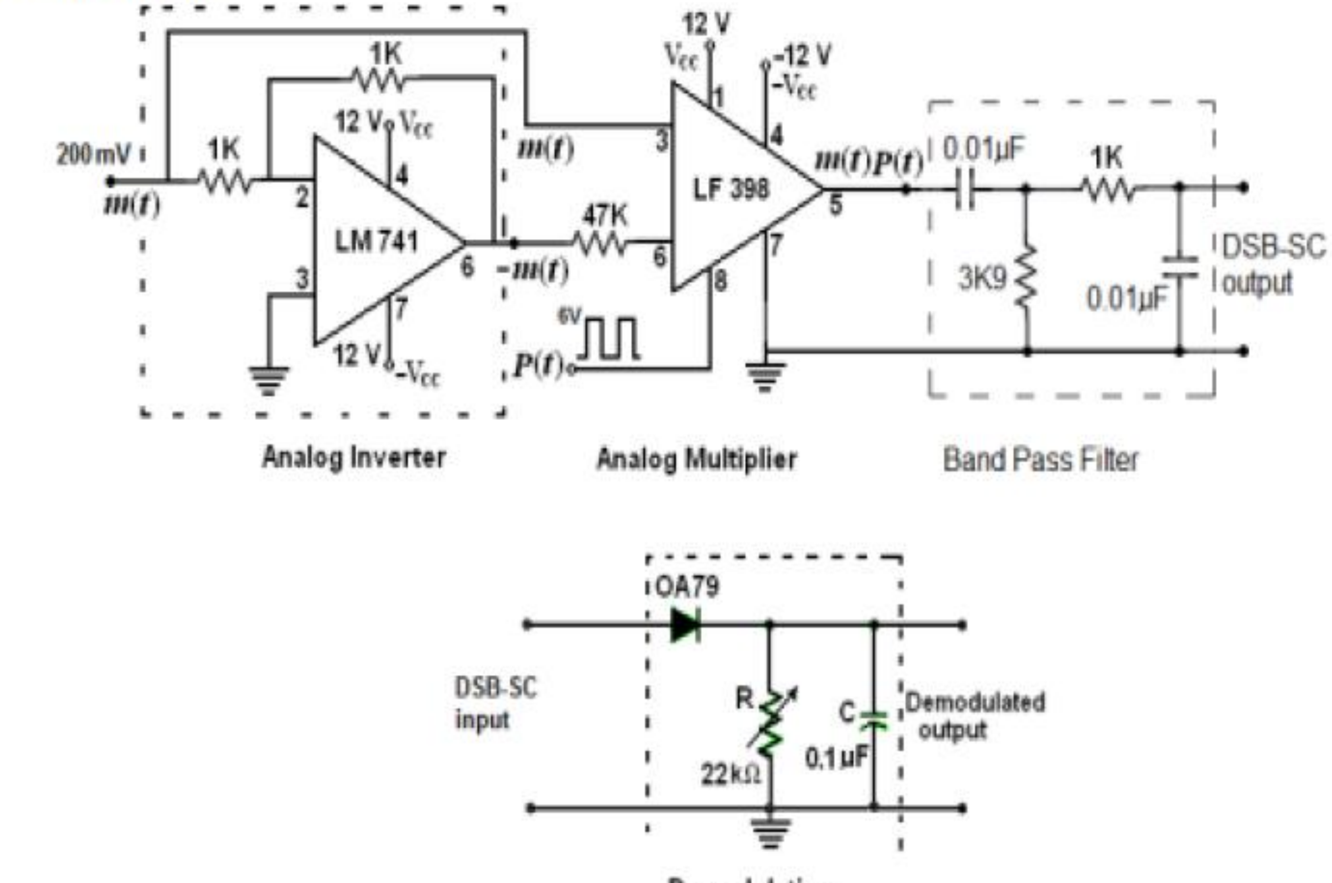
Sl. No.	Vo in Volt	fo in Hz

Transfer Characteristic Curve :



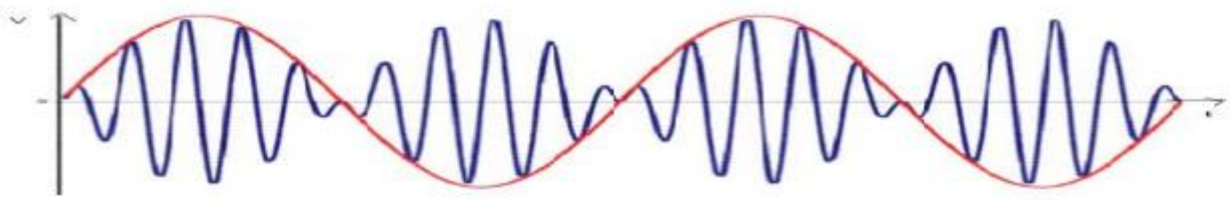
DSBSC Modulation

Circuit Diagram:



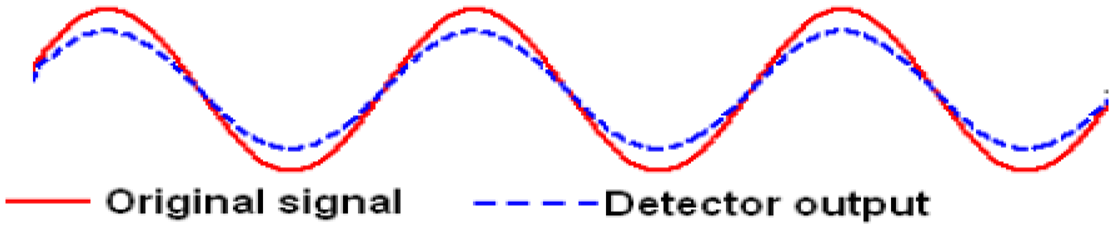
Circuit diagram of DSB-SC Modulation and Demodulation

Waveform:(b)



DSBSC

Waveform: Envelope Detector output



B. DSBSC Generation and demodulation using LM 741 & LF398 ICs

Aim: To generate AM- Double sideband Suppressed carrier signal (DSB-SC) signal.

Components:

SL NO	Name of the Component/Equipment	Specifications/Range	Quantity
	IC LM 741	Std. Op-amp (General Purpose)	1
	IC LF 398	1 Monolithic Sample and Hold Circuit (10-µs acquisition, 7-mV offset)	1
	Diode (0A79)	Max Current 35mA	1
	Resistors	1 47KΩ ,22KΩ, 3.9KΩ, 6.8KΩ, 1KΩ,	1 each
	Capacitors	0.1µF	1
		0.01µF	2
	Variable Resistor (Pot)	0-50KΩ	1

Procedure:

DSB-SC Modulation: Analog Inverter:

1. Initially wire the circuit for analog inverter circuit as shown in Fig.
2. Set audio signal generator (modulating signal) to 1 kHz sine wave with 200 mV peak.
3. Now observe the output wave form at the output of analog inverter (pin No6 of LM 741). This waveform should be inversion of the input sine wave. Analog Multiplier:
4. Now wire the analog multiplier circuit as shown in Fig..
5. A square wave of 10 kHz with 6 Vpp is connected to the Pin. No.8 of LF 398.
6. Observe the DSB-SC output at Pin No. 5 of LF 398.
7. Now slightly increase and decrease the modulating signal and note how the DSBSC modulation changes. Demodulation:

Design: Envelope Detector

1/fm>RC>1/fc, hence 2ms>RC>20µs

Let RC =50/fc=1 ms

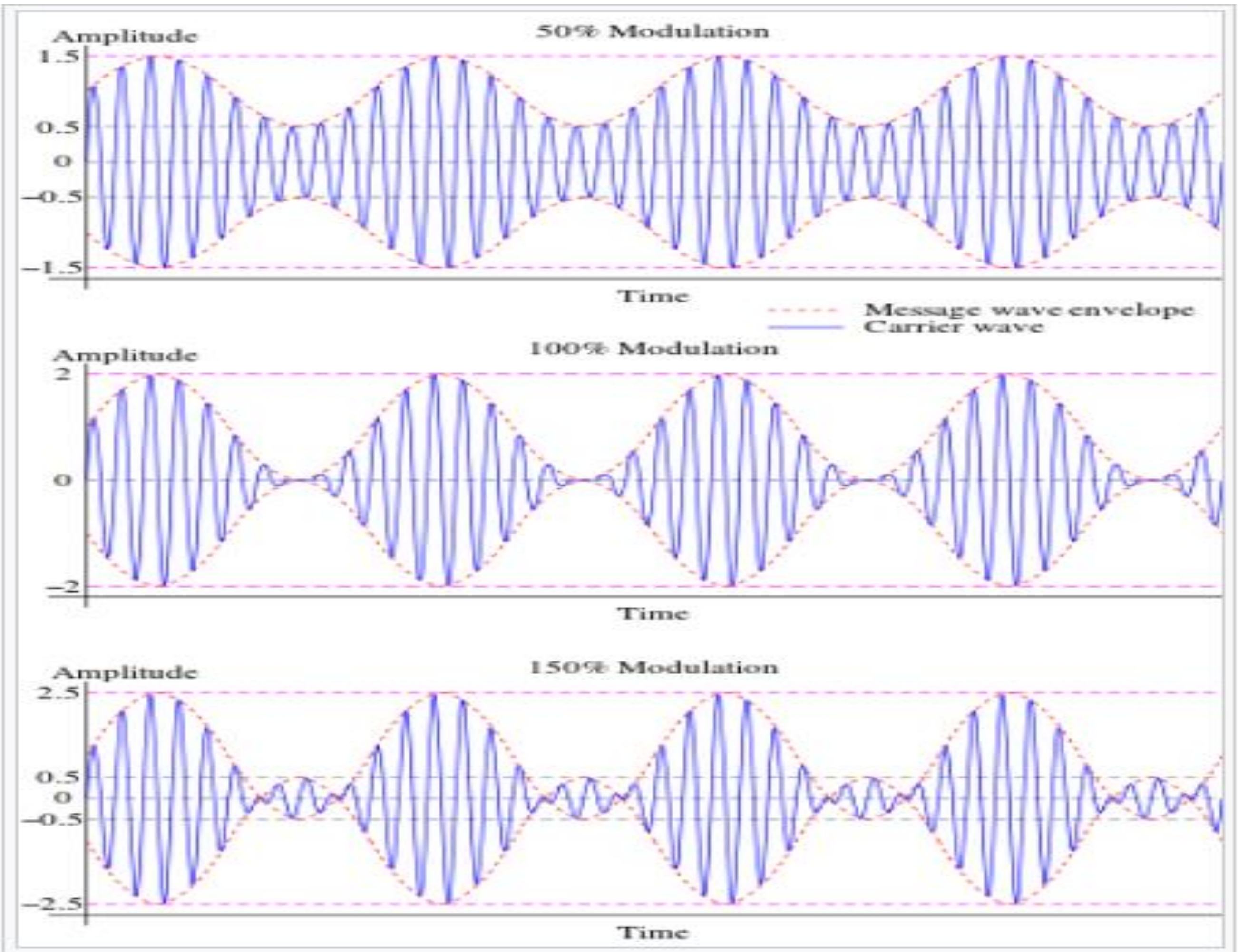
Assume **C=0.01 µF**, then **R=100 kΩ**

Sample Readings:

Table 1: fm= _________hz, fc=___________hz, Ac= _________V_{p-p}

Sl.No	Vm(Volts)	Emax(Volts)	Emin(Volts)	µ	% µ

Waveform for different modulation index:



Note: By varying frequency of the carrier i.e. fc<fm, fc≥fm& fc>>fm likewise observe undermodulaton, 100%modulaton &overmodulaton respectively.

Table 2: Am= _________ hz, fc=___________ hz, Ac= _________V_{p-p}

Sl.No	fm(Khz)	Emax(Volts)	Emin(Volts)	μ	% μ

$\mu = \frac{V_{max}-V_{min}}{V_{max}-V_{min}}$ Where, **μ**=modulation index

V_{max}=maximum peak to peak envelope amplitude (volts)

V_{min}=minimum peak to peak envelope amplitude (volts)

Result:

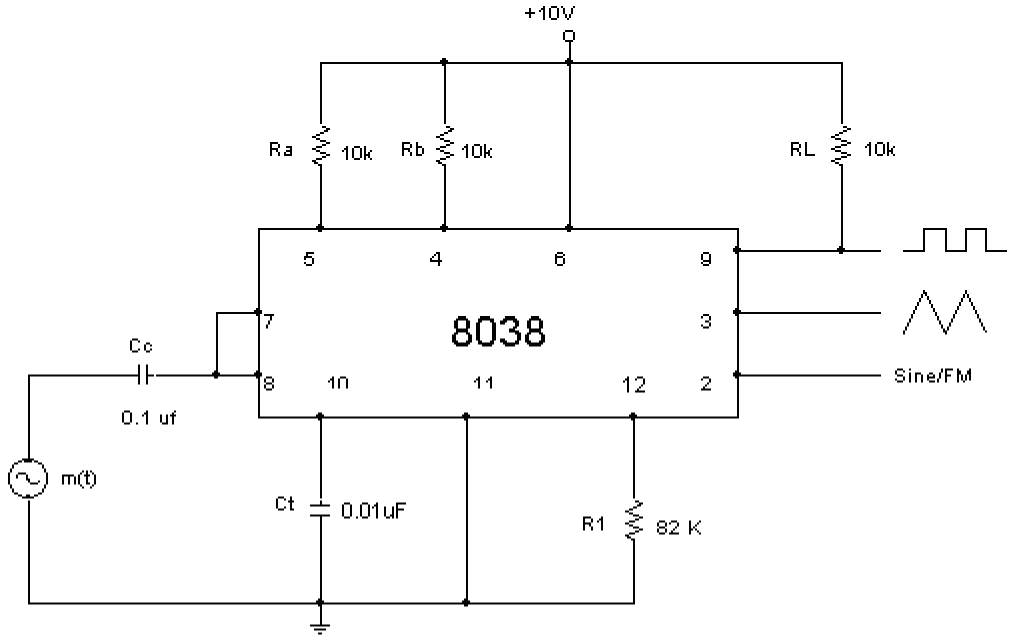
1.The AM Modulated output is observed for the carrier frequency__________ and the modulation index________________ with the increase in the message signal.

2.The message signal frequency _________ and the demodulated signal frequency ___________.

VIVA Questions

1) Why modulation is necessary?
2) Define AM and draw its spectrum? What is its band width?
3) Why percentage modulation is always less than 100 % in case of A.M.?
4) Give the significance of modulation index?
5) What are the different degrees of modulation?
6) What will be the change in modulation index if there is change in amplitude of modulating signal ?
7) What will be the change in modulation index if there is change in frequency of modulating signal ?
8) Compare linear and nonlinear modulators?
9) Explain how AM wave is detected?
10) What are the different types of distortions that occur in an envelope detector? How can they be eliminated?
11) How many channels are contained in the AM broadcast band?
12) What is the bandwidth of each of the channels in the AM broadcast band?
13) Draw AM signal in which carrier signal is sinusoidal and modulating signal is triangular wave.
14) An audio signal of 7.5 KHz with a peak of 4.5 Volts modulates the carrier of 7.5 Volts peak with frequency 510 KHz. Find out the modulation index.
15) What is the bandwidth requirement for the AM signal when the frequencies of the modulating signals 200 Hz, 400 Hz and 800 Hz are transmitted simultaneously?
16) What are discrete frequencies in DSB-SC?
17) What is the advantage of DSB-SC over AM?
18) Mention the names of methods for DSB-SC generation?
19) What do you mean by coherence detection and non-coherent detection?
20) How a message signal recovered from DSBSC wave?
21) What is the disadvantage of DSB-SC?
22) What is the bandwidth of DSB-SC?
23) Why DSB-SC is not used for commercial broad casting?
24) Mention few applications for DSB-SC.

Circuit Diagram: FM Modulation



Design :

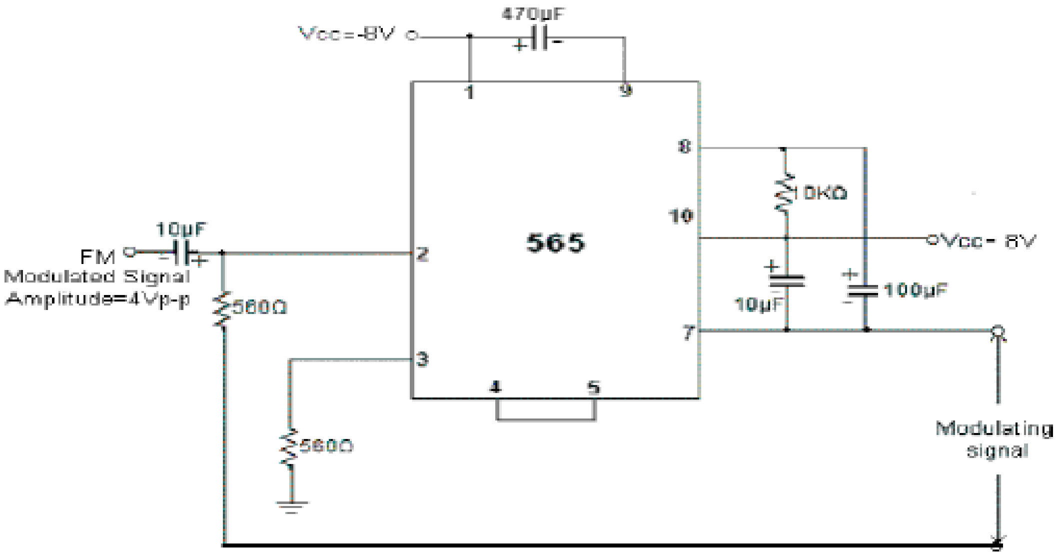
Specifications : Carrier frequency f_c = 3 kHz

$fc = 0.3 / (R C_t)$ Where $R = R_a = R_b$

Assume $R = R_a = R_b = 10\ k\Omega$ then $C_t = 0.01\ \mu F$

Choose RL = 10 kΩ, R1 = 82 kΩ, C_c= 0.1 μF

Circuit Diagram: Demodulation:



ExperimentNo.2 **Date:___/___/_______**

Frequency Modulation Using IC 8038/2206 And Demodulation

Aim: To generate Frequency Modulated wave and to demodulate it. Also find frequency deviation and modulation index.

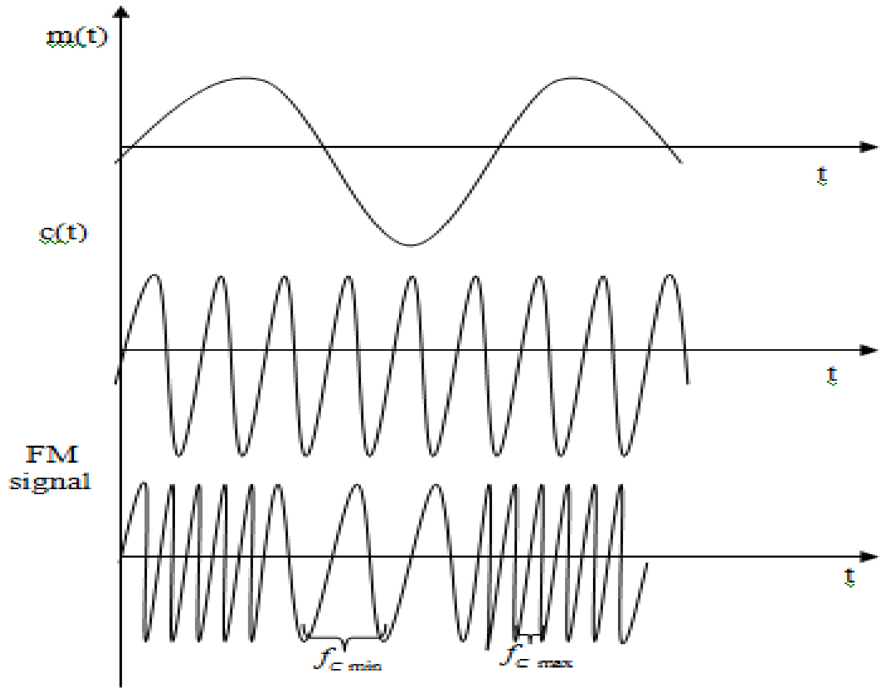
Apparatus Required:

Sl.No.	Particulars	Range	Quantity
1.	IC 8038	-	4
2.	Resistors & Capacitors	As per design	1 each
3.	CRO Probes	-	2 set

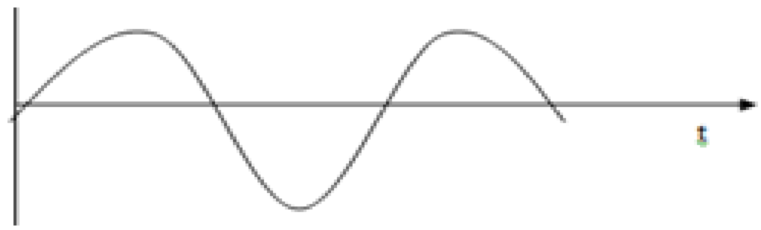
Procedure:

1. Check the components/Equipments for their working condition.
2. Connections are made as shown in the circuit diagram-2.1.
3. By switching off the modulating signal m(t) note the frequency of the carrier wave at Pin No.2 of IC-8038.
4. Apply the modulating signal with suitable amplitude to get the FM signal.
5. Note the maximum(f_{cmax}) and minimum(f_{cmin}) frequency of the carrier wave in FM signal.
6. Calculate the frequency deviation, modulation index and bandwidth.
7. Feed the FM wave to the demodulator circuit and observe the output.
8. Note down frequency and amplitude of the demodulated output waveform.

Waveforms:



Demodulated signal



Tabular Column:

fc = ____________ Hz, fm = ____________ Hz

Sl. No.	Vm in V	fc max In Hz	fc min In Hz	δ1 in Hz	δ2 in Hz	δ in Hz	β = δ/fm	BT =2δ+2fm In Hz

Where $\partial_1 = f_{C\max} - f_C$, $\partial_2 = f_C - f_{C\min}$

Result:

Modulation index = _________

Maximum Frequency Deviation = _____Hz.

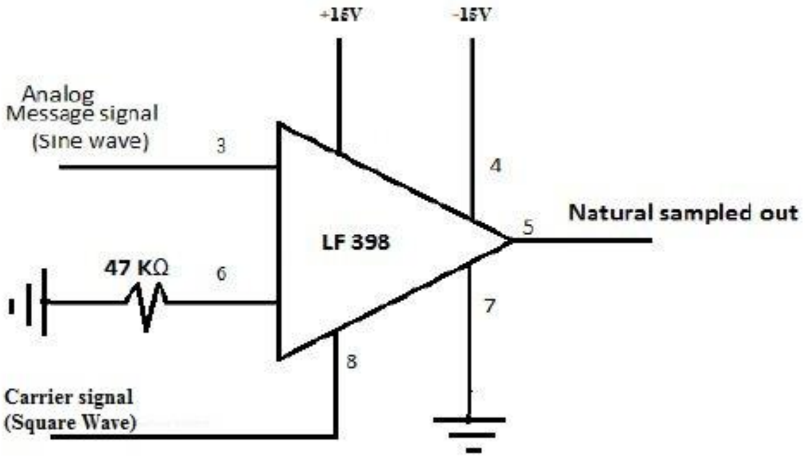
Bandwidth of Operation = ___________ Hz.

Demodulated frequency=_____________Hz.

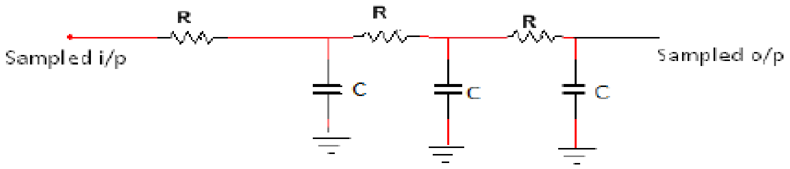
VIVA Questions

1. Define frequency modulation?
2. Mention the advantages of indirect method of FM generation?
3. Define modulation index and frequency deviation of FM?
4. What are the advantages of FM?
5. What is narrow band FM?
6. Compare narrow band FM and wide band FM?
7. Differentiate FM and AM?
8. How FM wave can be converted into PM wave?
9. State the principle of reactance tube modulator?
10. Draw the circuit of varactor diode modulator?
11. What is the bandwidth of FM system?
12. Want is the function of FM discriminator?
13. How does ratio detector differ from fosterseely discriminator?
14. What is meant by linear detector?
15. What are the drawbacks of slope detector?

