SCHEME: 23 Series

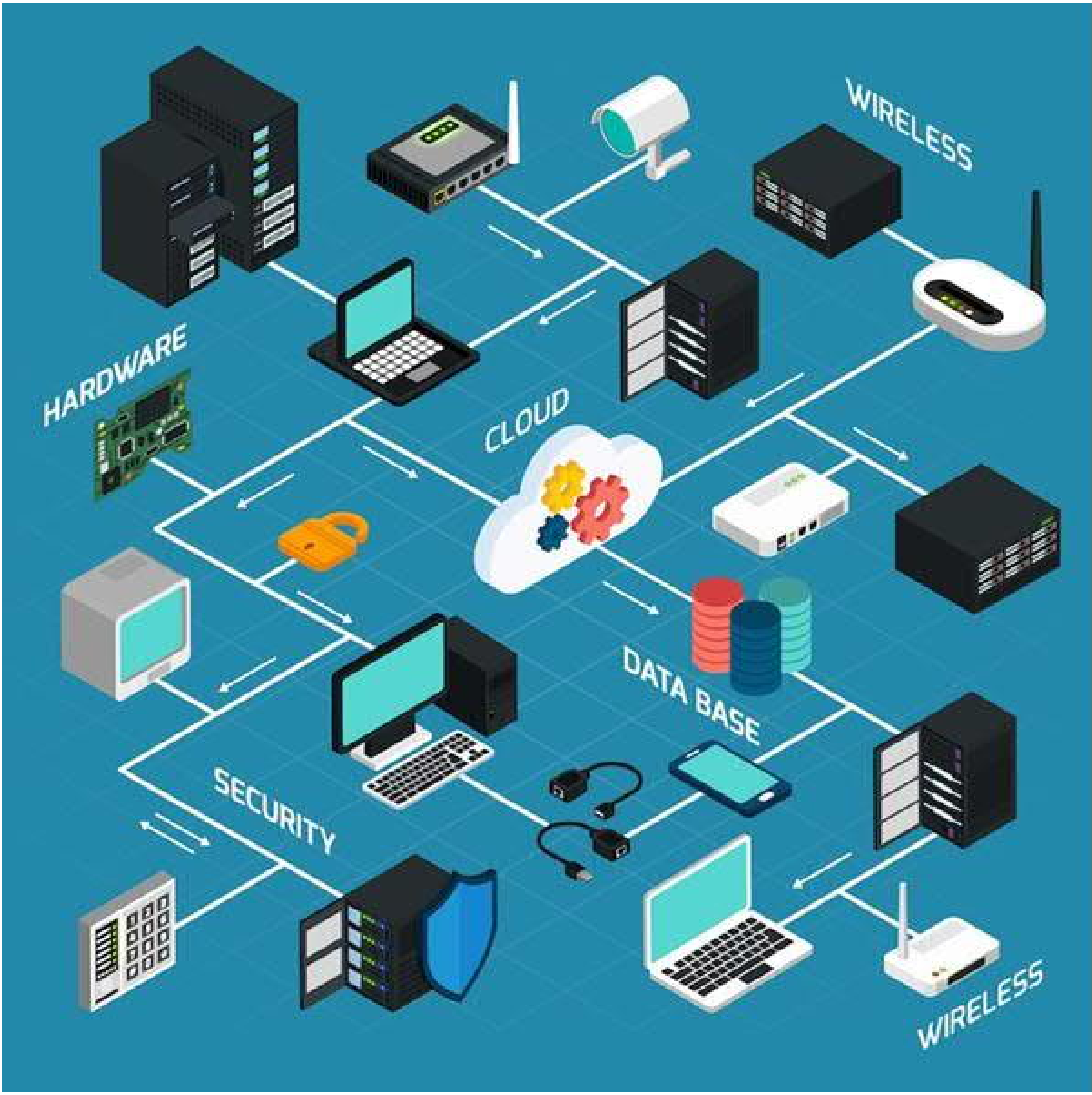
Name: ______________________

Spn. No.: ______________________

Year: 20 ______ 20 ______

LABORATORY MANUAL FOR

DATA COMMUNICATION & COMPUTER NETWORKING (23504)



ST. XAVIER'S TECHNICAL INSTITUTE, MUMBAI

(Autonomous)

ST. XAVIER'S TECHNICAL INSTITUTE

To Nurture the Joy of Excellence in the World of High Technology

CERTIFICATE

This is to certify that Mr./Ms.. having SPN. No. ...., of Fifth Semester of Diploma in Electronics and Telecommunication Engineering.

He/She has completed the term work satisfactorily in course Data Communication and Computer Networking (23504) for the academic year 20.......... to 20...as prescribed in the curriculum.

Place: ....   Date: ....

Dr. Mahesh Munde	**Dr. Vijay Rathod**	**Dr. Shivaji Ghungrad**
Subject Teacher	Head of the Department	Principal

Seal of the Institute

St. Xavier's Technical Institute

Mahim, Mumbai 400016

Department of Electronics and Telecommunication Engineering

Institute Vision

To nurture the joy of excellence in a world of high technology

Institute Mission

To strive to match global standards in technical education by

- Interaction with Industry
- Continuous Staff training
- Development of quality of life

Department Vision

To become a center of excellence and to produce high quality self-motivated creative and ethical diploma engineers and technologists, contributing effectively to universal engineering and contemporary education.

Department Mission

To prepare the students of the Department of Electronics and Telecommunication Engineering for a brilliant career / entrepreneurship along with the development of knowledge, skills, attitude and teamwork ideal for a professional through the designed programme.

The faculty of the department continually seeks to enhance their knowledge to competently lead and empower students.

To impart high quality engineering education and ethics to the students & to provide the best facilities, infrastructure, environment to the students and faculty members, creating an ambience conducive for excellence in technical education and research.

St. Xavier's Technical Institute

Mahim, Mumbai 400016
Department of Electronics and Telecommunication Engineering

Program Outcomes (POs)

1. **Basic and Discipline specific knowledge:** Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the engineering problems.

2. **Problem analysis:** Identify and analyse well-defined engineering problems using codified standard methods.

3. **Design/ development of solutions:** Design solutions for well-defined technical problems and assist with the design of systems components or processes to meet specified needs.

4. **Engineering Tools, Experimentation and Testing:** Apply modern engineering tools and appropriate technique to conduct standard tests and measurements.

5. **Engineering practices for society, sustainability and environment:** Apply appropriate technology in context of society, sustainability, environment and ethical practices.

6. **Project Management:** Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.

7. **Life-long learning:** Ability to analyse individual needs and engage in updating in the context of technological changes.

ST. XAVIER'S TECHNICAL INSTITUTE

To Nurture the Joy of Excellence in the World of High Technology

DIPLOMA IN ELECTRONICS AND TELECOMMUNICATION ENGINEERING (DETE)
THIRD YEAR SEMESTER-V
DATA COMMUNICATION AND COMPUTER NETWORKING LABORATORY MANUAL

Document Number: 2627-JUN 26-DETE-504

00	19th Jun 2026	Laboratory Manual for DCCN (23504)	MMM	VRR	SBG
REV. NO.	**DATE**	**DESCRIPTION**	**PREPARED BY**	**CHECKED BY**	**APPROVED BY**

REVISION HISTORY

Rev. No.	Date	Pages	Description
00	19th Jun 2026	71	Laboratory Manual: Data Communication and Computer Networking

HOLD LIST

Hold No.	Pages	Description
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EXECUTIVE SUMMARY

Laboratory Manual is prepared by Dr. Mahesh Munde, reviewed by Dr. Vijay Rathod and approved by Dr. Shivaji Ghungrad consisting Ten (10) laboratory experiments covering four course outcomes (CO 504.1 to CO 504.4).

This course on Data Communication and Computer Networking (DCCN) is designed to provide students with a fundamental understanding of data communication principles, networking concepts, and practical implementation of computer networks. The curriculum focuses on developing theoretical knowledge and hands-on skills required for designing, configuring, and managing modern communication networks.

Students are also exposed to practical concepts beginning with crimping of cables, installation and configuration of client and server operating systems, implementation of network services, and resource sharing techniques. The practicals emphasize on routing and switching concepts using the Boson Network Simulator, providing a simulation-based environment for network design, configuration, and analysis. This enables students to gain practical exposure to network implementation and troubleshooting without requiring physical network infrastructure.

Further, the course covers Internetworking Models and Transmission Errors: Detection and Correction, helping learners understand layered communication architectures, reliable data transmission methods, and mechanisms for maintaining data integrity in communication systems.

Overall, the course integrates theoretical understanding with simulation-based laboratory practices through tools such as Boson Network Simulator, equipping students with practical networking competencies and preparing them for industry applications and advanced studies in communication and networking technologies.

Dr. Mahesh Munde	Dr. Vijay Rathod	Dr. Shivaji Ghungrad
Lecturer (Selection Grade), DETE	HOD, DETE	Principal

Index:

LAB EXPERIMENT 1: CRIMPING OF UTP/STP CABLE FOR LAN (CO 504.2)

A. Prerequisites:

- Basics of computer networking and LAN concepts.
- Knowledge of EIA/TIA 568A & B Standards.
- Understanding of UTP/STP cables and RJ45 connectors.

B. Skills Required:

- Cable handling and crimping skills.
- Observation and troubleshooting skills.
- Teamwork and communication.
- Safety awareness while handling tools.

C. Objective:

- To understand the construction and use of UTP/STP cables.
- To learn the procedure of crimping LAN cables using RJ45 connectors.
- To prepare straight-through and crossover LAN cables.

D. Learning Outcomes (LO):

- LO1: Identify different types of twisted pair cables, crimping tools, LAN cable tester.
- LO2: Understand EIA / TIA Standards (568A & 568 B).
- LO3: Perform crimping of UTP/STP cables using crimping tools and prepare straight-through and crossover cables correctly.
- LO4: Test LAN cable continuity using LAN cable tester.

E. Materials Required:

1 UTP/STP Cable
2 Crimping Tool
3 RJ-45 Connectors
4 Wire Stripper
5 LAN Cable Tester

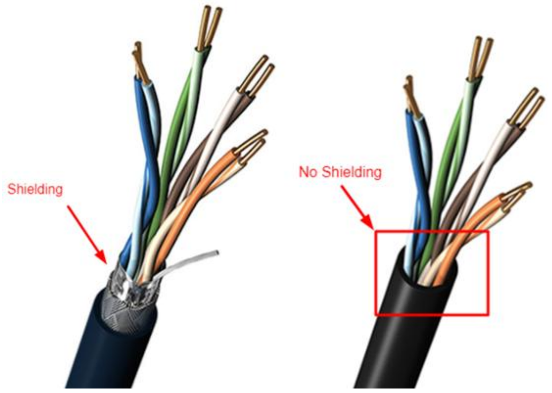


Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

F. Procedure:

Step 1: Take the required length of UTP/STP cable.

Fig. 6

Step 2: Remove approximately 1 inch of outer insulation using wire stripper.

Fig. 7

Step 3: Untwist and arrange wires according to T568A or T568B standard.

T568A	
1	White/Green
2	Green
3	White/Orange
4	Blue
5	White/Blue
6	Orange
7	White/Brown
8	Brown

T568B	
1	White/Orange
2	Orange
3	White/Green
4	Blue
5	White/Blue
6	Green
7	White/Brown
8	Brown

Fig. 8

Step 4: Straighten and trim the wires evenly with the help of cutter.

Fig. 9

Step 5: Insert wires carefully into RJ45 connector.

Fig. 10

Step 6: Place the RJ-45 connector into crimping tool and press firmly.

Fig. 11

Step 7: Repeat the process for the other end of the cable.

Step 8: Test the cable using LAN cable tester for continuity.

Fig. 12

G. Students Observations:

H. Conclusion:

- Students successfully learned the crimping process of UTP/STP cables.
- Students understood LAN cable standards and testing procedures.
- Students developed practical networking skills useful for LAN installation.

I. Questions

1. What is the difference between UTP and STP cable?
2. What is the purpose of RJ45 connector?
3. Differentiate between straight-through and crossover cable.
4. What are T568A and T568B standards?
5. Why is cable testing necessary after crimping?

LAB EXPERIMENT 2: INSTALLATION OF WINDOWS AND LINUX CLIENT OPERATING SYSTEMS

(CO 504.1)

A. Prerequisites:

- Basics of computer systems and operating systems.
- Knowledge of booting process and storage devices.
- Understanding of file systems and disk partitions.
- Familiarity with BIOS/UEFI settings.

B. Skills Required:

- System handling and installation skills.
- Observation and troubleshooting skills.
- Ability to configure system settings.
- Safety awareness while handling computer hardware.

C. Objective:

- To understand the installation procedure of Windows and Linux operating systems.
- To learn disk partitioning and boot configuration.
- To install and configure client operating systems successfully.
- To verify system functionality after installation.

D. Learning Outcomes (LO):

- LO1: Identify the hardware and software requirements for OS installation.
- LO2: Understand bootable media creation and BIOS/UEFI configuration.
- LO3: Perform installation of Windows and Linux client operating systems.
- LO4: Configure user settings, drivers, and verify system operation.

E. Materials Required:

- Computer/Laptop with Virtual Machine
- Minimum 4 GB RAM
- USB Flash Drive (8 GB or above)
- Windows ISO File
- Ubuntu ISO File
- Bootable USB creation software
- Internet connection (optional)

F. Procedure:

Part A: Installation of Windows Operating System:

Step 1: Launch Virtualization Software

- Open VirtualBox or VMware Workstation.

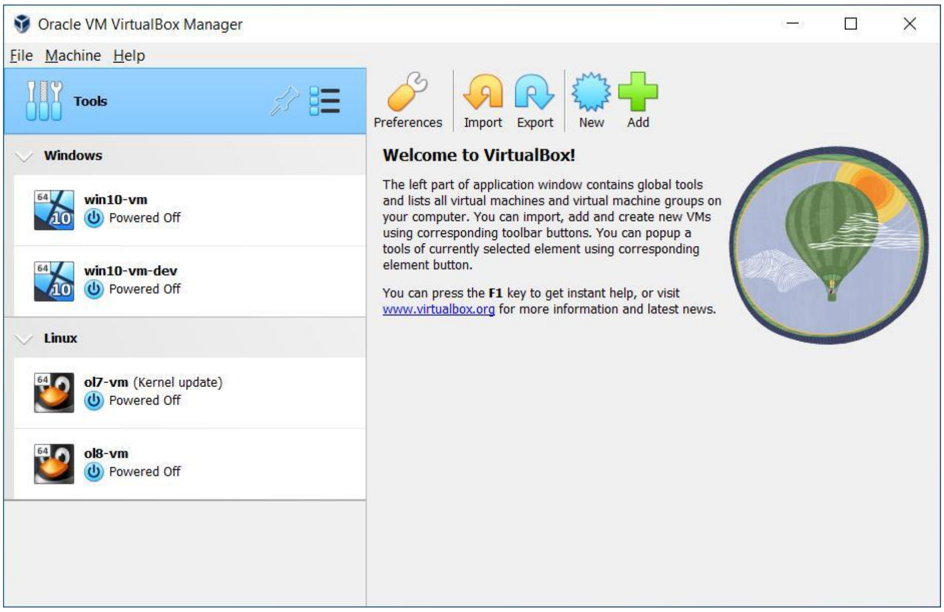


Fig. 1

Step 2: Create a New Virtual Machine

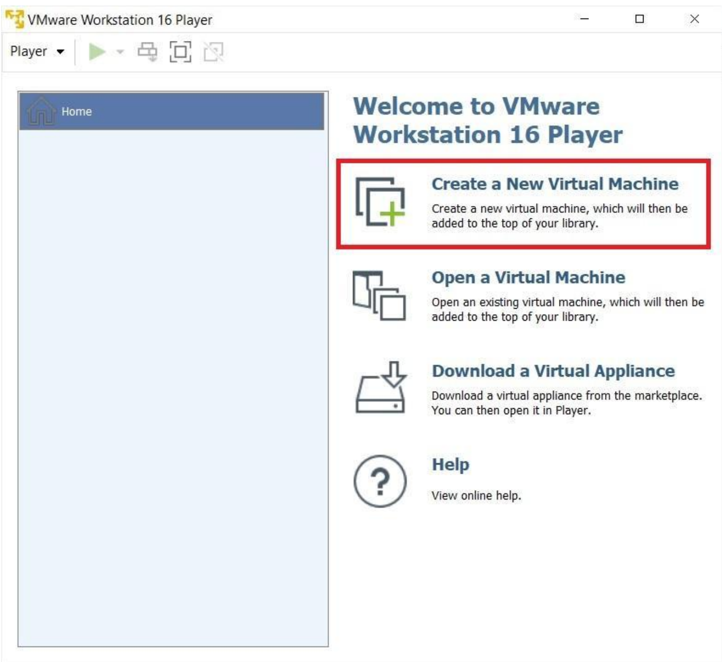


Fig. 2

Step 3: Enter VM Name: SPN. No.

Fig. 3

Step 4: Allocate Resources

- Assign RAM (minimum 4 GB recommended).
- Create a virtual hard disk (40–60 GB).

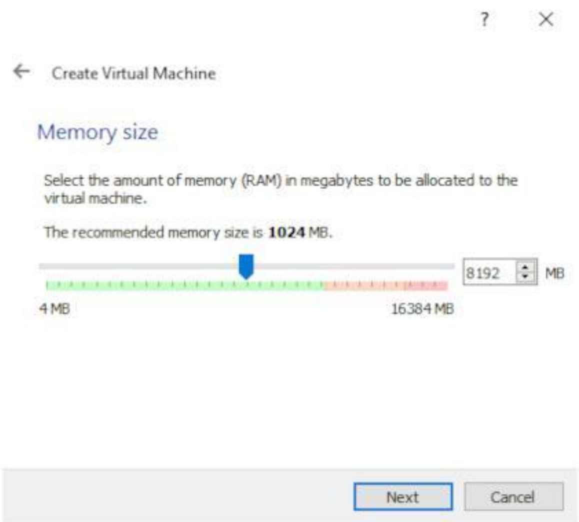


Fig. 4 **Fig. 5**

Step 5: Attach Windows ISO: Write path below:

- Mount the Windows ISO file to the virtual optical drive.
-

Step 6: Start the VM

- Click **Start**.
- Windows Setup screen will appear.

Step 7: Install Windows

- Select Language, Time, and Keyboard.
- Click **Install Now**.
- Accept license terms.
- Select **Custom Installation**.
- Choose the virtual disk and click **Next**.

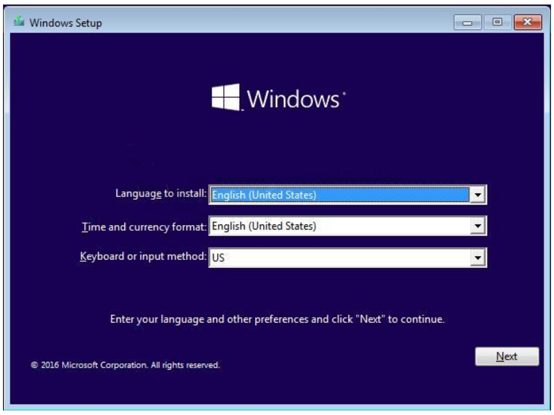


Fig. 6

Fig. 7

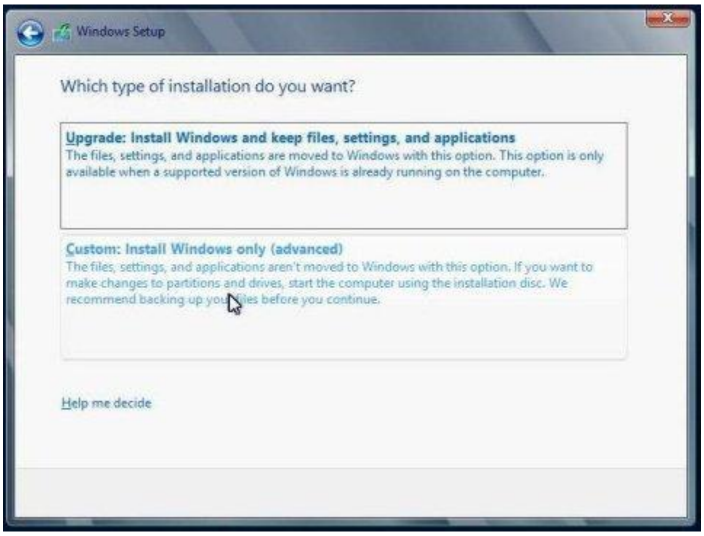


Fig. 8

Step 8: Complete Initial Configuration

- Create user account.
- Configure password.
- Set region and preferences.
- Finish setup and log in.

Part B: Installation of Linux Operating System: Ubuntu

Step 1: Create a New Virtual Machine (Similar to Part A)

- Click **New**.
- Enter VM Name: *Ubuntu Client*.
- Select **Linux** and choose **Ubuntu (64-bit)**.

Step 2: Allocate Resources (Similar to Part A)

- RAM: Minimum 4 GB.
- CPU: 2 cores or more.
- Virtual Disk: 25–40 GB.

Step 3: Attach Ubuntu ISO: Write path below (Similar to Part A)

-

Step 4: Start the Virtual Machine

- Click **Start** to boot from the Ubuntu ISO.

Step 5: Begin Ubuntu Installation

- Select language.
- Click **Install Ubuntu**.
- Select keyboard layout.
- Choose **Normal Installation**.

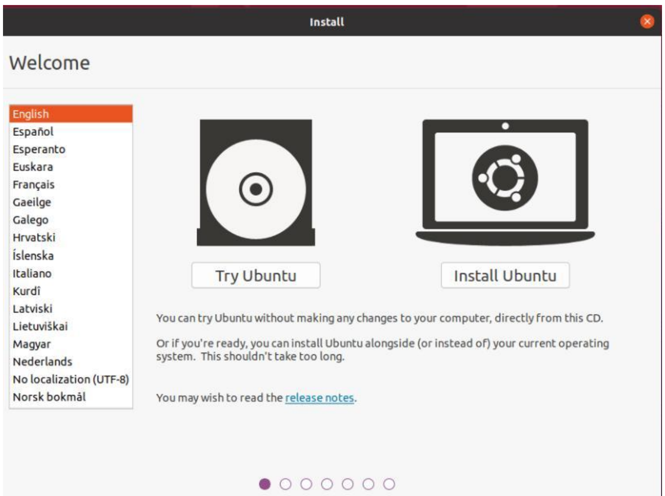


Fig. 9

Step 6: Configure Storage

- Select **Erase Disk and Install Ubuntu** (affects only the virtual disk).
- Click **Install Now**.
- Confirm disk changes.

Step 7: User Configuration

- Select time zone.
- Enter username and password.
- Click **Continue**.

Step 8: Complete Installation

- Wait for installation to finish.
- Click **Restart Now**.

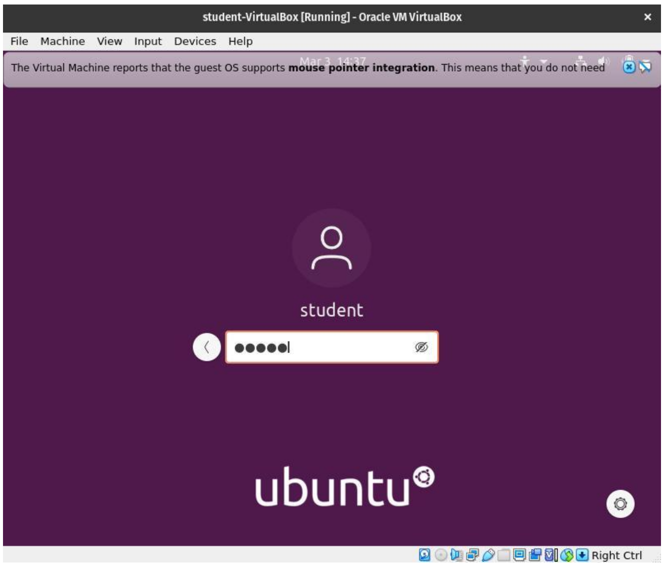


Fig. 10

G. Observations:

H. Conclusion:

- Students successfully learned installation of Windows and Linux operating systems.
- Students understood bootable media creation and partitioning process.
- Students developed practical skills related to client OS installation and configuration.