Circuit Diagram: (Natural sampling)



Reconstruction Circuit:



Filter design:fs= 1/ Ts

Ts=RC

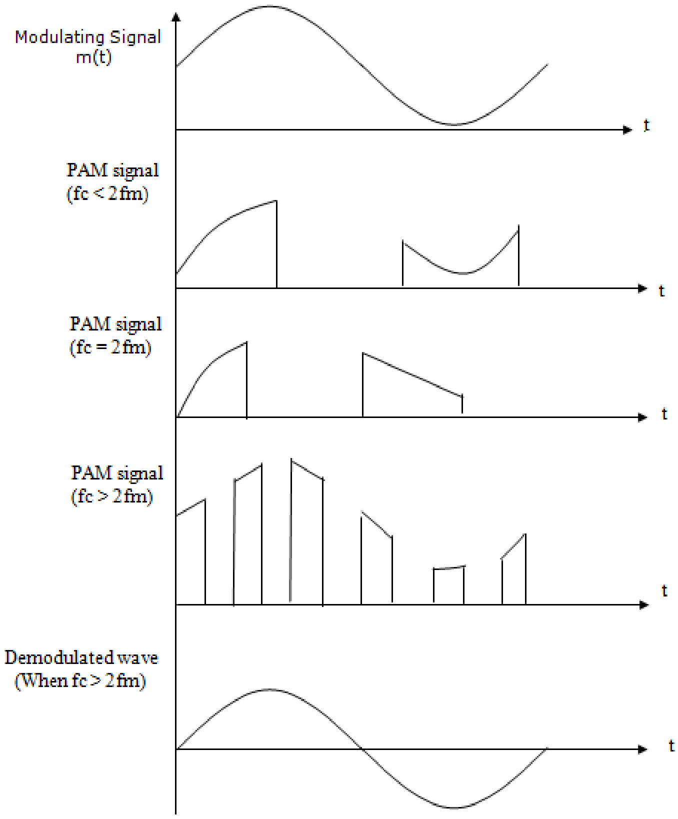
R=Ts/C

Cut off frequency of the filter fo >> fm

Choose fo = 2kHz, fo = 1 / 2πRC

Assume **C = 0.1 μf,then R = 500 Ω**

Waveforms:



ExperimentNo.3 **Date:___/___/_______**

PULSE SAMPLING, FLAT-TOP SAMPLING AND RECONSTRUCTION

A. Pulse Sampling and Reconstruction

Aim: To conduct an experiment to generate pulse sampling and to demodulate the same.

Apparatus Required:

Sl. No.	Apparatus	Range	Quantity
1	Transistor SL 100	-	1
2	Resistors & Capacitor	As Per the design	-
3	Springboard + connecting wires	-	1 Set

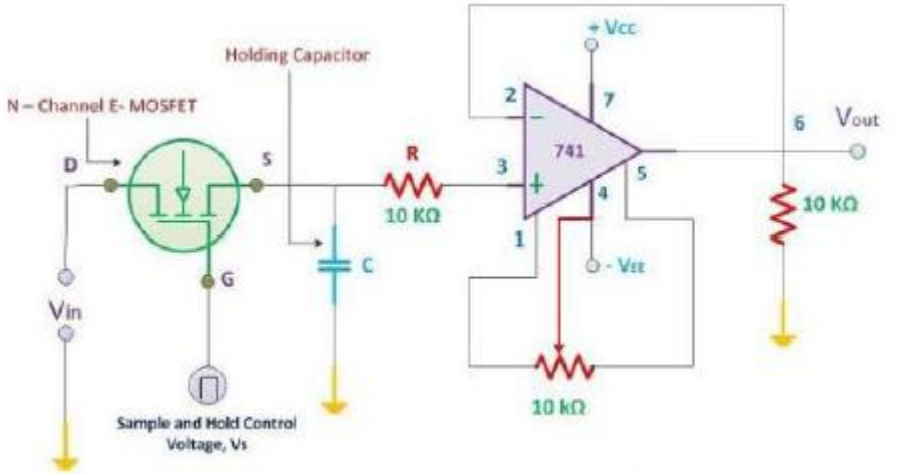
Procedure:

1. Check the components/Equipments for their working condition.
2. Connections are made as shown in the circuit diagram-3.1.
3. Apply the square wave carrier signal of 15-20KHz of 20% duty cycle.
4. Apply sine wave modulating signal of frequency f_m = 1kHz with 5V peak to peak amplitude.
5. Turn on the offset and vary the offset voltage until desired waveform is observed on CRO.
6. Observe the output waveform.
7. Connect the sampled output as a input to the low pass filter and reconstruct the original message signaland note f_o and V_o.
8. Repeat the above steps for $f_c = 2f_m$ and $f_c<2f_m$.

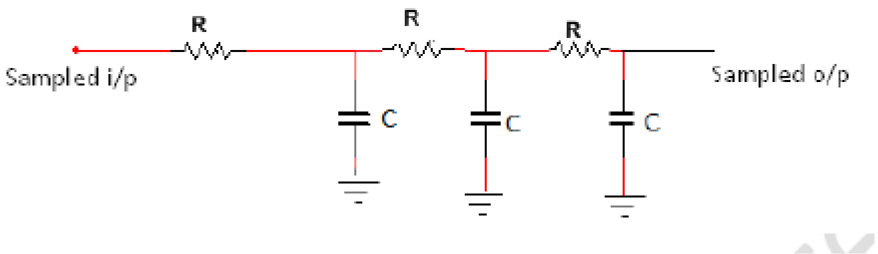
Tabular Column: Vc(p-p)=_______V Vm(p-p)=________V

Sl. No.	Sampling methods	fc in Hz	fm in Hz	Vo of demodulated signal in Volt	fo of demodulated signal in Hz
1	Under Sampling (fc<2fm)				
2	Nquist Rate fc=2fm				
3	Over Sampling fc>2fm				

Circuit Diagram:(Flat top sampling)



Reconstruction Circuit:



Filter design: fs= 1/ Ts

Ts=RC
R=Ts/C

Cut off frequency of the filter fo >> fm

Choose fo = 2kHz, fo = 1 / 2πRC

Assume **C = 0.1 μf,then R = 500** Ω

B. Flat Top Sampling and Reconstruction

Aim: To design a circuit for generating flat top samples and to verify Sampling theorem.

Apparatus Required:

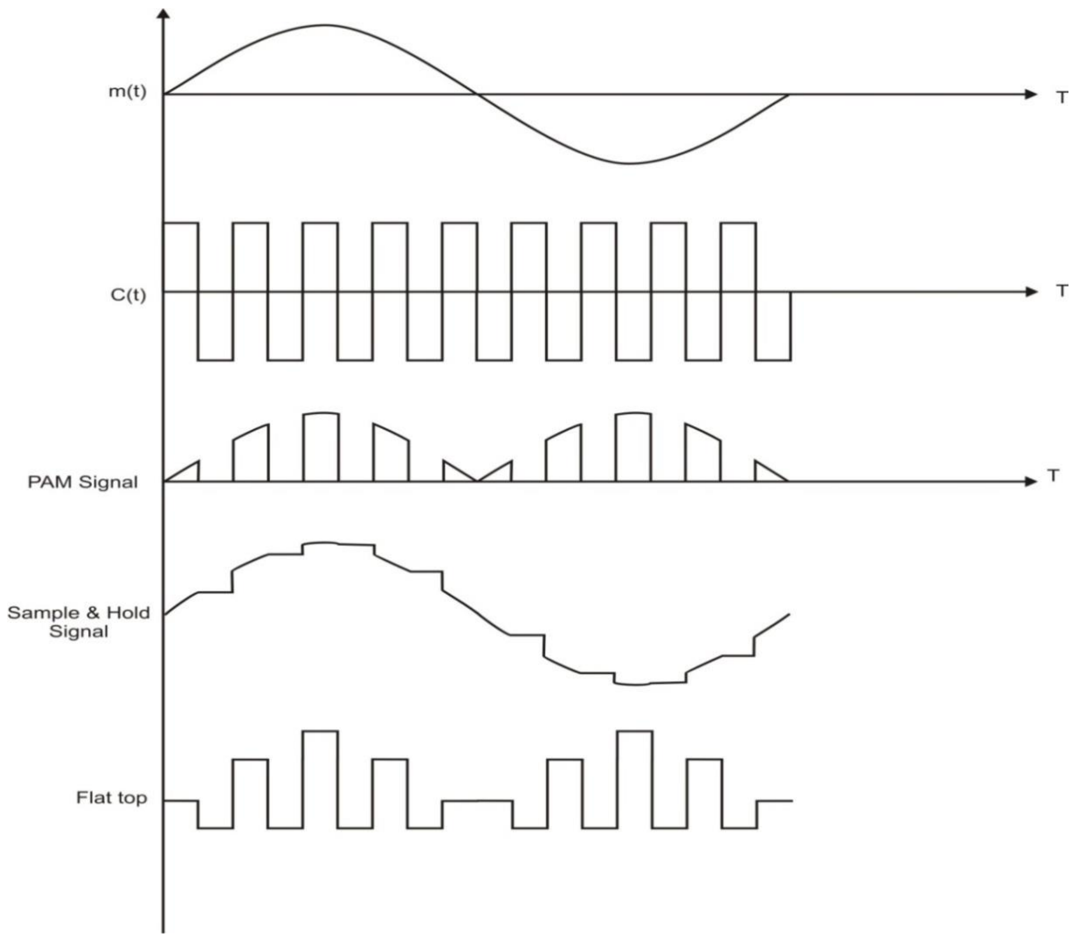
Sl.No.	Particulars	Range	Quantity
1.	MOSFET	-	01
2	OP-Amp	uA741	01
3.	Resistors	10k	03
4.	Capacitors	0.1uF	01

Procedure:

1. The circuit is connected as per the circuit diagram shown in the fig
2. Switch on the power supply. And set at +12V and -12V.
3. Apply the sinusoidal signal of approximately 3V (p-p) at 100-500 Hz frequency and pulse signal of 5V (p-p) with frequency between 100Hz and 10 KHz.
4. Connect the sampling circuit output and AF signal to the two inputs of oscilloscope
5. Initially set the sampling frequency to 200Hz and observe the output on the CRO. Now vary the amplitude of modulating signal and observe the output of sampling circuit. Note that the amplitude of the sampling pulses will be varying in accordance with the amplitude of the modulating signal.
6. Design the reconstructing circuit. 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
8. Observe the output of the reconstructing circuit (AF signal) for different sampling frequencies. The

Result:

Waveforms:



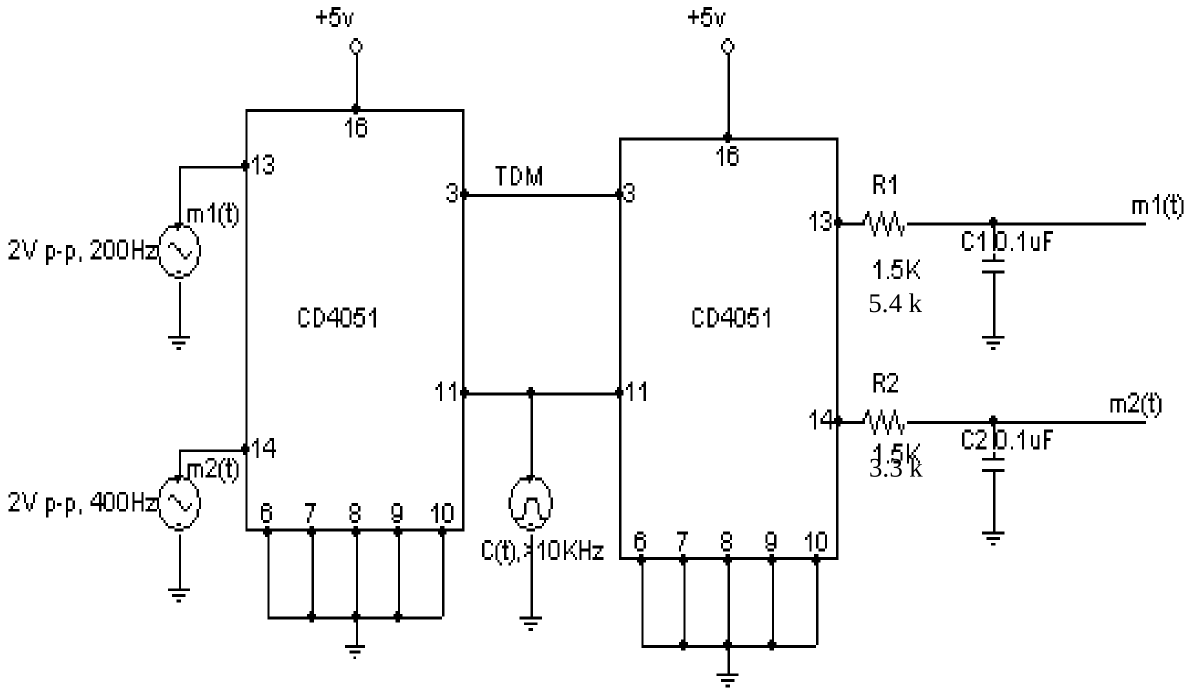
Tabular Column: Vc(p-p)=_______V Vm(p-p)=________V

Sl. No.	Sampling methods	fc in Hz	fm in Hz	Vo of demodulated signal in Volt	fo of demodulated signal in Hz
1	Under Sampling (fc<2fm)				
2	Nquist Rate fc=2fm				
3	Over Sampling fc>2fm				

VIVA Questions

1. What is Sampling?
2. Define Sampling theorem?
3. What is Nyquist Rate?
4. How many types of samplings are their? Explain briefly?
5. What is aliasing effect? How to overcome it?
6. What is natural sampling?
7. What is flattop sampling?
8. What are the Analog pulse modulation methods?
9. Define Pulse amplitude modulation?
10. Define Pulse width modulation?
11. Define Pulse position modulation?

Circuit diagram: TDM of 2 band-limited signals



Design:

Low pass filter:

a) **For messagesignal-1**

$f_c = 1/(2\pi RC)$

Let f_c = 300 Hz, and $C_1 = 0.1\mu F$.

$R_1 = 1/(2\pi x300x0.1x10^{-6})$

$R_1 = 5.305\ k\Omega \approx 5.4\ k\Omega$

b) **For messagesignal-2**

$f_c = 1/(2\pi RC)$

Let f_c = 500 Hz, and $C_2 = 0.1\mu F$.

$R_2\ 1/(2\pi x500x0.1x10^{-6})$

$R_2 = 3.183\ k\Omega \approx 3.3k\Omega$

ExperimentNo.4 **Date:___/___/_______**

TIME DIVISION MULTIPLEXING

Aim: To study Time Division Multiplexing for 2 band-limited signals.

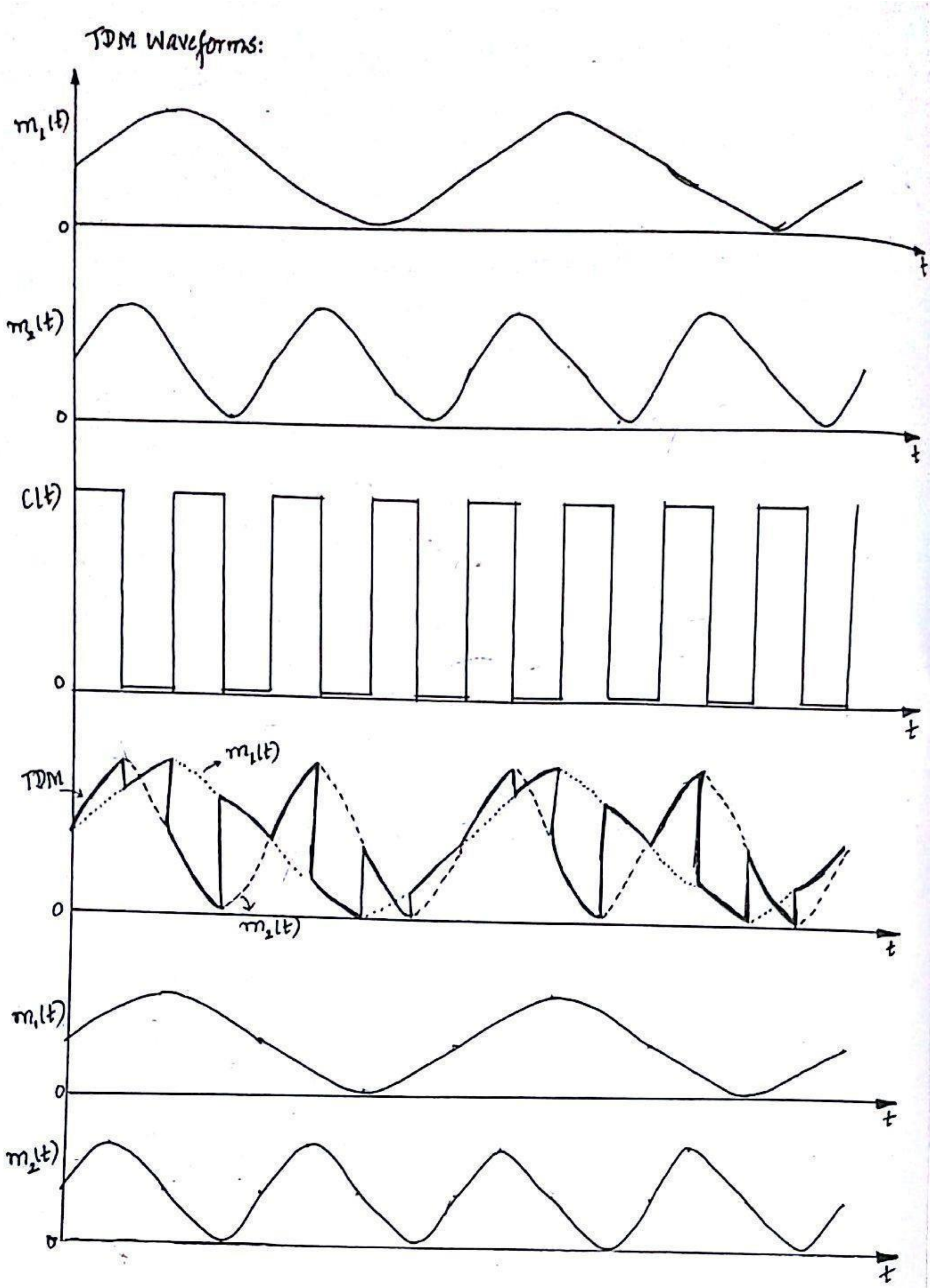
Apparatus Required:

Sl No	Apparatus	Range	Quantity
1	IC CD 4051		2
2	Resistors	As Per Design	2
3	Capacitor	As Per Design	2

Procedure:

1. Connections are made as shown in the circuitdiagram.
2. Apply a square wave (TTL) carrier signal of 2 kHz (or >2 kHz) of 5Vamplitude.
3. Apply $m_1(t)$ and $m_2(t)$ whose frequencies are f_1 (200 Hz, with DC offset) and f_2 (400 Hz, with DCoffset).
4. Observe TDM waveform at pin number 3 of ICCD4051.
5. Observe the reconstructed message waveforms $m_1(t)$ and $m_2(t)$ at pin numbers 13 and 14 of 2^{nd} ICCD4051.
6. The ripples in the demodulated signals can be reduced by increasing the order of thefilter or by increasing the carrierfrequency.

TDM Waveforms:

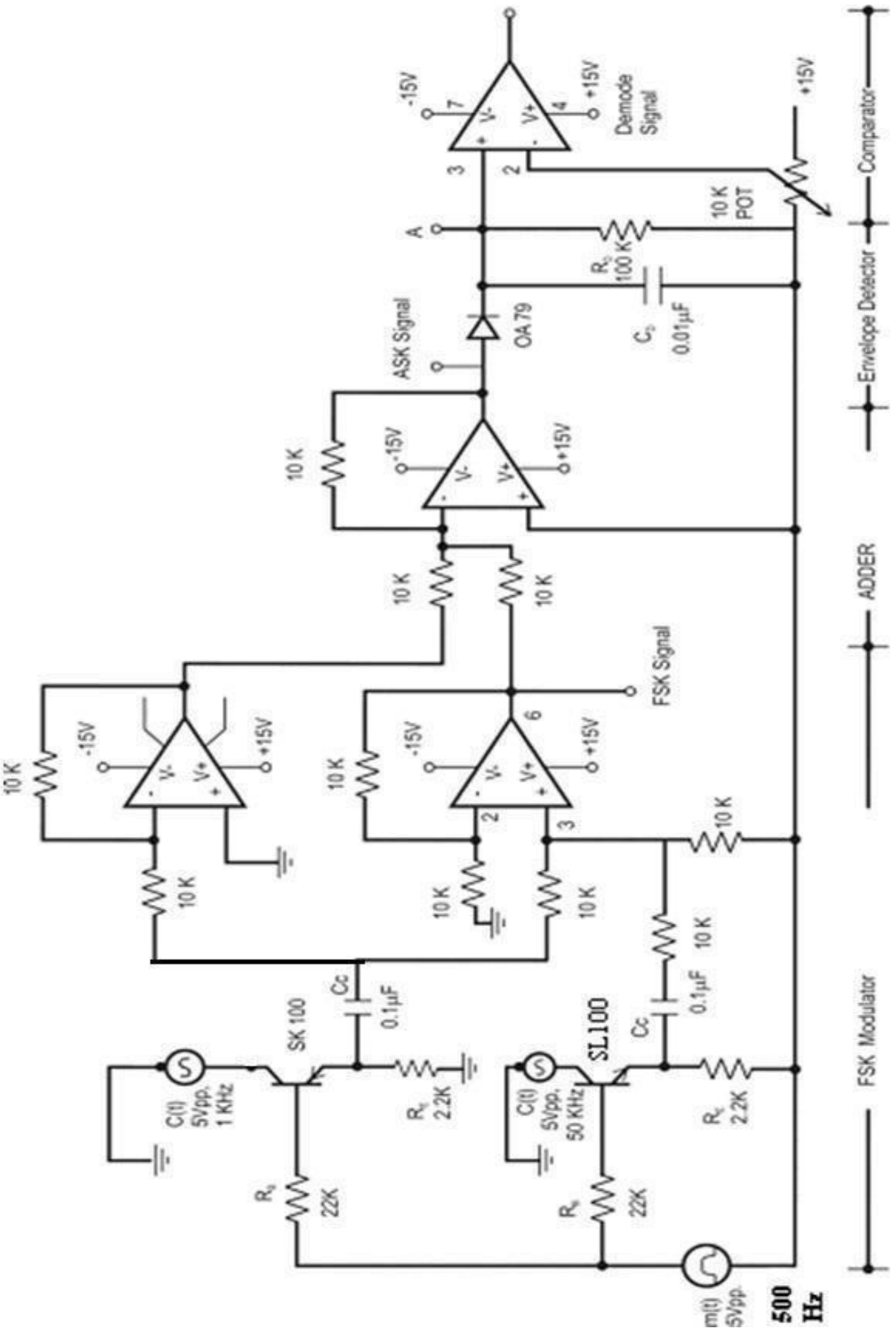


Result:

VIVA Questions

1. What do you mean by Multiplexing ?
2. Explain Frequency Division Multiplexing (FDM).
3. Explain Time Division Multiplexing (TDM).
4. What is Transmission Bandwidth of a PAM/TDM Channel ?
5. What is Crosstalk in PAM/TDM system ?
6. Write the advantages of TDM.
7. Write the disadvantages of TDM.
8. Explain the principle of Digital Multiplexing.
9. What is TDM? How is it different from FDM ?
10. When do you prefer TDM to FDM ?
11. When would you prefer FDM to TDM ?
12. What is meant by signaling rate?
13. What is the minimum rate of sending the TDM signals ?
14. Distinguish between the two basic multiplexing techniques?
15. Why sync pulse is required in TDM?

Circuit Diagram-5.1: FSK modulator and demodulator



ExperrimentNo.5 **Date:___/___/______**

FREQUENCY SHIFT KEYING&PHASE SHIFT KEYING

A. FREQUENCY SHIFT KEYING

FREQUENCY SHIFT KEYING

Aim: To generate FSK signal and to demodulate the FSK signal.

ApparatusRequired:

Sl.No	Apparatus	Range	Quantity
1	IC1458		2
2	Transistor	SL100 SK100	1 1
3	Diode	OA79	1
4	Resistors	AsPerDesign	16
5	Potentiometer	10KΩ	1
6	Capacitor	AsPerDesign	3

Procedure:

1. Connectionsaremadeasshownincircuitdiagram-3.
2. Applyasquarewavemodulatingsignalof100Hz(200bits/sec)and 10V_{P-P}amplitude.
3. Applyasine wavecarriersignal-1of1kHz,5V peak topeakamplitude andsignal-2of50kHz,5Vpeaktopeakamplitude.
4. ObserveFSKwaveformatpointA.

Demodulate the FSK signal using the coherent detector (Adder + Envelope Detector). Theerrorin thedemodulatedwaveformcanbeminimizedbyadjustingtheV_{ref}using10kPOT**Aim:** To generate FSK signal and to demodulate the FSK signal.

TabularColumn:

Vc in volts	f_{c1} in Hz	f_{c2} in Hz	Vm in volts	f_m in Hz	Error in detection in ms

VIVA Questions

1. What is Frequency Shift Keying?
2. What is digital modulation and state various techniques?
3. Write the advantage of FSK compared to ASK?
4. What is the disadvantage of FSK compared with ASK & PSK?
5. What is the effect of R1, C2 values on the output?
6. Which type of modulation is used in TV transmission?
7. What is the difference between detector and demodulator?
8. What is the difference between coherent and non-coherent demodulation?
9. What are the applications of FSK.

Design:

Let V_c = 5 volts peak-to-peak, V_m =10 volts peak-to-peak, f_m = 500 Hz, f_c =50 kHz.Assumeh_{fe}=30,V_{BEsat}=0.7volts,V_{CEsat}= 0.3volts,I_c=1mA,I_c=I_e.

$V_{cpeak}=V_{CEsat}+I_eR_e$

2.5=0.3+(1m)R_e, => R_e=2.2kΩ

$V_{mpeak}=R_bI_b+V_{BEsat}+I_eR_e$

5 = R_bI_b+ 0.7 + 2.2,where

$I_b=I_c/h_{fe}$then R_{bmax} = 63 kΩ , ChooseR_b

=22 KΩ**EnvelopeDetector:**

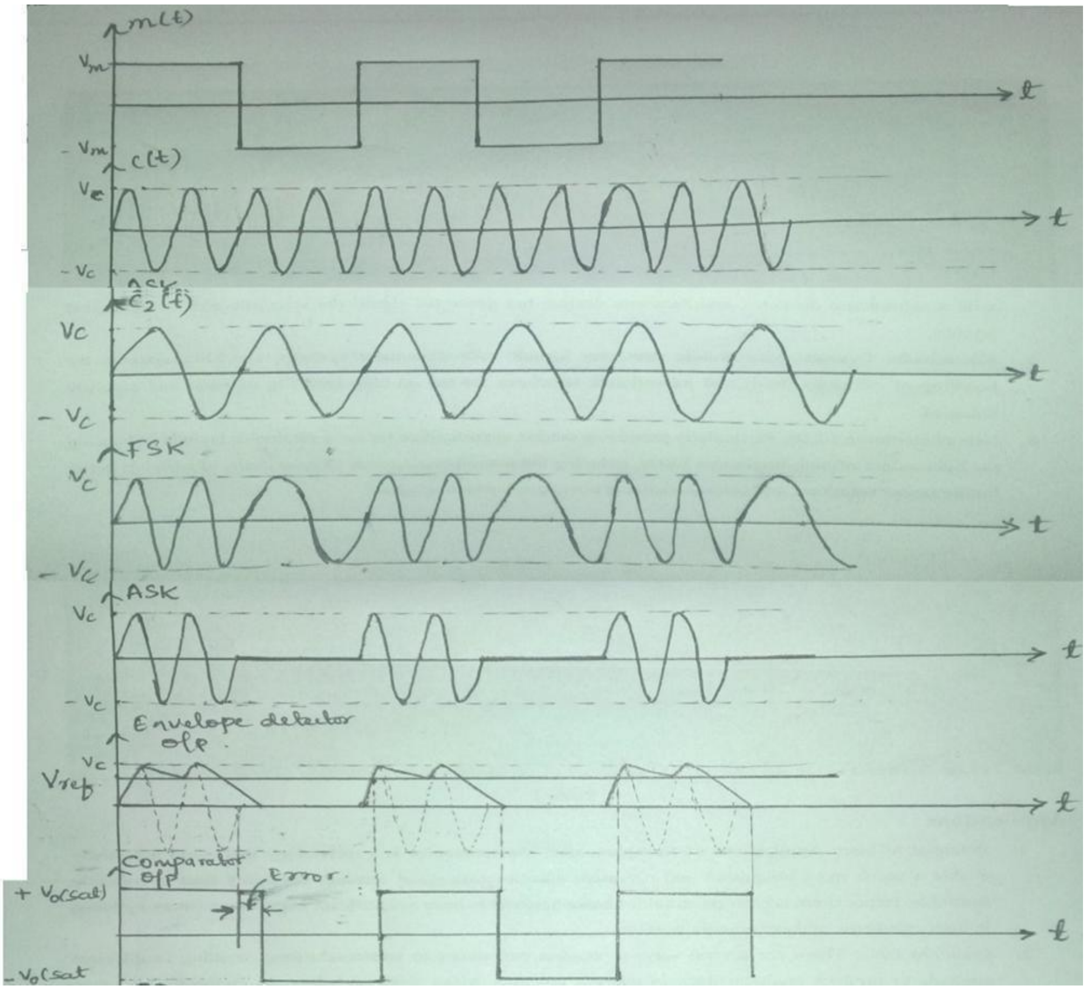
$1/f_m > R_dC_d > 1/f_c$,hence2ms>R_dC_d>20μsLe

tR_dC_d =50/fc=1ms

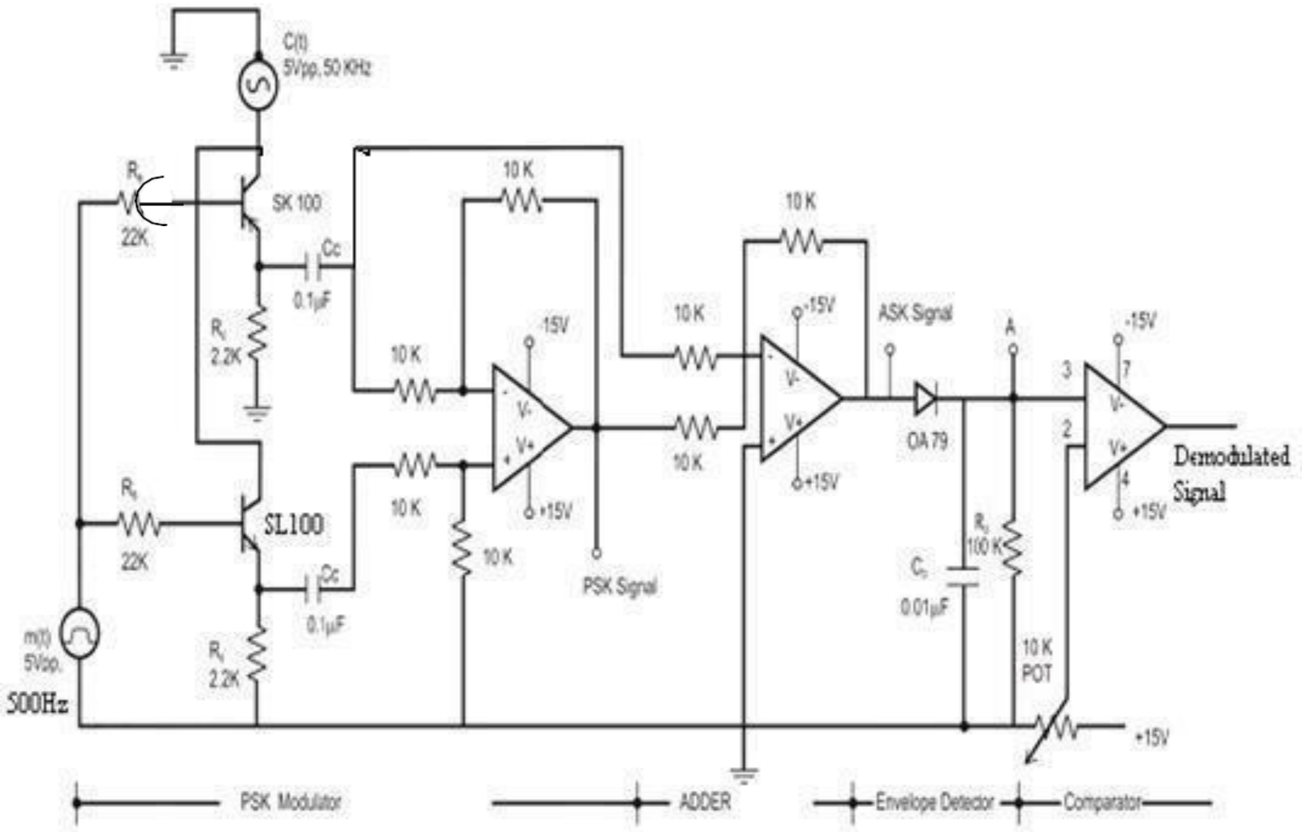
AssumeC_d=0.01μF,thenR_d=100kΩ

TabularColumn:

Vcinvolts	f_{c1}in Hz	f_{c2}in Hz	Vmin volts	f_m in Hz	Error indetectioninms



BPSK modulation & demodulation :



Let V_c = 5 volts peak-to-peak, V_m =10 volts peak-to-peak, f_m = 500 Hz, f_c =50 kHz.Assumeh_{fe}=30,V_{BEsat}=0.7 volts,V_{CEsat}= 0.3volts,I_c=1mA, I_c=I_e.

$V_{cpeak}=V_{CEsat}+I_eR_e$

$2.5=0.3+(1m)R_e$, => $R_e=2.2k\Omega$

$V_{mpeak}=R_bI_b+V_{BEsat}+I_eR_e$

$5=R_bI_b+0.7+2.2$, where

$I_b=I_c/h_{fe}$Then$R_{bmax}=63k\Omega$,ChooseR_b=2

2kΩ

EnvelopeDetector:

$1/f_m>R_dC_d>1/f_c$, hence

ms>R_dC_d>20µsLetR_dC_d =50/fc=1ms
AssumeC$_d$=0.01µF,then R_d=100kΩ

Result:

Error=…………………ms

BINARY PHASE SHIFT KEYING

Aim: To generate PSK signal and to demodulate the PSK signal.

ApparatusRequired:

Sl.No.	Apparatus	Range	Quantity
1	IC1458		2
2	Transistor	SL100 SK100	1 1
3	Diode	OA79	1
4	Resistors	AsPerDesign	16
5	Potentiometer	10KΩ	1
6	Capacitor	AsPerDesign	3

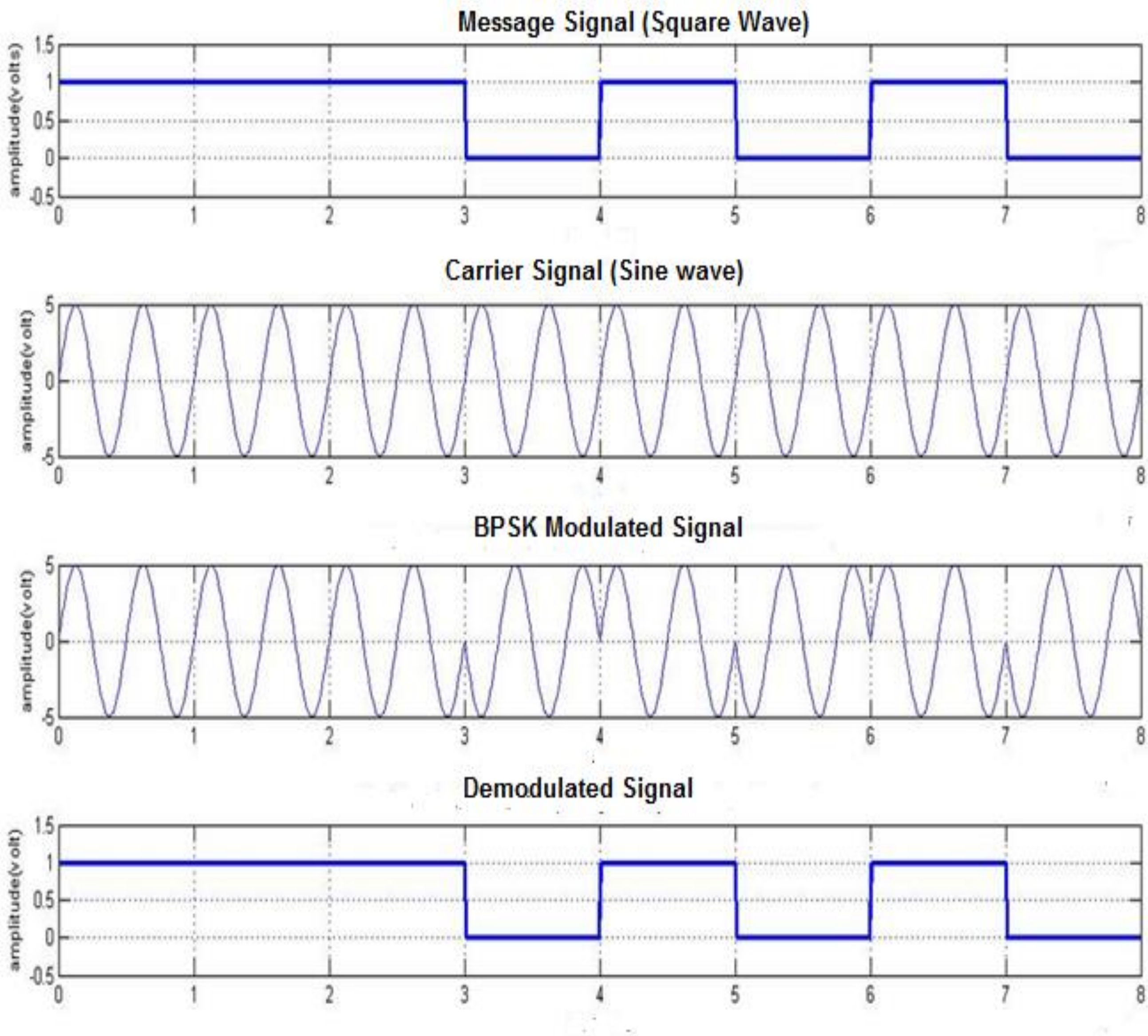
Procedure:

1. Connectionsaremadeasshowninthecircuitdiagram-4.
2. Applysquarewavemodulatingsignalof500Hz(1000bits/sec)of10V_{P-P}.
3. Apply asinewavecarrier signalof50kHz of5Vpeakamplitude.
4. ObserveBPSK waveformatpointA.
5. DemodulatetheBPSKsignalusingthecoherentdetector(Adder+EnvelopeDetector). The error in the demodulated wave can be minimized by adjusting the V_{ref}using10kpot.

Tabular Column:

Vc in volts	fc in Hz	Vm in volts	fm in Hz	Error in detection in ms

PSK modulation & demodulation waveforms:



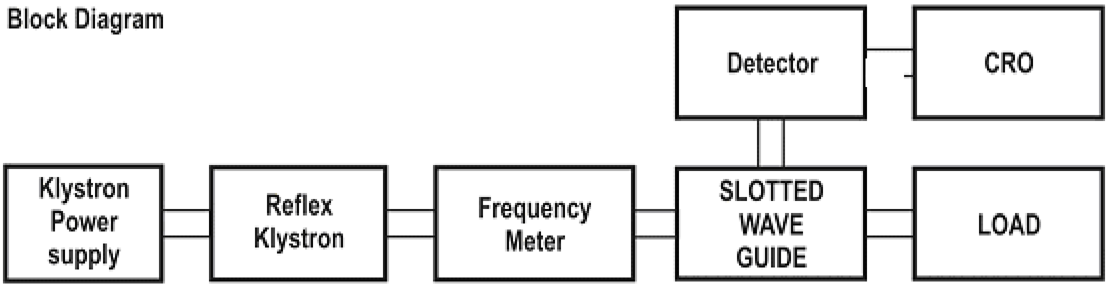
Result:

Error= ....ms

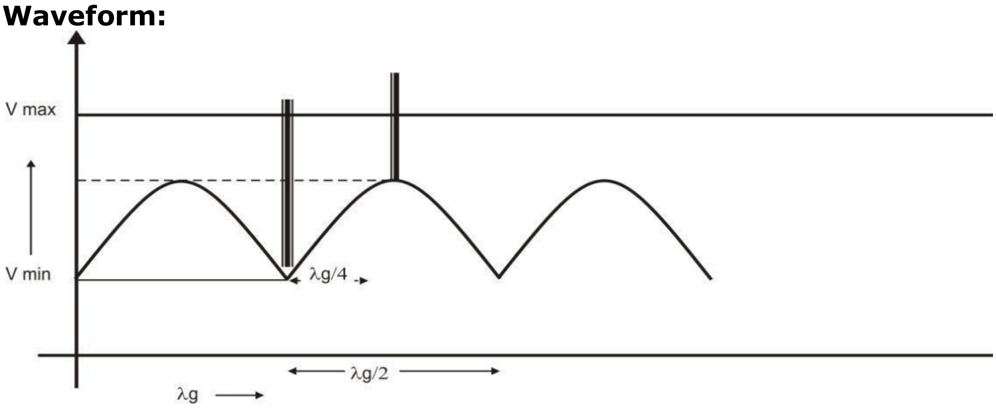
VIVA Questions

1. What is PSK.
2. What are different forms of PSK.
3. What are the advbantages of BPSK.
4. What are the application of BPSK.
5. What are the application of BPSK.
6. Drawback of DPSK compared to BPSK?
7. Write the advantage of QPSK over the BPSK?
8. What is the effect of carrier amplitude on the output?
9. What is the effect of modulating signal frequency on the output?

Circuit Diagram-6: Microwave test bench set up



Waveform:



λ_c=2a
a=2.54cm

Tabular Column:

Load	V max	V min	VSWR
Horn			
Short Circuit			
Open Circuit			
Match Termination			

X1= MSR + (CVDx LC) **LC =0.01cm** **λ_g =2($X_1 \approx X_2$)cm=……………,**

$$\lambda_o = \sqrt{\frac{(\lambda_g \times \lambda_c)^2}{(\lambda_g^2 + \lambda_c^2)}}$$

Load		X_1	X_2	λ_g	λc	λ_0	f_0 GHz
Horn							
Short Circuit							
Open Circuit							
Match Termination							

VSWR = V_{max}/ V_{min}

ExperimentNo.6 **Date:___/___/ _____**

MEASUREMENT OF FREQUENCY, λ_g, VSWR

Aim: To measure the frequency, guide wavelength, power and VSWR of a microwave guide.

Procedure:

1. Setupthemicrowavebenchasshownincircuitdiagram-6.
2. With Reflector voltage in maximum position and beam voltage in minimum position switch on the Klystron power supply (Both main and HT switch) wait until current reaches 10 to12mA.
3. Observe the signal at the output of the detector if it is not a square wave then reduce the reflector voltage until a square wave signal isobtained.
4. Observe the standing wave pattern on SWG (Slotted Wave Guide), note the maximum and minimum voltage levels of the standing wave pattern of the connectedload.
5. Note the positions of any 2 consecutive minima X_1 and X_2 (or maxima); twice the difference between these will give the guide wavelengthλ_g.

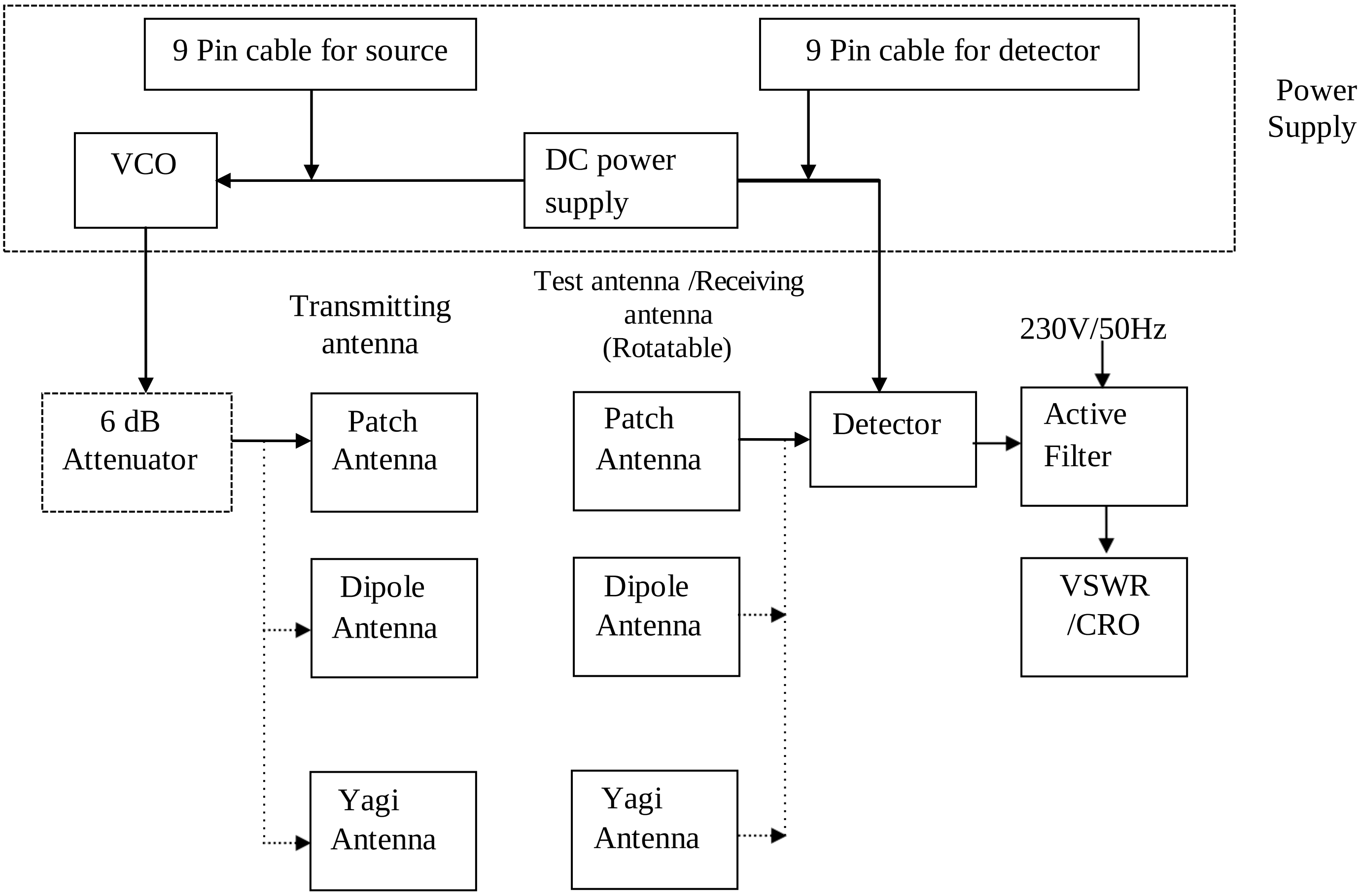
Result:

λ_g =………….. f_o =…………….

VIVA Questions

1. DefineVSWR.
2. Define Characteristicsimpedance.

Circuit Diagram-7: The radiation pattern of microstrip antennas



Tabulation:

Angle	Output on oscilloscope or VSWR meter	
	Output (Clockwise)	Output (AntiClockwise)
0°		
5°		
10°		
15°		
20°		
25°		
30°		
35°		

ExperimentNo.7 **Date:___/___/ _____**

RADIATION PATTERN OF MICROSTRIP ANTENNAS

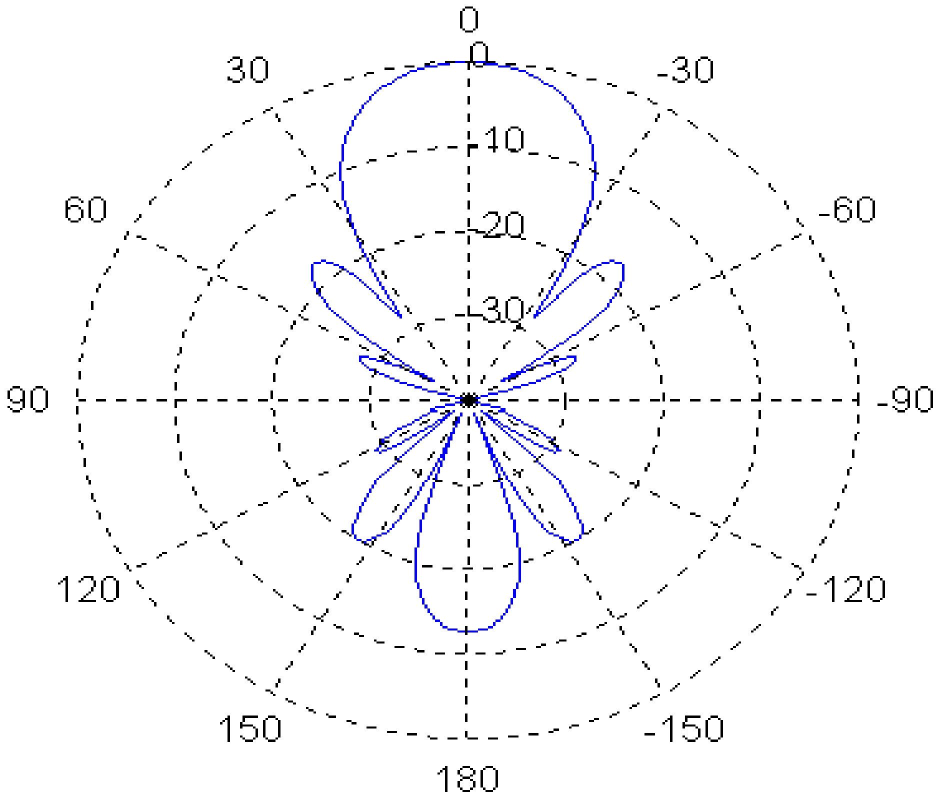
Aim: To conduct an experiment to obtain radiation pattern and to measure the directivity and gain of the following antennas:

1) Standard dipole (or printeddipole)
2) Micro strip patchantenna,
3) Yagi antenna(printed)

Procedure:

1. Set up the system as shown in circuit diagram-7 for a standard dipoleantenna.
2. Keeping the voltage at minimum, switch on the power thesupply.
3. Vary the power supply voltage and check the output for different VCO frequencies. The frequency at which the output becomes maximum is the resonantfrequency.
4. At the resonant frequency, adjust the distance between the transmitting and receiving antennas using the formula $S=2d^2/\lambda$
   where d is the broader dimension of the antenna.
5. Keepingboththeantennasinlineofsight(0^oattheturntable),tabulatethe output(E_t)
6. Rotate the turn table in clock-wise and anti clock-wise for different anglesof deflectionand tabulate the output for everyangle(E_r).
7. Plot a graph of angle vs.output.
8. Find the half power beam width (HPBW) from the points where the power becomes half(3 dB points or 0.707 VPoints)
9. Calculate Directivity and gain of the antenna by using theformula.
10. Repeat the experiment for a patch antenna and a yagiantenna.