I. Questions

1. What is an operating system?
2. What is disk partitioning?
3. Differentiate between Windows and Linux operating systems.
4. What is the function of device drivers?
5. What is a file system?

LAB EXPERIMENT 3: INSTALLATION OF WINDOWS SERVER OPERATING SYSTEM

(CO 504.1)

A. Aim:

- To install Windows Server Operating System on a virtual machine using virtualization software and perform initial system configuration.

B. Prerequisites:

- Basic knowledge of computer hardware and operating systems
- Understanding of virtualization concepts
- Familiarity with boot process and storage devices
- Basic knowledge of networking concepts and IP addressing
- Availability of virtualization software and Windows Server ISO file.

C. Skills Required:

- Operating virtualization software such as Oracle VM VirtualBox or VMware Workstation
- Creating and configuring virtual machines
- Managing virtual storage and memory allocation
- Installing operating systems using ISO images
- Performing basic Windows Server configuration and administration.

D. Objectives:

- To understand the concept of virtualization and virtual machines
- To create and configure a virtual machine environment
- To install Windows Server operating system on a virtual machine
- To perform initial server configuration after installation
- To understand virtual networking modes such as NAT and Bridged networking.

E. Learning Outcomes (LO):

- LO1: Install Windows Server operating system in a virtual environment.
- LO2: Configure basic server settings including administrator account and networking.
- LO3: Perform initial server administration tasks in Windows Server environment.

F. Hardware & Software Required:

- Processor: 64-bit CPU with virtualization support (Intel VT-x / AMD-V enabled)
- RAM: Minimum 8 GB (recommended 16 GB for smooth VM performance)

- Storage: Minimum 80 GB free space
- Internet connection (for updates, optional)
- Virtualization Software: Oracle VM VirtualBox or VMware Workstation
- Windows Server ISO 2007
- Virtual network adapters (NAT / Bridged / Host-only)

G. Theory:

Virtual machines allow multiple operating systems to run on a single physical system by simulating hardware resources. Windows Server installed on a VM behaves like a physical server, enabling practice of enterprise services such as Active Directory, DNS, DHCP, and networking without requiring dedicated hardware.

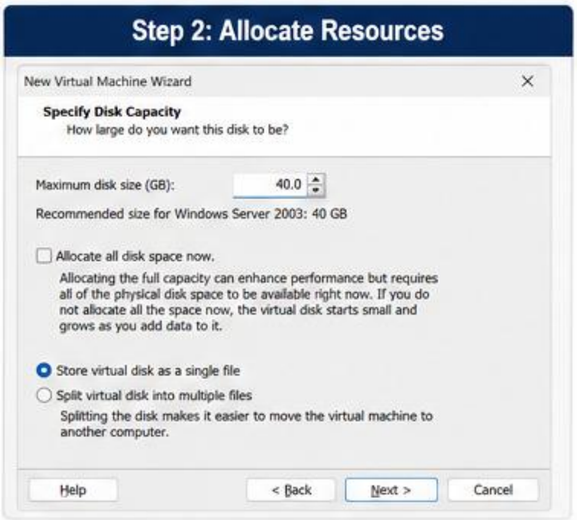
H. Procedure:

Step 1: Create a New Virtual Machine

- Open VirtualBox / VMware.

Step 2: Allocate Resources

- RAM: 4096 MB (minimum), 8192 MB recommended
- Storage: Create virtual hard disk (VHD/VMDK)
- Size: 60–80 GB (dynamically allocated preferred)

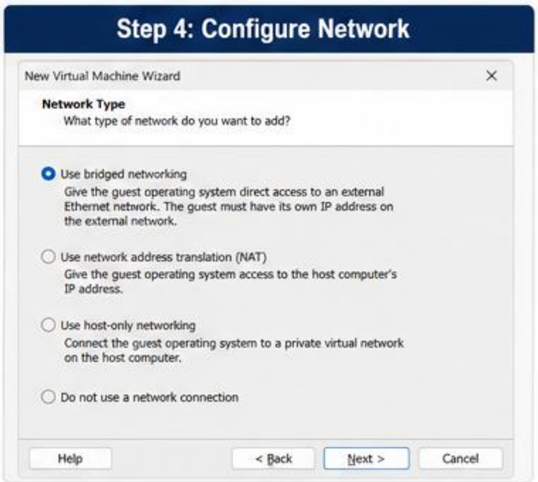


Step 3: Attach ISO File

- Go to VM settings → Storage
- Mount Windows Server ISO file under optical drive

Step 4: Configure Network

- Select Network mode:
- NAT (basic internet access) OR
- Bridged Adapter (LAN network simulation)



Step 5: Boot the Virtual Machine

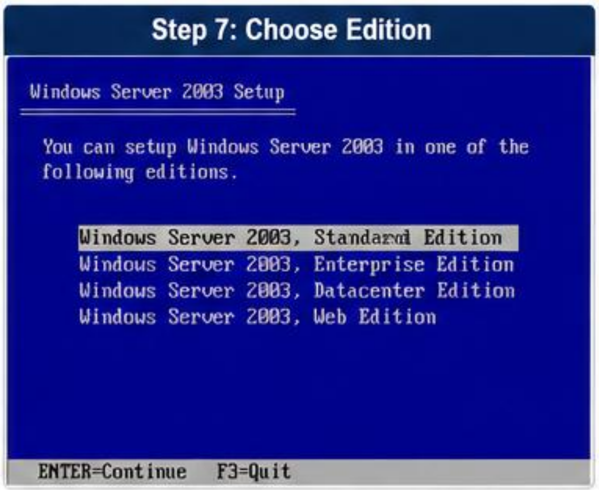
- Start VM
- System boots from ISO file

Step 6: Windows Setup

- Select language, time, and keyboard
- Click Install Now

Step 7: Choose Edition

- Select:
- Windows Server Standard / Data center
- Desktop Experience (for GUI)



Step 8: Installation Type

- Choose: Custom: Install Windows only (advanced)

Step 9: Disk Setup

- Select virtual disk
- Create partition (if required)
- Format as NTFS
- Proceed with installation

Step 10: Installation Process

- Files are copied
- Features installed
- VM restarts automatically

Step 11: Administrator Setup

- Set Administrator password
- Login to Windows Server environment

Step 12: Post Installation Configuration

- Rename server
- Set static IP (recommended for server role practice)
- Define a role or multiple roles for the server depending on requirement of the organization.

I. Observation

J. Result

Windows Server Operating System was successfully installed and configured on a virtual machine environment and role for the server is defined.

K. Precautions

- Allocate sufficient RAM and CPU to avoid VM lag.
- Do not interrupt installation process.
- Always verify ISO file integrity before mounting.

L. Questions

1. What is Windows Server?
2. What is the purpose of Windows Server?
3. What is an ISO file?
4. Why is virtualization useful in labs?
5. What is a virtual hard disk?
6. What is the Administrator account in Windows Server?
7. What file system is commonly used in Windows Server?
8. Why is static IP configuration important for servers?
9. What are server roles?
10. What is Active Directory?

LAB EXPERIMENT 4: INSTALLATION OF UBUNTU SERVER OPERATING SYSTEM

(CO 504.1)

A. Aim:

- To install Ubuntu Server Operating System on a virtual machine using virtualization software and perform initial system configuration.

B. Prerequisites:

- Basic knowledge of computer hardware and operating systems
- Understanding of virtualization concepts
- Familiarity with boot process and storage devices
- Basic knowledge of Linux commands and networking concepts
- Availability of virtualization software and Ubuntu Server ISO file.

C. Skills Required:

- Operating virtualization software such as Oracle VM VirtualBox or VMware Workstation
- Creating and configuring virtual machines
- Managing virtual storage and memory allocation
- Installing operating systems using ISO images
- Performing basic Ubuntu Server configuration and administration
- Using basic Linux terminal commands.

D. Objectives:

- To install Ubuntu Server operating system on a virtual machine
- To perform initial server configuration after installation
- To understand Linux server environment and networking basics.

E. Learning Outcomes (LO):

- LO1: Install Ubuntu Server operating system in a virtual environment.
- LO2: Configure basic server settings including user account and networking.
- LO3: Perform initial server administration tasks in Ubuntu Server environment.

F. Hardware & Software Required:

- Processor: 64-bit CPU with virtualization support (Intel VT-x / AMD-V enabled)
- RAM: Minimum 4 GB (recommended 8 GB)
- Storage: Minimum 40 GB free space

- Internet connection (optional for updates)
- Virtualization Software: Oracle VM VirtualBox or VMware Workstation
- Ubuntu Server ISO image
- Virtual network adapters (NAT / Bridged / Host-only).

G. Theory:

Ubuntu Server is a Linux-based server operating system widely used for web hosting, networking, cloud computing, and enterprise applications. Installing Ubuntu Server on a virtual machine allows users to practice Linux server administration without requiring dedicated physical hardware.

Virtualization enables multiple operating systems to run simultaneously on a single physical computer by sharing hardware resources efficiently.

H. Procedure:

Step 1: Create a New Virtual Machine

- Create a New Virtual Machine
- Open VirtualBox / VMware
- Click Create New VM
- Enter name: Ubuntu Server
- Select:
- Type: Linux
- Version: Ubuntu (64-bit).

Step 2: Allocate Resources

- RAM: 2048 MB minimum, 4096 MB recommended
- CPU: 2 cores or more
- Storage: Create virtual hard disk (VDI/VMDK)
- Size: 25–40 GB (dynamically allocated preferred).

Step 3: Attach ISO File

- Go to VM Settings → Storage
- Mount Ubuntu Server ISO file under optical drive.

Step 4: Configure Network

- Select Network mode:
- NAT (basic internet access) OR
- Bridged Adapter (LAN network simulation)

Step 5: Boot the Virtual Machine

- Start VM
- System boots from Ubuntu Server ISO file.

Step 6: Ubuntu Server Setup

- Select language
- Choose keyboard layout
- Select **Install Ubuntu Server**

Step 7: Configure Network

- Configure DHCP or set static IP address
- Continue installation.

Step 8: Configure Storage

- Select disk layout
- Choose:
- Use Entire Disk
- Confirm partition settings.

Step 9: Create User Account

- Enter:
- Server name
- Username
- Password.

Step 10: Install OpenSSH Server

- Select **Install OpenSSH Server** (optional but recommended.

Step 11: Installation Process

- Ubuntu Server packages are installed
- System restarts automatically after completion.

Step 12: Login to Ubuntu Server

- Remove ISO if prompted
- Login using created username and password.

Step 13: Post Installation Configuration

- Update system packages using:
- </> Bash
  - *sudo apt update*
  - *sudo apt upgrade*

- Verify network connectivity
- Install VM tools if required:
- VirtualBox Guest Additions
- VMware Tools.

I. Observation

- Virtual machine successfully created and configured.
- Ubuntu Server installed without errors.
- System booted into command-line interface successfully.
- User login and network connectivity verified.

J. Result

Ubuntu Server Operating System was successfully installed and configured on a virtual machine environment.

K. Precautions

- Ensure virtualization is enabled in BIOS/UEFI.
- Allocate sufficient RAM and CPU resources.
- Verify Ubuntu ISO file integrity before installation.
- Do not interrupt installation process during package installation.
- Ensure proper network settings are selected.

L. Questions

1. What is Ubuntu Server?
2. Why is Ubuntu Server widely used?
3. What is the difference between Ubuntu Desktop and Ubuntu Server?
4. What is OpenSSH Server?
5. What is the purpose of static IP addressing in servers?
6. What is the use of the *sudo* command in Linux?
7. What is a Linux file system?
8. Why are software updates important in Ubuntu Server?
9. What is NAT networking?
10. What is a bridged network adapter?

LAB EXPERIMENT 5: SHARING OF RESOURCES (FILES, FOLDERS AND PRINTER)

(CO 504.1 & CO 504.2)

A. Aim:

- To configure and share files, folders, and printers on Windows operating system and access shared resources through a network.

B. Prerequisites:

- Basic knowledge of Windows operating system
- Understanding of computer networking concepts
- Knowledge of IP addressing and workgroup settings
- Systems connected through LAN/Wi-Fi network
- Administrator privileges on Windows system.

C. Skills Required:

- Configuring network settings in Windows
- Enabling file and printer sharing
- Creating and managing shared folders
- Assigning sharing permissions
- Configuring printer sharing
- Accessing shared resources using network paths.

D. Objectives:

- To understand resource sharing in Windows networks
- To configure file and folder sharing in Windows
- To configure and use printer sharing
- To understand user permissions and access control
- To verify resource accessibility across systems.

E. Learning Outcomes (LO):

- LO1: Configure and manage file and folder sharing in Windows.
- LO2: Access shared resources from remote systems.
- LO3: Configure and use shared printers in Windows network environment.
- LO4: Understand sharing permissions and network security concepts.

F. Hardware & Software Required:

- Two or more computers with Windows operating system
- LAN/Wi-Fi network connectivity
- Network Interface Card (NIC)
- Printer (physical or virtual printer)
- Ethernet cable / Wireless network
- Windows operating system.

G. Theory:

Resource sharing in Windows allows users to share files, folders, and printers over a network. Shared resources can be accessed by authorized users connected to the same network. Windows uses the SMB (Server Message Block) protocol for file and printer sharing.
File and folder sharing enables centralized storage and collaboration, while printer sharing allows multiple users to use a single printer connected to one system. Permissions such as Read, Change, and Full Control help secure shared resources.

H. Procedure:

Part A: File and Folder Sharing

Step 1: Connect Systems to Network

- Connect all systems to the same LAN/Wi-Fi network.
- Verify network connectivity using Command Prompt:
  - *</> cmd*
  - *ping IP Address*

Step 2: Enable Network Discovery and Sharing

- Open:
- *Control Panel → Network and Sharing Center*
- Click:
- *Change advanced sharing settings*
- Enable:
- *Turn on Network Discovery*
- *Turn on File and Printer Sharing*.

Step 3: Create a Shared Folder

- *Create a folder named: DCCN*
- *Right-click the folder → Properties*
- *Select Sharing tab*
- *Click Advanced Sharing*
- *Check:*

- *Share this folder.*

Step 4: Configure Sharing Permissions

- *Click Permissions*
- *Assign permissions:*
- *Read*
- *Change*
- *Full Control*
- *Click Apply → OK.*

Step 5: Access Shared Folder from Another System

- *Press: Windows + R*
- *Enter: </> cmd*
- *\\ IP Address*
- *Open shared folder*

Step 6: Transfer Files

- *Copy files into shared folder*
- *Verify accessibility from client system.*

Part B: Printer Sharing

Step 1: Connect Systems to Network

- *Connect printer to host computer*
- *Install printer drivers.*

Step 2: Enable Printer Sharing

- *Open: Control Panel → Devices and Printers*
- *Right-click printer → Printer Properties*
- *Open Sharing tab*
- *Enable: Share this printer.*

Step 3: Access Shared Printer from Client System

- *Open Run dialog: </> cmd*
- *\\ IP Address*
- *Double-click shared printer*
- *Install printer drivers if prompted*

Step 4: Print Test Page

- *Send a test print from client system*

- *Verify successful printing.*

I. Observation

- Systems successfully communicated over network.
- Shared folder accessed from remote system successfully.
- Files transferred successfully between systems.
- Shared printer detected and connected.
- Test print executed successfully.

J. Result

Files, folders, and printers were successfully shared and accessed over Windows network environment.

K. Precautions

- Ensure all systems are connected to the same network.
- Verify Windows Firewall settings allow file and printer sharing.
- Use proper permissions to avoid unauthorized access.
- Do not share sensitive files publicly.
- Ensure printer drivers are properly installed.

L. Questions

1 What is SMB protocol?
2 Why are permissions important in shared folders?
3 What is the purpose of Network Discovery?
4 What is the difference between Read and Full Control permissions?
5 What is the use of IP address in network sharing?
6 What are the advantages of resource sharing?
7 What is Windows Firewall?
8 Why is printer sharing useful in organizations?
9 Why is network connectivity verification necessary before sharing resources?

LAB EXPERIMENT 6: ROUTING BASICS USING BOSON NETWORK SIMULATOR

(CO 504.2, CO 504.3 & CO 504.4)

A. Aim:

- To study and configure basic routing between networks using routers in Boson Network Simulator.

B. Prerequisites:

- Basic knowledge of computer networks and IP addressing
- Understanding of routers and network devices
- Knowledge of subnet masks and default gateways
- Familiarity with Boson Network Simulator interface.

C. Skills Required:

- Creating network topology in Boson Network Simulator
- Configuring routers and PCs
- Assigning IP addresses to interfaces
- Configuring static routes
- Verifying connectivity using ping command
- Using basic Cisco IOS commands.

D. Objectives:

- To understand the concept of routing
- To configure routers for inter-network communication
- To assign IP addresses to router interfaces and PCs
- To configure static routing between networks
- To test communication between different networks.

E. Learning Outcomes (LO):

- LO1: Create and configure a simple routed network.
- LO2: Configure IP addressing on routers and PCs.
- LO3: Configure static routing commands.
- LO4: Verify communication between different networks.

F. Hardware & Software Required:

- Computer system with minimum 4 GB RAM
- Boson Network Simulator software
- Windows operating system
- Basic network topology consisting of:
  - 2 Routers
  - 2 Switches
  - 2 PCs.

G. Theory:

Routing is the process of forwarding data packets from one network to another using routers. Routers use routing tables to determine the best path for packet delivery.

Static routing is a manually configured routing method where routes are entered by the network administrator. It is simple and suitable for small networks.

Boson Network Simulator provides a virtual environment for configuring Cisco devices and testing networking concepts without physical hardware.

H. Procedure:

Step 1: Create Network Topology

- *Open Boson Network Simulator*
- *Create the following topology:*
  - *Router R1*
  - *Router R2*
  - *Switch S1 and S2*
  - *PC1 and PC2*
- *Connect devices using appropriate cables.*

Draw Topology:

Step 2: Assign IP Addresses

PC1 Configuration:

Device	*IP Address*	*Subnet Mask*	*Default Gateway*
PC1	*192.168.1.2*	*255.255.255.0*	*192.168.1.1*

PC2 Configuration:

Device	*IP Address*	*Subnet Mask*	*Default Gateway*
PC2	*192.168.2.2*	*255.255.255.0*	*192.168.2.1*

Step 3: Configure Router R1

- *Router> enable*
- *Router# configure terminal*
- *Router(config)# interface fastethernet0/0*
- *Router(config-if)# ip address 192.168.1.1 255.255.255.0*
- *Router(config-if)# no shutdown*
- *Router(config-if)# exit*
- *Router(config)# interface serial0/0*
- *Router(config-if)# ip address 10.0.0.1 255.255.255.252*
- *Router(config-if)# no shutdown*
- *Router(config-if)# exit*

Step 4: Configure Router R2

- *Router> enable*
- *Router# configure terminal*
- *Router(config)# interface fastethernet0/0*
- *Router(config-if)# ip address 192.168.2.1 255.255.255.0*
- *Router(config-if)# no shutdown*
- *Router(config-if)# exit*
- *Router(config)# interface serial0/0*
- *Router(config-if)# ip address 10.0.0.2 255.255.255.252*
- *Router(config-if)# no shutdown*
- *Router(config-if)# exit*

Step 5: Configure Static Routing

- ***On Router R1***
- *Router(config)# ip route 192.168.2.0 255.255.255.0 10.0.0.2*

- ***On Router R2***
- *Router(config)# ip route 192.168.1.0 255.255.255.0 10.0.0.1*

Step 6: Save Configuration

- *Router# write memory*

Step 7: Verify Routing Table

- *Router# show ip route*

Step 8: Test Connectivity

- *Open Command Prompt on PC1.*
- *Ping PC2 IP address:*
- *ping 192.168.2.2*
- *Verify successful replies*

I. Observation

- Routers were configured successfully.
- Static routes were added correctly.
- Routing table displayed configured routes.
- PCs from different networks communicated successfully.
- Ping replies were received without packet loss.

J. Result

Basic routing between two different networks was successfully configured and verified using Boson Network Simulator.

K. Precautions

- Assign correct IP addresses and subnet masks.
- Ensure interfaces are enabled using ***no shutdown***.
- Verify cable connections between devices.
- Configure correct default gateways on PCs.
- Save router configuration after completion.

L. Questions

1 What is static routing?
2 What is the purpose of a routing table?
3 What is the use of the ip route command?
4 Why is the no shutdown command used?
5 What is a default gateway?

6 What is the difference between static and dynamic routing?

7 What is subnet mask?

8 What is the purpose of ping command?

9 What is inter-network communication?

10 Why are routers required in networks?

11 What is the use of show ip route command?

12 What happens if routing is not configured?

13 What are the advantages of network simulators?

LAB EXPERIMENT 7: ROUTING USING RIP (ROUTING INFORMATION PROTOCOL) IN BOSON NETWORK SIMULATOR

(CO 504.2, CO 504.3 & CO 504.4)

A. Aim:

- To configure dynamic routing using RIP protocol and enable communication between multiple networks in Boson Network Simulator.

B. Prerequisites:

- Basic understanding of routing concepts
- Knowledge of IP addressing and subnetting
- Familiarity with router configuration commands
- Understanding of static routing.

C. Skills Required:

- Creating multi-router topology
- Configuring router interfaces
- Enabling RIP routing protocol
- Verifying routing tables
- Testing network connectivity using ping.

D. Objectives:

- To understand dynamic routing concepts
- To configure RIP on routers
- To enable automatic route sharing between routers
- To verify end-to-end connectivity in a multi-network setup.

E. Learning Outcomes (LO):

- LO1: Configure RIP routing protocol on routers.
- LO2: Enable dynamic route exchange between routers.
- LO3: Analyze routing table updates automatically.
- LO4: Test connectivity across multiple networks.

F. Hardware & Software Required:

- Computer system with Boson Network Simulator
- Minimum 3 routers, 3 switches, 3 PCs
- Ethernet/Serial links for router connections
- Windows OS.

G. Theory:

RIP (Routing Information Protocol) is a distance vector routing protocol used to dynamically share routing information between routers.

Key characteristics:

- Uses hop count as metric
- Maximum hop count = 15 (16 = unreachable)
- Periodic updates every 30 seconds
- Simple configuration suitable for small networks

Unlike static routing, RIP automatically updates routing tables when network topology changes.