An example of a Polar plot:



Calculation and observation:

***** Directivity of the antenna can be calculated by using the formula.

D=41253 / (HPBW)²

HPBW is the half power beam width in degrees.

* Gain of the antenna can be calculated using the formula:

$$G = \left(\frac{4\pi S}{\lambda}\right)\sqrt{\frac{P_r}{P_t}} \qquad G = \left(\frac{4\pi S}{\lambda}\right)\frac{E_r}{E_t}$$ **Gain in dB=10 log G.**

Where,

E_t and E_r are the signal strength measured using an oscilloscope at the transmitting end and at the receiving end respectively, when there the antennas are in line of sight

S is the actual distance kept between the antennas

λ is the wavelength found using the formula λ= c / f (f= frequency of operation)

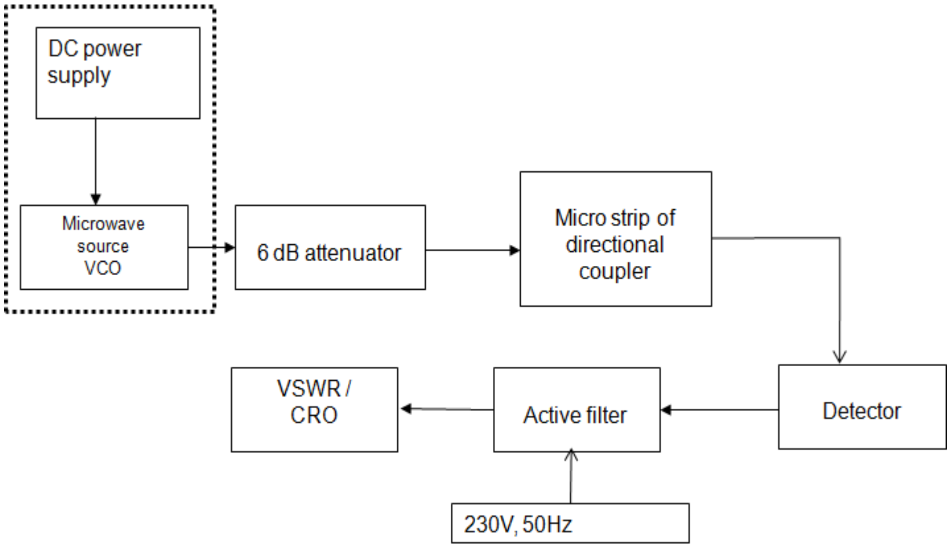
Note: For micro strip antenna $\boldsymbol{\lambda = \lambda_o / \epsilon_r}$

Result:

VIVA Questions

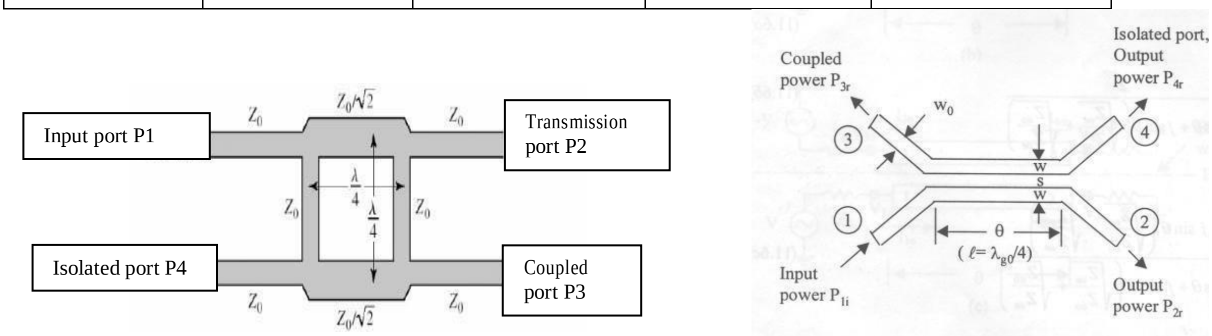
1. Define a Waveguide.
2. Give the S-Matrix for an idealwaveguide.
3. What is an optical fiber? What are itsadvantages?
4. Explain the principle of total internalreflection
5. What is meant by numericalaperture?
6. What is a ringresonator?
7. Define the following: Isolation, Coupling factor, and Insertionloss.
8. Mention the range of microwavefrequencies.
9. Explain the operation of a reflexklystron.

Circuit Diagram-8.1: To measure the characteristics of microstrip directional coupler



Calculation andobservation:

	Insertion loss	Coupling factor	Isolation	Directivity
VSWR meter	P_1-P_2	P_1-P_3	P_1-P_4	P_3-P_4
CRO	$20\log(V_1/V_2)$	$20\log(V_1/V_3)$	$20\log(V_1/V_4)$	$20\log(V_3/V_4)$



(a) **(b)**

Figure 11.2 Ports of adirectionalcoupler a)Branchline b) Parallelline

Tabulation:

I/P at port 1	O/P at port 2	O/P at port 3	O/P at port 4	Insertion loss	Isolation	Coupling factor	directivity

ExperimentNo.8 **Date:___/___/ _____**

A. DIRECTIONALCOUPLER

Aim: To conduct an experiment to measure the coupling factor, directivity, isolation characteristics of the directional coupler.

Components required:

Sl No	Apparatus	Range	Quantity
1	Power supply	-	1
2	transmission line	50 Ω	
3	Directional coupler		1
4	terminators	50 Ω	2
5	Oscilloscope / VSWR meter	-	1

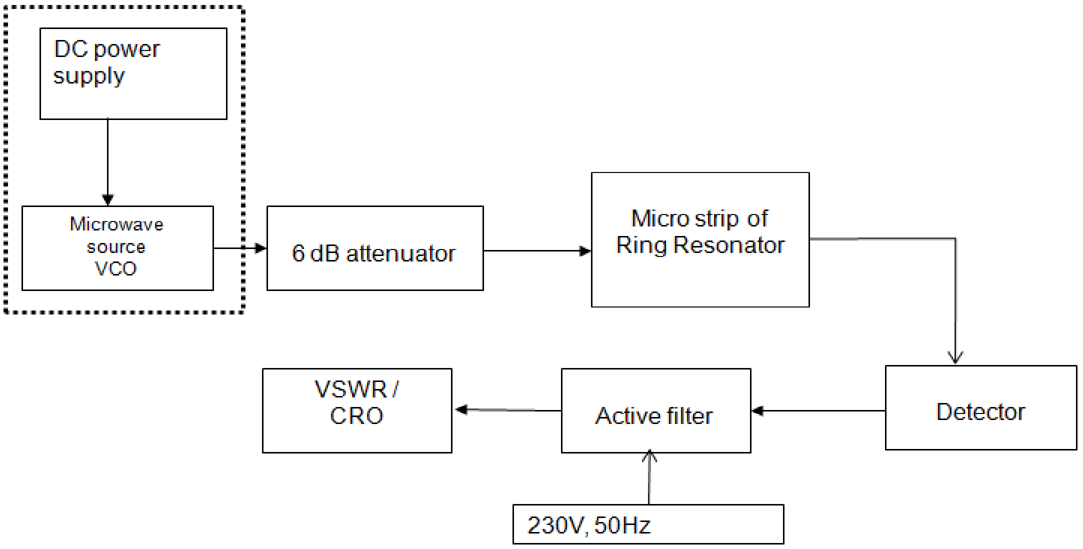
Procedure:

1. Set up the system as shown in circuitdiagram-8.1.
2. Keeping the voltage at minimum, switch on the powersupply.
3. Insert a 50 Ω transmission line and check for the output at the end of thesystem using a CRO/ VSWRmeter.
4. Vary the power supply voltage and check the output for different VCOfrequencies.
5. Note down the output for different outputfrequencies.
6. Replace the 50 Ω transmission line with branch linecoupler.
7. Check the output at port 2(throughput), 3(Coupled output), 4(isolatedoutput).
8. Calculate insertion loss, coupling factor and isolation using the formulaegiven.

Note: The coupled and Isolated ports of branch line Directional Coupler are respectively Isolated and Coupled ports in Parallel line Directional Coupler

Result:

Circuit Diagram-8.2: To measure the characteristics of microstrip Ring Resonator



Calculation and observation:

$$\lambda_1 = c/f_1 \quad ....(1)$$

$$\lambda_2 = c/f_2 \quad ....(2)$$

The effective dielectric constant of any material can be found using the formula:

$$\frac{\varepsilon_r+1}{2}+\left\{\frac{\varepsilon_r-1}{2}\left(\left[1+\frac{12h}{w}\right]^{-\frac{1}{2}}\right)\right\} ....(3)$$

Where, h= height of the known sample(substrate used for ring resonator)

w= width of ring resonator

The effective dielectric constant of the unknown material can be found using the relation

$$\pi d_m = \lambda_1/\epsilon_1 = \lambda_2/\epsilon_2 ....(4)$$

where d_m = diameter of the ring resonator

ϵ_1 = effective dielectric constant of known material

ϵ_2 **=** effective dielectric constant of unknown material

Now Using equation (3) find the dielectric constant ϵ_r of the unknown material

B. RING RESONATOR

Aim: To conduct an experiment to measure resonance characteristics of a micro strip ring resonator and to determine the dielectric constant of the substrate.

Components required:

Sl No	Apparatus	Range	Quantity
1	Power supply	-	1
2	Transmission line	50 Ω	
3	Ring resonator	-	1
4	Terminators	50 Ω	1
5	Oscilloscope / VSWR meter	-	1

Procedure:

Part (a)

1. Set up the system as shown in circuitdiagram-8.2.
2. Keeping the voltage at minimum, switch on the powersupply.
3. Insert a 50 Ω transmission line and check for the output at the end of thesystem using a CRO/ VSWRmeter
4. Vary the power supply voltage and check the output for different VCO frequencies. Set the frequency to the maximum outputvoltage.
5. Replace the 50 Ω transmission lines with ringresonator.
6. Vary the supply voltage, tabulate VCO frequency vs.output.
7. Plot a graph frequency vs. output and find the resonantfrequency

Part (b)

1. Select a VCO frequency (say f_1) where there is a measurable output. Note down the magnitude /power level of theoutput.
2. Placetheunknowndielectricmaterialontopofthe ringresonator.Ensurethatthere is no air gap between dielectric piece and the resonatorsurface.
3. Observe the change in magnitude /power level at theoutput.
4. Now reduce the supply voltage till maximum power level (before inserting the dielectric) is achieved. This is the new resonance condition due to the insertion of new dielectric material (eg:Teflon)
5. Note down the VCO frequency (sayf_2)
6. Calculate the dielectric constant of the unknown material by using theformula

Tabular Column:

f_1	λ_1	f_2	λ_2	Effective dielectric constant of the unknown material, ϵ_r

Sample calculation:

For the known material:

f_1 = 5GHz, h=0.762 mm w=1.836 mm ϵ_{r1} = 3.2

$\lambda_1 = c/f_1 = 3 \times 10^{10} / 5 \times 10^{09}$ = 6cm

$\epsilon_{eff\ 1} = \epsilon_1 = [(3.2+1)/2] + [(3.2-1)/2] \{ [1+(12x0.762/1.836)]^{-1/2} \}$

= 2.717

For the unknown material

f_2= 4.6 GHz h=0.762 mm w=1.836 mm ϵ_{r2} = ?

$\lambda_2 = c/f_2 = 3 \times 10^{10} / 4.6 \times 10^{09}$ = 6. 52cm

Using the values of $\boldsymbol{\lambda_1}$ and $\boldsymbol{\lambda_2}$ in equation 4 calculate the effective dielectric constant of the unknownmaterial

$\lambda_1 / \epsilon_1 = \lambda_2 / \epsilon_2$

$6/2.712 = 6.52 / \epsilon_2$

ϵ_2 =2.947

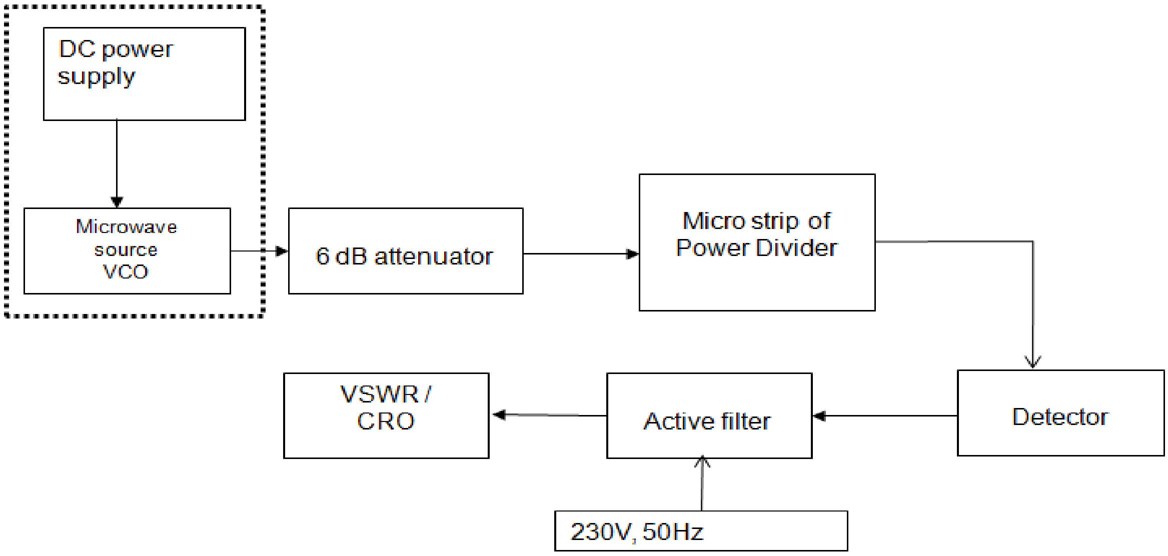
Using this value in equation (3)

$\epsilon_{eff\ 2} = \epsilon_2$ =2.947= $[(\epsilon_r+1)/2] + ([(\epsilon_r-1)/2] \{ [1+(12x0.762/1.836)]^{-1/2} \})$

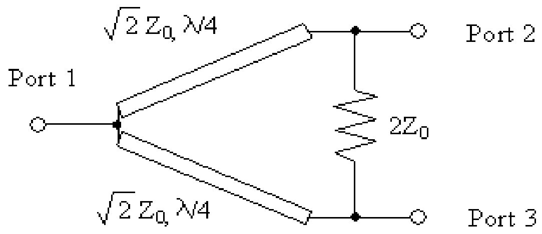
The effective dielectric constant of the unknown material, ϵ_{r2} =2.59

Result:

Circuit Diagram: Setup to measure the characteristics of microstrip power divider



Calculation and observations:



With VSWR meter:

Isolation in dB = $P_3 - P_2$

Power division in dB at arm 3 = $P_3 - P_1$

Power division in dB at arm 2 = $P_2 - P_1$

Figure 12.4 PowerDivider

WithCRO:

Isolation between port 2 and 3 = $20 \log (V_3/V_2)$

Coupling factor in dB at arm 3 = $20 \log (V_3/V_1)$

Coupling factor in dB at arm 2 = $20 \log (V_2/V_1)$

Tabulation:

I/P at port 1	O/P at port 2	O/P at port 3	Isolation between port 2&3	Coupling factor at arm 2	Coupling factor at arm 3

C. POWERDIVIDER

Aim: To conduct an experiment to measure power division and isolation characteristics of micro strip 3dB power divider.

Components required:

Sl No	Apparatus	Range	Quantity
1	Power supply	-	1
2	Transmission line	50 Ω	
3	Power divider	-	1
4	Terminators	50 Ω	1
5	Oscilloscope / VSWR meter	-	1

Procedure:

1. Set up the system as shown in circuitdiagram-8.3.
2. Keeping the voltage at minimum, switch on the powersupply.
3. Insert a 50 Ω transmission line and check for the output at the end of thesystem using a CRO/ VSWRmeter
4. VarythepowersupplyvoltageandchecktheoutputfordifferentVCOfrequencies.Set the frequency to the maximum outputvoltage.
5. Replace the 50 Ω transmission lines with the Wilkinson powerdivider.
6. Tabulate the output at ports 2 and3
7. Calculate insertion loss and coupling factoring each coupledarm
8. Calculate the isolation between ports 2 and 3 by feeding the input to port 2 and measure output at port 3 by terminating port1.

Result:

VIVA Questions

1. Define a Waveguide.
2. Give the S-Matrix for an idealwaveguide.
3. What is an optical fiber? What are itsadvantages?
4. Explain the principle of total internal reflection.

MATLAB-SIMULINK

Simulink is asimulation and model-based design environment for dynamic and embedded systems, integrated with MATLAB. Simulink, also developed by MathWorks, is a dataflow graphical programming language tool for modelling, simulating and analyzing multi-domain dynamic systems. It is basically a graphical block diagramming tool with customizable set of block libraries. It allows you to incorporate MATLAB algorithms into models as well as export the
Simulation results into MATLAB for further analysis.

Simulink supports−

- System leveldesign
- Simulation
- Automatic code generation
- testingandverificationofembeddedsystems

There are several other add-on products provided by MathWorks and third-party hardware and software products that are available for use with Simulink.

The following listgives brief description of some of them−

Stateflowallowsdevelopingstatemachinesandflowcharts.

SimulinkCoderallowsthegenerationofCsourcecodeforreal-timeimplementationofsystemsautomatically.

xPCTargettogetherwith **x86-basedreal-timesystems** providean environment tosimulateandtestSimulinkandStateflowmodelsinreal-timeonthephysicalsystem.

EmbeddedCodersupportsspecificembeddedtargets.

HDLCoderallowstoautomaticallygeneratesynthesizableVHDLandVerilog.

SimEventsprovidesalibraryofgraphicalbuildingblocksformodellingqueuingsystems.

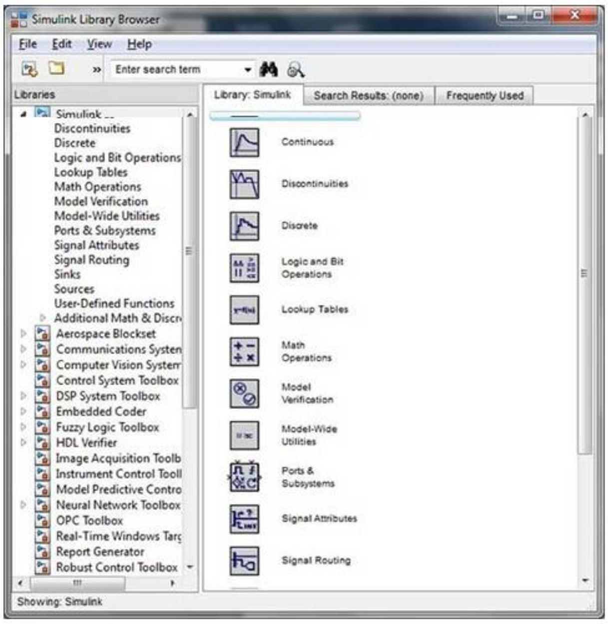
Simulinkiscapableofsystematicverificationandvalidationofmodelsthrough modellingstylechecking,requirementstraceabilityandmodelcoverage analysis. SimulinkDesignVerifierallowsyoutoidentifydesignerrorsandtogeneratetest casescenariosformodelchecking.

Using Simulink

ToopenSimulink,typeintheMATLABworkspace−

```
simulink
```

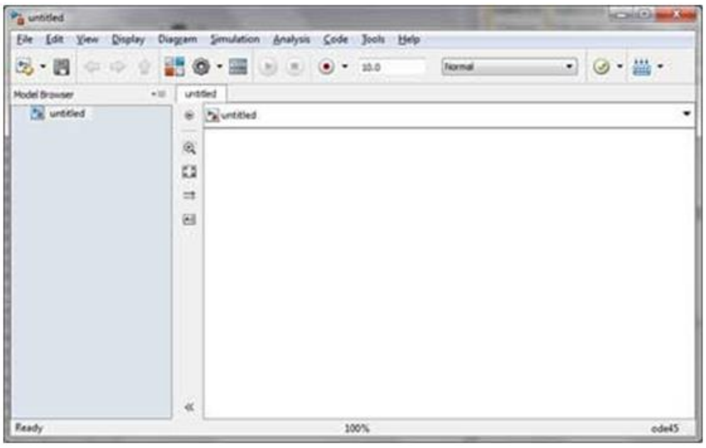
Simulinkopenswiththe**LibraryBrowser**.TheLibraryBrowserisusedforbuilding simulationmodels.



Ontheleftsidewindowpane,youwillfindseverallibrariescategorizedonthebasisofvarioussystems,clicking on eachonewill displaythedesign blockson therightwindowpane.

Building Models

TocreateanewModel,clickthe**New**buttonontheLibraryBrowser'stoolbar.Thisopens anewuntitledmodelwindow.



Simulinkmodelisablockdiagram.

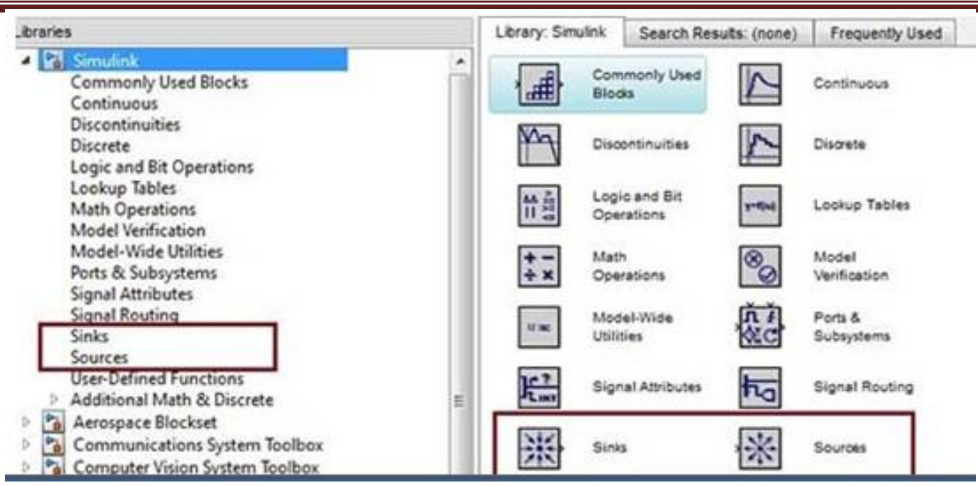
Modelelementsareaddedbyselectingtheappropriateelementsfromthe Library Browseranddraggingthemintothe Modelwindow.

Alternately,youcancopythemodelelementsandpastethemintothemodelwindow.

Examples

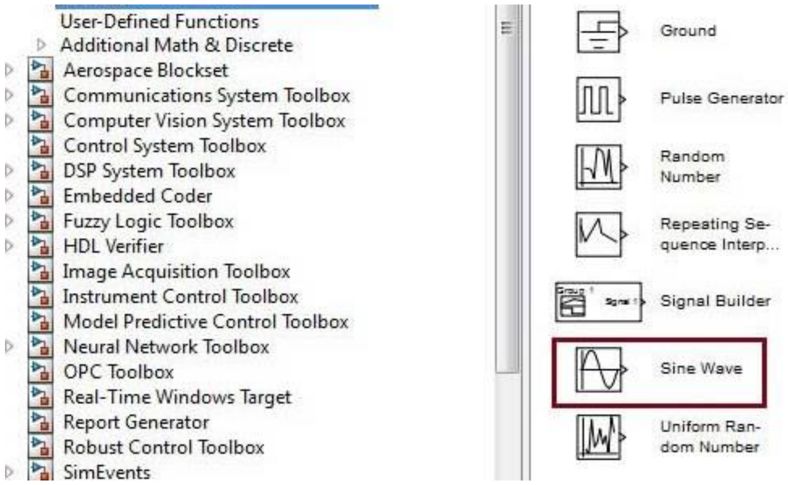
Draganddropitems fromtheSimulinklibrary tomakeyourproject.

For the purpose of this example, two blocks will be used for the simulation - A **Source** *asignal* and a**Sink** *ascope*. A signal generator *thesource* generates an analog signal, which will then be graphicallyvisualizedbythescope*thesink*.

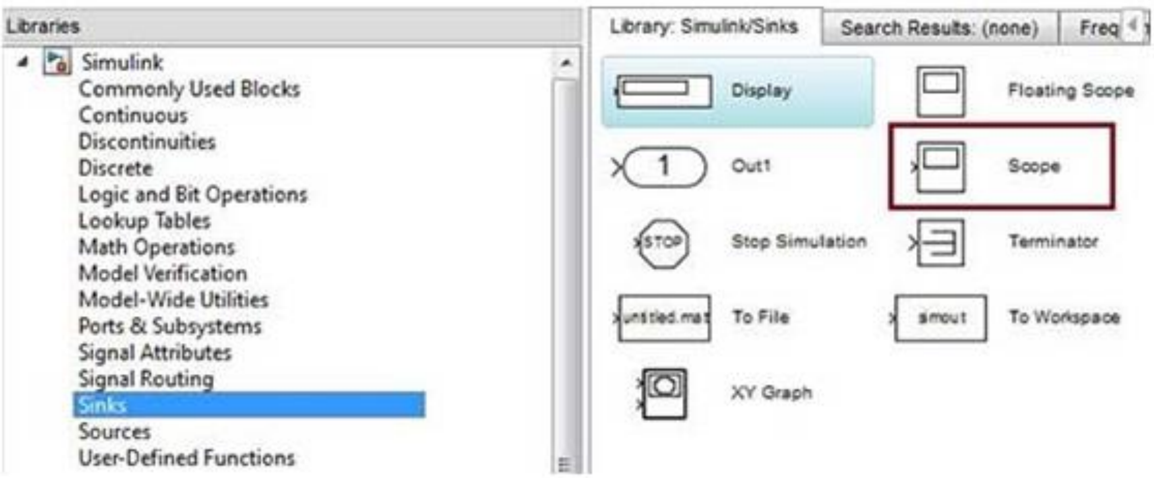


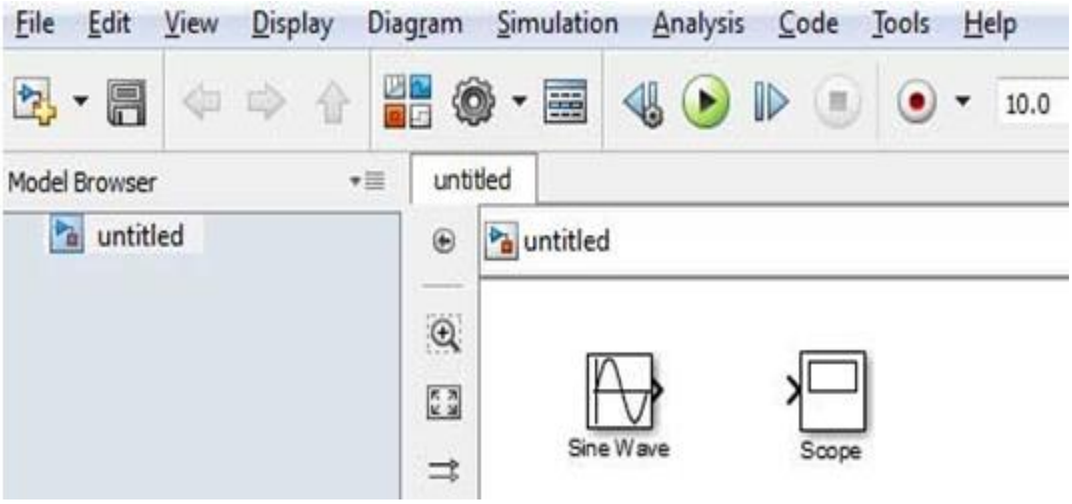
Begin by dragging the required blocks from the library to the project window. Then, connect theblockstogetherwhichcanbedonebydraggingconnectorsfromconnectionpointsononeblocktot hoseofanother.

Letusdraga'SineWave'blockintothemodel.

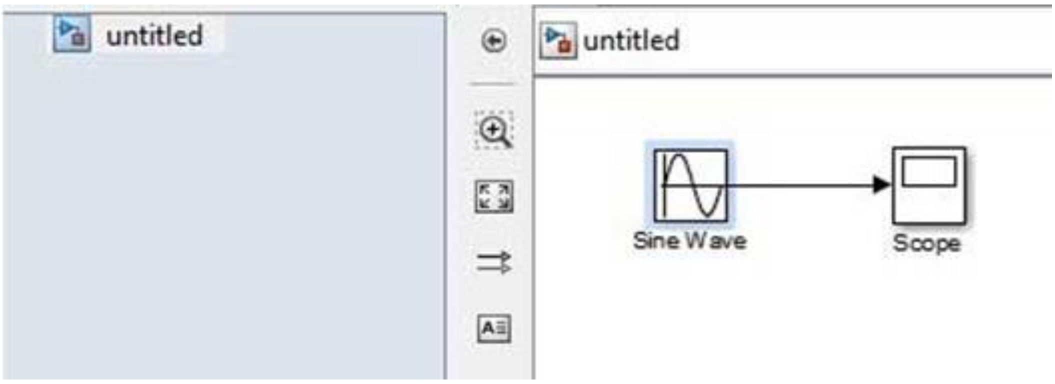


Select'Sinks'fromthelibraryanddraga'Scope'blockintothemodel.



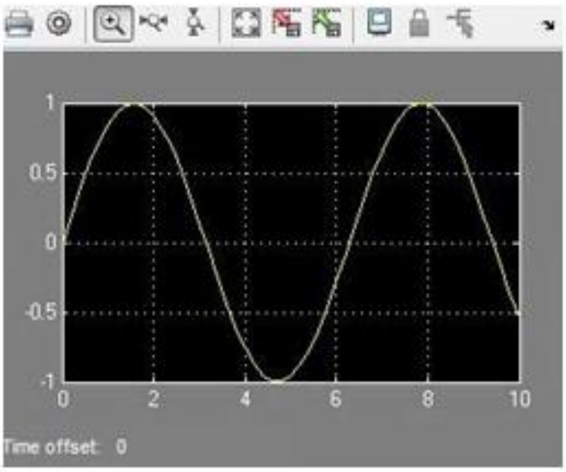


DragasignallinefromtheoutputoftheSineWaveblocktotheinputoftheScopeblock.

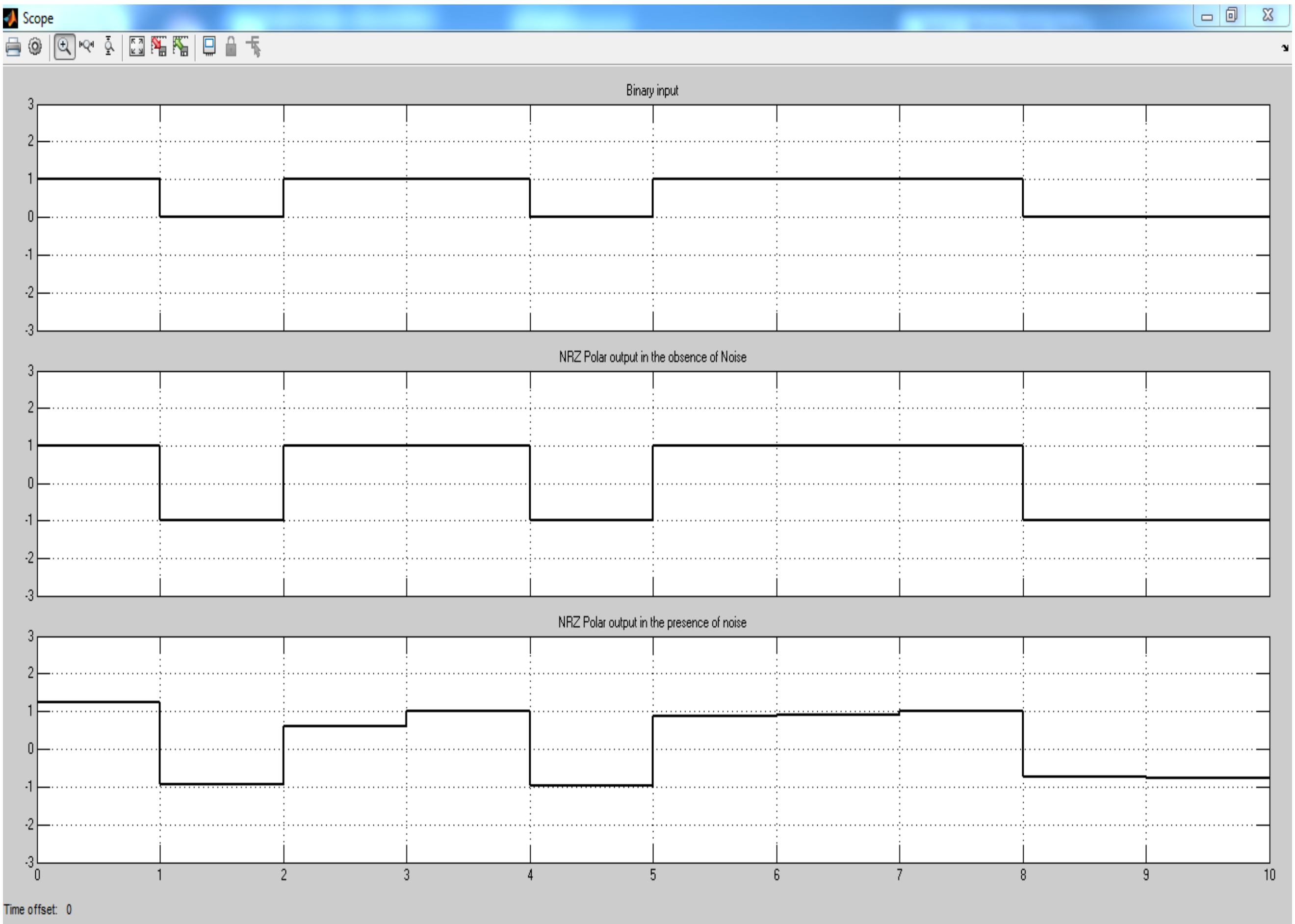


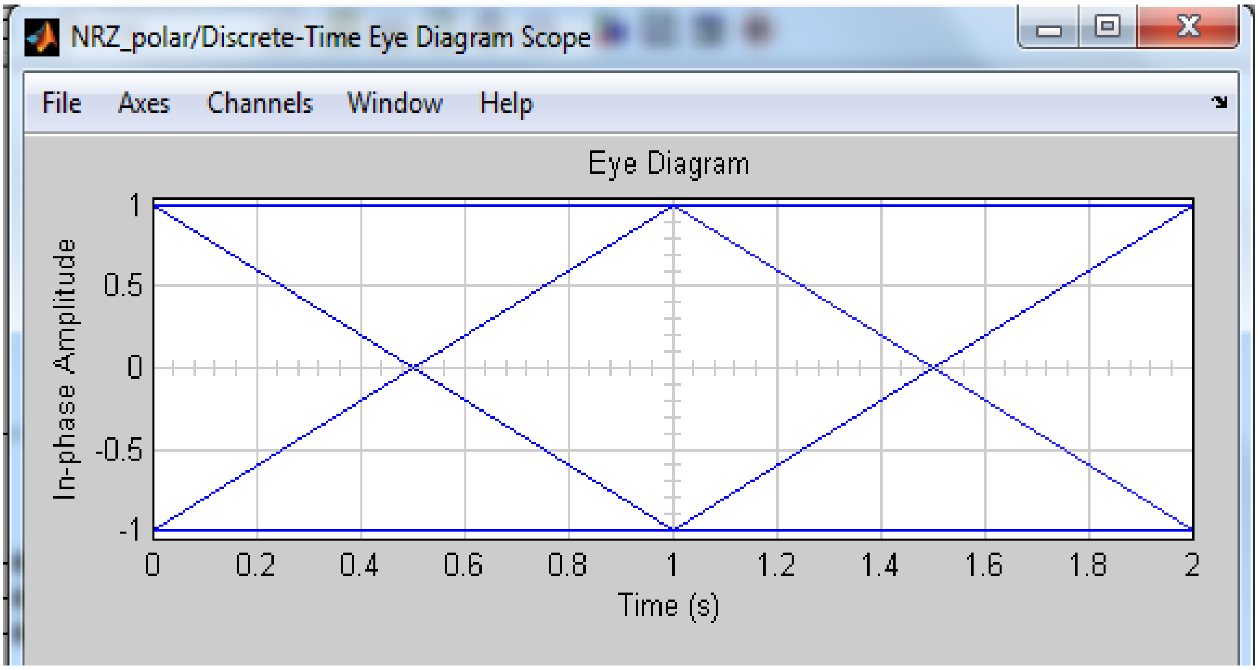
Runthesimulationbypressingthe'**Run**'button,keepingallparametersdefault
YoucanchangethemfromtheSimulationmenu.

Youshouldgetthebelowgraphfromthescope



Simulation Waveform:





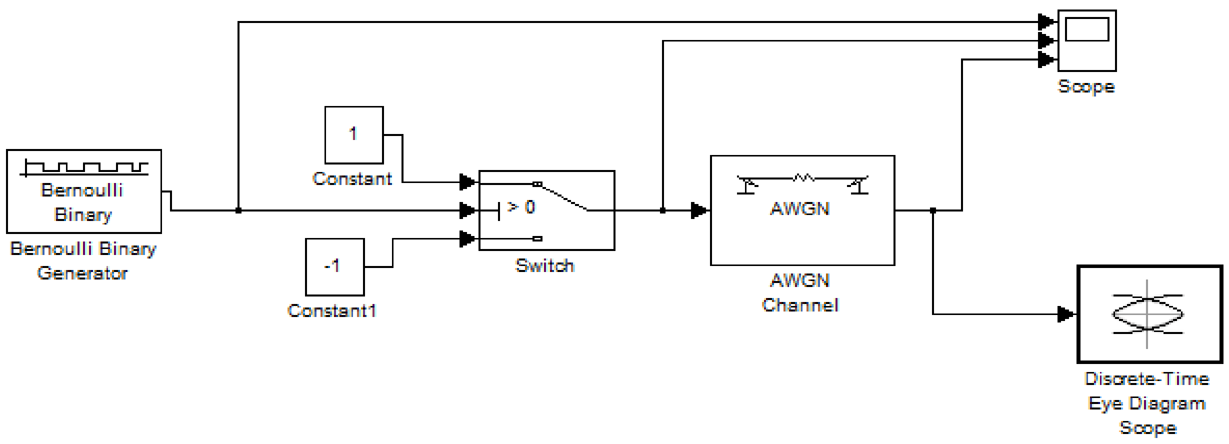
ExperimentNo.9 **Date:___/___/_______**

GENERATION OF LINE CODES

A. NRZ Polar

Aim: Simulate NRZ and generate eye diagram for binary polar signaling

Block Diagram of simulink:

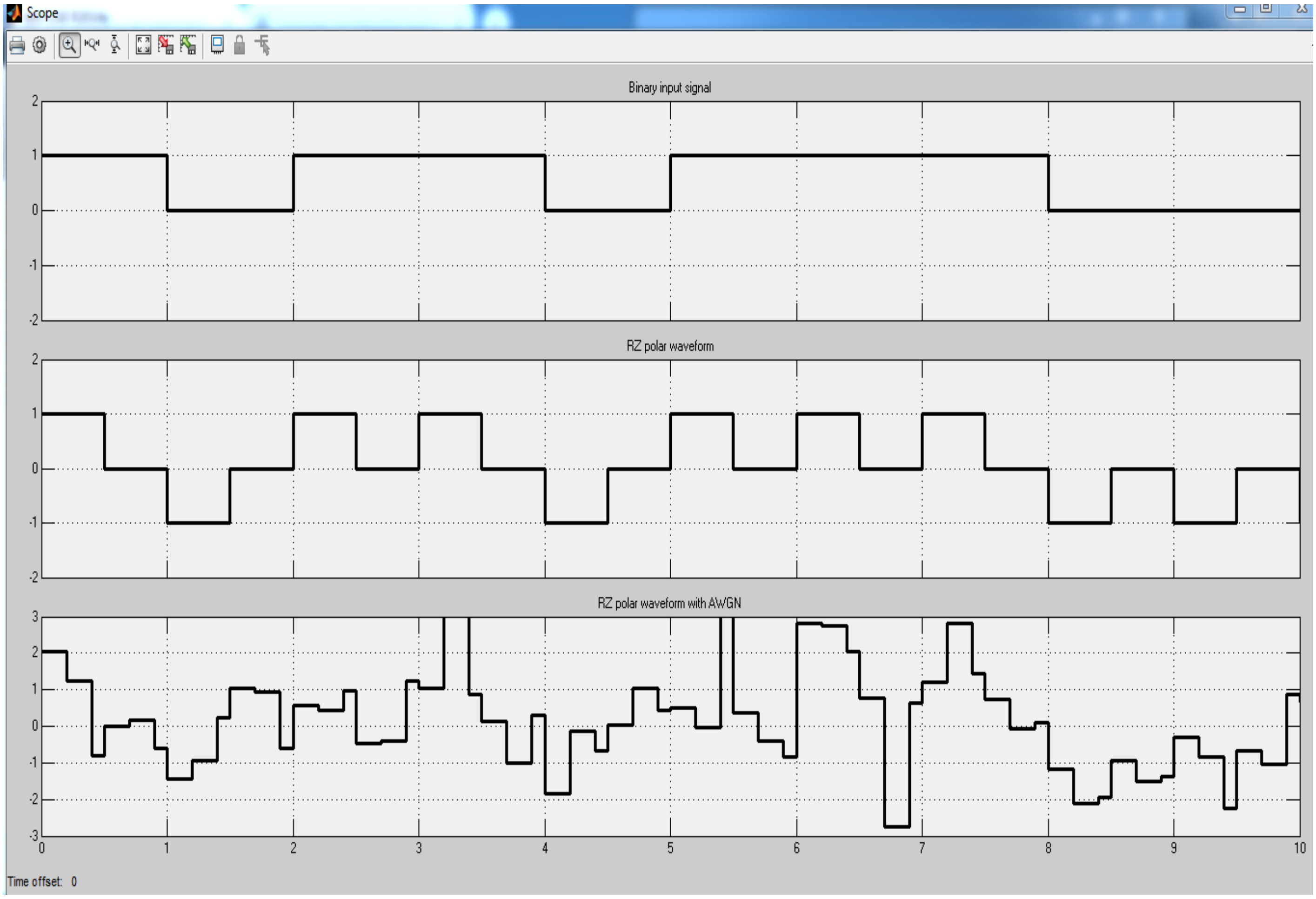


Parameter Settings for the Various Blocks in the Models of NRZ polar:

Name of Block	**Parameter to be set**
Bernoulli binary generator	Probability of zero=0.5
Constant & constant 1	1 & -1
Switch	Threshold =0
Awgn channel/ Bandlimited noise	Mode=SNR(Eb /No)/ Noise power =0.001
Discrete time Eye diagram scope	Samples Per symbol 8 or 2, symbols per trace=50
Scope	
Simulation time	Set to 100

Result:

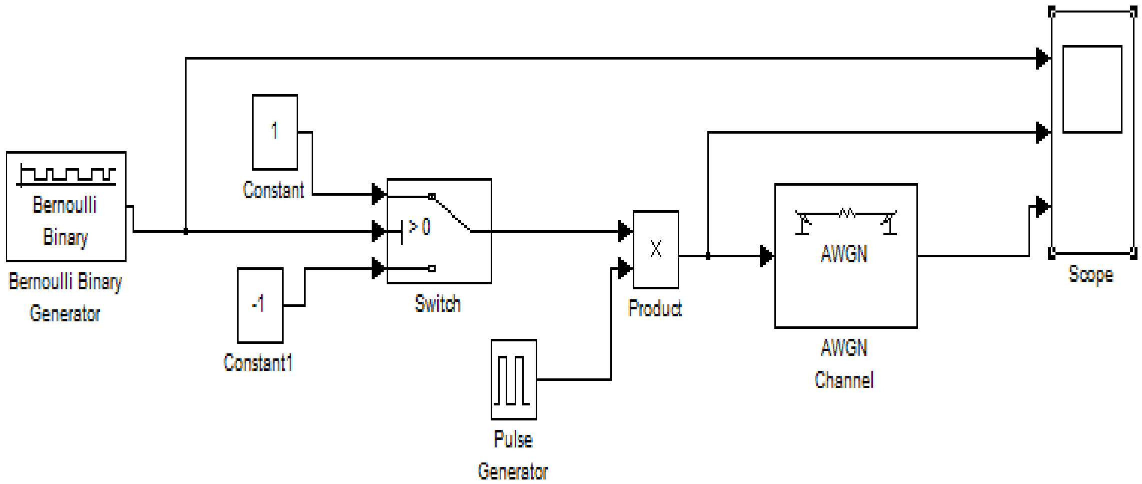
Simulation Waveform:



B. RZ Polar

Aim: Simulate RZ in the presence of AWGN channel and analyze the waveform.

Block Diagram of simulink:

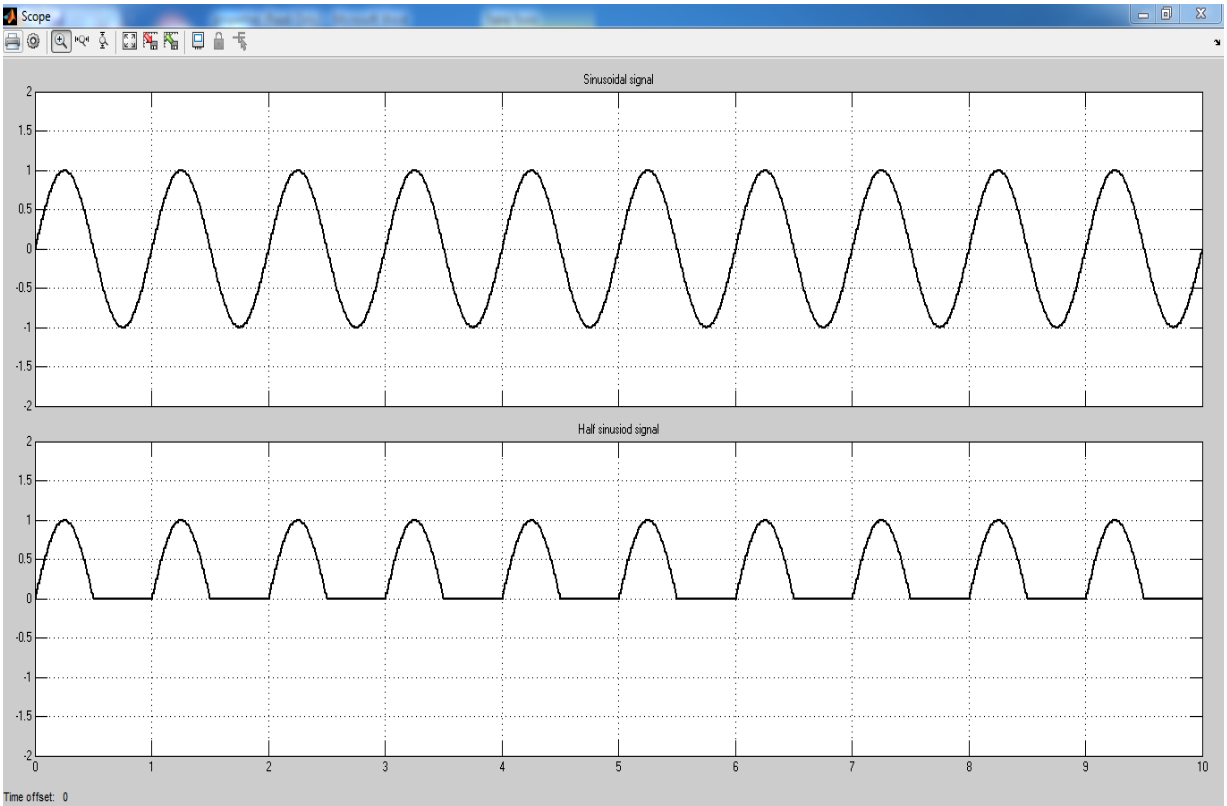


Parameter Settings for the Various Blocks in the Model of NRZ polar:

Name of Block	**Parameter to be set**
Bernoulli binary generator	Probability of zero=0.5
Constant & constant 1	1 & -1
Switch	Threshold =0
Pulse generator	Amp=1, freq=1,pulse width=50
Awgn channel	Mode=Variance from mask
Scope	

Result:

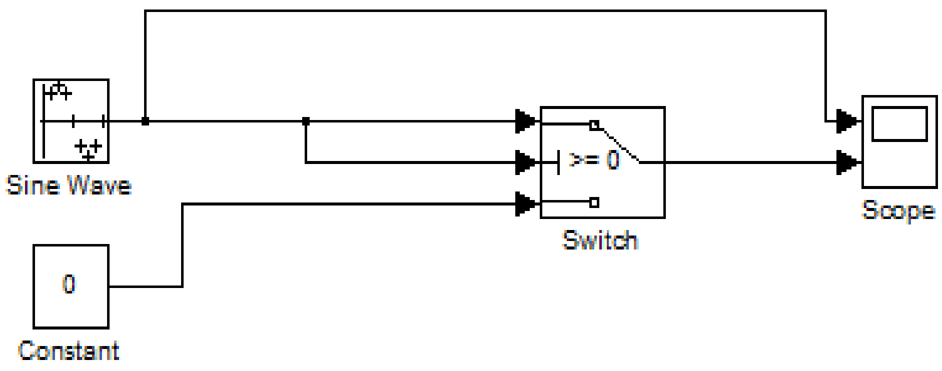
Simulation Waveform:



C. Half sinusoid

Aim: Simulate Half sinusoid pulse analyze the waveform.