H. Procedure:

Step 1: Create Network Topology

- *Design a multi-router network: Router R1 → Router R2 → Router R3*
- *Each router connected to a LAN:*
  - *LAN1: 192.168.1.0/24*
  - *LAN2: 192.168.2.0/24*
  - *LAN3: 192.168.3.0/24.*

Draw Topology:

Step 2: Assign IP Addresses

PC Configuration:

Device	*IP Address*	*Subnet Mask*	*Default Gateway*
PC1	192.168.1.2	255.255.255.0	192.168.1.1
PC2	192.168.2.2	255.255.255.0	192.168.2.1
PC3	192.168.3.2	255.255.255.0	192.168.3.1

Step 3: Configure Router Interfaces

- ***Router R1***
- *enable*
- *configure terminal*
- ***interface fastethernet0/0***
- *ip address 192.168.1.1 255.255.255.0*
- *no shutdown*
- ***interface serial0/0***
- *ip address 10.0.0.1 255.255.255.252*
- *no shutdown*
- ***Router R2***
- *enable*
- *configure terminal*
- ***interface fastethernet0/0***
- *ip address 192.168.2.1 255.255.255.0*
- *no shutdown*
- ***interface serial0/0***
- *ip address 10.0.0.2 255.255.255.252*
- *no shutdown*
- ***interface serial0/1***
- *ip address 10.0.1.1 255.255.255.252*
- *no shutdown*
- ***Router R3***
- *enable*
- *configure terminal*
- ***interface fastethernet0/0***
- *ip address 192.168.3.1 255.255.255.0*
- *no shutdown*
- ***interface serial0/0***

- *ip address 10.0.1.2 255.255.255.252*
- *no shutdown*

Step 4: Enable RIP Routing (All Routers)

- ***On R1***
- *router rip*
- *version 2*
- *network 192.168.1.0*
- *network 10.0.0.0*
- *no auto-summary*
- ***On R2***
- *router rip*
- *version 2*
- *network 192.168.2.0*
- *network 10.0.0.0*
- *network 10.0.1.0*
- *no auto-summary*
- ***On R3***
- *router rip*
- *version 2*
- *network 192.168.3.0*
- *network 10.0.1.0*
- *no auto-summary*

Step 5: Verify Routing Table

- *show ip route*
- *Look for routes marked with R (RIP routes)*

Step 6: Test Connectivity

- ***From PC1:***
- *ping 192.168.2.2*
- *ping 192.168.3.2*

I. Observation

- RIP protocol successfully enabled on all routers
- Routers exchanged routing information automatically
- Routing tables updated dynamically
- End-to-end connectivity established between all LANs

- Ping between different networks successful.

J. Result

Dynamic routing using RIP protocol was successfully configured and verified using Boson Network Simulator.

K. Precautions

- Ensure correct network statements in RIP configuration
- Verify interfaces are up using no shutdown
- Use correct subnet masks and IP addressing
- Avoid overlapping IP networks
- Ensure serial links are properly connected.

L. Questions

1 What is dynamic routing?
2 Difference between RIP and static routing?
3 What is no auto-summary used for?
4 What command enables RIP?
5 What is routing table?
6 What does "R" mean in routing table?
7 Why is RIP not suitable for large networks?
8 What is periodic update in RIP?
9 What is convergence in routing?
10 What happens if RIP is not configured?
11 What are the limitations of RIP?

LAB EXPERIMENT 8: BASIC SWITCH CONFIGURATION IN BOSON NETWORK SIMULATOR

(CO 504.2, CO 504.3 & CO 504.4)

A. Aim:

- To configure a basic Layer 2 switch using Boson Network Simulator and verify connectivity between end devices in a LAN.

B. Prerequisites:

- Basic understanding of IP addressing and subnetting
- Knowledge of LAN components (PC, Switch, Ethernet cable)
- Familiarity with Boson Network Simulator interface.

C. Skills Required:

- Awareness of basic Ethernet cabling and device connections in a LAN
- Knowledge of **IP addressing and subnetting (IPv4 fundamentals)**
- Familiarity with network devices such as switches, hubs, and PCs
- Understanding of **Layer 2 switching concepts** (MAC addressing and frame forwarding).

D. Objectives:

- To configure a switch-based LAN topology
- To assign IP addresses to end devices
- To enable communication between multiple PCs through a switch
- To verify network connectivity using ping command
- To understand basic switch operation in a LAN.

E. Learning Outcomes (LO):

- LO1: Configure a basic switch-based LAN topology in a network simulator.
- LO2: Establish connectivity between multiple hosts using IP configuration in the same subnet.
- LO3: Verify network communication using ping and analyze connectivity results.

F. Hardware & Software Required:

- Boson Network Simulator
- PCs (virtual nodes)
- Layer 2 Switch (e.g., 2960 or generic switch in Boson).

G. Theory:

A switch is a Layer 2 networking device that connects multiple devices within a LAN and forwards data based on MAC addresses. In basic switch configuration, devices are connected physically and assigned IP addresses in the same subnet to enable communication.

Key points:

Switch operates at Data Link Layer

Uses MAC address table for forwarding frames

Does not require routing for communication within same subnet.

H. Procedure:

Step 1: Create Network Topology

- *Network Topology*
- *1 Switch*
- *2–4 PCs connected to the switch*
- *Same IP subnet (e.g., 192.168.10.0/24)*
- *Example IPs:*
  - *PC1 → 192.168.10.1*
  - *PC2 → 192.168.10.2*
  - *PC3 → 192.168.10.3*

Draw Topology:

Step 2: Assign IP Addresses

- *Assign IP addresses to all PCs within the same subnet.*

Step 3: Verify Connectivity

- *Open command prompt on PC1*
- *Use ping command:*
- *ping 192.168.10.2*

Step 4: Observe Results

- *Check successful ICMP replies*
- *Confirm communication between all PCs*

I. Observation

- All PCs in the same subnet can communicate via switch
- Switch forwards frames based on MAC address learning
- No routing device is required for intra-LAN communication.

J. Result

A basic switched LAN was successfully configured in Boson Network Simulator, and communication between end devices was verified using ping.

K. Precautions

- Use correct subnet masks and IP addressing
- Avoid overlapping IP networks.

L. Questions

1 What is the role of a switch in a LAN?
2 Why do all PCs need to be in the same subnet?
3 What happens if IP addresses are incorrectly configured?
4 How does a switch forward data frames?
5 Can two PCs communicate without a router in this setup?

LAB EXPERIMENT 9: SWITCHING USING BOSON NETWORK SIMULATOR

(CO 504.2, CO 504.3 & CO 504.4)

A. Aim:

- To understand and implement LAN switching concepts using Boson Network Simulator and observe how a switch forwards frames using MAC address learning.

B. Prerequisites:

- Basic knowledge of Ethernet LAN and MAC addressing
- Understanding of hubs vs switches.

C. Skills Required:

- Awareness of basic Ethernet cabling and device connections in a LAN
- Knowledge of **IP addressing and subnetting (IPv4 fundamentals)**
- Familiarity with network devices such as switches, hubs, and PCs
- Understanding of **Layer 2 switching concepts** (MAC addressing and frame forwarding).

D. Objectives:

- To configure a switched LAN in Boson Network Simulator
- To observe MAC address learning behaviour of a switch
- To verify frame forwarding based on MAC address table
- To understand unicast, broadcast, and unknown unicast flooding.

E. Learning Outcomes (LO):

- LO1: Demonstrate the working of a Layer 2 switch in a simulated LAN environment using Boson Network Simulator.
- LO2: Explain and analyze MAC address learning and frame forwarding behaviour in a switch.
- LO3: Differentiate between unicast, broadcast, and unknown unicast traffic handling in switching.
- LO4: Interpret packet flow and switching decisions to evaluate network communication efficiency.

F. Hardware & Software Required:

- Boson Network Simulator (Boson NetSim / Boson Simulation Tool)
- Basic network topology setup (PCs, Switch).

Theory:

A switch is a Layer 2 networking device that forwards data frames based on MAC addresses. Unlike hubs, switches intelligently send frames only to the intended destination.

MAC Address Table (CAM Table):

- Switch maintains a table mapping MAC addresses to switch ports
- Learns MAC addresses dynamically when frames are received
- Uses this table to make forwarding decisions

Switching Process:

- When a frame arrives, switch reads source MAC address and updates table
- Checks destination MAC address
- If known → forwards to specific port
- If unknown → floods to all ports except incoming port
- Broadcast frames are sent to all ports.

G. Procedure:

Step 1: Create Network Topology

- *1 Switch (e.g., 2960 or generic switch in Boson)*
- *3–4 PCs connected via Ethernet*
- *IP addressing in same subnet (e.g., 192.168.1.0/24)*
- *Example:*
    - *PC1 → 192.168.1.1*
    - *PC2 → 192.168.1.2*
    - *PC3 → 192.168.1.3*

Draw Topology:

Step 2: Assign IP Addresses

- *Assign IP addresses to all PCs within the same subnet.*

Step 3: Start Simulation Mode

- *Switch to simulation/packet tracing mode (if available).*

Step 4: Generate Traffic

- *Use ping command:*
- *ping 192.168.1.2*
- *Send traffic from PC1 to PC2.*

Step 5: Observe Switch Behaviour

- *First frame will be flooded (unknown MAC)*
- *Switch learns MAC addresses*
- *Subsequent frames are forwarded directly.*

Step 6: Verify MAC Table

- *Check switch MAC address table (if simulation supports CLI)*
- *Observe learned entries.*

H. Observation

- Initial communication causes flooding
- Switch learns MAC addresses dynamically
- After learning, unicast communication occurs efficiently
- Broadcast packets are sent to all devices.

I. Result

The switching mechanism was successfully implemented in Boson Network Simulator. It was observed that the switch learns MAC addresses and forwards frames intelligently, reducing unnecessary traffic compared to a hub.

J. Precautions

- Use correct subnet masks and IP addressing
- Avoid overlapping IP networks.

K. Questions

1 How does switch differ from a hub?
2 What is MAC address learning?
3 What happens when destination MAC is unknown?
4 What is flooding in switching?

5 What is the role of CAM table?

LAB EXPERIMENT 10: ERROR DETECTION / ERROR CORRECTION USING BOSON NETWORK SIMULATOR

(CO 504.3 & CO 504.4)

A. Aim:

- To simulate and understand error detection (and basic error handling behaviour) in data transmission using Boson Network Simulator.

B. Prerequisites:

- Knowledge of data transmission errors (noise, corruption, packet loss)
- Basic understanding of ping and packet flow.

C. Skills Required:

- Knowledge of binary numbers and data representation
- Basic troubleshooting and analytical skills
- Understanding of CRC, parity check, and Hamming code techniques

D. Objectives:

- To observe how errors affect data transmission in a simulated network
- To understand the concept of error detection mechanisms in networking
- To analyze packet delivery with and without transmission errors
- To relate simulation behaviour with real-world error control techniques.

E. Learning Outcomes (LO):

- LO1: Understand the concept of transmission errors in data communication.
- LO2: Perform error detection techniques such as parity check and CRC using the simulator.
- LO3: Analyze how error correction methods like Hamming Code improve data reliability.
- LO4: Simulate and observe packet transmission and error handling in a network environment.
- LO5: Identify and troubleshoot errors occurring during data transmission.
- LO6: Interpret simulator results and evaluate the effectiveness of error control techniques.

F. Hardware & Software Required:

- Boson Network Simulator
- PCs (virtual nodes) and Switch or simple network topology.

G. Theory:

- Errors occur when transmitted data is altered due to noise, interference, or signal degradation. Common types include:
  - Single-bit error
  - Multi-bit error
  - Burst error
- Error detection ensures that the receiver can identify whether data has been corrupted. Common techniques include:
  - Parity check
  - Checksum
  - CRC (Cyclic Redundancy Check)
- Error correction not only detects errors but also attempts to correct them using redundancy techniques such as:
  - Hamming Code
  - Forward Error Correction (FEC)
- In Boson Network Simulator, error behaviour is typically observed through packet loss, failed ping replies, or corrupted frame simulation (depending on module support).

H. Procedure:

Part-A: Simple Error Detection:

Step 1: Create Network Topology

- *2–3 PCs*
- *1 Switch (optional)*
- *All devices in same subnet (e.g., 192.168.1.0/24)*
- *Add PCs and connect them via switch*

Draw Topology:

Step 2: Assign IP Addresses

- *Assign IP addresses to all PCs within the same subnet.*
  Example:
  PC1 → 192.168.1.1
  PC2 → 192.168.1.2

Step 3: Generate Normal Traffic

- *Use ping command:*
- *ping 192.168.1.2*
- *Observe successful packet transmission.*

Step 4: Simulate Error Condition

- *Disable interface temporarily, OR*
- *Introduce link degradation / packet drop (if supported), OR*
- *Disconnect and reconnect link.*

Step 5: Observe Behaviour

- *Packet loss or failed ICMP replies*
- *Timeout messages*
- *Retransmission attempts (if simulation supports TCP behaviour).*

Part-B: To simulate a simple network in Boson Network Simulator and observe error detection behaviour through packet loss, timeout, and failed connectivity scenarios.

Step 1: Network Topology:

- *2 PCs (PC0, PC1)*
- *1 Switch (optional but recommended)*
- *Copper straight-through cables*

Step 2: IP Addressing Table:

Device	IP Address	Subnet Mask
PC0	192.168.1.1	255.255.255.0
PC1	192.168.1.2	255.255.255.0

Step 3: Configure IP Addresses

- *Click PC0 → Desktop → IP Configuration*
- *IP: 192.168.1.1, Mask: 255.255.255.0*
- *Click PC1 → Desktop → IP Configuration*
- *IP: 192.168.1.2, Mask: 255.255.255.0*

Step 4: Verify Normal Connectivity (Baseline Test)

- *Open PC0 → Command Prompt*
- *Run: ping 192.168.1.2*
- *Expected Result:*
- *Reply from 192.168.1.2*
- *0% packet loss*

Step 5: Introduce Error Condition

- *Method A: Disable Port*
- *Click switch port connected to PC1*
- *Shut down interface (if CLI supported) OR*
- *Method B: Disconnect Cable*
- *Remove cable between PC1 and switch temporarily*

Step 6: Re-Test Connectivity

- *Again, run ping from PC0:*
- *ping 192.168.1.2*
- *Expected Result:*
- *Request timed out*
- *Packet loss observed*

Step 7: Restore Network

- *Reconnect cable OR enable port again*

Step 8: Final Verification

- *Run ping again*
- *Confirm successful packet delivery restored*

I. Observation

- Under normal conditions, packets are delivered successfully
- When error conditions are introduced, packet loss or failure is observed
- Network protocols detect errors using acknowledgment and timeout mechanisms
- Data integrity is maintained through retransmission in reliable protocols.

J. Result

The behaviour of error detection in data transmission was successfully observed using Boson Network Simulator. Packet loss and transmission failures demonstrated the need for error detection mechanisms in networking.

K. Precautions

- Disable and Enable link properly
- Use correct IP Address.

L. Questions

1 What is the difference between error detection and error correction?
2 What is CRC used for?
3 Why do packets get dropped in a network?
4 How does TCP handle transmission errors?
5 What happens when a link is disconnected in a network?
6 What does "request timed out" mean in ping results?
7 How does a switch respond to link failure?
8 What is packet loss?
9 How is error detection reflected in this simulation?
10 What is CRC and why is it used?
11 How does CRC detect errors in data transmission?
12 What happens when CRC check fails?
13 Is CRC error correction or error detection?
14 At which layer is CRC performed?
15 What is Hamming Code used for?
16 What is the role of parity bits?
17 What is a syndrome in Hamming Code?
18 How many errors can Hamming Code correct?
19 What is the difference between CRC and Hamming Code?

SCHEME: 23 Series

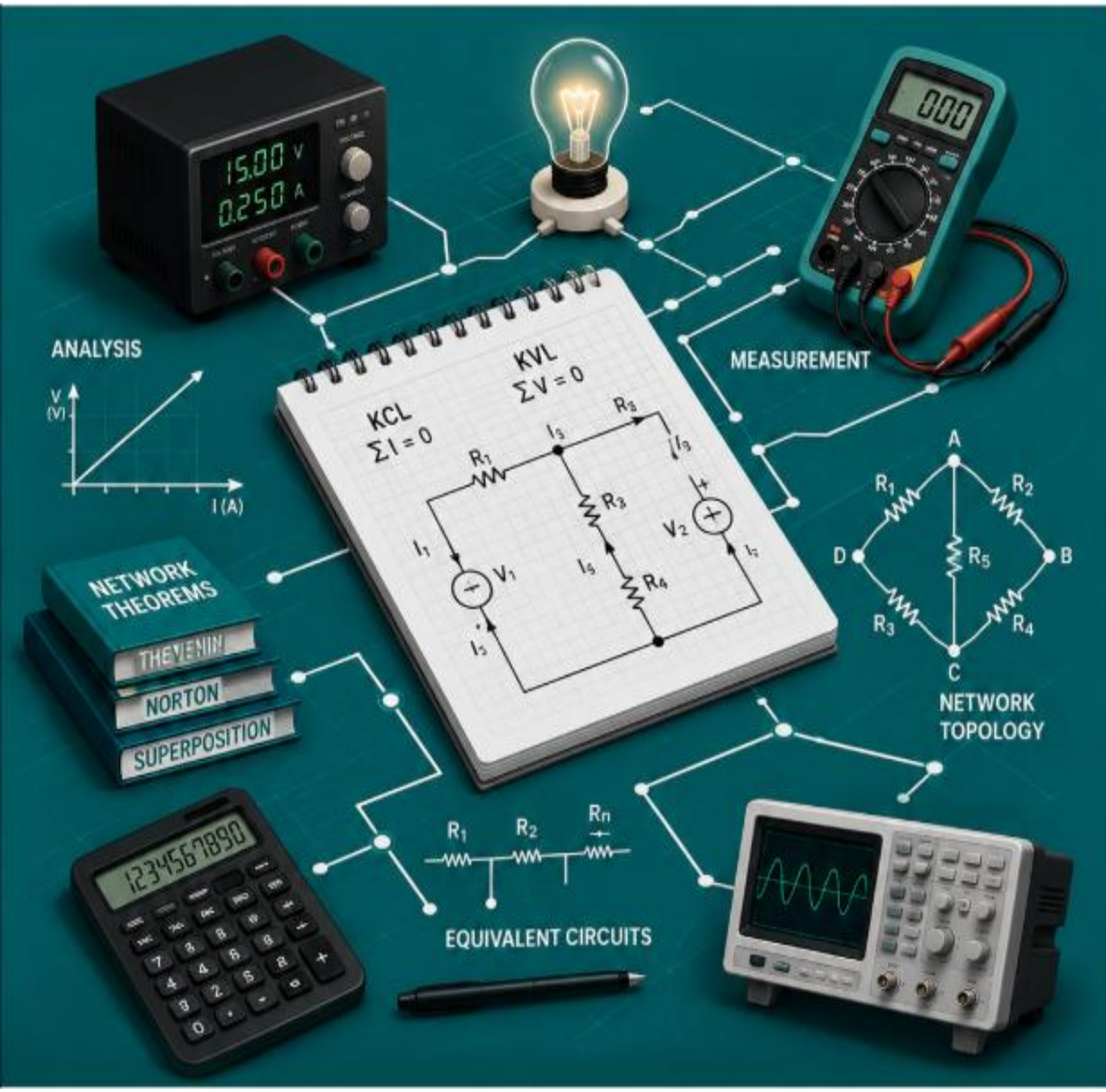
Name: ____________________________

SPN No.: __________________________

Year: 20______20_______

LABORATORY MANUAL FOR

FUNDAMENTAL OF ELECTRICAL NETWORK (23103)



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This is to certify that Mr./Ms.. having SPN. No. ...., of First Semester of Diploma in Electronics and Telecommunication Engineering.

He/She has completed the term work satisfactorily in course **Fundamental of Electrical Network (23103)** for the academic year 20.......... to 20..............as prescribed in the curriculum.

Place: ....

Date: ....

Mr. Sanjiv Borkar
Subject Teacher

Dr. Vijay Rathod
Head of the Department

Dr. Shivaji Ghungrad
Principal

Seal

St. Xavier's Technical Institute

Mahim, Mumbai 400016

Department of Electronics and Telecommunication Engineering

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Department of Electronics and Telecommunication Engineering

Program Outcomes (POs)

1. **Basic and Discipline specific knowledge:** Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the engineering problems.

2. **Problem analysis:** Identify and analyse well-defined engineering problems using codified standard methods.

3. **Design/ development of solutions:** Design solutions for well-defined technical problems and assist with the design of systems components or processes to meet specified needs.

4. **Engineering Tools, Experimentation and Testing:** Apply modern engineering tools and appropriate technique to conduct standard tests and measurements.

5. **Engineering practices for society, sustainability and environment:** Apply appropriate technology in context of society, sustainability, environment and ethical practices.

6. **Project Management:** Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.

7. **Life-long learning:** Ability to analyse individual needs and engage in updating in the context of technological changes.

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DIPLOMA IN ELECTRONICS AND TELECOMMUNICATION ENGINEERING (DETE)
FIRST YEAR SEMESTER-I
FUNDAMENTAL OF ELECTRICAL NETWORK LABORATORY MANUAL

Document Number: 2627-JUN 26-DETE-103

00	19th Jun 2026	Laboratory Manual for FEN (23103)	SRB	VRR	SBG
REV. NO.	**DATE**	**DESCRIPTION**	**PREPARED BY**	**CHECKED BY**	**APPROVED BY**

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Rev. No.	Date	Pages	Description
00	19th Jun 2026	82	Laboratory Manual: Fundamental of Electrical Network

HOLD LIST

Hold No.	Pages	Description
NIL	NA	--

EXECUTIVE SUMMARY

Laboratory Manual of Fundamental of Electrical Network (FEN) is prepared by Mr. Sanjiv R. Borkar, reviewed by Dr. Mahesh Munde, and approved by Dr. Vijay Rathod and Dr. Shivaji Ghungrad, consisting of Ten (14) laboratory experiments covering the prescribed Course Outcomes (COs).

Fundamentals of electrical technology introduce the basic principles governing electricity, circuits, and electrical systems. Electricity is based on the movement of electric charge, typically carried by electrons in a conductor. Key quantities include voltage (the potential difference driving current), current (the flow of charge), and resistance (the opposition to current flow). These are related through Ohm's Law.

Electrical circuits are the backbone of the subject and are categorized mainly into direct current (DC) and alternating current (AC) systems. DC circuits provide a constant flow of current in one direction, while AC circuits involve current that periodically reverses direction, which is widely used in power systems due to its efficiency in transmission.

Basic circuit components include resistors, capacitors, and inductors. Capacitors store electrical energy in an electric field. Inductors store energy in a magnetic field.

Analysis techniques such as Kirchhoff's Laws help determine current and voltage in complex circuits. These laws are essential for solving network problems and designing electrical systems.

Overall, the fundamentals of electrical technology provide the foundation for advanced study in areas such as Units, power systems, electronics, control systems, and communication engineering, enabling the development and maintenance of modern electrical infrastructure.

Mr. Sanjiv Borkar Lecturer, DETE	Dr. Vijay Rathod HOD, DETE	Dr. Shivaji Ghungrad Principal

INDEX

Experiment 01: Study of Breadboard, Multimeter and DC Power Supply (CO 103.1)

Aim: To study and understand the functions and applications of the Breadboard, Regulated DC Power Supply, and Digital Multimeter, and to perform basic voltage and resistance measurements.

Prerequisites:

- Voltage, current, and resistance.
- SI units of basic electrical quantities.
- Operating of measuring instruments.
- Basic laboratory safety practices.

Learning Objectives:

- Study the construction and internal connections of a breadboard.
- Understand the operation of a Regulated DC Power Supply.
- Understand the functions of a Digital Multimeter.
- Measure DC voltage using a Digital Multimeter.
- Measure resistance and compare it with the value obtained from the resistor colour code.

Learning Outcomes:

- Use a breadboard for basic circuit connections.
- Operate a Regulated DC Power Supply.
- Use a Digital Multimeter for basic electrical measurements.
- Measure DC voltage and resistance.
- Determine and verify resistor values using colour codes and a Digital Multimeter.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Breadboard	Standard solderless breadboard	1
2	Regulated DC Power Supply	0–32 V DC	1
3	Digital Multimeter	Digital type	1
4	Resistors	Different values	10
5	Connecting Wires	As required	As required

Theory:

Breadboard: A breadboard is used to make quick and temporary electrical connections between electronic components such as resistors, LEDs, capacitors, and other components. It allows electronic circuits to be assembled and tested without soldering.

Characteristics:

- A breadboard contains a matrix of holes that are internally connected.
- The holes are arranged in groups to provide electrical connections between components.
- Components and connecting wires can be easily inserted and removed.
- It is commonly used for circuit prototyping, testing, and laboratory experiments.

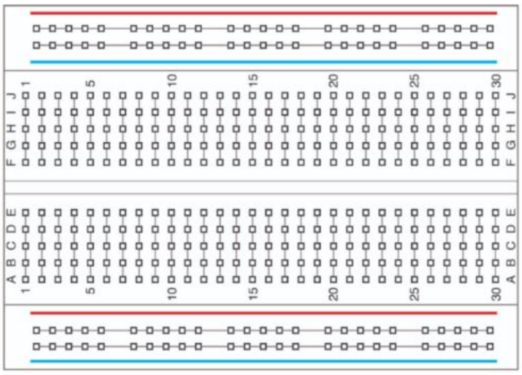

Fig. 1.1: Breadboard and its Internal Connections

Regulated DC Power Supply: A Regulated DC Power Supply is used to provide a stable DC voltage and current to electrical and electronic circuits.

Function: To supply regulated DC power to electrical and electronic circuits.

Characteristics:

- Provides a variable DC output in the range of 0–32 V.
- The output voltage can be adjusted according to circuit requirements.
- The output is obtained through the positive (+) and negative (−) terminals.
- It is commonly used to power and test laboratory circuits.

Fig. 1.2: Regulated DC Power Supply

Digital Multimeter: A Digital Multimeter (DMM) is an electronic measuring instrument used to measure various electrical quantities.

Functions: A Digital Multimeter can be used to measure:

- DC and AC voltage.
- DC current.
- Resistance.

Depending on the model, it may also be used to test electronic components such as diodes, transistors, and capacitors.

Characteristics:

- Different measurement functions and ranges can be selected using the rotary selector switch.
- The red probe is generally used as the positive (+) probe.
- The black probe is connected to the COM terminal and used as the common or negative (−) probe.
- The correct function and range must be selected before taking a measurement.

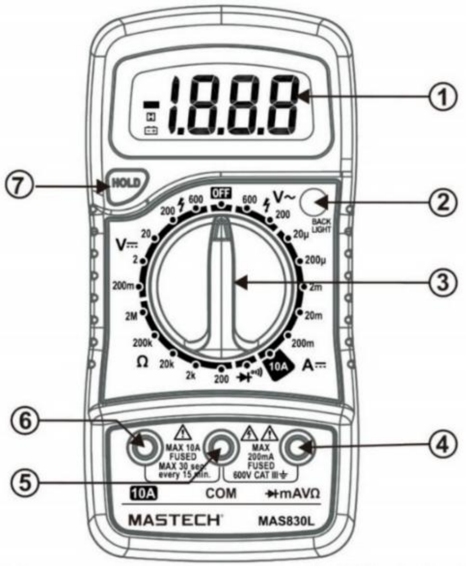

Fig. 1.3: Digital Multimeter

Connection Diagram:

Part A: DC Voltage Measurement:

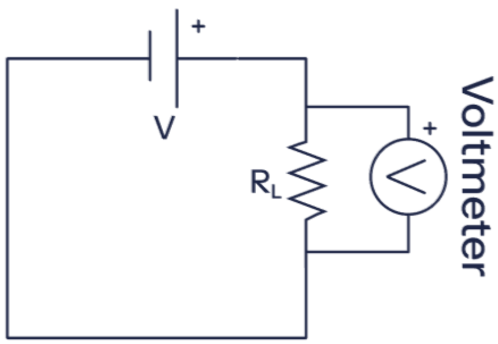

Fig. 1.4: Connection for DC Voltage Measurement

Part B: Resistance Measurement:

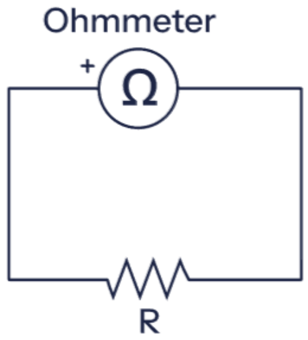

Fig. 1.5: Connection for Resistance Measurement

Procedure:

Part A: DC Voltage Measurement

- Ensure the Regulated DC Power Supply is OFF, connect the Digital Multimeter across the output terminals, and set it to the appropriate DC Voltage (V) range.
- Switch ON the power supply and set the output voltage to 5 V.
- Measure and record the output voltage displayed on the Digital Multimeter.
- Repeat the measurement for 10 V, 15 V, 20 V, and 25 V, recording all readings in the observation table.
- After completing the measurements, reduce the output voltage to minimum and switch OFF the power supply.

Part B: Resistance Measurement

- Select ten resistors of different values and determine their nominal resistance using the resistor colour code.
- Set the Digital Multimeter to the appropriate Resistance (Ω) range.
- Connect the DMM probes across each resistor and measure its resistance.
- Repeat the measurement for all selected resistors, recording the measured values in the observation table.
- Compare the measured resistance values with the corresponding colour-code values and note the observations.

Precautions:

- Switch OFF the power supply before making or changing connections.
- Select the correct function and range on the Digital Multimeter before measurement.
- Maintain correct polarity while measuring DC voltage.
- Never measure resistance in a powered circuit.
- Ensure that all connections are firm and secure.
- Do not exceed the measurement limits of the instruments.

Observation Tables:

Table 1.1: DC Voltage Measurement

Parameter	**Reading 1**	**Reading 2**	**Reading 3**	**Reading 4**	**Reading 5**
Voltage set on DC Power Supply (V)	5	10	15	20	25
Voltage measured using DMM (V)					

Table 1.2: Resistance Measurement

Sr. No.	**Resistance Colour Code**	**Resistance from Colour Code (Ω)**	**Resistance Measured using DMM (Ω)**
1			
2			
3			
4			
5			

Calculations: The resistance value is determined from the resistor colour code and compared with the value measured using the Digital Multimeter.

For a four-band resistor:

R = (First two significant digits) × Multiplier

Colour Code: ______________________________

Calculated Resistance: ____________________ Ω

Measured Resistance: ______________________ Ω

Result: The functions and operation of the Breadboard, Regulated DC Power Supply, and Digital Multimeter were studied successfully. DC voltage and resistance measurements were performed using the Digital Multimeter.

Conclusion: The experiment provided practical understanding of the basic laboratory equipment used in electrical and electronic circuits. Students studied the use of a breadboard, operated a Regulated DC Power Supply, and performed DC voltage and resistance measurements using a Digital Multimeter. These basic instrument-handling and measurement skills are essential for performing subsequent electrical network experiments.

Review Questions:

1. Write the functions of the breadboard.
2. Differentiate between voltage, current and resistance measurements using a Digital Multimeter

Experiment 02: Demonstration of Errors in Measurement Using a Multimeter and DC Power Supply (CO 103.1)

Aim: To demonstrate errors in voltage measurement using a Digital Multimeter and DC Power Supply, and to determine the mean absolute error from repeated measurements.

Prerequisites:

- Operation of a Digital Multimeter.
- Operation of a Regulated DC Power Supply.
- Basic arithmetic operations and calculation of an average value.

Learning Objectives:

- Understand the concept of error in electrical measurements.
- Identify the common types and sources of measurement errors.
- Perform repeated voltage measurements using a Digital Multimeter.
- Determine the actual or most probable value from repeated measurements.
- Calculate absolute error and mean absolute error.

Learning Outcomes:

- Perform repeated DC voltage measurements using a Digital Multimeter.
- Identify systematic and random errors in measurement.
- Calculate the actual or most probable value from a set of measured readings.
- Determine the absolute error for individual measurements.
- Calculate the mean absolute error of the measurement.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	Variable DC Output	1
2	Digital Multimeter	DC Voltage Measurement	1
3	Connecting Wires	As required	As required

Theory:

Measurement Error: Measurement error is the difference between the true (actual) value and the measured value of a quantity. The error may be positive or negative depending on whether the measured value is higher or lower than the actual value.

Measurement errors are classified into:

- Systematic Errors
- Random Errors

Systematic Errors: Systematic errors occur in a consistent and predictable manner due to the measuring instrument, observation method, or environmental conditions.

Observational Errors: Observational errors occur due to incorrect observation or interpretation of instrument readings.

Minimization:

- Taking readings carefully.
- Using the correct viewing position.
- Following the proper measurement procedure.

Environmental Errors: Environmental errors are caused by external conditions affecting the measuring instrument or measurement process.

Common causes:

- Temperature
- Humidity
- Dust
- Vibration
- External electrical interference

Minimization: Perform measurements under stable environmental conditions.

Instrumental Errors: Instrumental errors occur due to faulty, uncalibrated, or improperly used instruments.

Minimization:

- Properly calibrate the instrument.
- Select the correct measurement range.
- Use the instrument within its specified operating limits.

Random Errors: Random errors occur unpredictably and vary in magnitude and direction between measurements.

They can be reduced by:

- Taking repeated measurements.
- Calculating the arithmetic mean.

Actual (Most Probable) Value: The arithmetic mean of repeated measurements is considered the actual (most probable) value.

$$X_a = \frac{X_1 + X_2 + \cdots + X_n}{n}$$

Where:

- X_a = Actual (most probable) value

- $X_1, X_2, \ldots, X_n =$ Individual measured values
- $n =$ Number of measurements

Absolute Error: Absolute error is the magnitude of the difference between the measured value and the actual (most probable) value.

$$E_a = | X_a - X_i |$$

Where:

- $E_a =$ Absolute error
- $X_a =$ Actual (most probable) value
- $X_i =$ Individual measured value

Mean Absolute Error: Mean Absolute Error (MAE) is the arithmetic mean of all individual absolute errors.

$$\text{MAE} = \frac{E_1 + E_2 + \cdots + E_n}{n}$$

Where:

- $E_1, E_2, \ldots, E_n =$ Individual absolute errors
- $n =$ Number of measurements

Connection Diagram:

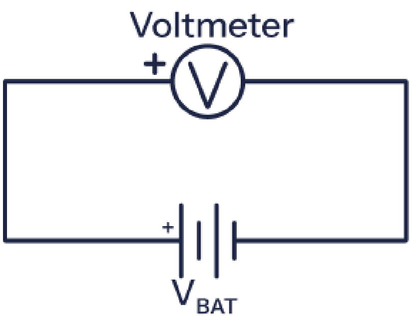

Fig. 2.1: Connection Diagram for Measuring Voltage Error

Procedure:

- Ensure the Regulated DC Power Supply is OFF, connect the Digital Multimeter across its output terminals, and set the DMM to the appropriate DC Voltage range.
- Switch ON the DC Power Supply and set the required output voltage.
- Measure the output voltage using the Digital Multimeter and record the reading.
- Repeat the measurement ten times and record all readings in the observation table.
- Calculate the arithmetic mean of the ten readings to determine the actual (most probable) value (X_a).
- Calculate the absolute error for each measured value.
- Calculate the mean absolute error and record all calculated values in the observation table.

Precautions:

- Ensure that the Digital Multimeter is set to the correct DC Voltage measurement mode.
- Select an appropriate measurement range before taking readings.
- Maintain correct polarity while connecting the Digital Multimeter.
- Ensure that all connections are firm and secure.
- Take all readings under the same measurement conditions.
- Do not change the set voltage while taking repeated measurements.
- Switch OFF the power supply after completing the experiment.

Observation Table:

Table 2.1: Measurement of Error Voltage

Sr. No.	Voltage Set on DC Power Supply (V)	Voltage Measured Using DMM Xi (V)	Actual / Most Probable Value Xa (V)	Absolute Error Ea = |Xa – Xi| (V)
1				
2				
3				
4				
5				
6				
7				
8				

Mean Absolute Error = ____________________ V

Calculations:

Actual or Most Probable Value:

$$X_a = (X_1 + X_2 + X_3 + \ldots + X_{10})/10$$

X_a = ____________________ **V**

Absolute Error:

For each measured value:

$$E_a = |X_a - X_i|$$

For Reading 1:

$$E_1 = |X_a - X_1|$$

E_1= ____________________ V

Similarly, calculate the absolute error for all remaining readings.

Mean Absolute Error:

$$\boldsymbol{Mean\ Absolute\ Error = (E_1 + E_2 + E_3 + \ldots + E_{10})/10}$$

$\boldsymbol{Mean\ Absolute\ Error}$ = ____________________ V

Result: Repeated DC voltage measurements were performed using a Digital Multimeter and DC Power Supply. The actual or most probable value, individual absolute errors, and mean absolute error of the measured voltage were determined successfully.

Conclusion: The experiment demonstrated that repeated measurements of the same electrical quantity may show small variations due to systematic and random errors. By taking multiple voltage readings and calculating their arithmetic mean, the most probable value of the measurement was determined. The calculation of absolute error and mean absolute error provided a quantitative understanding of measurement accuracy and the importance of careful measurement practices.

Review Questions:

1. Differentiate between systematic errors and random errors in electrical measurements.
2. Suggest two methods to minimize measurement errors while performing electrical experiments.

Experiment 03: Measurement of Fundamental AC Parameters Using CRO and Function Generator (CO 103.2)

Aim: To understand and measure the fundamental parameters of a sinusoidal AC waveform using a Cathode Ray Oscilloscope (CRO) and Function Generator.

Prerequisites:

- Alternating voltage and sinusoidal waveforms.
- Basic operation of a Function Generator.
- Basic operation of a Cathode Ray Oscilloscope (CRO).
- Units of voltage, time, and frequency.

Learning Objectives:

- Understand the fundamental parameters of a sinusoidal AC waveform.
- Generate a sinusoidal waveform using a Function Generator.
- Observe and adjust the waveform on a CRO.
- Measure the maximum voltage and time period of an AC waveform.
- Calculate the frequency of the waveform from the measured time period.

Learning Outcomes:

- Generate and observe a sinusoidal AC waveform.
- Identify the fundamental parameters of an AC waveform.
- Measure the maximum voltage using the vertical scale of a CRO.
- Measure the time period using the horizontal scale of a CRO.
- Calculate the frequency of an AC waveform from its measured time period.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Cathode Ray Oscilloscope (CRO)	Dual Channel	1
2	Function Generator	Sine Wave Output	1
3	Multimeter	Digital Type	1
4	CRO Probe / Connecting Cable	Suitable Type	As Required

Theory:

An Alternating Current (AC) waveform continuously changes its magnitude and direction with respect to time. A sinusoidal waveform is one of the most commonly used AC waveforms. In this experiment, a Function Generator is used to generate a sinusoidal waveform, while a Cathode Ray Oscilloscope (CRO) is used to display and measure its fundamental parameters.

The basic parameters of an AC waveform are described below.

Frequency (f): Frequency is defined as the number of complete cycles of a periodic waveform occurring in one second. It is measured in Hertz (Hz).

$$\boldsymbol{f = 1/T}$$

Where:

- f = Frequency in Hertz (Hz)
- T = Time period in seconds (s)

Time Period (T): The time period is the time required by a periodic waveform to complete one full cycle. It is measured in seconds (s).

$$\boldsymbol{T = 1/f}$$

Maximum Voltage $(\boldsymbol{V_m})$: The maximum voltage, also known as the peak voltage, is the maximum value reached by an AC waveform with respect to the zero-reference level.

For a waveform displayed on the CRO:

$$\boldsymbol{V_m = Number\ of\ Vertical\ Divisions \times VOLTS/DIV\ Setting}$$

Peak-to-Peak Voltage $(\boldsymbol{V_{PP}})$: Peak-to-peak voltage is the voltage measured from the maximum negative peak to the maximum positive peak of an AC waveform.

For a symmetrical sinusoidal waveform:

$$\boldsymbol{V_{pp} = 2V_m}$$

Phase Angle (θ): The phase angle represents the angular position of a sinusoidal waveform with respect to a reference. It is generally measured in degrees (°) or radians (rad).

Phase Difference: Phase difference is the angular difference between two sinusoidal waveforms of the same frequency. Depending on their relative position, one waveform may lead or lag the other.

Instantaneous Value: The instantaneous value is the magnitude of an alternating voltage or current at a particular instant of time.

For a sinusoidal voltage:

$$\boldsymbol{v = V_m \times sin(\omega t)}$$

Where:

- v = Instantaneous voltage
- V_m = Maximum voltage
- ω = Angular frequency
- t = Time

Angular Frequency (ω): Angular frequency represents the rate of change of the phase angle of a sinusoidal waveform.

$$\omega = 2\pi f$$

Where:

- ω = Angular frequency in rad/s
- f = Frequency in Hz

Connection Diagram:

Procedure:

- Ensure the Function Generator and CRO are OFF, then connect the Function Generator output to the CRO input using a suitable probe or connecting cable.
- Switch ON both instruments, select a sinusoidal waveform, and set the required frequency and amplitude.
- Adjust the VOLTS/DIV and TIME/DIV controls to obtain a clear and stable waveform.
- Measure the vertical divisions from the zero-reference level to the positive peak, note the VOLTS/DIV setting, and calculate the maximum voltage \left(V_{m}\right).
- Measure the horizontal divisions for one complete cycle, note the TIME/DIV setting, and calculate the time period T.
- Calculate the frequency using f=\frac{1}{T}, repeat the measurements for different waveform settings, and record all observations.
- After completing the experiment, switch OFF the Function Generator and CRO.

Precautions:

- Ensure that all connections are made correctly before switching ON the instruments.
- Use the appropriate CRO input channel and probe connection.
- Select suitable VOLTS/DIV and TIME/DIV settings to obtain a clear waveform.
- Ensure that the waveform is stable before taking measurements.
- Count the waveform divisions carefully to minimize measurement errors.
- Note the units of the VOLTS/DIV and TIME/DIV settings before performing calculations.

- Do not apply a signal exceeding the input rating of the CRO.
- Switch OFF the instruments after completing the experiment.

Observation Tables:

Table 3.1: Measurement of Maximum Voltage

Sr. No.	Vertical Divisions on CRO A	VOLTS/DIV Setting B (V/div)	Maximum Voltage $V_m = A \times B\ (V)$
1			
2			
3			
4			
5			

Table 3.2: Measurement of Time Period and Frequency

Sr. No.	Horizontal Divisions for One Cycle A	TIME/DIV Setting B (s/div)	Time Period $T = A \times B(s)$	Frequency $f = 1/T\ (Hz)$
1				
2				
3				
4				
5				

Calculations:

Maximum Voltage:

$V_m = Number\ of\ Vertical\ Divisions \times VOLTS/DIV\ Setting$

$V_m = A \times B$

$V_m =$ ____________________ V

Time Period:

$T = Number\ of\ Horizontal\ Divisions\ for\ OneCycle \times TIME/DIV\ Setting$

$T = A \times B$

T = ____________________ s

Frequency:

$f = 1/T$

$f = 1/$____________________

f= ____________________ **Hz**

Result: The sinusoidal AC waveform was generated using the Function Generator and observed on the CRO. The maximum voltage, time period, and frequency of the waveform were measured and calculated successfully.

Maximum Voltage, $V_m =$ ____________________ **V**

Time Period, $T =$ ____________________ **s**

Frequency, $f =$ ____________________ **Hz**

Conclusion: The experiment provided practical understanding of the fundamental parameters of a sinusoidal AC waveform. The maximum voltage and time period were measured using the vertical and horizontal scales of the CRO, and the frequency was calculated from the measured time period. The experiment also developed basic skills in operating a Function Generator and CRO for AC waveform generation and measurement.

Review Questions:

1. Define RMS value, peak value and peak-to-peak value of a sinusoidal waveform.
2. Explain the relationship between frequency and time period.

Experiment 04: Measurement of Phase Difference Between Two AC Signals and Identification of Leading and Lagging Signals (CO 103.2)

Aim: To measure the phase difference between two AC signals using a Cathode Ray Oscilloscope (CRO) and identify the leading and lagging signals.

Prerequisites:

- Sinusoidal AC waveforms.
- Time period and frequency of an AC signal.
- Basic operation of a Function Generator and CRO.

Learning Objectives:

- Understand the concept of phase and phase difference.
- Observe two AC waveforms simultaneously on a CRO.
- Measure the phase difference between voltage and current waveforms.
- Identify in-phase and out-of-phase waveforms.
- Identify leading and lagging signals in resistive, capacitive, and inductive networks.

Learning Outcomes:

- Observe and compare two AC waveforms using a CRO.
- Measure the phase difference between two sinusoidal signals.
- Distinguish between in-phase and out-of-phase waveforms.
- Identify whether one waveform leads or lags another.
- Relate phase difference to resistive, capacitive, and inductive circuit behaviour.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Cathode Ray Oscilloscope (CRO)	Dual Channel	1
2	Function Generator	Sinusoidal Output	1
3	Resistive Network	Suitable Value	1
4	Capacitive Network	Suitable Value	1
6	CRO Probes / Connecting Wires	As Required	As Required

Theory:

Phase: Phase is the angular position of a sinusoidal waveform with respect to a reference point.

One complete cycle corresponds to:

$$360^\circ = 2\pi \text{ radians}$$

Phase Difference: Phase difference is the angular displacement between two sinusoidal waveforms of the same frequency. It is expressed in degrees (°) or radians (rad).

$$\Phi = \left(\frac{\Delta t}{T}\right) \times 360^\circ$$

Where:

- Φ = Phase difference
- Δt = Time difference between corresponding points
- T = Time period of one cycle

In-Phase Waveforms: Two waveforms are in phase if they reach their corresponding maximum, minimum, and zero values at the same instant. For a purely resistive circuit:

$$\Phi = 0^\circ$$

Therefore, voltage and current are in phase.

Leading and Lagging:

- A waveform reaching a point earlier is said to lead.
- A waveform reaching the same point later is said to lag.

Phase Relationship in AC Circuits:

Circuit Phase Relationship

- **Resistive (R): Voltage and Current are in phase (0°)**
- **Capacitive (C): Current leads Voltage by 90°**
- **Inductive (L): Current lags Voltage by 90°**

Circuit Diagram:

Part A: Resistive Circuit (In-Phase):

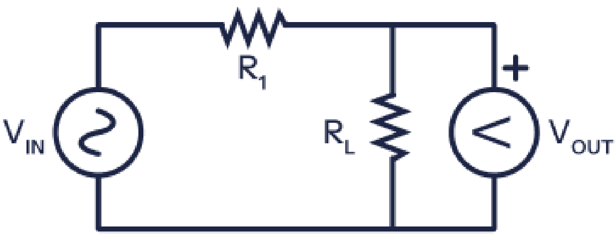

Fig. 4.1: Connection Diagram for In Phase Circuit

Part B: Capacitive Circuit (Out of Phase):

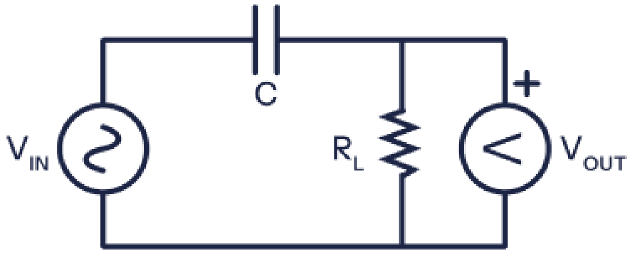

Fig. 4.2: Connection Diagram for Out of Phase Circuit

Procedure:

Part A: Resistive Network

- Connect the resistive network as shown in the circuit diagram and connect the voltage and current-related signals to the two channels of the CRO.
- Apply a sinusoidal AC signal using the Function Generator and adjust the CRO controls to obtain clear and stable waveforms.
- Observe the relative positions of the voltage and current waveforms.
- Measure the time displacement Δt and the time period T, then calculate the phase difference.
- Record the calculated phase difference and the corresponding observations.