Block Diagram of simulink:

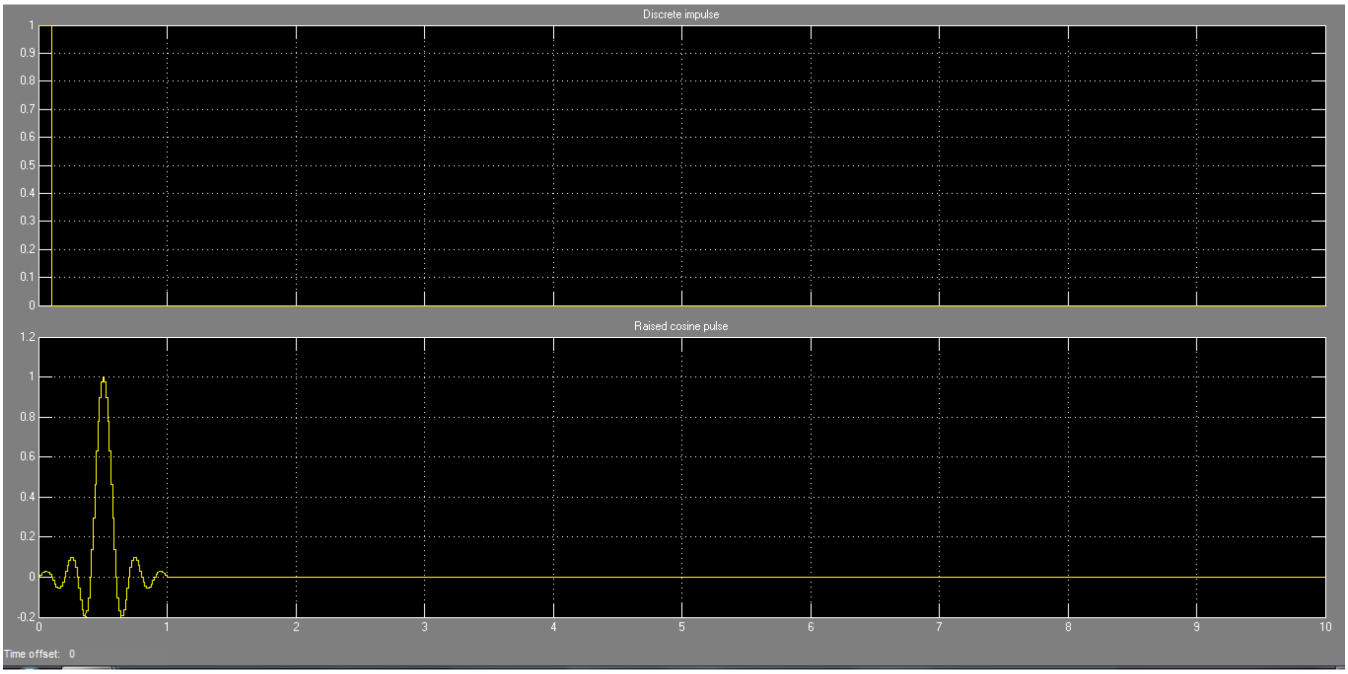


Parameter Settings for the Various Blocks in the Model of half sinusoid :

Name of Block	Parameter to be set
Sine wave	Sine type=sample based, Amp=1, samples per period=100, sample time =0.01
constant	Value=0
Switch	Threshold=0
Scope	

Result:

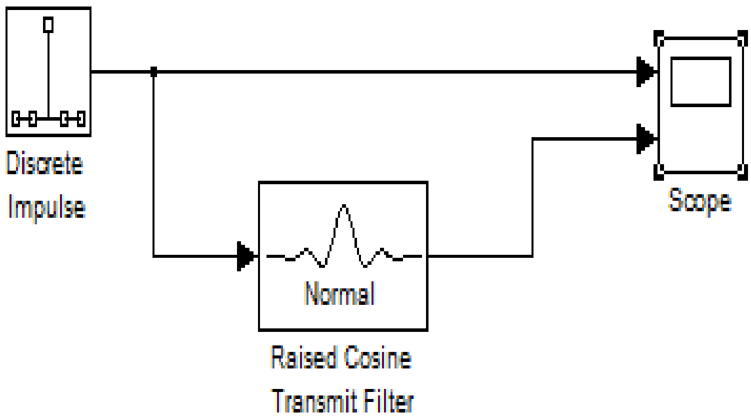
Simulation Waveform:



D. Raised cosine

Aim: Simulate Raised cosine pulse and analyze the waveform.

Block Diagram of simulink:

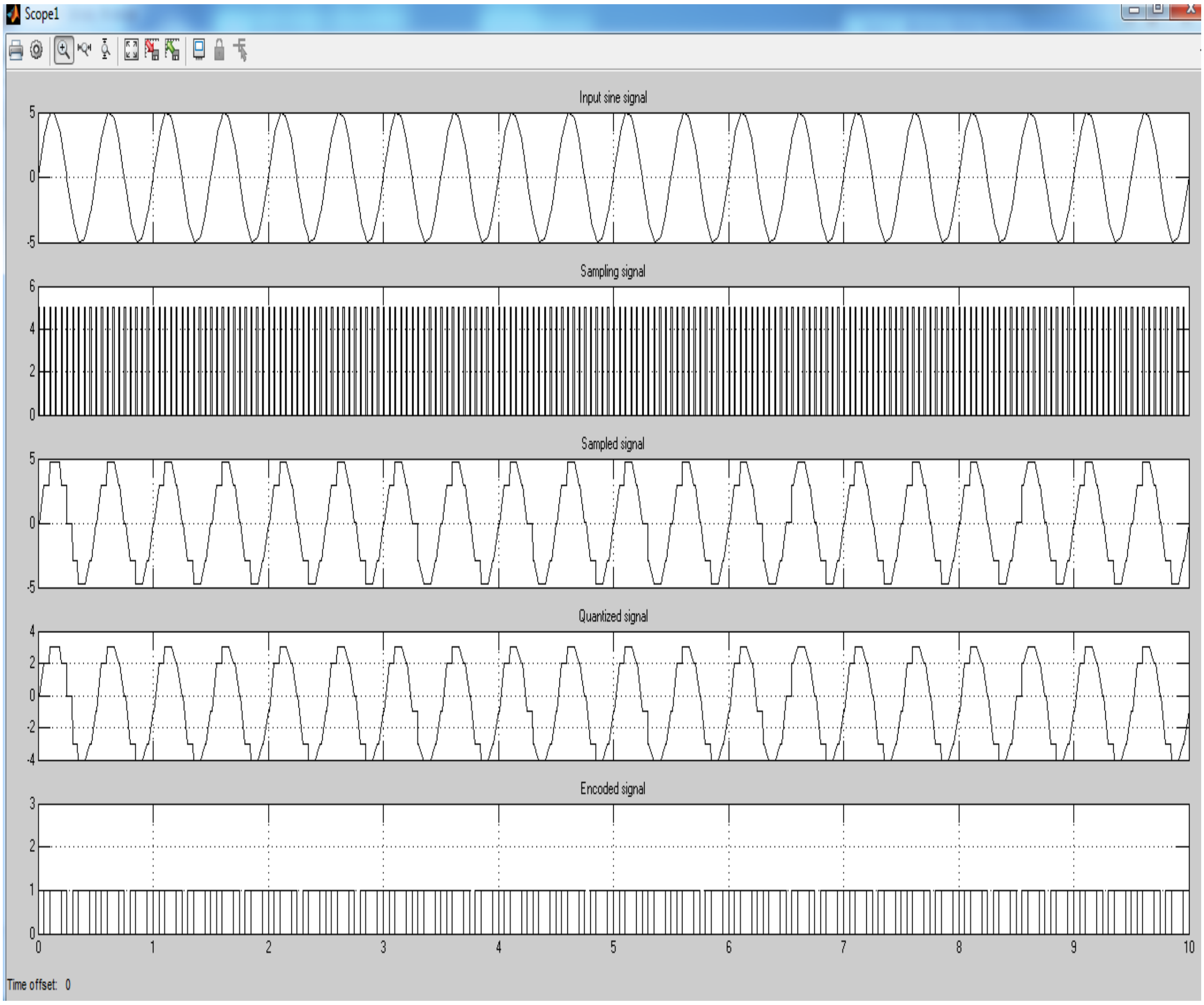


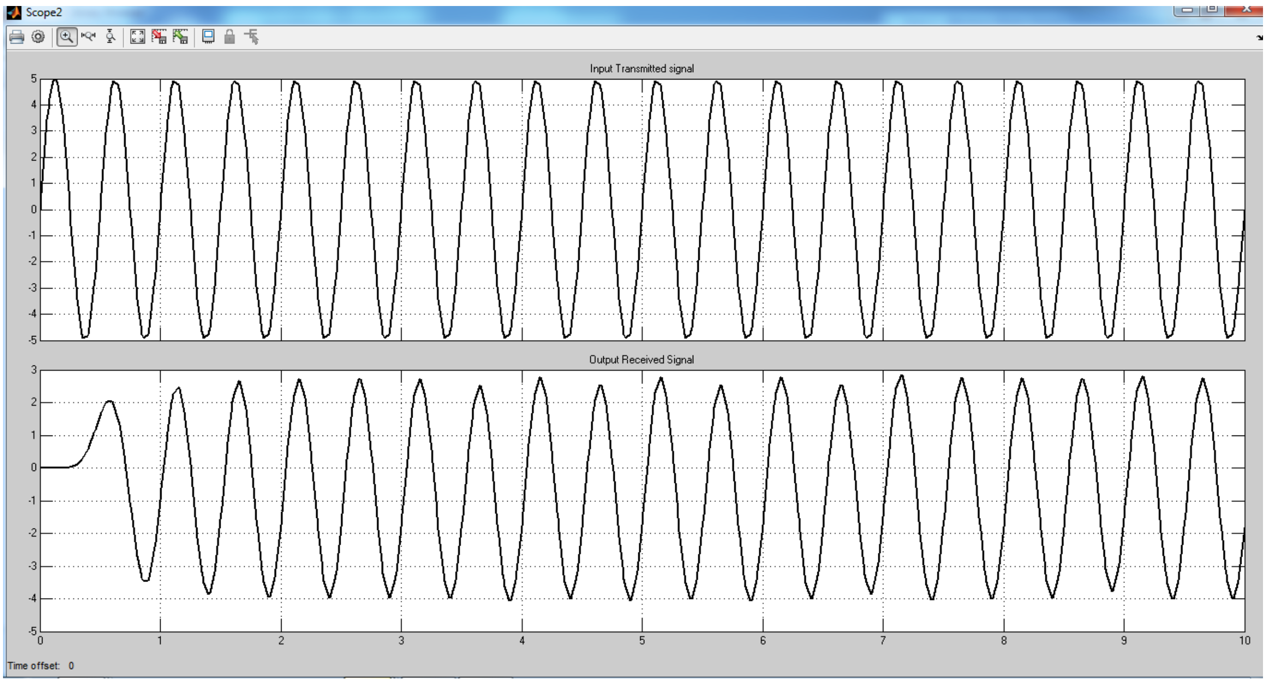
Parameter Settings for the Various Blocks in the Model of raised cosine:

Name of Block	Parameter to be set
Discrete impulse	Sample time=0.1
Raised cosine transmit filter	Filter shape=normal output samples per symble=100 amplitude gain=32, Input processing =elements as channel(sample based)
Scope	

Result:

Simulation Waveform:





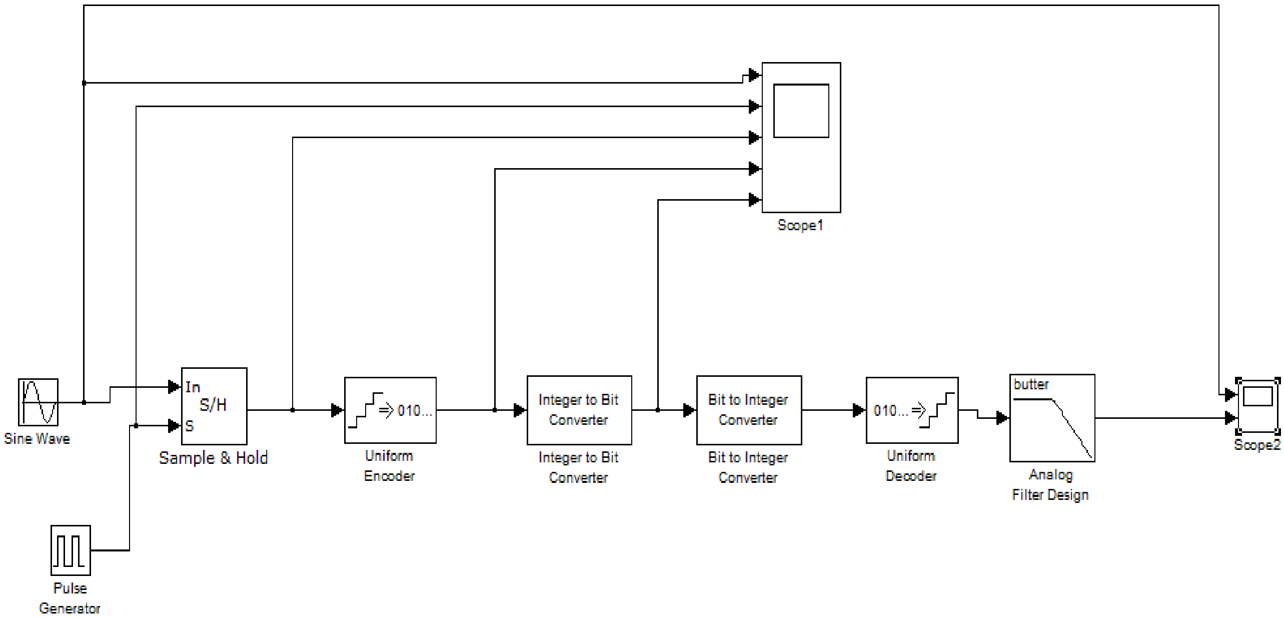
Result:

ExperimentNo.10 **Date:___/___/_______**

PCM

Aim: simulate pulse code modulation and demodulation system

Block Diagram of simulink:



Parameter Settings for the Various Blocks in the Model of PCM:

Name of Block	Parameter to be set
Sine wave	Amp=5, freq=2*pi*2
Pulse generator	Amp=5, freq=1/20,pulse width=20
Sample and hold	
Uniform encoder	Peak=5,bits=3,output type =signed
Integer to bit converter	Number of bits per integer =3,input type =signed
Bit to integer converter	Number of bits per integer =3,input type=signed
Uniform decoder	Peak=5,bits=3,output type =signed
Analog filter design	Pass band edge frequency=2*pi*2
scope	

Simulation Waveform:

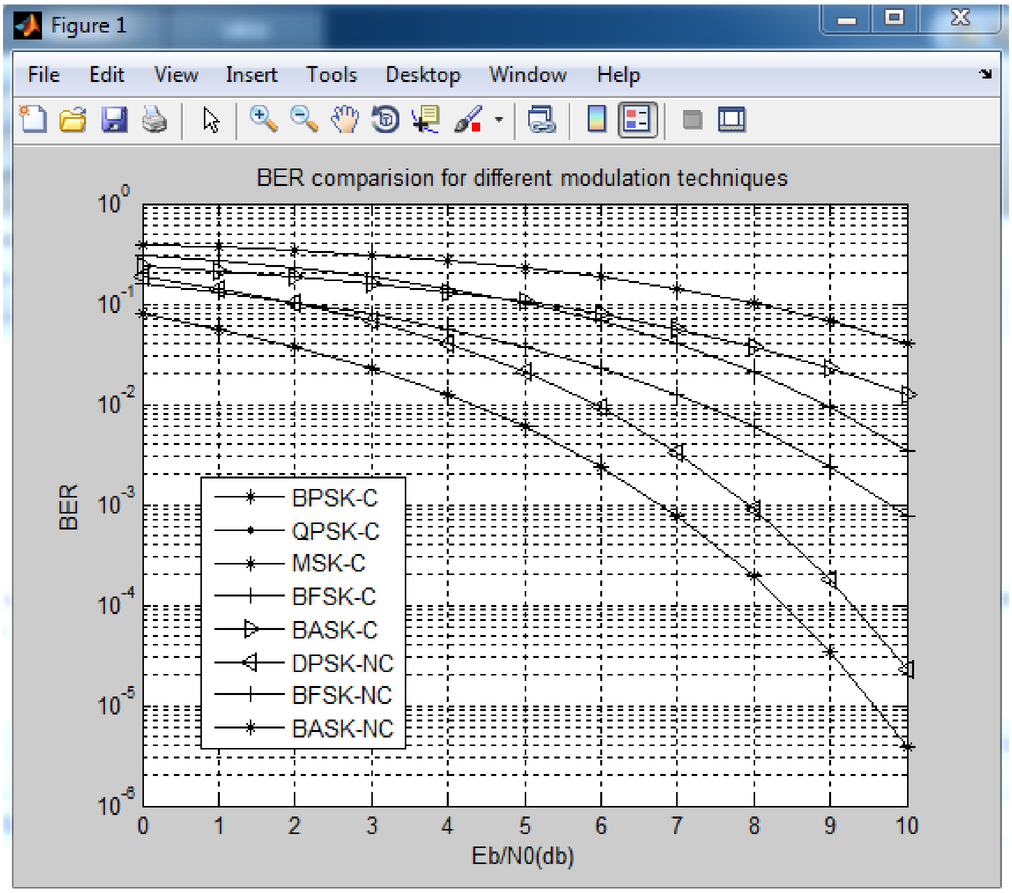


Figure 1
File Edit View Insert Tools Desktop Window Help
BER comparision for different modulation techniques
BER
Eb/N0(db)
BPSK-C
QPSK-C
MSK-C
BFSK-C
BASK-C
DPSK-NC
BFSK-NC
BASK-NC
0 1 2 3 4 5 6 7 8 9 10

ExperimentNo.11 **Date:___/___/_______**

BER Performance Analysis of M-ary DPSK Techniques

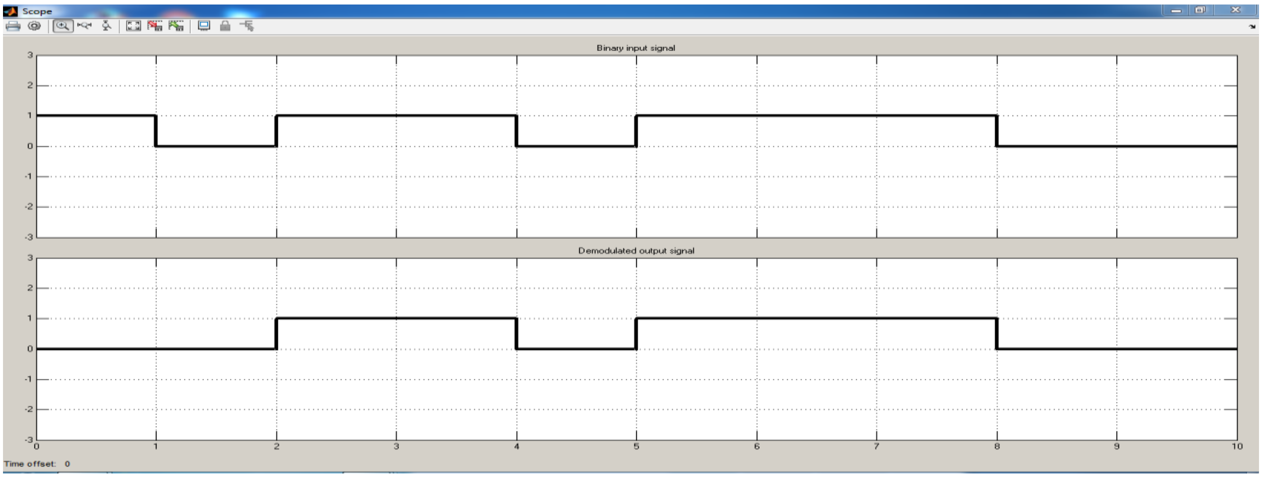
Aim: simulate pulse code modulation and demodulation system

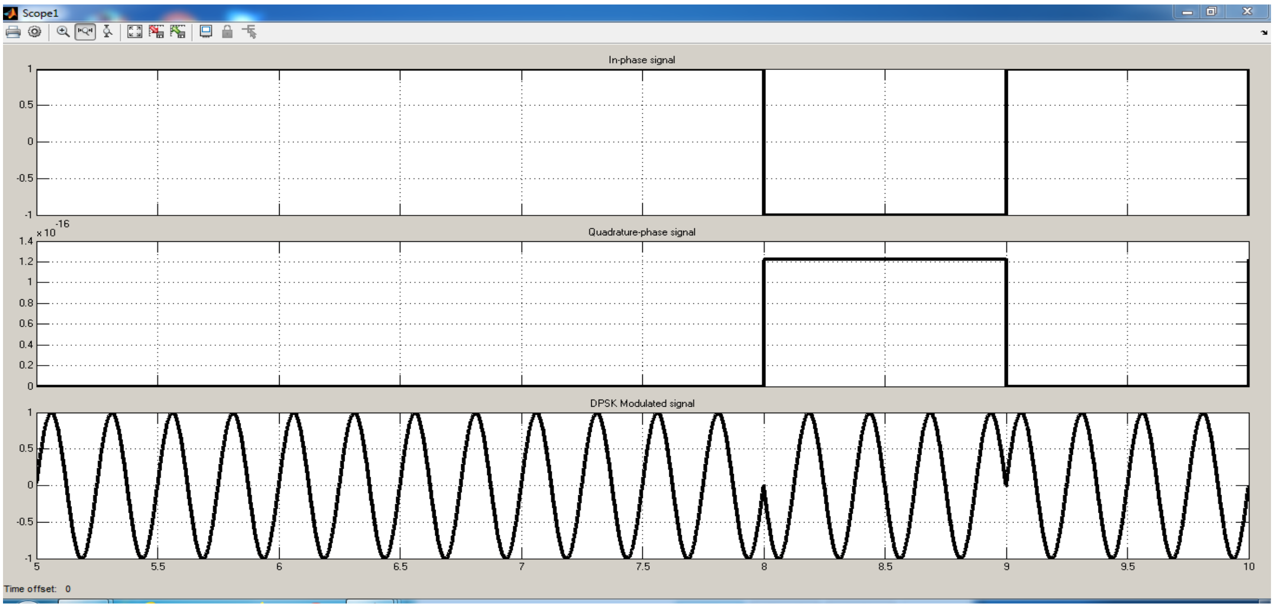
PROGRAM:

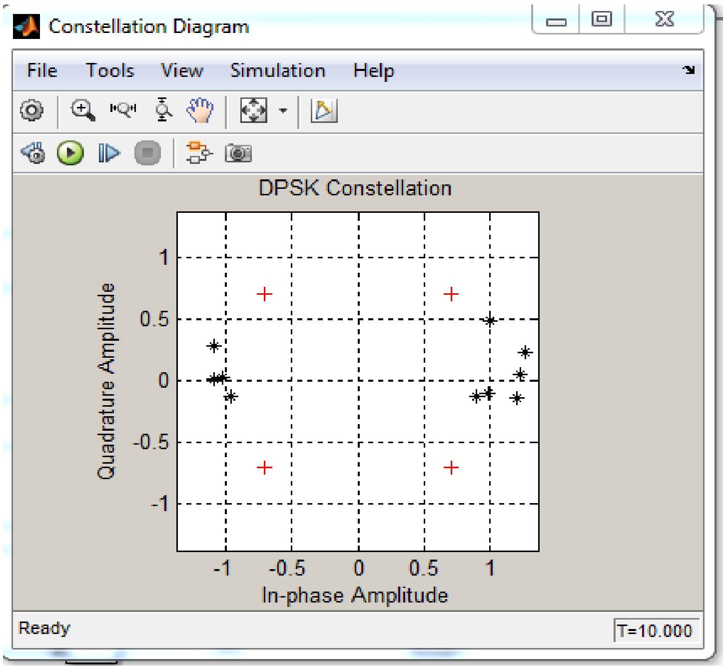
```
%BER Comparision of various modulation schemes

EbN0dB=0:10
EbN0=10.^(EbN0dB/10);
pe_bpsk=0.5*erfc(sqrt(EbN0));
pe_qpsk=0.5*erfc(sqrt(EbN0));
pe_msk=0.5*erfc(sqrt(EbN0));
pe_bfsk=0.5*erfc(sqrt(EbN0/2));
pe_bask=0.5*erfc(sqrt(EbN0/4));
pe_dpsk=0.5*exp(-EbN0);
pe_bfsk_nc=0.5*exp(-EbN0/2);
pe_bask_nc=0.5*exp(-EbN0/4);
semilogy(EbN0dB,pe_bpsk,'r*-',EbN0dB,pe_qpsk,'b.-',
         EbN0dB,pe_msk,'r*-',EbN0dB,pe_bfsk,'k+-',
         EbN0dB,pe_bask,'m>-',EbN0dB,pe_dpsk,'g<-',
         EbN0dB,pe_bfsk_nc,'b+-',EbN0dB,pe_bask_nc,'c*-');
 legend('BPSK-C','QPSK-C','MSK-C','BFSK-C','BASK-C',
        'DPSK-NC','BFSK-NC','BASK-NC');
 xlabel('Eb/N0(db)');
 ylabel('BER');
 title('BER Comparison for different modulation techniques');
 grid on
```