Part B: Capacitive Network

- Connect the capacitive network as shown in the circuit diagram and apply the same sinusoidal AC signal.
- Observe the voltage and current-related waveforms on the CRO and adjust the display if required.
- Measure the time displacement Δt and the time period T.
- Calculate the phase difference between the waveforms.
- Identify the leading and lagging waveform, and record the phase difference and observations.

Precautions:

- Ensure that all circuit connections are correct before switching ON the instruments.
- Use the same signal frequency while comparing the two waveforms.
- Adjust the CRO controls to obtain clear and stable waveforms.
- Use corresponding points on both waveforms while measuring the time displacement.
- Note the TIME/DIV setting correctly before calculating the phase difference.
- Ensure that both CRO channels use a common reference where required.
- Do not exceed the input voltage rating of the CRO.
- Switch OFF all instruments after completing the experiment.

Observation Table:

Table 4.1: Measurement of Phase Difference

Sr. No.	Type of Network	Time Period, T (s)	Time Displacement, t(s)	Phase Difference, Φ (°)	Phase Relationship
1	Resistive				
2	Capacitive				

Calculations:

Phase Difference:

$$\boldsymbol{\Phi = (\Delta t / T) \times 360°}$$

Where:

- Φ = Phase difference in degrees
- Δt = Time displacement between the two waveforms
- T = Time period of one complete cycle

For the observed waveform:

$\boldsymbol{\Delta t}$ **= ____________________ s**

$\boldsymbol{T}$ **= ____________________ s**

Therefore,

$\boldsymbol{\Phi}$ **= (____________________ / ____________________) × 360°**

$\boldsymbol{\Phi}$ **= ____________________°**

Repeat the calculation for each network.

Result: The voltage and current-related AC waveforms of resistive, capacitive, and inductive networks were observed using the CRO, and their phase differences were measured. The leading and lagging relationships between the waveforms were identified successfully.

Conclusion: The experiment demonstrated the phase relationships between voltage and current in resistive, capacitive, and inductive AC networks. In the resistive network, the voltage and current were observed to be in phase. In the capacitive network, current was observed to lead voltage, whereas in the inductive network, current was observed to lag voltage. Thus, the experiment provided practical understanding of phase difference and the identification of leading and lagging AC signals.

Review Questions:

1. Differentiate between leading and lagging waveforms.
2. Draw the In-phase and out of phase sinusoidal waveforms.

Experiment 05: Construction of a Capacitor Charging Circuit and Measurement of Voltage Across Resistor and Capacitor (CO 103.3)

Aim: To construct a series RC circuit and measure the voltage across the resistor and capacitor for different values of DC supply voltage.

Prerequisites:

- Resistors and capacitors.
- Voltage measurement using a Digital Multimeter.
- Series circuit connections.
- Basic operation of a Regulated DC Power Supply.

Learning Objectives:

- Understand the charging behaviour of a capacitor through a resistor.
- Construct a series RC circuit.
- Measure the voltage across the resistor and capacitor.
- Observe the distribution of supply voltage across the resistor and capacitor.
- Verify the relationship between supply voltage, resistor voltage, and capacitor voltage.

Learning Outcomes:

- Construct a series RC circuit on a breadboard.
- Measure the voltage across a resistor and capacitor using a Digital Multimeter.
- Explain the basic charging action of a capacitor through a resistor.
- Calculate the time constant of an RC circuit.
- Verify the relationship between the applied supply voltage and the voltages across the resistor and capacitor.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	Variable DC Output	1
2	Digital Multimeter	DC Voltage Measurement	1
3	Breadboard	Standard Solderless Breadboard	1
4	Resistor	Suitable Value	1
5	Capacitor	Suitable Value	1
6	Connecting Wires	As Required	As Required

Theory:

Capacitor Charging: When a capacitor is connected to a DC supply through a resistor, the capacitor begins to charge.

During charging:

- Electric charge accumulates on the two plates of the capacitor.
- The two plates acquire equal and opposite charges.
- The voltage across the capacitor gradually increases.
- The charging current gradually decreases as the capacitor voltage increases.
- The capacitor approaches the applied supply voltage when it becomes fully charged.

The resistor connected in series limits the charging current and controls the rate at which the capacitor charges.

Series RC Circuit: A series RC circuit consists of a resistor (R) and capacitor (C) connected in series with a DC voltage source. The applied supply voltage is distributed across the resistor and capacitor.

According to Kirchhoff's Voltage Law:

$$\boldsymbol{V = V_{\mathrm{r}} + V_c}$$

Where:

- V = Applied supply voltage
- V_{r} = Voltage across the resistor
- V_c = Voltage across the capacitor

Therefore, the sum of the voltages across the resistor and capacitor should be approximately equal to the applied supply voltage.

Time Constant: The rate at which a capacitor charges depends on the resistance and capacitance of the circuit.

The time constant of an RC circuit is given by:

$$\boldsymbol{\tau = RC}$$

Where:

- τ = Time constant in seconds (s)
- R = Resistance in ohms (Ω)
- C = Capacitance in farads (F)

Circuit Diagram:

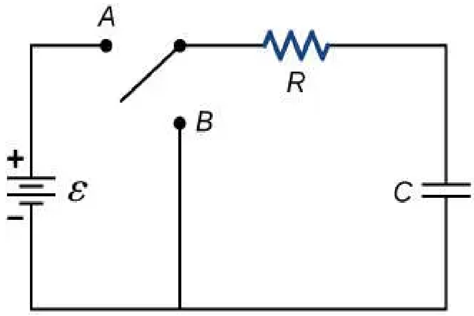

Fig. 5.1: Connection diagram for Charging of Capacitor

Procedure:

- Identify the required resistor and capacitor values, then connect them in series on the breadboard as shown in the circuit diagram.
- Connect the RC circuit to the Regulated DC Power Supply, verify all connections, and switch ON the power supply.
- Set the supply to the first required voltage and measure the voltages across the resistor (V_R) and capacitor (V_C) using the Digital Multimeter.
- Record the supply voltage V, resistor voltage (V_R), and capacitor voltage (V_C) in the observation table.
- Repeat the measurements for different supply voltage values and record all readings.
- For each set of readings, calculate (V_R+V_C), compare it with the applied supply voltage V, and calculate the time constant using $\tau = RC$.
- After completing the experiment, reduce the power supply output to minimum and switch OFF the power supply.

Precautions:

- Ensure that the power supply is switched OFF while making or changing circuit connections.
- Check the polarity of the capacitor before connecting it if a polarized capacitor is used.
- Do not apply a voltage greater than the rated voltage of the capacitor.
- Select the correct DC voltage measurement mode and range on the Digital Multimeter.
- Connect the voltmeter in parallel with the component whose voltage is being measured.
- Ensure that all circuit connections are firm and secure.
- Allow the capacitor to charge before recording the steady-state voltage readings.
- Discharge the capacitor safely before modifying or dismantling the circuit.

Observation Table

Table 5.1: Measurement of Voltage Across Resistor and Capacitor

Sr. No.	Supply Voltage, V (V)	Voltage Across Resistor, V_r (V)	Voltage Across Capacitor Vc (V)	$V_r + V_c$ (V)	Verification
1					
2					
3					
4					
5					

Calculations:

Verification of Supply Voltage:

According to Kirchhoff's Voltage Law:

$$V = V_{\mathrm{r}} + V_c$$

For one set of observed readings:

V = ____________________ V

V_{r} = ____________________ V

V_c = ____________________ V

Therefore,

$V_{\mathrm{r}} + V_c$ = ____________________ + ____________________

$V_{\mathrm{r}} + V_c$ = ____________________ V

Hence,

$$V \approx V_{\mathrm{r}} + V_c$$

Time Constant:

$$\tau = RC$$

Where:

R = ____________________ Ω,

C = ____________________ F

Therefore,

τ = ____________________ × ____________________

τ = ____________________ s

Result: The series RC circuit was constructed successfully, and the voltages across the resistor and capacitor were measured for different values of the applied DC supply voltage. The relationship $(V \approx V_R + V_C)$ was verified experimentally, and the time constant of the RC circuit was calculated.

Conclusion: The experiment demonstrated the behaviour of a resistor and capacitor connected in series with a DC supply. The voltages across the resistor and capacitor were measured and their sum was found to be approximately equal to the applied supply voltage. The experiment also introduced the concept of the RC time constant, which determines the rate at which a capacitor charges through a resistor.

Review Questions:

1. Write the charging process of a capacitor in an RC circuit.

Experiment 06: Verification of Ohm's Law and Plotting of V–I Characteristics (CO 103.4)

Aim: To construct a resistive circuit, verify Ohm's Law, and plot the V–I characteristics of a resistor.

Prerequisites:

- Voltage, current, and resistance.
- Series and parallel connection of measuring instruments.
- Operation of a Regulated DC Power Supply.
- Measurement of voltage and current.
- Basic graph plotting.

Learning Objectives:

- Understand the relationship between voltage, current, and resistance.
- Construct a circuit for the verification of Ohm's Law.
- Measure current for different values of applied voltage while keeping resistance constant.
- Calculate resistance using measured voltage and current values.
- Plot and analyze the V–I characteristics of a resistor.

Learning Outcomes:

- Construct a basic resistive circuit.
- Connect an ammeter in series and a voltmeter in parallel.
- Measure voltage and current in a DC circuit.
- Verify Ohm's Law experimentally.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	Variable DC Output	1
2	Breadboard	Standard Solderless Breadboard	1
3	Ammeter / Digital Multimeter	DC Current Measurement	1
4	Voltmeter / Digital Multimeter	DC Voltage Measurement	1
5	Resistor	Suitable Value	1
6	Connecting Wires	As Required	As Required

Theory:

Ohm's Law: Ohm's Law states that: At constant temperature and other physical conditions, the current flowing through a conductor is directly proportional to the voltage applied across it.

Therefore:

$$\boldsymbol{V \propto I}$$

Introducing the constant of proportionality, resistance (R):

$$\boldsymbol{V = IR}$$

Where:

- V = Voltage across the resistor in volts (V)
- I = Current through the resistor in amperes (A)
- R = Resistance in ohms (Ω)

The resistance can therefore be calculated as:

$$\boldsymbol{R = V/I}$$

For a resistor whose resistance remains constant, increasing the applied voltage causes a proportional increase in current.

V–I Characteristics: The relationship between voltage and current can be represented graphically by plotting the measured values.

For an ohmic resistor:

- Voltage is directly proportional to current.
- The V–I characteristic is a straight line.
- A linear graph verifies that the resistance remains constant.

The resistance can also be determined from the ratio:

$$\boldsymbol{R = V/I}$$

Circuit Diagram:

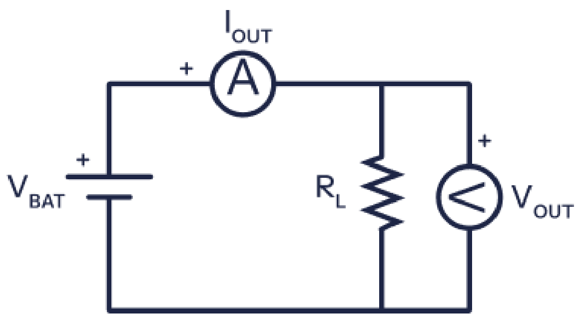

Fig. 6.1: Connection Diagram for Ohms Law

Procedure:

- Identify the resistor value and construct the circuit on the breadboard as shown in the circuit diagram, with the ammeter in series and the voltmeter in parallel.
- Verify all connections, switch ON the DC Power Supply, and set it to a low initial voltage.
- Measure the voltage across the resistor and the corresponding current flowing through it.
- Record the voltage and current readings in the observation table.
- Gradually increase the supply voltage and record a total of ten sets of voltage and current readings while keeping the resistance constant.
- Calculate the resistance using R=\frac{V}{I} for a selected reading, then plot the V–I characteristic and verify the relationship between voltage and current.
- After completing the experiment, reduce the supply voltage to minimum and switch OFF the power supply.

Precautions:

- Ensure that the power supply is switched OFF while making or changing circuit connections.
- Connect the ammeter in series with the circuit.
- Connect the voltmeter in parallel across the resistor.
- Select the correct measurement mode and range before taking readings.
- Increase the supply voltage gradually.
- Do not exceed the power rating of the resistor.
- Ensure that all circuit connections are firm and secure.
- Take readings carefully and avoid unnecessary heating of the resistor.

Observation Table:

Resistance, R = ____________________ Ω

Table 6.1: Voltage and Current Measurements

Sr. No.	Source Voltage, V (V)	Current Through Resistor, I (mA)
1		
2		
3		
4		
5		
6		
7		

8		
9		
10		

Calculations:

Using one set of observed readings:

V **= ____________________ V**

I **= ____________________ A**

According to Ohm's Law:

$$R = V/I$$

Therefore:

R **= ____________________ / ____________________**

Calculated Resistance, *R* = ____________________ Ω

Given Resistance = ____________________ Ω

Calculated Resistance = ____________________ Ω

Result: Ohm's Law was verified experimentally by measuring the current through a resistor for different values of applied voltage while keeping the resistance constant. The plotted V–I characteristic was found to be approximately linear, confirming that voltage is directly proportional to current.

Given Resistance = ____________________ Ω

Calculated Resistance = ____________________ Ω

Conclusion: The experiment demonstrated the relationship between voltage, current, and resistance in an ohmic conductor. As the applied voltage was increased, the current increased proportionally, producing an approximately linear V–I characteristic. The resistance calculated using (R = V/I) was found to be approximately equal to the given resistance value, thereby verifying Ohm's Law under constant physical conditions.

Review Questions:

1. State Ohm's Law with its equation.
2. Explain why the V-I characteristic of an ohmic resistor is a straight line.

Experiment 07: Verification of Voltage Divider Equation (CO 103.4)

Aim: To construct a voltage divider circuit and verify that the source voltage is equal to the sum of the voltage drops across the series-connected resistors.

Prerequisites:

- Voltage, current, and resistance.
- Ohm's Law.
- Series connection of resistors.
- Voltage measurement using a Digital Multimeter.
- Basic operation of a Regulated DC Power Supply.

Learning Objectives:

- Understand the working principle of a voltage divider circuit.
- Construct a series resistive voltage divider circuit.
- Measure the voltage drop across individual resistors.
- Verify the voltage divider relationship experimentally.

Learning Outcomes:

- After completing this experiment, students will be able to:
- Construct a voltage divider circuit using series-connected resistors.
- Measure the source voltage and individual voltage drops.
- Calculate voltage drops across series-connected resistors.
- Compare measured and calculated voltage values.
- Verify the voltage divider equation experimentally.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	Variable DC Output	1
2	Breadboard	Standard Solderless Breadboard	1
3	Digital Multimeter	Voltage and Current Measurement	1
4	Resistors, R_1 and R_2	Suitable Values	2
5	Connecting Wires	As Required	As Required

Theory:

Voltage Divider Circuit: A voltage divider is a series resistive circuit used to obtain different voltage levels from a common voltage source.

In a series circuit:

- The same current flows through all resistors.
- The source voltage is divided across the resistors according to their resistance values.

For two resistors R_1 and R_2:

$$V = V_{R1} + V_{R2}$$

Where:
V = Source voltage
V_{R1} = Voltage across R_1
V_{R2} = Voltage across R_2

Current in a Series Circuit:

The total resistance is:

$$R_T = R_1 + R_2$$

According to Ohm's Law:

$$I = \frac{V}{R_1 + R_2}$$

Since the resistors are connected in series:

$$I = I_{R1} = I_{R2}$$

Voltage Divider Equation:

The voltage across each resistor is:

$$V_{R1} = I \times R_1 , V_{R2} = I \times R_2$$

or directly using the voltage divider equations:

$$V_{R1} = V \times \frac{R_1}{R_1+R_2} , V_{R2} = V \times \frac{R_2}{R_1+R_2}$$

Thus, the source voltage is divided in proportion to the resistor values.

Voltage Drop: The potential difference developed across a resistor due to current flow is called the voltage drop. Its polarity depends on the direction of current flow.

Circuit Diagram:

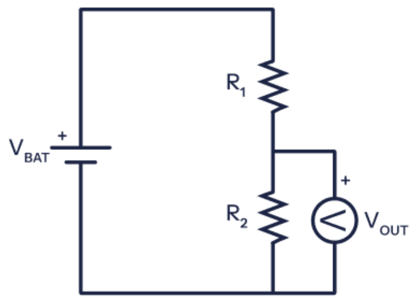

Fig. 7.1: Connection Diagram for Voltage Divider Circuit

Procedure:

- Identify the values of resistors R_1 and R_2, connect them in series on the breadboard as shown in the circuit diagram, and connect the circuit to the Regulated DC Power Supply.
- Verify all connections, switch ON the power supply, and set the source voltage to the required value.
- Measure the source voltage Vand the voltage drops across $R_1(V_{R1})$and $R_2(V_{R2})$ using the Digital Multimeter.
- Record the measured values in the observation table.
- Repeat the measurements for different source voltage values.
- Calculate $(V_{R1}+V_{R2})$, the circuit current, and the theoretical voltage drops across $R_1$and R_2, then compare the calculated and measured values.
- After completing the experiment, reduce the power supply output to minimum and switch OFF the power supply.

Precautions:

- Ensure that the power supply is switched OFF while making or changing circuit connections.
- Verify the resistor values before constructing the circuit.
- Connect the resistors correctly in series.
- Connect the Digital Multimeter in parallel while measuring voltage.
- Select the correct DC voltage measurement mode and range.
- Increase the source voltage gradually.
- Do not exceed the power rating of the resistors.
- Ensure that all connections are firm and secure.
- Record all readings carefully with the correct units.

Observation Table:

R_1 = __________________ Ω, R_2 = __________________ Ω

Table 7.1: Verification of Voltage Divider Equation

Sr. No.	Source Voltage, V (V)	Voltage Across R_1, (V_{r_1}) (V)	Voltage Across R_2, (V_{r_2}) (V)	$V_{r_1} + V_{r_2}$ (V)
1	1 V			
2	2 V			
3	3 V			
4	4 V			
5	5 V			
6	6 V			

7	7 V			
8	8 V			
9	9 V			
10	10 V			

Calculations:

Total Resistance:

$$R_t = R_1 + R_2$$

R_t = ____________________ + ____________________

R_t = ____________________ Ω

Circuit Current:

$$I = V/R_t$$

I = ____________________ / ____________________

I = ____________________ A

Voltage Drop Across R_1:

$$V_{r1} = I \times R_1$$

V_{r1} = ____________________ × ____________________

V_{r1} = ____________________ V

Voltage Drop Across R_2:

$$V_{r2} = I \times R_2$$

V_{r2} = ____________________ × ____________________

V_{r2} = ____________________ V

Verification:

$$V = V_{r1} + V_{r2}$$

Source Voltage, V = ____________________ V

$V_{r1} + V_{r2}$ = ____________________ + ____________________

$V_{r1} + V_{r2}$ = ____________________ V

Therefore:

$$V \approx V_{r1} + V_{r2}$$

Hence, the voltage divider relationship is verified.

Result: The voltage divider circuit was constructed successfully, and the voltage drops across the series-connected resistors were measured for different values of the source voltage. The sum of the individual voltage drops was found to be approximately equal to the applied source voltage, thereby verifying the voltage divider equation.

Conclusion: The experiment demonstrated the operation of a voltage divider circuit using series-connected resistors. It was observed that the same current flows through the series circuit while the applied source voltage is divided across the resistors according to their resistance values. The measured voltage drops satisfied the relationship $(V \approx V_{R1} + V_{R2})$, thereby verifying the voltage divider equation experimentally.

Review Questions:

1. State the Voltage Divider Rule.
2. Calculate the voltage across one resistor using the Voltage Divider Rule for a given series circuit.

Experiment 08: Verification of Current Divider Equation (CO 103.4)

Aim: To construct a current divider circuit and verify that the total source current is equal to the sum of the currents flowing through the parallel branches.

Prerequisites:

- Ohm's Law.
- Parallel connection of resistors.
- Current measurement using a Digital Multimeter.
- Kirchhoff's Current Law (KCL).

Learning Objectives:

- Understand the working principle of a current divider circuit.
- Construct a parallel resistive circuit.
- Measure the total source current and individual branch currents.
- Calculate branch currents using voltage and resistance values.
- Verify the current divider relationship experimentally.

Learning Outcomes:

- Construct a current divider circuit using parallel-connected resistors.
- Measure the total current and individual branch currents.
- Calculate branch currents using Ohm's Law.
- Compare the total current with the sum of the branch currents.
- Verify the current divider equation experimentally.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	Variable DC Output	1
2	Breadboard	Standard Solderless Breadboard	1
3	Digital Multimeter	Voltage and Current Measurement	As Required
4	Resistors, R_1 and R_2	Suitable Values	2
5	Connecting Wires	As Required	As Required

Theory:

Current Divider Circuit: A current divider is a parallel circuit in which the source current divides into two or more branch currents.

In a parallel circuit:

- The voltage across all branches is the same.
- The source current divides among the branches.
- The branch current depends on the resistance of each branch.

For two resistors R_1 and R_2 connected in parallel:

$$\boldsymbol{V = V_{R1} = V_{R2}}$$

Where:

V = Source voltage

V_{R1} = Voltage across R_1

V_{R2} = Voltage across R_2

Total and Branch Currents: The source current (I_T) divides into branch currents (I_{R1}) and (I_{R2}).

According to Kirchhoff's Current Law (KCL):

$$\boldsymbol{I_T = I_{R1} + I_{R2}}$$

Thus, the total current entering a junction equals the total current leaving it.

Branch Current Calculation: Using Ohm's Law, the branch currents are:

$$\boldsymbol{I_{R1} = \frac{V}{R_1}, I_{R2} = \frac{V}{R_2}}$$

Therefore,

$$\mathbf{I_T = I_{R1} + I_{R2} = \frac{V}{R_1} + \frac{V}{R_2}}$$

Equivalent Resistance: For two resistors connected in parallel:

$$\boldsymbol{\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}}$$

The total source current is:

$$\boldsymbol{I_T = \frac{V}{R_T}}$$

This relationship verifies the current division in a parallel resistive circuit.

Circuit Diagram:

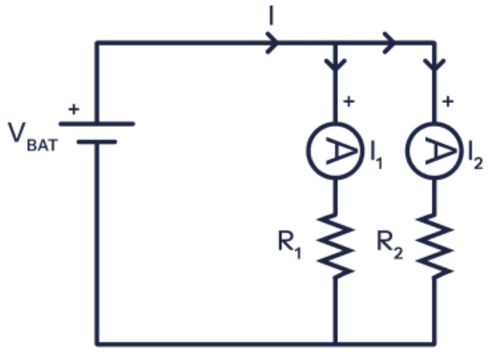

Fig. 8.1: Connection Diagram for Verifying Current Division Circuit

Procedure:

- Identify the values of resistors R_1 and R_2 , connect them in parallel on the breadboard as shown in the circuit diagram, and connect the circuit to the Regulated DC Power Supply.
- Connect the ammeter in series with the source to measure the total current (I_T) , and then connect it in series with each branch to measure I_{R1} and I_{R2}.
- Set the source voltage to 2 V and record the total current and branch currents in the observation table.
- Repeat the measurements for source voltages of 4 V, 6 V, 8 V, 10 V, 12 V, 14 V, 16 V, and 18 V.
- Calculate $(I_{R1}+I_{R2})$ and compare it with the measured total current (I_T).
- Calculate the theoretical branch currents using the measured voltage and resistance values, and compare them with the measured currents to verify $I_T \approx I_{R1} + I_{R2}$.
- After completing the experiment, reduce the power supply output to minimum and switch OFF the power supply.

Precautions:

- Ensure that the power supply is switched OFF while making or changing circuit connections.
- Verify the resistor values before constructing the circuit.
- Connect the resistors correctly in parallel.
- Connect the ammeter in series with the path whose current is to be measured.
- Never connect an ammeter directly across the power supply.
- Select the correct DC current measurement mode and range before taking readings.
- Increase the source voltage gradually.
- Do not exceed the power rating of the resistors.
- Ensure that all connections are firm and secure.

Observation Table:

R_1 = ____________________ Ω, R_2 = ____________________ Ω

Table 8.1: Verification of Current Divider Equation

Source Voltage, V (V)	Source Current, I_t (mA)	Branch Current, I_{r_1} (mA)	Branch Current, I_{r_2} (mA)	$I_{r_1} + I_{r_2}$ (mA)
1 V				
2 V				
3 V				
4 V				
5 V				
6 V				

Calculations:

Branch Current Through R_1

$$I_{r1} = V/R_1$$

I_{r1} = ____________________ / ____________________

I_{r1} = ____________________ **A**

Branch Current Through R_2

$$I_{r2} = V/R_2$$

I_{r2} = ________________ / ________________

I_{r2} = ________________ A

Total Current: According to Kirchhoff's Current Law:

$$I_t = I_{r1} + I_{r2}$$

I_t = ____________________ + ____________________

I_t = ____________________ **A**

Verifications:

Measured Source Current, I_t = ____________________ **A**

Sum of Branch Currents, $I_{r1} + I_{r2}$ = ____________________ **A**

Therefore:

$$I_t \approx I_{r1} + I_{r2}$$

Hence, the current divider relationship is verified.

Result: The current divider circuit was constructed successfully, and the total source current and individual branch currents were measured for different values of the source voltage. The total source current was found to be approximately equal to the sum of the individual branch currents, thereby verifying the current divider equation.

Conclusion: The experiment demonstrated the division of current in a parallel resistive circuit. It was observed that the same voltage appears across each parallel branch while the total source current divides between the branches according to their resistance values. The measured currents satisfied the relationship ($I_T \approx I_{R1} + I_{R2}$), thereby verifying the current divider equation experimentally.

Review Questions:

1. State the Current Divider Rule.
2. Calculate the current through one branch of a parallel circuit using the Current Divider Rule.

Experiment 09: Verification of Kirchhoff's Current Law (KCL) (CO 103.5)

Aim: To construct a parallel resistive circuit and verify Kirchhoff's Current Law (KCL) by measuring the currents entering and leaving a node.

Prerequisites:

- Ohm's Law.
- Series and parallel circuit connections.
- Current measurement using a Digital Multimeter.
- Concept of nodes and branches in an electrical circuit.

Learning Objectives:

- Understand the concept of a node and branch in an electrical circuit.
- Understand Kirchhoff's Current Law.
- Construct a parallel resistive circuit.
- Measure the current entering and leaving a node.
- Verify Kirchhoff's Current Law experimentally.

Learning Outcomes:

- Identify nodes and branches in an electrical circuit.
- Apply Kirchhoff's Current Law at a circuit node.
- Measure the main current and individual branch currents.
- Compare the incoming current with the sum of the outgoing currents.
- Verify Kirchhoff's Current Law experimentally.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	Variable DC Output	1
2	Breadboard	Standard Solderless Breadboard	1
3	Digital Multimeter / Ammeter	DC Current Measurement	As Required
4	Resistors, R_1 and R_2	Suitable Values	2
5	Connecting Wires	As Required	As Required

Theory:

Kirchhoff's Current Law: Kirchhoff's Current Law (KCL) is one of the fundamental laws used for the analysis of electrical circuits. It states that:

The total current entering a node is equal to the total current leaving that node.

Therefore, the algebraic sum of all currents at a node is zero.

$$\boldsymbol{\Sigma I = 0}$$

While applying the sign convention:

- Currents entering the node may be considered positive.
- Currents leaving the node may be considered negative.

Thus:

$$\boldsymbol{\Sigma I_{\text{in}} - \Sigma I_{\text{out}} = 0 \;\; or \;\; \Sigma I_{\text{in}} = \Sigma I_{\text{out}}}$$

Application of KCL to the Experimental Circuit: In the experimental circuit, the main current (I_T) enters the node and divides into two branch currents (I_1) and (I_2).

Therefore: $\boldsymbol{I_{\text{t}} = I_1 + I_2}$

Rearranging: $\boldsymbol{I_{\text{t}} - I_1 - I_2 = 0}$

Thus, the algebraic sum of currents at the node is zero.

Circuit Diagram:

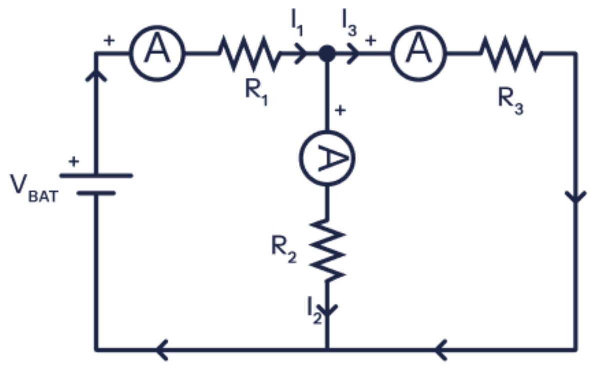

Fig. 9.1: Connection Diagram to Verify KCL

At the selected node:

Incoming Current = I_1

Outgoing Currents = $I_2 \; and \; I_3$

Therefore: $\boldsymbol{I_1 = I_2 + I_3}$

Procedure:

- Identify the values of resistors $R_1$and R_2, construct the circuit on the breadboard as shown in the circuit diagram, and connect the Regulated DC Power Supply.
- Connect the ammeter in series with the source to measure the main current (I_T), then connect it in series with each branch to measure the branch currents $(I_1)$and (I_2).

- Verify all connections, switch ON the power supply, and set the source voltage to the required value.
- Measure and record the main current $(I_T)$and the branch currents $(I_1)$and (I_2)in the observation table.
- Repeat the measurements for different source voltage values.
- Calculate (I_1+I_2), compare it with the measured main current (I_T), and verify Kirchhoff's Current Law (KCL).
- After completing the experiment, reduce the power supply output to minimum and switch OFF the power supply.

Precautions:

- Ensure that the power supply is switched OFF while making or changing circuit connections.
- Connect the ammeter in series with the path whose current is to be measured.
- Never connect an ammeter directly across the power supply.
- Select the correct DC current measurement mode and range before taking readings.
- Maintain correct polarity while connecting the measuring instrument.
- Ensure that all circuit connections are firm and secure.
- Increase the source voltage gradually.
- Do not exceed the current or power rating of the circuit components.

Observation Table:

R_1 = ____________________ Ω, R_2 = ____________________ Ω, R3= ____________________ Ω

Table 9.1: Verification of Kirchhoff's Current Law

Source Voltage, V (V)	Main Current, I_t (mA)	Branch Current, I_1 (mA)	Branch Current, I_2 (mA)	Branch Current, I_3 (mA)	$I_1 + I_2 + I_3$ (mA)
1 V					
2 V					
3 V					
4 V					
5 V					

Calculations:

According to Kirchhoff's Current Law:

$$I_t = I_1 + I_2$$

For one set of observed readings:

Main Current, I_t = ____________________ mA

Branch Current, I_1 = ____________________ mA

Branch Current, I_2 = ____________________ mA

Branch Current, I_3 = ____________________ mA

Therefore:

$I_1 + I_2 + I_3$ = ____________________ + ____________________ + ________________________

$I_1 + I_2 + I_3$= ____________________ *mA*

Verification:

Incoming Current, I_t = ____________________ mA

Outgoing Current, $I_1 + I_2 + I_3$ = ____________________ mA

Therefore:

$$I_t = I_1 + I_2 + I_3$$

Hence, Kirchhoff's Current Law is verified.

Result: Kirchhoff's Current Law was verified experimentally by measuring the main current entering a node and the individual branch currents leaving the node. The incoming current was found to be approximately equal to the sum of the outgoing branch currents.

Conclusion: The experiment demonstrated Kirchhoff's Current Law in a parallel resistive circuit. It was observed that the total current entering a node is approximately equal to the sum of the currents leaving the node. Thus, the algebraic sum of all currents at a node is approximately zero, verifying Kirchhoff's Current Law and the principle of conservation of electric charge.

Review Questions:

1. State Kirchhoff's Current Law. Verify it by one example.

____

____

____

____

Experiment 10: Verification of Kirchhoff's Voltage Law (KVL) (CO 103.5)

Aim: To construct a series resistive circuit and verify Kirchhoff's Voltage Law (KVL) by measuring the source voltage and voltage drops across the resistors.

Prerequisites:

- Ohm's Law.
- Series connection of resistors.
- Voltage measurement using a Digital Multimeter.
- Concept of a closed loop in an electrical circuit.

Learning Objectives:

- Understand Kirchhoff's Voltage Law.
- Understand the sign convention used while applying KVL.
- Construct a series resistive circuit.
- Measure the source voltage and individual voltage drops.
- Verify Kirchhoff's Voltage Law experimentally.

Learning Outcomes:

- Identify a closed loop in an electrical circuit.
- Apply the appropriate voltage polarity and sign convention.
- Measure voltage drops across series-connected resistors.
- Formulate the KVL equation for a closed loop.
- Verify Kirchhoff's Voltage Law experimentally.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	Variable DC Output	1
2	Breadboard	Standard Solderless Breadboard	1
3	Digital Multimeter / Voltmeter	DC Voltage Measurement	1
4	Resistors, R_1, R_2 and R_3	Suitable Values	3
5	Connecting Wires	As Required	As Required

Theory:

Kirchhoff's Voltage Law (KVL): Kirchhoff's Voltage Law (KVL) states that the algebraic sum of all voltages in a closed loop is zero.

$$\sum V = 0$$

Thus, the total source voltage is equal to the sum of all voltage drops in the loop.

For a circuit with one source and three series resistors:

$$V_S - V_1 - V_2 - V_3 = 0 \text{ or } V_S = V_1 + V_2 + V_3$$

Where:

- V_S= Source voltage
- V_1, V_2, V_3= Voltage drops across R_1, R_2,and R_3

Voltage Drops in a Series Circuit: In a series circuit, the same current flows through all resistors.

$$I = I_1 = I_2 = I_3$$

Using Ohm's Law:

$$V_1 = IR_1, V_2 = IR_2, V_3 = IR_3$$

Hence,

$$V_S = I(R_1 + R_2 + R_3)$$

Sign Convention for KVL: While applying KVL, choose a direction around the loop and use it consistently.

- Moving from negative to positive terminal of a source → Voltage Rise (+)
- Moving from positive to negative terminal of a source → Voltage Drop (−)
- Across a resistor, moving with the current → Voltage Drop
- Across a resistor, moving opposite to the current → Voltage Rise

Significance of KVL: KVL is based on the law of conservation of energy, which states that the energy supplied by the source equals the energy absorbed by the circuit elements.

Applications:

- Series circuit analysis
- Mesh analysis
- Determination of unknown voltages and currents
- Analysis of electrical networks

Circuit Diagram:

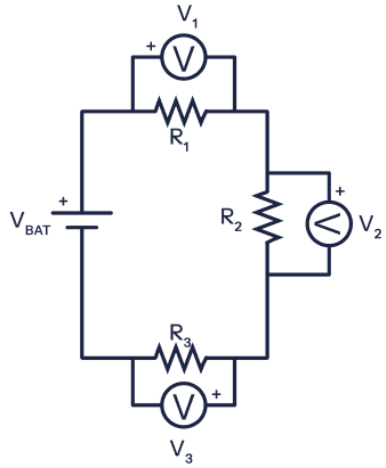

Fig. 10.1: Connection Diagram to Verify KVL

For the closed loop: $V_{BAT} - V_1 - V_2 - V_3 = 0 \quad or \quad V_{BAT} = V_1 + V_2 + V_3$

Procedure:

- Identify the values of resistors R_1, R_2, and R_3, connect them in series on the breadboard as shown in the circuit diagram, and connect the circuit to the Regulated DC Power Supply.
- Verify all connections, switch ON the power supply, and set the source voltage to 2 V.
- Measure and record the source voltage $(V_S)$and the voltage drops across R_1, R_2, and R_3 using the Digital Multimeter.
- Calculate $(V_1+V_2+V_3)$ and compare it with the applied source voltage (V_S).
- Repeat the measurements for source voltages of 4 V, 6 V, 8 V, 10 V, 12 V, 14 V, and 16 V.
- Verify that the source voltage is approximately equal to the sum of the individual voltage drops, confirming Kirchhoff's Voltage Law (KVL).
- After completing the experiment, reduce the power supply output to minimum and switch OFF the power supply.

Precautions:

- Ensure that the power supply is switched OFF while making or changing circuit connections.
- Verify the resistor values before constructing the circuit.
- Connect the voltmeter in parallel across the component whose voltage is to be measured.
- Select the correct DC voltage measurement mode and range.
- Maintain correct polarity while measuring voltage.
- Increase the source voltage gradually.
- Do not exceed the power rating of the resistors.

Observation Table:

R_1 = ____________________ Ω

R_2 = ____________________ Ω

R_3 = ____________________ Ω

Table 10.1: Verification of Kirchhoff's Voltage Law

Source Voltage, V_s (V)	Voltage Across R_1, V_1 (V)	Voltage Across R_2, V_2 (V)	Voltage Across R_3, V_3 (V)	$V_1 + V_2 + V_3$ (V)
1 V				
2 V				
3 V				
4 V				
5 V				
6 V				
7 V				
8 V				

Calculations:

Total Resistance:

$$R_t = R_1 + R_2 + R_3$$

R_t = ____________________ + ____________________ + ____________________

R_t = ____________________ Ω

Circuit Current:

Using Ohm's Law:

$$I = V_s / R_t$$

I = ____________________ / ____________________

I = ____________________ A

Voltage Drop Across R_1:

$$V_1 = I \times R_1$$

V_1 = ____________________ × ____________________

V_1 = ____________________ V

Voltage Drop Across R_2:

$$V_2 = I \times R_2$$

V_2 = ____________________ × ____________________

V_2 = ____________________ V

Voltage Drop Across R_3:

$$V_3 = I \times R_3$$

V_3 = ____________________ × ____________________

V_3 = ____________________ V

Verification of KVL: According to Kirchhoff's Voltage Law:

$$V_s - V_1 - V_2 - V_3 = 0 \quad \text{or} \quad V_s = V_1 + V_2 + V_3$$

For one set of observed readings:

Source Voltage, V_s = ____________________ V

$V_1 + V_2 + V_3$ = ____________________ + ____________________ + ____________________

$V_1 + V_2 + V_3$ = ____________________ V

Therefore:

$$V_s \approx V_1 + V_2 + V_3 \quad \text{or} \quad V_s - V_1 - V_2 - V_3 \approx 0$$

Hence, Kirchhoff's Voltage Law is verified.

Result: Kirchhoff's Voltage Law was verified experimentally by measuring the source voltage and individual voltage drops across three series-connected resistors. The source voltage was found to be approximately equal to the sum of the individual voltage drops.

Conclusion: The experiment demonstrated Kirchhoff's Voltage Law in a series resistive circuit. It was observed that the algebraic sum of all voltages around the closed loop is approximately zero. The applied source voltage was approximately equal to the sum of the voltage drops across the individual resistors, thereby verifying Kirchhoff's Voltage Law and the principle of conservation of energy.

Review Questions:

1. State Kirchhoff's Voltage Law. Verify KVL by one example.
2. Explain the sign convention used while applying KVL.

Experiment 11: Verification of Superposition Theorem (CO 103.5)

Aim: To construct a linear bilateral network containing two independent voltage sources and verify the Superposition Theorem by measuring the currents produced by each source acting individually and collectively.

Prerequisites:

- Ohm's Law.
- Kirchhoff's Laws.
- Series and parallel electrical networks.
- Voltage and current measurement using a Digital Multimeter.
- Independent voltage and current sources.

Learning Objectives:

- Understand the principle of the Superposition Theorem.
- Understand the procedure for deactivating independent sources.
- Construct a linear resistive network containing two voltage sources.
- Measure the current contribution produced by each source independently.
- Verify the total branch currents using the algebraic sum of individual current contributions.

Learning Outcomes:

- Apply the Superposition Theorem to a linear resistive network.
- Deactivate an independent voltage source correctly.
- Determine the individual contribution of each source.
- Apply the appropriate sign according to the direction of current flow.
- Verify the total response of a network using superposition.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	DC Voltage Source	2
2	Breadboard	Standard Solderless Breadboard	1
3	Digital Multimeter / Ammeter	DC Current Measurement	As Required
4	Resistor, R_1	100 Ω	1
5	Resistor, R_2	220 Ω	1
6	Resistor, R_3	330 Ω	1
7	Connecting Wires	As Required	As Required

Theory:

Superposition Theorem: The Superposition Theorem states that in a linear bilateral circuit containing two or more independent sources, the voltage or current in any element is the algebraic sum of the individual responses produced by each source acting alone, while all other independent sources are replaced by their internal resistances. This simplifies the analysis of multi-source circuits by considering one source at a time.

Principle of Superposition: For a circuit with two independent sources, V_1 and V_2:

- Determine the response due to V_1 acting alone.
- Determine the response due to V_2 acting alone.
- Add the individual responses algebraically, considering their directions.
- Responses in the same direction are added.
- Responses in opposite directions are subtracted.

Deactivation of Independent Sources: While analysing one source, all other independent sources are deactivated.

- Voltage Source → Replace with a Short Circuit
- Current Source → Replace with an Open Circuit

Note: Dependent sources, if present, are not deactivated.

Application and Limitations:

For the experimental circuit:

- Measure the branch currents with both sources active.
- Measure the currents with each source acting independently.
- Verify that the currents with both sources are approximately equal to the algebraic sum of the individual current contributions.

Limitations:

- Applicable only to linear networks.
- Used to determine voltages and currents.
- Cannot be used directly to calculate power, since power is a nonlinear quantity.

Circuit Diagram:

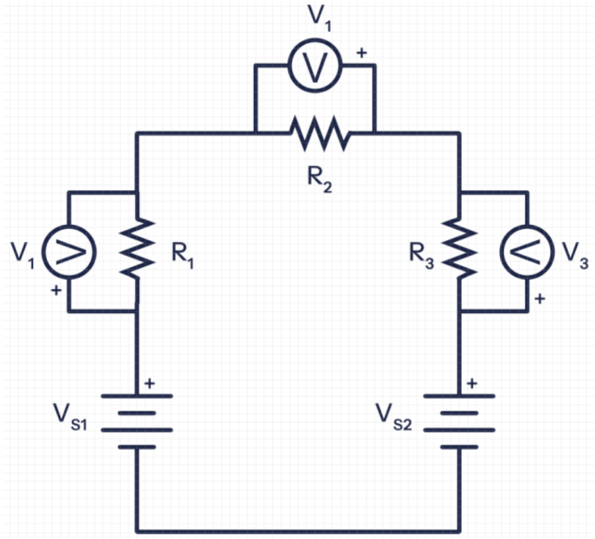

Fig.11.1: Connection Diagram to Verify Superposition Theorem

Procedure:

Part A: Current Measurement

- Identify the values of resistors R_1,R_2, and R_3, then construct the circuit on the breadboard as shown in the circuit diagram.
- Connect both voltage sources V_1 and V_2 with the specified values and polarities, verify all connections, and switch ON the power supplies.
- Measure the branch currents I_1 , I_2, and I_3, and record the readings in the observation table.
- Keep V_1 active and deactivate V_2 by replacing it with a short circuit. Measure and record the branch currents I_1', I_2', and I_3'.
- Restore the original circuit, keep V_2 active and deactivate V_1 by replacing it with a short circuit. Measure and record the branch currents I_1'', I_2'', and I_3''.

Part B: Verification

- Calculate the algebraic sum of the individual current contributions:
- $I_1 = I_1' - I_1''$, $I_2 = I_2'' - I_2'$, $I_3 = I_3' + I_3''$
- Compare the calculated currents with the currents measured when both sources were active.
- Verify the Superposition Theorem from the observed and calculated results.
- After completing the experiment, switch OFF both power supplies.

Precautions:

- Ensure that both power supplies are switched OFF while making or changing circuit connections.
- Verify the values of all resistors before constructing the circuit.
- Maintain the correct magnitude and polarity of both voltage sources.

- Deactivate a voltage source by replacing it with a short circuit.
- Never short-circuit an active voltage source.
- Connect the ammeter in series with the branch whose current is being measured.
- Maintain a consistent reference direction for all current measurements.
- Consider the direction of each current before performing algebraic addition or subtraction.
- Ensure that all circuit connections are firm and secure.

Observation Table:

R_1 = 100 Ω, R_2 = 220 Ω, R_3 = 330 Ω, V_1 = ____________________V, V_2 = ____________________ V

Table 11.1: Verification of Superposition Theorem

Voltages V1 and V2	Both V_1 and V_2 Active (mA)	Only V_1 Active, V_2 Shorted (mA)	Only V_2 Active, V_1 Shorted (mA)	Algebraic Sum of Individual Responses (mA)
V1 = 4 V V2 = 2 V	I1 =	I_1' =	I_1'' =	$I_1' - I_1''$ =
V1 = 2 V V2 = 4 V	I2 =	I_2' =	I_2'' =	$I_2'' - I_2'$ =
V1 = 5 V V2 = 3 V	I3 =	I_3' =	I_3'' =	$I_3' - I_3''$ =

Calculations:

Verification of Current I_1:

$$I_1 = I_1' - I_1''$$

I_1 = ____________________ – ____________________

Calculated I_1 = ____________________ mA

Measured I_1 = ____________________ mA

Verification of Current I_2

$$I_2 = I_2'' - I_2'$$

I_2 = ____________________ – ____________________

Calculated I_2 = ____________________ mA

Measured I_2 = ____________________ mA

Verification of Current I_3

$$I_3 = I_3' - I_3''$$

I_3 = ____________________ + ____________________

Calculated I_3 = ____________________ mA

Measured I_3 = ____________________ mA

Verification: The currents measured with both sources active are compared with the algebraic sums of the individual current contributions.

Measured $I_1 \approx I_1' - I_1''$

Measured $I_2 \approx I_2'' - I_2'$

Measured $I_3 \approx I_3' - I_3''$

Hence, the Superposition Theorem is verified.

Result: The Superposition Theorem was verified experimentally by measuring the branch currents with both voltage sources acting simultaneously and with each source acting individually. The measured branch currents were found to be approximately equal to the algebraic sums of the corresponding individual current contributions.

Conclusion: The experiment demonstrated the application of the Superposition Theorem to a linear bilateral network containing two independent voltage sources. The contribution of each source was determined separately by deactivating the other voltage source, and the individual responses were combined algebraically according to their directions. The resulting currents were approximately equal to the currents measured with both sources active, thereby verifying the Superposition Theorem experimentally.

Review Questions:

1. State the Superposition Theorem. Explain it by example.

Experiment 12: Verification of Thevenin's Theorem (CO 103.5)

Aim: To determine the Thevenin equivalent voltage (V_{TH}) and Thevenin equivalent resistance (R_{TH}) of a linear resistive network and verify Thevenin's Theorem by comparing the calculated and measured load currents.