Result:

Simulation Waveform:







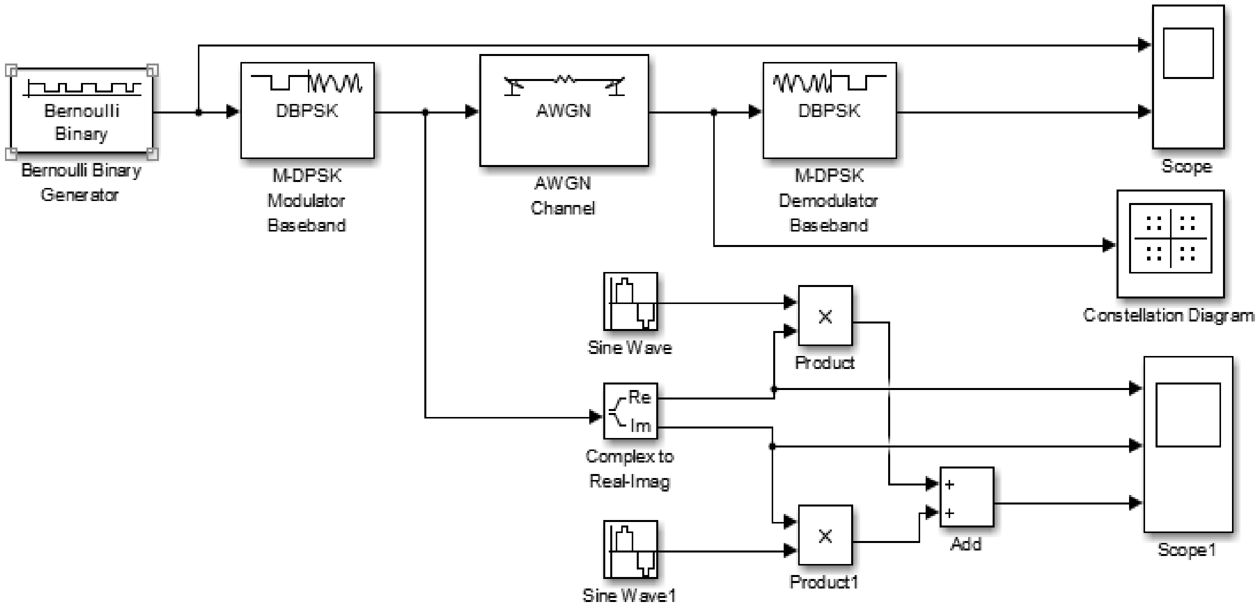
ExperimentNo.12 **Date:___/___/_______**

Digital Modulation schemes: DPSK & QPSK

A. Simulation of DPSK transmitter and receiver. Plot the signals and its constellation diagram:

Aim: Simulation of DPSK transmitter and receiver & Plot the signals and its constellation diagram:

Block Diagram of Simulink:

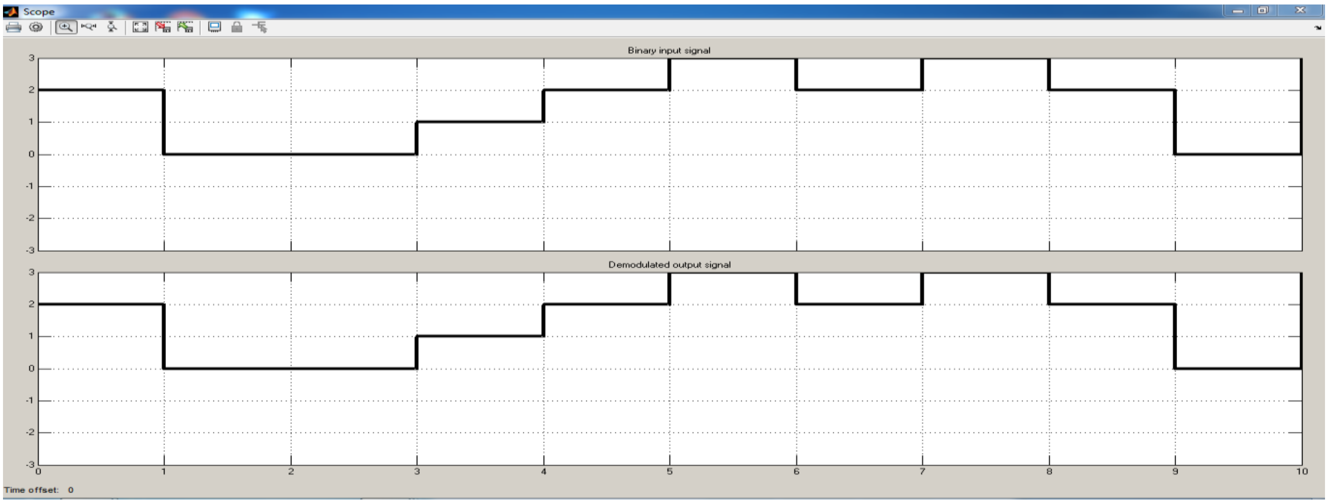


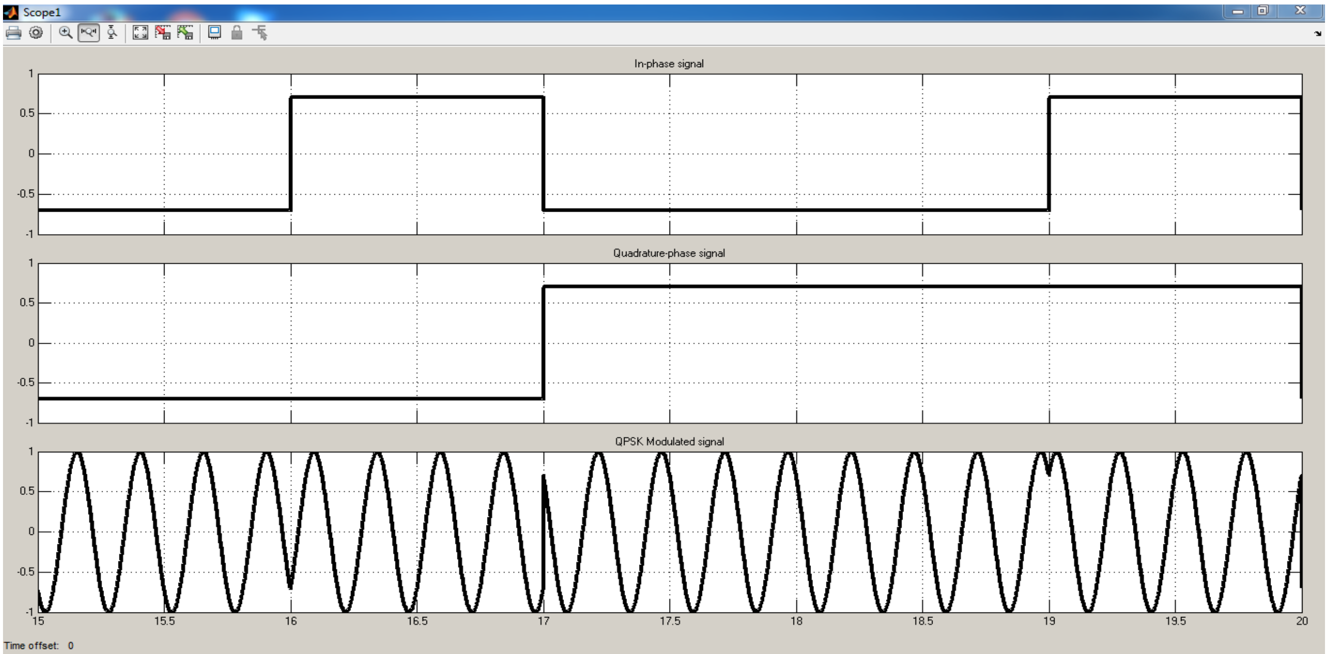
Parameter Settings for the Various Blocks in the Model of QPSK(Tx & Rr):

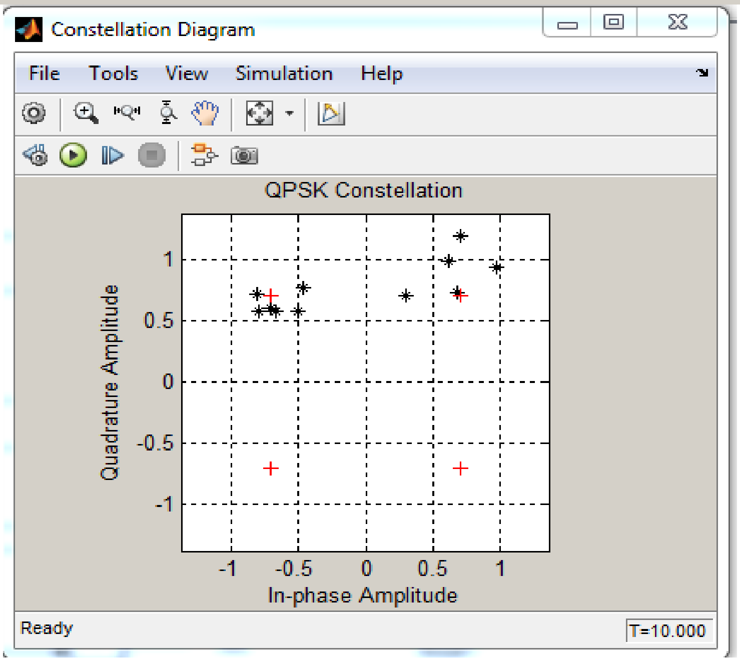
Name of Block	Parameter to be set
Bernouli binary generator	M-ary number =2
Dpsk modulator	M-ary number =2,Phase rotation =pi
Dpsk demodulator	M-ary number =2, Phase rotation =pi
Awgn channel	-
Complex to real & imaginary	-
Sine wave	Freq=8*pi ,phase= 0, sample time =0.001
Sine wave 1	Freq=8*pi ,phase =pi/2, sample time =0.001
Product	-
Add	-
Scope	-
Constellation diagram	Symbols to display=choose user defined set to 1000

Result:

Simulation Waveform:



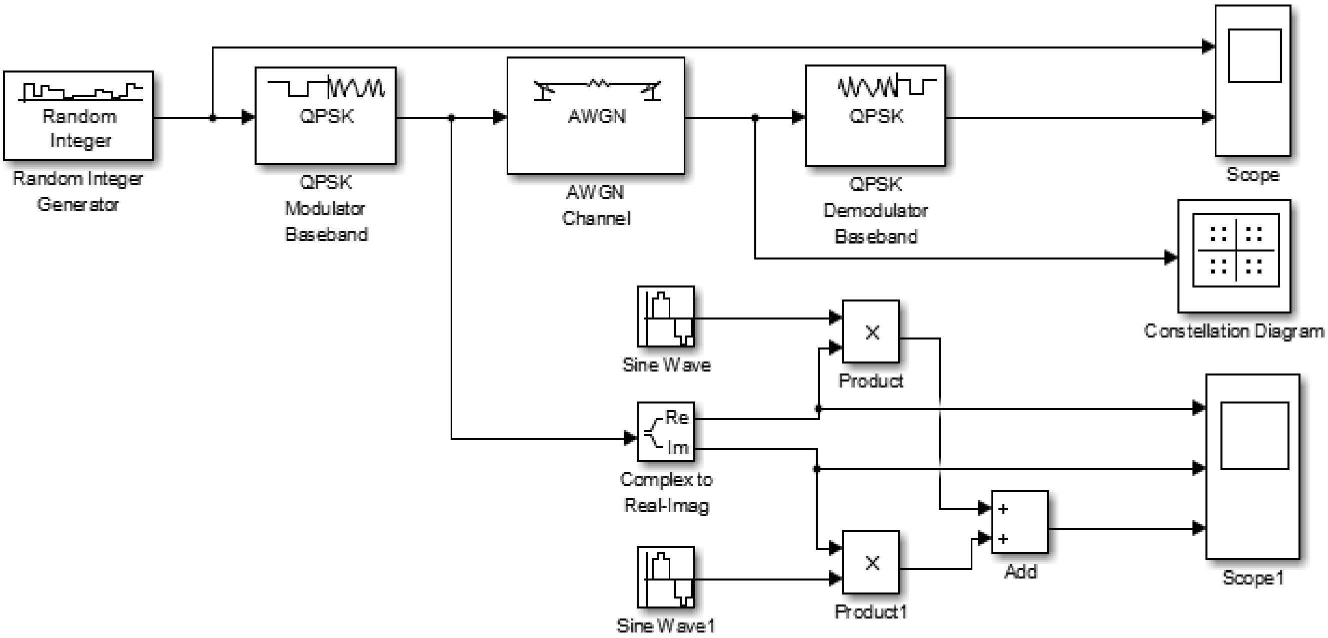




B. Simulation of QPSK transmitter and receiver. Plot the signals and its constellation diagram:

Aim: Simulation of QPSK transmitter and receiver & Plot the signals and its constellation diagram:

Block Diagram of Simulink :



Parameter Settings for the Various Blocks in the Model of QPSK(Tx & Rr):

Random integer generator	Set size =4
Qpsk modulator	Phase offset =pi/4
Qpsk demodulator	Phase offset=pi/4
Awgn channel	Inputs per symbol =2
Complex to real & imaginary	-
Sine wave	Freq=8*pi ,phase= 0, sample time =0.001
Sine wave 1	Freq=8*pi ,phase =pi/2, sample time =0.001
product	-
add	-
scope	-
Constellation diagram	Symbols to display=choose user defined set to 1000

Result:

Sample Viva questions on Part B Experiments

1. What are line codes.
2. What are the different types of linecodes.
3. What are the applications of line codes.
4. What are the advantages of line codes.
5. What is Half sinusoid
6. What is raised cosine pulse.
7. Represent binary data 10100011 using NRZ polar ,bipoar, machestor coding techniques.
8. Represent binary data 10100011 using RZ polar ,bipoar, machestor coding techniques.
9. What is PCM.
10. What are the advantages of PCM.
11. What are the applications of PCM.
12. What is QPSK?
13. What is DPSK?
14. What are the advantages of QPSK over BPSK?
15. What are the advantages of DPSK over BPSK?
16. What are the advantages of DPSK over QPSK?
17. What is matlab simulink.
18. What are the advantages of simulink over matlab coding.

References

1. Simon Haykin, "Digital Communications", John Wiley & Sons,2008.
2. K. N. Hari Bhat and D. Ganesh Rao, "Digital Communications", Pearson , 3rdedition.
3. K. Sam Shanmugam, "An introduction to Analog and Digital Communication",John Wiley India Pvt. Ltd,2008.
4. John D. Krauss, "Antennas and Wave Propagation, 4th Edition, McGraw-Hill International edition,2010.
5. Annapurna Das, Sisir K. Das, " Microwave Engineering", Tata McGraw-Hill Education, 2nd edition,2000

Question Bank

1. Design and simulate an ASK system to transmit digital data using a suitable carrier. Demodulate the ASK signal with the help of suitable circuit. Determine the minimum frequency of carrier for properdetection.

2. Design and simulate the working of FSK with a suitable circuit for Hz and Hz carrier signals. Demodulate the FSK signal with the help of suitablecircuit.

3. Designandsimulatetheworkingof BPSKmodulatedsignalforagivencarriersignalof _______Hz. Demodulate the BPSK signal to recover the digitaldata.

4. Design and simulate the working of TDM for PAMsignalswith________Hzand_______Hz message signals. Also demultiplex the messagesignals.

5. Conduct a suitable experiment using slotted line carriage to obtain the following for the given load. a) λg and λob)VSWR

6. Conduct a suitable experiment using fiber optic trainer kit todetermine:
   a) Attenuation b) Bending loss c) Numericalaperture

7. With the help of suitable block diagram demonstrate the working of DPSK encoder and Decoder for the specified input stream and carrier frequency usingSimulink.

8. With the help of a suitable block diagram demonstrate the working of QPSK modulator and demodulator usingSimulink.

9. Conduct an experiment to obtain radiation pattern of micro strip dipole antenna. Also calculate the directivity and gain of theantenna.

10. Conduct an experiment to obtain radiation pattern of micro strip yagi antenna. Also calculate the directivity and gain of theantenna.

11. Conduct an experiment on a given micro strip directional coupler and power divider to determine the following: a) Isolation b) Coupling factor c) InsertionLoss

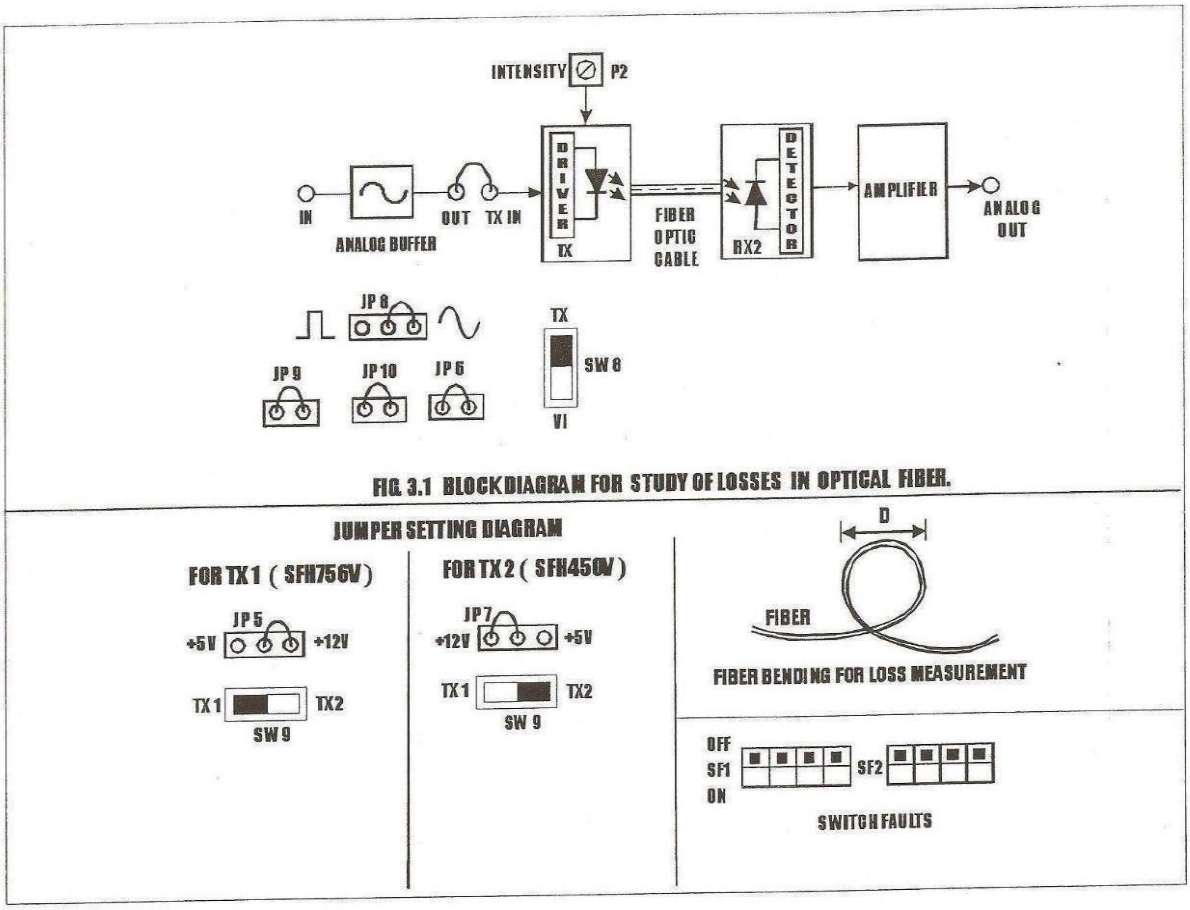
12. Conduct an experiment to find the characteristics of micro strip ring resonator. Also calculate the dielectric constant of the given dielectricmaterial.

13. Conduct an experiment to realize pulse code modulation usingMATLAB.

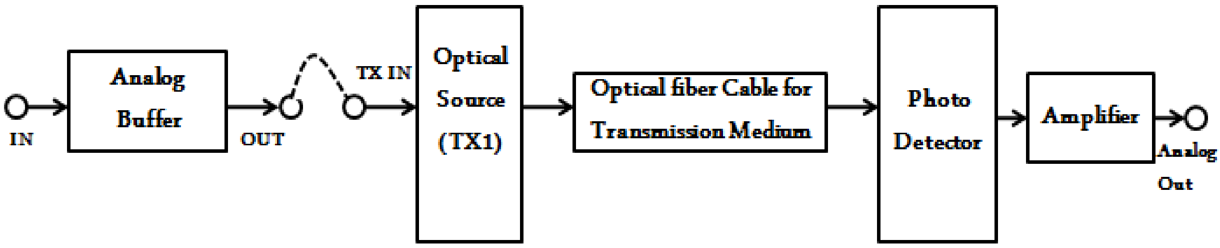
14. Simulate NRZ, RZ, half-sinusoid and raised cosine pulses for binary polar signalling.

BEYOND THE SYLLABUS: Extra Experiment

falcon fiber-optic kit set up for bending loss measurement



Block Diagram Representation:



EQUIPMENTS:

Link-B Kit with power supply patch chords
20 MHz Dual Channel Oscilloscope
1MHz Function Generator
1 & 3 Meter Fiber Cable

ExperimentNo.1 **Date:___/___/_______**

MEASURMENT OF LOSSES IN OPTICAL FIBER

Aim: To measure the losses in optical fiber also to obtain numerical aperture.

Apparatus Required:

Sl. No.	Apparatus	Range	Quantity
1	Link-B Kit		2
2	Link-B Kit Power Supply		1
3	Fiber Cable	1 Meter 0.5 m cable	1 1
4	Numerical Aperture measurement Jig		

Procedure to measure Attenuation (Falcon kit):

1. Make connections as shown in circuit diagram–9a Connect the power supply cables with proper polarity to Link-B kit, While connecting this, ensure that the power supply isOFF.
2. Keep SW9 towards TX1 position forSFH756.
3. Keep Jumpers & SW8 positions as shown. Keep Intensity control pot P2 towards minimum position. Switch ON the PowerSupply.
4. Apply 2Vpp sinusoidal signal of 1 kHz from the function generator to the INport of AnalogBuffer.
5. Connect the output port Out of Analog Buffer to the port TX IN ofTransmitter.
6. Connect the fiber from TX1 toRX2.
7. Observe the detected signal at port ANALOG OUT on oscilloscope. Adjust intensity to get 2Vpp amplitude at the Analog out. This voltage isV1.
8. Now replace 0.5 meter fiber by 1 meter fiber between same LED and Detector. Do not disturbanysettings.Againtakethepeakvoltagereadingandletitbe V2.

   If α is the attenuation of the Fiber then,

   $$\alpha_{dB} = (10/L_1 - L_2)\log_{10}(V_2/V_1)$$

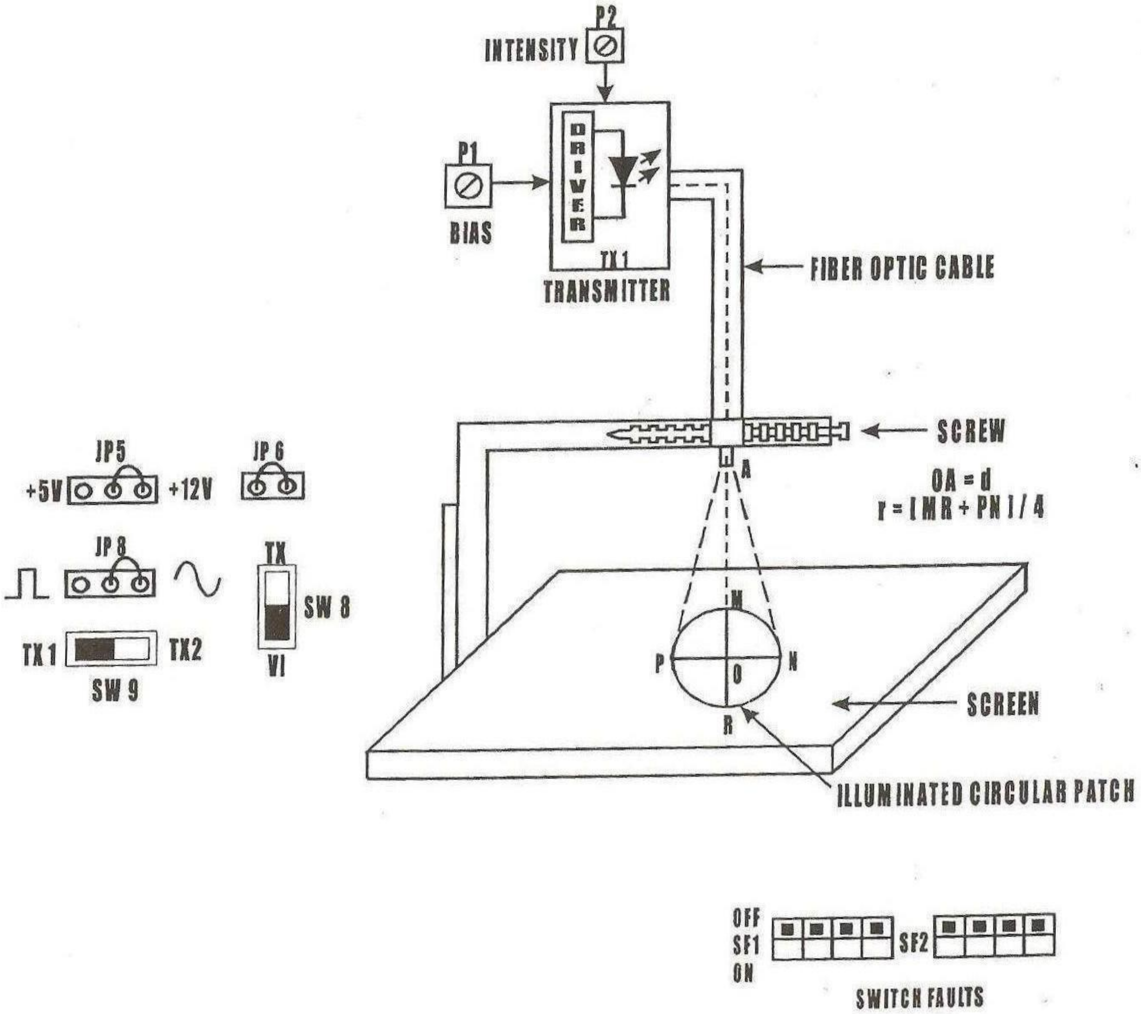
   where α = dB/Km

L1= Fiber Length for V1

L2=Fiber length for V2

This α is for peak wavelength of 660nm

Circuit Diagram-9b: Set up to measure NA



NOTE: KEEP ALL SWITCH FAULTS IN OFF POSITION.

Result:

Attenuation Loss=

Bending Loss=

Numerical Aperture=

Sl. No.	No. of turns	Output Voltage

Procedure to measure NA

Procedure to measure NA (Falcon kit):

1. Make connections as shown in Circuit Diagram-6. Connect the power supply cables with proper polarity to link-B kit. While connecting this, ensure that the power supply is OFF.
2. Keep Intensity control pot P2 towards minimum position.
3. Keep Bias control pot P1 fully clockwise position.
4. Switch ON the power supply.
5. Slightly unscrew the cap of SFH756V (660nm). Do not remove the cap from the connector. Once the cap is loosened, insert the 1 meter fiber into the cap. Now tighten the cap by screwing it back.
6. Insert the other end of the fiber into the numerical aperture measurement jig. Adjust the fiber such that its cut face is perpendicular to the axis of the fiber.
7. Now observe the illuminated circular patch of light on the screen.
8. Measure exactly the distance d and also the vertical and horizontal diameters MR and PN as indicated
9. Mean radius is calculated using the following formula

   $\mathbf{r = (MR+PN)/4}$

10. Find the numerical aperture of the fiber using the formula

    $\mathbf{NA = Sin\theta_{max} = r/\sqrt{(d^2 + r^2)}}$

    where θ_{max} is the maximum angle at which the light incident is properly transmitted through the fiber.

APPENDIX Specifications

5.1 Absolute MaximumRatings

over operating free-air temperature range (unless otherwise noted)(1)(2)(3)

		MIN	MAX	UNIT
Supply voltage	LM741, LM741A		±22	V
	LM741C		±18	
Power dissipation (4)			500	mW
Differential input voltage			±30	V
Input voltage (5)			±15	V
Output short circuit duration		Continuous		
Operating temperature	LM741, LM741A	–50	125	°C
	LM741C	0	70	
Junction temperature	LM741, LM741A		150	°C
	LM741C		100	
Soldering information	PDIP package (10 seconds)		260	°C
	CDIP or TO-99 package (10 seconds)		300	°C
Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect devicereliability.
(2) For military specifications see RETS741X for LM741 and RETS741AX forLM741A.
(3) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability andspecifications.
(4) Foroperationatelevatedtemperatures,thesedevicesmustbederatedbasedonthermalresistance,and$T_j$max.(listedunder"Absolute Maximum Ratings"). $T_j = T_A + (\theta_{jA} P_D)$.
(5) For supply voltages less than ±15 V, the absolute maximum input voltage is equal to the supplyvoltage.

5.2 ESDRatings

			VALUE	UNIT
$V_{(ESD)}$	Electrostaticdischarge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±400	V

(1) Level listed above is the passing level per ANSI, ESDA, and JEDEC JS-001. JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

5.3 Recommended OperatingConditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
Supply voltage (VDD-GND)	LM741, LM741A	±10	±15	±22	V
	LM741C	±10	±15	±18	
Temperature	LM741, LM741A	–55		125	°C
	LM741C	0		70	

5.4 ThermalInformation

THERMAL METRIC(1)		LM741			UNIT
		LMC (TO-99)	NAB (CDIP)	P (PDIP)	
		8 PINS	8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermalresistance	170	100	100	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermalresistance	25	—	—	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.

5.5 Electrical Characteristics,LM741[(1)]

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input offset voltage		$R_S \le 10\ k\Omega$	$T_A = 25°C$		1	5	mV
			$T_{AMIN} \le T_A \le T_{AMAX}$			6	mV
Input offset voltage adjustment range		$T_A = 25°C$, $V_S = \pm20\ V$			±15		mV
Input offset current		$T_A = 25°C$			20	200	nA
		$T_{AMIN} \le T_A \le T_{AMAX}$			85	500	
Input bias current		$T_A = 25°C$			80	500	nA
		$T_{AMIN} \le T_A \le T_{AMAX}$				1.5	µA
Input resistance		$T_A = 25°C$, $V_S = \pm20\ V$		0.3	2		MΩ
Input voltage range		$T_{AMIN} \le T_A \le T_{AMAX}$		±12	±13		V
Large signal voltage gain		$V_S = \pm15\ V$, $V_O = \pm10\ V$, $R_L \ge 2\ k\Omega$	$T_A = 25°C$	50	200		V/mV
			$T_{AMIN} \le T_A \le T_{AMAX}$	25			
Output voltage swing		$V_S = \pm15\ V$	$R_L \ge 10\ k\Omega$	±12	±14		V
			$R_L \ge 2\ k\Omega$	±10	±13		
Output short circuit current		$T_A = 25°C$			25		mA
Common-mode rejection ratio		$R_S \le 10\ \Omega$, $V_{CM} = \pm12\ V$, $T_{AMIN} \le T_A \le T_{AMAX}$		80	95		dB
Supply voltage rejection ratio		$V_S = \pm20\ V$ to $V_S = \pm5\ V$, $R_S \le 10\ \Omega$, $T_{AMIN} \le T_A \le T_{AMAX}$		86	96		dB
Transient response	Rise time	$T_A = 25°C$, unity gain			0.3		µs
	Overshoot				5%		
Slew rate		$T_A = 25°C$, unity gain			0.5		V/µs
Supply current		$T_A = 25°C$			1.7	2.8	mA
Power consumption		$V_S = \pm15\ V$	$T_A = 25°C$		50	85	mW
			$T_A = T_{AMIN}$		60	100	
			$T_A = T_{AMAX}$		45	75	

(1) Unless otherwise specified, these specifications apply for $V_S = \pm15\ V$, $-55°C \le T_A \le +125°C$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0°C \le T_A \le +70°C$.

5.6 Electrical Characteristics,LM741A[(1)]

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input offset voltage	$R_S \le 50\ \Omega$	$T_A = 25°C$		0.8	3	mV
		$T_{AMIN} \le T_A \le T_{AMAX}$			4	mV
Average input offset voltage drift					15	µV/°C
Input offset voltage adjustment range	$T_A = 25°C$, $V_S = \pm20\ V$		±10			mV
Input offset current	$T_A = 25°C$			3	30	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$				70	
Average input offset current drift					0.5	nA/°C
Input bias current	$T_A = 25°C$			30	80	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$				0.21	µA
Input resistance	$T_A = 25°C$, $V_S = \pm20\ V$		1	6		MΩ
	$T_{AMIN} \le T_A \le T_{AMAX}$, $V_S = \pm20\ V$		0.5			
Large signal voltage gain	$V_S = \pm20\ V$, $V_O = \pm15\ V$, $R_L \ge 2\ k\Omega$	$T_A = 25°C$	50			V/mV
		$T_{AMIN} \le T_A \le T_{AMAX}$	32			
	$V_S = \pm5\ V$, $V_O = \pm2\ V$, $R_L \ge 2\ k\Omega$, $T_{AMIN} \le T_A \le T_{AMAX}$		10			

(1) Unless otherwise specified, these specifications apply for $V_S = \pm15\ V$, $-55°C \le T_A \le +125°C$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0°C \le T_A \le +70°C$.

Electrical Characteristics, LM741A(1)(continued)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Output voltage swing		V_S = ±20 V	R_L ≥ 10 kΩ	±16			V
			R_L ≥ 2 kΩ	±15			
Output short circuit current		T_A = 25°C		10	25	35	mA
		T_{AMIN} ≤ T_A ≤ T_{AMAX}		10		40	
Common-mode rejection ratio		R_S ≤ 50 Ω, V_{CM} = ±12 V, T_{AMIN} ≤ T_A ≤ T_{AMAX}		80	95		dB
Supply voltage rejection ratio		V_S = ±20 V to V_S = ±5 V, R_S ≤ 50 Ω, T_{AMIN} ≤ T_A ≤ T_{AMAX}		86	96		dB
Transient response	Rise time	T_A = 25°C, unity gain			0.25	0.8	μs
	Overshoot				6%	20%	
Bandwidth (2)		T_A = 25°C		0.437	1.5		MHz
Slew rate		T_A = 25°C, unity gain		0.3	0.7		V/μs
Power consumption		V_S = ±20 V	T_A = 25°C		80	150	mW
			T_A = T_{AMIN}			165	
			T_A = T_{AMAX}			135	

(2) Calculated value from: BW (MHz) = 0.35/Rise Time(μs).

5.7 Electrical Characteristics,LM741C(1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Input offset voltage		R_S ≤ 10 kΩ	T_A = 25°C		2	6	mV
			T_{AMIN} ≤ T_A ≤ T_{AMAX}			7.5	mV
Input offset voltage adjustment range		T_A = 25°C, V_S = ±20 V			±15		mV
Input offset current		T_A = 25°C			20	200	nA
		T_{AMIN} ≤ T_A ≤ T_{AMAX}				300	
Input bias current		T_A = 25°C			80	500	nA
		T_{AMIN} ≤ T_A ≤ T_{AMAX}				0.8	μA
Input resistance		T_A = 25°C, V_S = ±20 V		0.3	2		MΩ
Input voltage range		T_A = 25°C		±12	±13		V
Large signal voltage gain		V_S = ±15 V, V_O = ±10 V, R_L ≥ 2 kΩ	T_A = 25°C	20	200		V/mV
			T_{AMIN} ≤ T_A ≤ T_{AMAX}	15			
Output voltage swing		V_S = ±15 V	R_L ≥ 10 kΩ	±12	±14		V
			R_L ≥ 2 kΩ	±10	±13		
Output short circuit current		T_A = 25°C			25		mA
Common-mode rejection ratio		R_S ≤ 10 kΩ, V_{CM} = ±12 V, T_{AMIN} ≤ T_A ≤ T_{AMAX}		70	90		dB
Supply voltage rejection ratio		V_S = ±20 V to V_S = ±5 V, R_S ≤ 10 Ω, T_{AMIN} ≤ T_A ≤ T_{AMAX}		77	96		dB
Transient response	Rise time	T_A = 25°C, Unity Gain			0.3		μs
	Overshoot				5%		
Slew rate		T_A = 25°C, Unity Gain			0.5		V/μs
Supply current		T_A = 25°C			1.7	2.8	mA
Power consumption		V_S = ±15 V, T_A = 25°C			50	85	mW

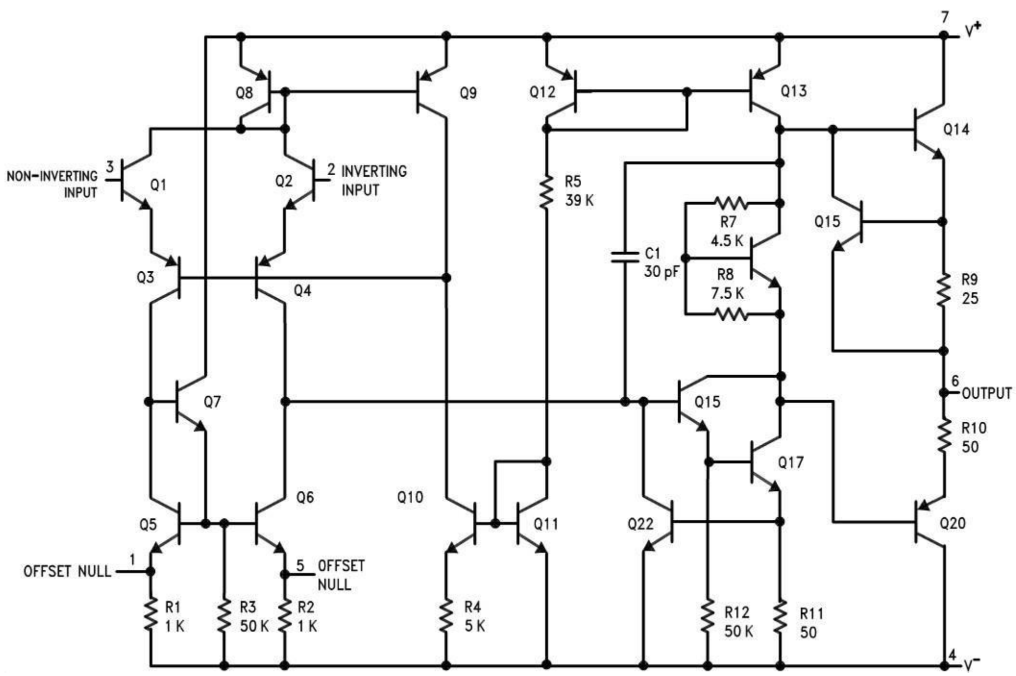
(1) Unless otherwise specified, these specifications apply for V_S = ±15 V, −55°C ≤ T_A ≤ +125°C (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to 0°C ≤ T_A ≤ +70°C.

7 DetailedDescription

7.1 Overview

The LM74 devices are general-purpose operational amplifiers which feature improved performance over industry standards like the LM709. It is intended for a wide range of analog applications. The high gain and wide range of operating voltage provide superior performance in integrator, summing amplifier, and general feedback applications. The LM741 can operate with a single or dual power supply voltage. The LM741 devices are direct, plug-in replacements for the 709C, LM201, MC1439, and 748 in most applications.

7.2 Functional BlockDiagram



7.3 FeatureDescription

7.3.1 OverloadProtection

The LM741 features overload protection circuitry on the input and output. This prevents possible circuit damage to thedevice.

7.3.2 Latch-upPrevention

The LM741 is designed so that there is no latch-up occurrence when the common-mode range is exceeded. This allows the device to function properly without having to power cycle the device.

7.3.3 Pin-to-PinCapability

The LM741 is pin-to-pin direct replacements for the LM709C, LM201, MC1439, and LM748 in most applications. Direct replacement capabilities allows flexibility in design for replacing obsolete parts.

7.4 Device FunctionalModes

7.4.1 Open-LoopAmplifier

The LM741 can be operated in an open-loop configuration. The magnitude of the open-loop gain is typically large thus for a small difference between the noninverting and inverting input terminals, the amplifier output will be driven near the supply voltage. Without negative feedback, the LM741 can act as a comparator. If the inverting input is held at 0 V, and the input voltage applied to the noninverting input is positive, the output will be positive. If the input voltage applied to the noninverting input is negative, the output will benegative.

7.4.2 Closed-LoopAmplifier

In a closed-loop configuration, negative feedback is used by applying a portion of the output voltage to the inverting input. Unlike the open-loop configuration, closed loop feedback reduces the gain of the circuit. The overall gain and response of the circuit is determined by the feedback network rather than the operational amplifier characteristics. The response of the operational amplifier circuit is characterized by the transferfunction.

8 Application andImplementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 ApplicationInformation

The LM741 is a general-purpose amplifier than can be used in a variety of applications and configurations. One common configuration is in a noninverting amplifier configuration. In this configuration, the output signal is in phase with the input (not inverted as in the inverting amplifier configuration), the input impedance of the amplifier is high, and the output impedance is low. The characteristics of the input and output impedance is beneficial for applications that require isolation between the input and output. No significant loading will occur from the previous stage before the amplifier. The gain of the system is set accordingly so the output signal is a factor larger than the inputsignal.

8.2 TypicalApplication

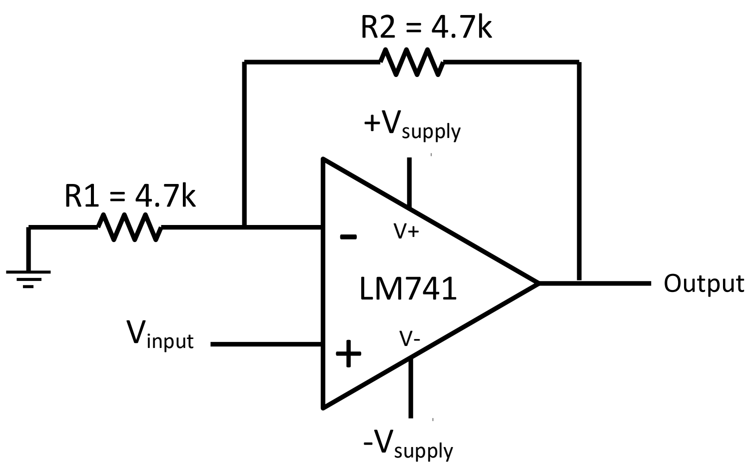


Figure 1. LM741 Noninverting Amplifier Circuit

8.2.1 DesignRequirements

As shown in Figure 1, the signal is applied to the noninverting input of the LM741. The gain of the system is determined by the feedback resistor and input resistor connected to the inverting input. The gain can be calculated by Equation1:

$$Gain = 1+(R2/R1) \quad (1)$$

The gain is set to 2 for this application. R1 and R2 are 4.7-k resistors with 5% tolerance.

8.2.2 Detailed DesignProcedure

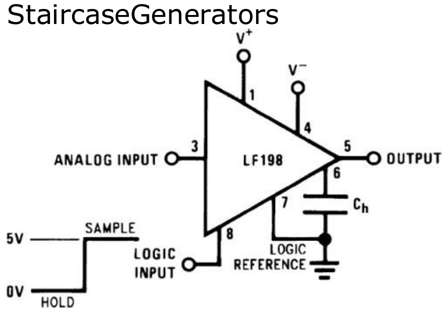
The LM741 can be operated in either single supply or dual supply. This application is configured for dual supply with the supply rails at ±15 V. The input signal is connected to a function generator. A 1-Vpp, 10-kHz sine wave was used as the signal input. 5% tolerance resistors were used, but if the application requires an accurate gain response, use 1% tolerance resistors.

Power SupplyRecommendations

- Operatesfrom±5-Vto±18-VSupplies
- Less than 10-µs AcquisitionTime
- LogicInputCompatibleWithTTL,PMOS,CMOS
- 0.5-mVTypicalHoldStepatCh=0.01µF
- Low InputOffset
- 0.002% Gain Accuracy
- LowOutputNoiseinHoldMode
- InputCharacteristicsDoNotChangeDuringHoldMode
- HighSupplyRejectionRatioinSampleorHold
- WideBandwidth
- SpaceQualified,JM38510

1 Applications

- Ramp GeneratorsWithVariableResetLevel
- Integrators WithProgrammableResetLevel
- SynchronousCorrelators
- 2-ChannelSwitches
- DCandACZeroing
- StaircaseGenerators



The LFx98x devices are monolithic sample-and-holdcircuits that use BI-FET technology to obtain ultrahighDC accuracy with fast acquisition of signal and lowdrooprate.Operatingasaunity-gainfollower,DCgainaccuracyis0.002%typicalandacquisitiontimeis as low as 6 µs to 0.01%. A bipolar input stage isusedtoachievelowoffsetvoltageandwidebandwidth. Input offset adjust is accomplished with asingle pin and does not degrade input offset drift. ThewidebandwidthallowstheLFx98xtobeincludedinsidethefeedbackloopof1-MHzoperationalamplifierswithouthavingstability problems.Inputimpedance of $10^{10}\Omega$ allows high-source impedancestobeusedwithoutdegradingaccuracy.

P-channel junction FETs are combined with bipolardevices in the output amplifier to give droop rates aslowas5mV/minwitha1-µFholdcapacitor.TheJFETshavemuchlowernoisethanMOSdevicesusedinpreviousdesignsanddonot exhibithightemperature instabilities. The overall design ensuresno feedthrough from input to output in the hold mode,evenforinputsignalsequaltothesupplyvoltages.

Logic inputs on the LFx98x are fully differential withlowinputcurrent,allowingfordirectconnectiontoTTL,PMOS,andCMOS.Differentialthresholdis 1.4 V. The LFx98x will operate from ±5-V to ±18-Vsupplies.

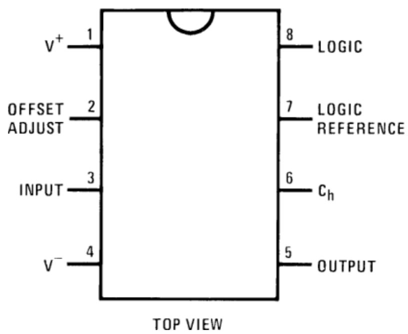
AnAversionisavailablewithtightenedelectricalspecifications.

DeviceInformation(1)

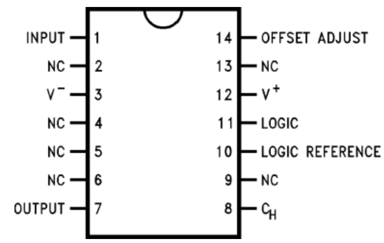
PARTNUMBER	PACKAGE	BODYSIZE(NOM)
LF298,LF398-N	SOIC(14)	8.65mm×3.91mm
LFx98x	TO-99(8)	9.08mm×9.08mm
LF398-N	PDIP(8)	9.81mm×6.35mm

PinConfigurationandFunctions

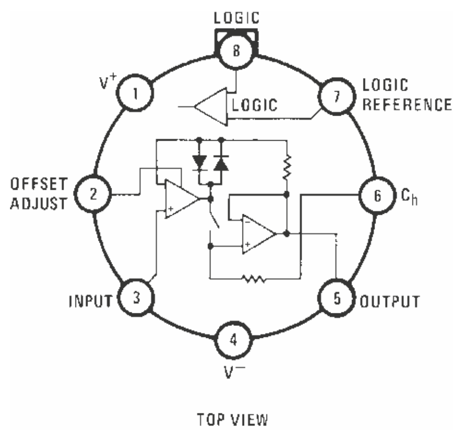
**P
Package
8-
PinPDIP
TopView**



**D
Package1
4-
PinSOIC
Top
View**



**LMC
Package8-
PinTO-99
Top View**



AmilitaryRETSelectricaltestspecificationisavailableonrequest.TheLF198-
NmayalsobeprocuredtoStandardMilitaryDrawing#5962-8760801GAortoMIL-STD-
38510partIDJM38510/12501SGA.

PinFunctions

PI N				TYPE(1)	DESCRIPTIO N
NAME	LF298,LF398 -N	LFx98 x	LF398- N		
	SOIC-14	TO-99	PDIP-8		
V^+	12	1	1	P	Positive supply
OFFSETADJUST	14	2	2	A	DCoffsetcompensationpin
INPUT	1	3	3	A	AnalogInput
V^-	3	4	4	P	Negativesupply
OUTPUT	7	5	5	O	Output
C_h	8	6	6	A	Holdcapacitor
LOGICREFERENCE	10	7	7	I	ReferenceforLOGICinput
LOGIC	11	8	8	I	LogicinputforSampleandHoldmodes
NC	2,4,5,6,9,13	—	—	NA	Noconnect

1)P=Power,G=Ground,I=Input,O=Output,A=Analog