Prerequisites:

- Ohm's Law.
- Kirchhoff's Laws.
- Series and parallel resistive networks.
- Open-circuit voltage.
- Voltage, current, and resistance measurement using a Digital Multimeter.

Learning Objectives:

- Understand the principle of Thevenin's Theorem.
- Determine the open-circuit Thevenin voltage (V_{TH}).
- Determine the Thevenin equivalent resistance (R_{TH}).
- Construct the Thevenin equivalent circuit.
- Compare the calculated load current with the directly measured load current.

Learning Outcomes:

- Apply Thevenin's Theorem to a linear resistive network.
- Determine the Thevenin equivalent voltage across load terminals.
- Determine the equivalent resistance seen from the load terminals.
- Calculate the load current using the Thevenin equivalent circuit.
- Verify Thevenin's Theorem experimentally.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	Variable DC Output	1
2	Breadboard	Standard Solderless Breadboard	1
3	Digital Multimeter	Voltage, Current and Resistance Measurement	As Required
4	Resistors, R_1, R_2 and R_3	Suitable Values	3
5	Load Resistor, R_l	Suitable Value	1
6	Connecting Wires	As Required	As Required

Theory:

Thevenin's Theorem: Thevenin's Theorem states that any linear bilateral two-terminal network containing sources and resistances can be replaced by an equivalent circuit consisting of a single voltage source (V_{TH})in series with an equivalent resistance (R_{TH}), connected to the load resistance (R_L).

The equivalent circuit consists of:

- Thevenin voltage (V_{TH})
- Thevenin resistance (R_{TH})
- Load resistance (R_L)

Thevenin Equivalent Voltage (V_{TH}): The Thevenin voltage is the open-circuit voltage measured across the load terminals after removing the load resistance.

$$V_{TH} = \textbf{Open-Circuit Voltage}$$

Thevenin Equivalent Resistance $(\mathbf{R_{TH}})$: The Thevenin resistance is the equivalent resistance seen from the load terminals after removing the load and deactivating all independent sources.

For an ideal voltage source: Replace the source with a short circuit. The resistance measured across the open load terminals is R_{TH}.

Load Current: The load current in the Thevenin equivalent circuit is calculated using Ohm's Law:

$$I_L(C) = \frac{V_{TH}}{R_{TH} + R_L}$$

Where:

- $I_L(C)$= Calculated load current
- V_{TH}= Thevenin voltage
- R_{TH}= Thevenin resistance
- R_L= Load resistance

For verification,

$$I_L(C) \approx I_L(M)$$

where $I_L(M)$is the measured load current in the original circuit.

Circuit Diagram:

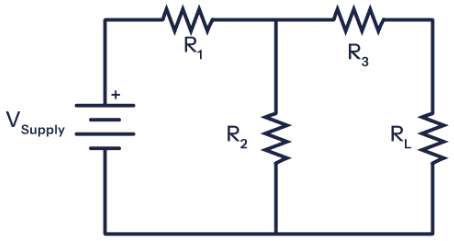

Fig.12.1: Connection Diagram to verify Thevenin's Theorem

Procedure:

Part A: Measurement

- Identify the values of R_1, R_2, R_3, and the load resistance R_L, then construct the original circuit as shown in the circuit diagram.
- Connect the ammeter in series with R_L, apply the source voltage $V_1 = 2$ V, measure the load current $\left(I_L(M)\right)$, and record it in the observation table.
- Switch OFF the power supply, remove R_L, connect the voltmeter across the open load terminals, then switch ON the power supply and measure the open-circuit voltage (V_{TH}).
- Switch OFF the power supply, replace the voltage source with a short circuit, connect the ohmmeter across the open load terminals, and measure the Thevenin resistance (R_{TH}).

Part B: Verification

- Calculate the load current using: $\boldsymbol{I_L(C)} = \frac{\boldsymbol{V_{TH}}}{\boldsymbol{R_{TH}+R_L}}$
- Compare the calculated load current $\left(I_L(C)\right)$ with the measured load current $\left(I_L(M)\right)$.
- Repeat the experiment for source voltages of 4 V, 6 V, 8 V, and 10 V, and record the observations.
- Verify that the calculated and measured load currents are approximately equal, then switch OFF the power supply.

Precautions:

- Ensure that the power supply is switched OFF while making or changing circuit connections.
- Verify all resistor values before constructing the circuit.
- Maintain the correct polarity of the voltage source and measuring instruments.
- Remove the load resistance before measuring (V_{TH}) and (R_{TH}).
- Deactivate the voltage source before measuring (R_{TH}).
- Never use the resistance measurement mode on a powered circuit.
- Connect the ammeter in series while measuring load current.
- Connect the voltmeter in parallel across the required terminals.
- Ensure that all circuit connections are firm and secure.

Observation Table:

R_1 = ____________________ Ω, R_2 = ____________________ Ω

R_3 = ____________________ Ω, RL = ____________________ Ω

Table 12.1: Verification of Thevenin's Theorem

Source Voltage, V_1 (V)	Thevenin Voltage, VTH (V)	Thevenin Resistance, RTH (Ω)	Measured Load Current, IL(M) (mA)	Calculated Load Current, IL(C) (mA)
2V				
4 V				
6 V				
8 V				
10 V				

Calculations:

Thevenin Equivalent Voltage: The open-circuit voltage measured across the load terminals is:

$$V_{TH} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ V}$$

Thevenin Equivalent Resistance: The equivalent resistance measured across the load terminals after deactivating the voltage source is:

$$R_{TH} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \ \Omega$$

Calculated Load Current:

$$I_L(C) = V_{TH}/(R_{TH} + R_L)$$

Substituting the observed values:

$I_L(C)$ = ____________________ / (____________________ + ____________________)

$I_L(C)$ = ____________________ mA

Verification:

Measured Load Current, $I_L(M)$ = ____________________ mA

Calculated Load Current, $I_L(C)$ = ____________________ mA

Therefore:

$$I_L(C) \approx I_L(M)$$

Hence, Thevenin's Theorem is verified.

Result: The Thevenin equivalent voltage (V_{TH}) and Thevenin equivalent resistance (R_{TH}) of the given linear resistive network were determined successfully. The load current calculated using the Thevenin equivalent circuit was found to be approximately equal to the load current measured in the original circuit.

$$I_L(C) \approx I_L(M)$$

Conclusion: The experiment demonstrated that a complex linear resistive network viewed from two load terminals can be replaced by an equivalent circuit consisting of a single Thevenin voltage source in series with a Thevenin resistance. The calculated load current using the Thevenin equivalent circuit was approximately equal to the directly measured load current, thereby verifying Thevenin's Theorem experimentally.

Review Questions:

1. State Thevenin's Theorem.
2. Explain the procedure for determining the Thevenin equivalent voltage and resistance of a network.

Experiment 13: Verification of Norton's Theorem (CO 103.5)

Aim: To determine the Norton equivalent current (I_N) and Norton equivalent resistance (R_N) of a linear resistive network and verify Norton's Theorem by comparing the calculated and measured load currents.

Prerequisites:

- Ohm's Law.
- Kirchhoff's Laws.
- Series and parallel resistive networks.
- Short-circuit current.
- Voltage, current, and resistance measurement using a Digital Multimeter.

Learning Objectives:

- Understand the principle of Norton's Theorem.
- Determine the short-circuit Norton current (I_N).
- Determine the Norton equivalent resistance (R_N).
- Construct the Norton equivalent circuit.
- Compare the calculated load current with the directly measured load current.

Learning Outcomes:

- Apply Norton's Theorem to a linear resistive network.
- Determine the Norton equivalent current at the load terminals.
- Determine the equivalent resistance seen from the load terminals.
- Calculate the load current using the Norton equivalent circuit.
- Verify Norton's Theorem experimentally.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	Variable DC Output	1
2	Breadboard	Standard Solderless Breadboard	1
3	Digital Multimeter	Voltage, Current and Resistance Measurement	As Required
4	Resistors, R_1, R_2, R_3 and R_L	Suitable Values	3
5	Connecting Wires	As Required	As Required

Theory:

Norton's Theorem: Norton's Theorem states that any linear bilateral two-terminal network containing sources and resistances can be replaced by an equivalent circuit consisting of a current source (I_N) in parallel with an equivalent resistance (R_N), connected to the load resistance (R_L).

The equivalent circuit consists of:

- Norton current (I_N)
- Norton resistance (R_N)
- Load resistance (R_L)

Norton Equivalent Current $(\boldsymbol{I_N})$: The Norton current is the short-circuit current flowing through the load terminals after removing the load resistance and short-circuiting the terminals.

Norton Equivalent Resistance $(\boldsymbol{R_N})$: The Norton resistance is the equivalent resistance seen from the load terminals after removing the load and deactivating all independent sources.

For an ideal voltage source: Replace the source with a short circuit.

For the same linear network,

$$\boldsymbol{R_N = R_{TH}}$$

Load Current: The load current in the Norton equivalent circuit is calculated using the current divider rule:

$$\boldsymbol{I_L(C) = I_N \times \frac{R_N}{R_N + R_L}}$$

Where:

- $I_L(C)$ = Calculated load current
- I_N = Norton current
- R_N = Norton resistance
- R_L = Load resistance

For verification,

$$\boldsymbol{I_L(C) \approx I_L(M)}$$

where $I_L(M)$is the measured load current.

Relationship Between Thevenin and Norton Equivalents: Thevenin and Norton circuits represent the same linear two-terminal network.

Their parameters are related by:

$$\boldsymbol{R_N = R_{TH}\,, V_{TH} = I_N R_N\,, I_N = \frac{V_{TH}}{R_{TH}}}$$

Circuit Diagram:

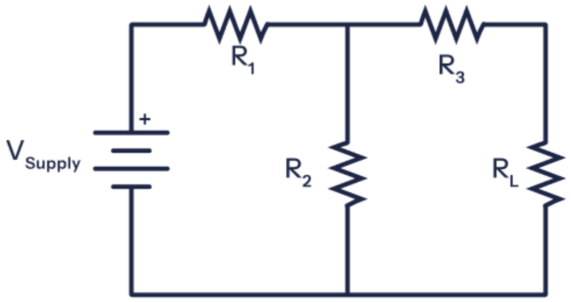

Fig.13.1: Connection Diagram to verify Norton's Theorem

Procedure:

Part A: Measurement

- Identify the values of R_1, R_2, R_3, and the load resistance R_L, then construct the original circuit as shown in the circuit diagram.
- Connect the ammeter in series with R_L, apply the source voltage $V_1 = 2$ V, measure the load current $\left(I_L(M)\right)$, and record it in the observation table.
- Switch OFF the power supply, remove R_L, connect the ammeter across the load terminals to create a short circuit, then switch ON the power supply and measure the Norton current (I_N).
- Switch OFF the power supply, replace the voltage source with a short circuit, connect the ohmmeter across the load terminals, and measure the Norton resistance (R_N).

Part B: Verification

- Calculate the load current using: $\boldsymbol{I_L(C) = I_N \times \frac{R_N}{R_N+R_L}}$
- Compare the calculated load current $\left(I_L(C)\right)$ with the measured load current $\left(I_L(M)\right)$.
- Repeat the experiment for source voltages of 4 V, 6 V, 8 V, 10 V, 12 V, 14 V, 16 V, 18 V, and 20 V, and record the observations.
- Verify that the calculated and measured load currents are approximately equal, then switch OFF the power supply.

Precautions:

- Ensure that the power supply is switched OFF while making or changing circuit connections.
- Maintain the correct polarity of the voltage source and measuring instruments.
- Remove the load resistance before determining (I_{N}) and (R_{N}).
- Connect the ammeter correctly while measuring the short-circuit current.
- Use the correct current range before measuring (I_{N}).
- Deactivate the voltage source before measuring (R_{N}).
- Never use the resistance measurement mode on a powered circuit.
- Ensure that all circuit connections are firm and secure.

Observation Table:

R_1 = ____________________ Ω, R_2 = ____________________ Ω,

R_3 = ____________________ Ω, R_l = ____________________ Ω

Table 13.1: Verification of Norton's Theorem

Source Voltage, V_1 (V)	Norton Current, I_N (mA)	Norton Resistance, R_N (Ω)	Measured Load Current, $I_L(M)$(mA)	Calculated Load Current, $I_L(C)$(mA)
2 V				
4 V				
6 V				
8 V				
10 V				

Calculations:

Norton Equivalent Current: The short-circuit current measured across the load terminals is:

I_N = ____________________ mA

Norton Equivalent Resistance: The equivalent resistance measured across the load terminals after deactivating the voltage source is:

R_N = ________________ Ω

Calculated Load Current:

Using the current divider equation:

$$I_L(C) = I_N \times R_N/(R_N + R_L)$$

Substituting the observed values:

$I_L(C)$ = _____________ × ______________ / (____________+ ____________)

$I_L(C)$ = _______________ A or $I_L(C)$ = ________________ mA

Verification:

Measured Load Current, $I_L(M)$ = ____________________ mA

Calculated Load Current, $I_L(C)$ = ____________________ mA

Therefore:

$$\boldsymbol{I_L(C) \approx I_L(M)}$$

Result: The Norton equivalent current (I_N) and Norton equivalent resistance (R_N) of the given linear resistive network were determined successfully. The load current calculated using the Norton equivalent circuit was found to be approximately equal to the load current measured in the original circuit.

$$I_L(C) \approx I_L(M)$$

Conclusion: The experiment demonstrated that a complex linear resistive network viewed from two load terminals can be replaced by an equivalent current source (I_N) in parallel with an equivalent resistance (R_N). The calculated load current using the Norton equivalent circuit was approximately equal to the directly measured load current, thereby verifying Norton's Theorem experimentally.

Review Questions:

1. State Norton's Theorem. Draw the Norton equivalent circuit.
2. Write the relationship between Thevenin's and Norton's equivalent circuits.

Experiment 14: Verification of Maximum Power Transfer Theorem (CO 103.5)

Aim: To construct a linear resistive network and verify the Maximum Power Transfer Theorem by varying the load resistance and determining the condition at which maximum power is transferred to the load.

Prerequisites:

- Ohm's Law.
- Kirchhoff's Laws.
- Series and parallel resistive networks.
- Thevenin's Theorem.
- Electrical power calculations.
- Voltage, current, and resistance measurement using a Digital Multimeter.

Learning Objectives:

- Understand the principle of the Maximum Power Transfer Theorem.
- Determine the Thevenin equivalent resistance (R_{TH}) of a linear resistive network.
- Observe the effect of varying load resistance (R_L) on load current and load power.
- Calculate the power delivered to the load for different values of (R_L).
- Plot the (P_L) versus (R_L) characteristic and determine the condition for maximum power transfer.

Learning Outcomes:

- Apply the Maximum Power Transfer Theorem to a DC resistive network.
- Determine the Thevenin equivalent parameters of a network.
- Measure load voltage and load current for different load resistances.
- Calculate the power absorbed by a load resistance.
- Experimentally verify that maximum power is transferred when $(R_L \approx R_{TH})$.

Apparatus Required:

Sr. No.	Apparatus / Component	Specification	Quantity
1	Regulated DC Power Supply	DC Voltage Source	1
2	Breadboard	Standard Solderless Breadboard	1
3	Digital Multimeter	Voltage, Current and Resistance Measurement	As Required
4	Fixed Resistors	Suitable Values	As Required
5	Variable Load Resistance / Resistance Box	Suitable Range	1
6	Connecting Wires	As Required	As Required

Theory:

Maximum Power Transfer Theorem: The Maximum Power Transfer Theorem states that maximum power is delivered to the load when the load resistance equals the Thevenin equivalent resistance of the source network.

$$\boldsymbol{R_L = R_{TH}}$$

Where:

- R_L = Load resistance
- R_{TH} = Thevenin equivalent resistance

Thevenin Equivalent Circuit: The source network can be replaced by its Thevenin equivalent, consisting of:

- Thevenin voltage (V_{TH})
- Thevenin resistance (R_{TH})
- Variable load resistance (R_L)

Load Current and Load Power:

The load current is:

$$\boldsymbol{I_L = \frac{V_{TH}}{R_{TH} + R_L}}$$

The load power is:

$$\boldsymbol{P_L = I_L^2 R_L}$$

Substituting the value of I_L:

$$\boldsymbol{P_L = \frac{V_{TH}^2 R_L}{(R_{TH} + R_L)^2}}$$

Condition for Maximum Power Transfer:

Maximum load power occurs when:

$$\boxed{\boldsymbol{R_L = R_{TH}}}$$

At this condition,

$$\boldsymbol{I_L = \frac{V_{TH}}{2R_{TH}}}$$

$$\boxed{\boldsymbol{P_{L(\max)} = \frac{V_{TH}^2}{4R_{TH}}}}$$

Power–Resistance Characteristic:

As the load resistance varies:

- $R_L < R_{TH}$: Load power increases.
- $R_L = R_{TH}$: Load power is maximum.
- $R_L > R_{TH}$: Load power decreases.

Thus, the Power–Resistance graph reaches its peak at:

$$\boldsymbol{R_L = R_{TH}}$$

Efficiency at Maximum Power Transfer:

At maximum power transfer,

$$\boldsymbol{R_L = R_{TH}}$$

the power dissipated in the load equals the power dissipated in the Thevenin resistance.

Therefore,

$$\boldsymbol{\eta = 50\%}$$

Hence, the theorem is useful when maximum power delivery is required, although it does not provide maximum efficiency.

Circuit Diagram:

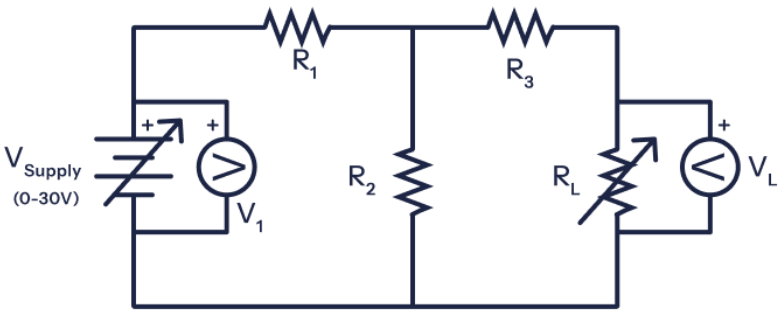

Fig.14.1: Connection Diagram for Maximum Power Transfer

Procedure:

Part A: Determination of Thevenin Parameters

- Identify the resistor values, construct the original circuit as shown in the circuit diagram, and remove the load resistance (R_L).
- Connect a voltmeter across the open load terminals, switch ON the DC power supply, measure the open-circuit voltage, and record it as the Thevenin voltage (V_{TH}).
- Switch OFF the power supply, replace the voltage source with a short circuit, and measure the equivalent resistance across the load terminals using an ohmmeter.
- Record the measured resistance as the Thevenin resistance (R_{TH}).

Part B: Verification of Maximum Power Transfer

- Restore the original circuit, reconnect the DC power supply, and connect the variable load resistance (R_L) across the load terminals.
- Vary R_L from values below, approximately equal to, and above R_{TH}. For each setting, measure the load voltage (V_L) and load current (I_L), and record the readings.
- Calculate the load power using $P_L = V_L I_L$ or $P_L = I_L^2 R_L$ Identify the value of R_L at which the load power is maximum.
- Plot the graph of P_L versus R_L, compare the load resistance at maximum power with R_{TH}, verify that $R_L \approx R_{TH}$, and switch OFF the power supply.

Precautions:

- Ensure the power supply is OFF while making or modifying circuit connections.
- Verify all resistor values and circuit connections before switching ON the power supply.
- Remove the load resistance before measuring V_{TH} and R_{TH}, and deactivate the voltage source before measuring R_{TH}.
- Never measure resistance using a powered circuit.
- Connect the voltmeter in parallel and the ammeter in series.
- Select load resistance values below and above R_{TH}, and ensure the load resistance does not exceed its power rating.
- Record all observations using consistent units.

Observation Table:

Thevenin Voltage, (V_{TH}) = ____________________ V

Thevenin Resistance, (R_{TH}) = ____________________ Ω

Table 14.1: Variation of Load Power with Load Resistance

Sr. No.	Load Resistance, (R_L) (Ω)	Load Voltage, (V_L) (V)	Load Current, (I_L) (mA)	Load Power, (P_L) (mW)
1				
2				
3				
4				
5				
6				

7				
8				
9				
10				

Calculations:

Thevenin Equivalent Voltage: The open-circuit voltage measured across the load terminals is:

$$V_{TH} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \text{ V}$$

Thevenin Equivalent Resistance: The equivalent resistance measured across the load terminals after deactivating the independent source is:

$$R_{TH} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \Omega$$

Load Power: For one set of observed readings:

R_L = ________________ **Ω**

V_L = ________________ **V**

I_L = ________________ **A**

Therefore:

$$P_L = V_L \times I_L$$

P_L=__________×__________

P_L=________________W

Theoretical Maximum Power:

The theoretical maximum power is:

$$P_{L(\max)} \frac{V_{TH}^2}{4R_{TH}}$$

Substituting the measured values:

$$P_{L(\max)} \frac{(\_\_\_\_\_\_\_\_)^2}{4(\_\_\_\_\_\_)}$$

$P_{L(\max)}$= ________________W

Verification:

Thevenin Resistance:

$\boldsymbol{R_{TH}} = \underline{\hspace{3cm}}\ \boldsymbol{\Omega}$

Load Resistance at Maximum Measured Power:

$$R_L = \underline{\hspace{3cm}}\ \Omega$$

Therefore:

$$\boxed{\boldsymbol{R_L \approx R_{TH}}}$$

Hence, the Maximum Power Transfer Theorem is verified.

Result: The load power was determined for different values of load resistance, and the (P_L) versus (R_L) characteristic was plotted. The maximum load power was observed when the load resistance was approximately equal to the Thevenin equivalent resistance of the source network.

$$\boxed{\boldsymbol{R_L \approx R_{TH}}}$$

Hence, the Maximum Power Transfer Theorem was verified experimentally.

Conclusion: The experiment demonstrated the relationship between load resistance and the power transferred from a linear DC network to the load. As the load resistance was varied, the load power increased, reached a maximum value, and then decreased. The maximum power was obtained when the load resistance was approximately equal to the Thevenin equivalent resistance of the source network, thereby verifying the Maximum Power Transfer Theorem experimentally.

Review Questions:

1. State the Maximum Power Transfer Theorem.
2. Why is the efficiency of a DC network only 50% at the maximum power transfer condition?

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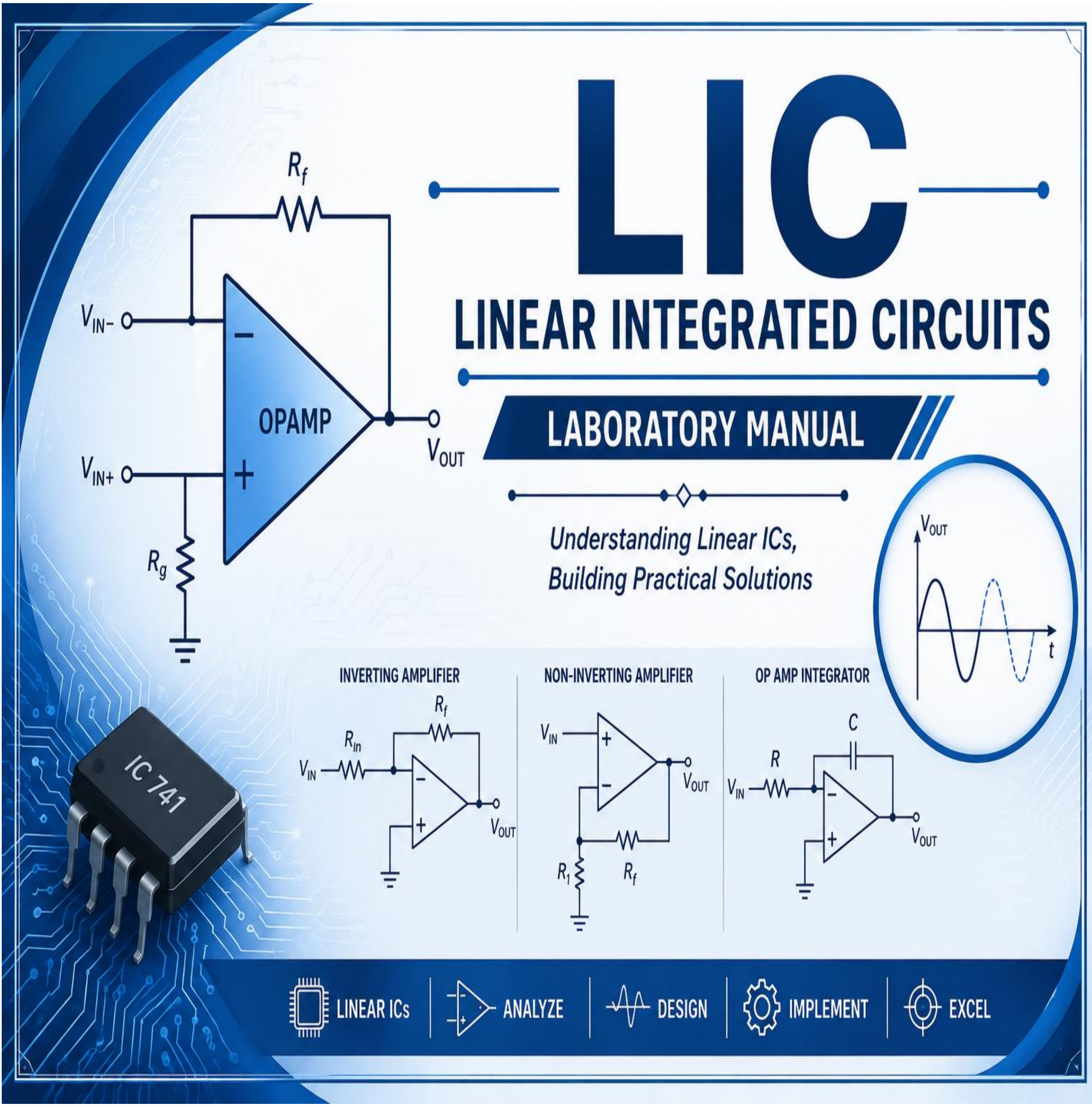
SCHEME: 23 Series

LABORATORY MANUAL FOR

LINEAR INTEGRATED CIRCUITS (23303)



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CERTIFICATE

This is to certify that Mr./Ms.. having SPN. No. ...., of Third Semester of Diploma in Electronics and Telecommunication Engineering.

He/She has completed the term work satisfactorily in course **Linear Integrated Circuits (23303)** for the academic year 20........ to 20.........as prescribed in the curriculum.

Place: ....

Date: ....

Mr. Vinay S. Nagalikar
Subject Teacher

Dr. Vijay Rathod
Head of the Department

Dr. Shivaji Ghungrad
Principal

Seal of the institute

St. Xavier's Technical Institute

Mahim, Mumbai 400016

Department of Electronics and Telecommunication Engineering

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Institute Mission

To strive to match global standards in technical education by

- Interaction with Industry
- Continuous Staff training
- Development of quality of life

Department Vision

To become a center of excellence and to produce high quality self-motivated creative and ethical diploma engineers and technologists, contributing effectively to universal engineering and contemporary education.

Department Mission

To prepare the students of the Department of Electronics and Telecommunication Engineering for a brilliant career / entrepreneurship along with the development of knowledge, skills, attitude and teamwork ideal for a professional through the designed programme.

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Mahim, Mumbai 400016

Department of Electronics and Telecommunication Engineering

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2. **Problem analysis:** Identify and analyse well-defined engineering problems using codified standard methods.

3. **Design/ development of solutions:** Design solutions for well-defined technical problems and assist with the design of systems components or processes to meet specified needs.

4. **Engineering Tools, Experimentation and Testing:** Apply modern engineering tools and appropriate technique to conduct standard tests and measurements.

5. **Engineering practices for society, sustainability and environment:** Apply appropriate technology in context of society, sustainability, environment and ethical practices.

6. **Project Management:** Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.

7. **Life-long learning:** Ability to analyse individual needs and engage in updating in the context of technological changes.

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DIPLOMA IN ELECTRONICS AND TELECOMMUNICATION ENGINEERING (DETE)
SECOND YEAR SEMESTER-III LINEAR INTEGRATED CIRCUITS LABORATORY MANUAL

Document Number: 2627-JUN 26-DETE-303

00	19th Jun 2026	Laboratory Manual for LIC (23303)	VN	VRR	SBG
REV. NO.	**DATE**	**DESCRIPTION**	**PREPARED BY**	**CHECKED BY**	**APPROVED BY**

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Rev. No.	Date	Pages	Description
00	19th Jun 2026	57	Laboratory Manual: Linear Integrated Circuits

HOLD LIST

Hold No.	Pages	Description
NIL	NA	--

EXECUTIVE SUMMARY

Laboratory Manual is prepared by Mr. Vinaykumar S. Nagalikar, reviewed by Dr. Mahesh Munde, Dr. Vijay Rathod and approved by Dr. Shivaji Ghungrad consisting Ten (10) laboratory experiments covering five course outcomes (CO 303.1 to CO303.5)

This subject comes under the Core Technology group and will enable the students to comprehend the theory, concepts, characteristics and working principles of basic electronic circuits. Linear Integrated Circuits hold an important unique place in the field of electronics. This subject is classified under Basic Technology group with a focus on imparting concepts, principles and applications of Linear/Analog integrated circuits in the field of Electronics. The prerequisite for this subject is knowledge of basic electronic devices and circuits.

The curriculum covers basic concepts on the operation of the operational Amplifier. Well known IC741 is used for explanation and experiments. In section 1 this course covers the basic concepts, parameters, open and closed loop applications. Detailed study on the mathematical concepts is illustrated with circuit diagrams and waveforms such as adder, subtractor, integrator, differentiator, log antilog and so on. Application on IC741 such as oscillator, filters, detectors and comparators are covered as well. In section 2 concepts on voltage-controlled oscillator and Phase locked loop are covered. DC Power supply circuits and voltage regulations circuits too are included.

Through structured laboratory experiments and practical exercises, learners gain competence building and testing basic electronic circuits using OP-AMP, which form the basis for Analog circuit design and testing. The course equips students with the core concepts of amplifier design and various other Analog circuits required across core engineering disciplines.

MR. VINAYKUMAR NAGALIKAR	DR. VIJAY RATHOD	DR. SHIVAJI GHUNGRAD
LECTURER (SEL)	HOD, DETE	PRINCIPAL

Index:

EXPERIMENT NO. 1: TO OBTAIN THE PRACTICAL GAIN OF INVERTING AMPLIFIER USING OPAMP IC-741. (CO 303.1)

AIM: To obtain the Practical Gain of Inverting Amplifier using OPAMP IC-741.

EXPERIENTIAL OBJECTIVES:

1. To build the Inverting Amplifier Circuit using IC-741 on the breadboard.
2. To provide correct power supply to the circuit and connecting required output measuring instruments.
3. To record the readings in the observation table and calculate the Practical Gain.
4. To measure the Theoretical Gain using the Gain Equation of inverting Amplifier.
5. To plot the Graph output (V_0) VS Input (V_{IN}).

RESOURCES REQUIRED:

1. Fixed Dual Power supply +15V & -15V. or two 9V battery with common ground
2. Regulated power supply 0-12V.
3. Multi-meter.
4. Resistors: - Input resistor 1kΩ, Feedback resistor 2kΩ, Load resistor 18kΩ.
5. Breadboard.
6. OPAMP IC-741.
7. Connecting Wires.

EXPERIMENT OUTCOME:

1. Operate the power supply.
2. Test IC 741.
3. Determine the values of resistors using colour code.
4. Build the Inverting Amplifier circuit on the breadboard.
5. Obtain the readings and record the readings in the manual.
6. Calculate Theoretical gain and Practical Gain.
7. Draw the Graph of Input Vs Output.

LLO:

LLO 1: Connect IC 741 in inverting and non-inverting mode.
LLO 2: Measure the voltage gain of inverting and non-inverting amplifier circuit using IC 741.
LLO 3: Identify the resistor with its color code.

CIRCUIT DIAGRAM:

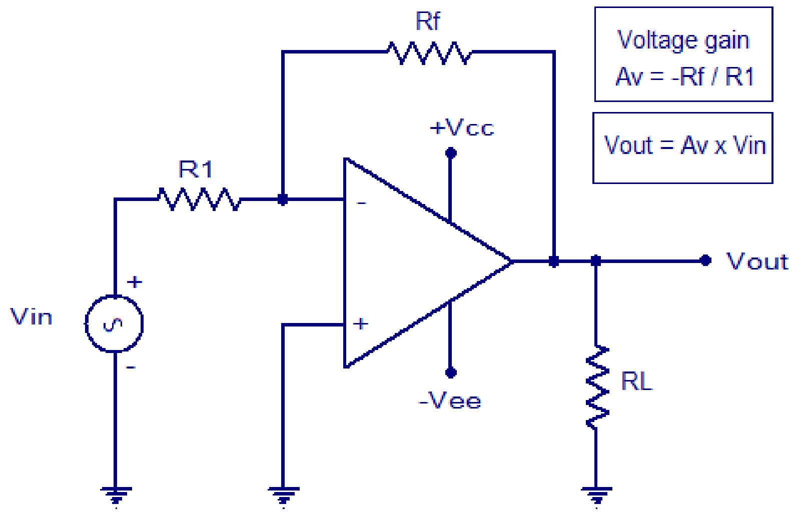


Fig. 1 Circuit Diagram of Inverting Amplifier

WAVEFORMS:

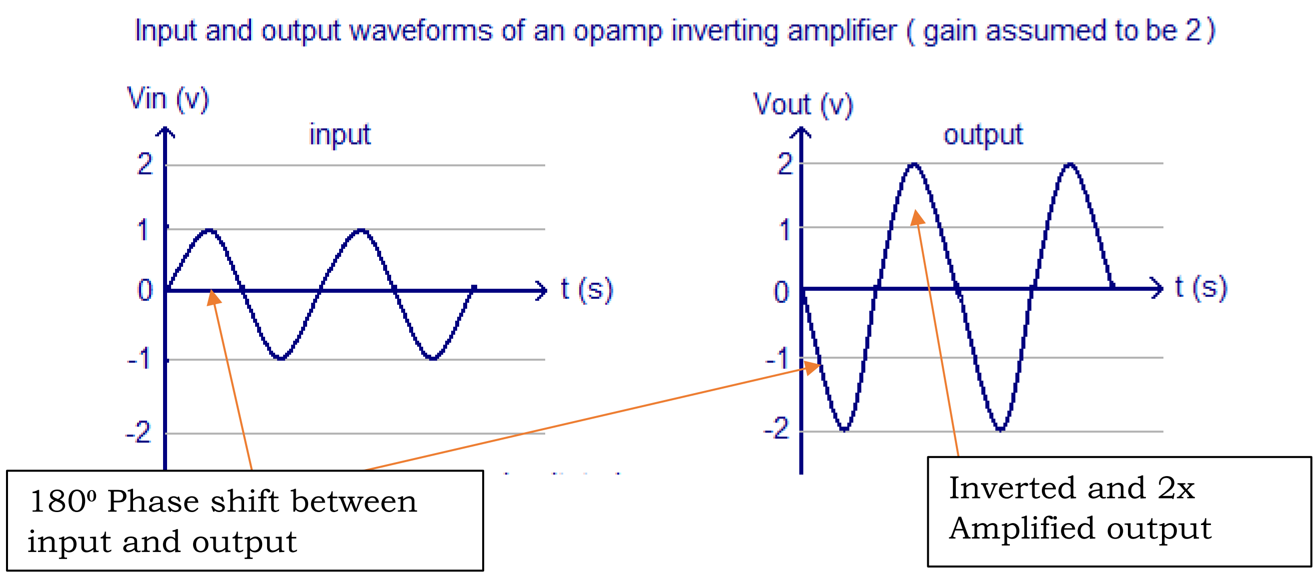


Fig. 2 Waveforms of Inverting Amplifier gain is set to 10

THEORY OF INVERTING AMPIFIER:

Inverting Amplifier is designed using IC 741. When the input signal is given to Inverting pin of IC 741 and keeping the non-inverting pin grounded, then this amplifier is called Inverting Amplifier. Inverting Amplifier has a phase difference of 180 degree between input and output. Also, it generates inverted output. i.e., Positive input will generate negative output and vice versa.

Connections:

The input signal Vin connects to the inverting input (–) via an input resistor Rin. The non-inverting input (+) connects directly to ground (0V). Feedback: A feedback resistor Rf links the output back to the inverting input terminal, creating negative feedback. Virtual Ground: Because the positive terminal is at 0V, the negative terminal stays close to 0V, acting as a virtual earth point

Principle of Operation:

When the op-amp is powered with a dual supply (e.g., ±12 V or ±15 V), negative feedback forces the voltage at the inverting terminal to be nearly equal to the voltage at the non-inverting terminal. Since the non-inverting terminal is grounded, the inverting terminal is maintained at approximately 0 V. This point is known as the virtual ground because it behaves like ground without being physically connected to it.

The input current flows through the input resistor Rin to the inverting terminal. Because the input impedance of the op-amp is extremely high, almost no current enters the op-amp input. Therefore, the entire input current flows through the feedback resistor Rf. The Gain of the Inverting amplifier is always negative. In case of AC signals the output is 180 degrees out of phase of input. Inverting mode can be used in linear and non-linear applications like amplifier, mathematical operations like adder, integrator, differentiator, comparators and detectors.

One final point to note about the Inverting Amplifier configuration when used for an operational amplifier. If the two resistors are of equal value, that is: Rin = Rƒ then the voltage gain of the amplifier will become –1 producing a complementary form of the input voltage at its output as Vout = –Vin.

Characteristics:

- Output is 180° out of phase with the input.
- Voltage gain is determined only by the ratio of Rf and Rin.
- High input impedance (due to the op-amp).
- Low output impedance.
- Excellent stability because of negative feedback.
- Good linearity and predictable performance.

PROCEDURE:

1. Build the Inverting Amplifier circuit on the bread board as per the circuit diagram.
2. Connect the Dual power supply to IC 741 as per the diagram.
3. Provide the Input voltage as per the observation table
4. Observe the reading on the multi-meter.
5. Ensure proper connections to power supply pins i.e., pin7 is +9V and pin4 is -9V

OBSERVATION:

Table 1. Observation Table for Inverting Amplifier

Positive Input (Vin)	Output (Vo)	Gain (Vo/Vin)	Negative Input (Vin)	Output (Vo)	Gain (Vo/Vin)
1			-1		
2			-2		
3			-3		
4			-4		
5			-5		
6			-6		

RESULT:

1. Theoretical Gain (as per the gain Formula): ________________________
2. Practical gain (as per the observation table readings): ________________________
3. Phase difference between Input and Output signals: ________________________

PRECUATIONS:

1. Do not Short circuit the connections.
2. Do not exceed the input signal beyond set limits
3. Keep all the instruments control knob to the minimum position before switching it ON.
4. Do not fiddle with the instruments.

GRAPH OF INPUT VS OUTPUT:

Draw the V_0 vs V_{in} for the positive Vin (Refer the readings)

Draw the V_0 vs V_{in} for the negative V_{in} (Refer the readings)

CONCLUSION:

The Inverting amplifier circuit was constructed on the breadboard. The readings indicated that the output is of opposite polarity w.r.t input and is amplified by the gain.

QUESTIONS:

1. How much output of an inverting amplifier is shifted w.r.t. input? Why?
2. What is the Gain formula of Inverting Amplifiers?
3. IF R_1= 10 ohms and R_f = 250 ohms calculate the gain of the inverting amplifier?
4. What are the Applications of Inverting and Non-Inverting Amplifiers?
5. Design the Inverting Amplifier having gain of 35?
6. Derive the gain formula of the inverting amplifier?

Evaluation	Circuit(10M)	Readings(10M)	Output(5M)	Total (25M)
Remarks:				

EXPERIMENT NO. 2: TO OBTAIN THE PRACTICAL GAIN OF NON-INVERTING AMPLIFIER USING OPAMP IC-741. (CO 303.1)

AIM: To obtain the Practical Gain of Non-Inverting Amplifier using OPAMP IC-741.

EXPERIENTIAL OBJECTIVES:

1. To build the Non-Inverting Amplifier Circuit using OPAMP IC-741 on the breadboard.
2. To provide correct power supply to the circuit and connecting required output measuring instruments.
3. To record the readings in the observation table and calculate the Practical Gain.
4. To measure the Theoretical Gain using the Gain Equation of Non-inverting Amplifier.
5. To plot the Graph output (V_0) VS Input (V_{IN}).

RESOURCES REQUIRED:

1. Fixed Dual Power supply +15V & -15V
2. Regulated power supply 0-12V
3. Multi-meter
4. Following Components are required
5. Resistors: - Input resistor 1kΩ, Feedback resistor 10kΩ, , Load resistor 25kΩ
6. Breadboard
7. OPAMP IC-741
8. Connecting Wires

EXPERIMENT OUTCOME:

1. Test IC 741.
2. Determine the values of resistors using colour code
3. Build the Inverting Amplifier circuit on the breadboard
4. Obtain the readings and record the readings in the manual.
5. Calculate Theoretical gain and Practical Gain.
6. Draw the Graph of Input Vs Output.

LLO:

LLO 1: Connect IC 741 in inverting and non-inverting mode.
LLO 2: Measure the voltage gain of inverting and non-inverting amplifier circuit using IC 741.

CIRCUIT DIAGRAM:

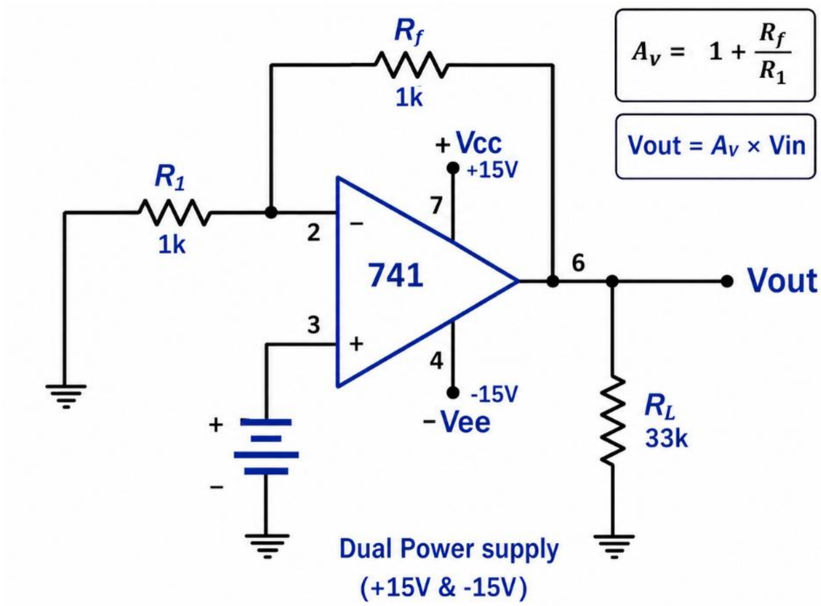


Fig. 1 Circuit Diagram of Non- Inverting Amplifier gain is set to 11

WAVEFORMS:

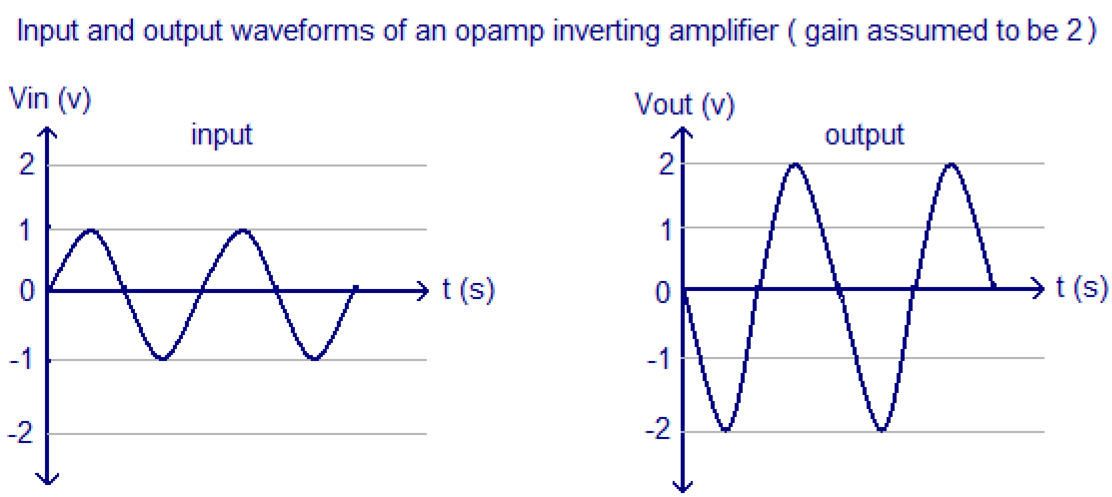


Fig. 2 Waveforms of Non-Inverting Amplifier gain is set to 2

THEORY:

Non-Inverting Amplifier is designed using IC 741. When the input signal is given to non-Inverting pin of IC 741 and keeping the inverting pin grounded, then this amplifier is called Non-Inverting Amplifier. Non-Inverting Amplifier has no phase difference between input and output.

Principle of Operation:

When negative feedback is applied, the op-amp adjusts its output so that the voltage at the inverting terminal (-) becomes nearly equal to the voltage at the non-inverting terminal (+).Since the input is applied directly to the non-inverting terminal, The feedback network acts as a voltage divider, supplying a fraction of the output voltage to the inverting input. Non-inverting amplifier will always have a minimum gain of 1. Inverting can have gain less than 1. In this non-inverting circuit configuration, the input impedance Rin has increased to infinity, while the feedback impedance Rƒ has reduced to zero. As the input impedance is extremely high, the unity gain buffer (voltage follower) can be used to provide a large power gain as the extra power comes from the op-amps supply rails and through the op-amps output to the load and not directly from the input.

Since the output is connected directly back to the negative inverting input terminal, the feedback is 100% so Vin is exactly equal to Vout giving it a fixed gain of 1 or unity.

Characteristics:

- Output is in phase (0° phase shift) with the input.
- Very high input impedance.
- Low output impedance.
- Gain is always greater than or equal to 1.
- Gain is determined by the resistor ratio.
- Stable operation due to negative feedback.

Advantages:

- High input impedance minimizes loading of the signal source.
- Simple circuit with stable gain.
- Low distortion.
- Good bandwidth (within the limitations of the IC 741).
- Suitable for amplifying weak signals.

PROCEDURE:

1. Build the Inverting Amplifier circuit on the bread board as per the circuit diagram.
2. Connect the Dual power supply to IC 741 as per the diagram.
3. Provide the Input voltage as per the observation table
4. Observe the reading on the multi-meter.
5. Ensure proper connections to power supply pins i.e., pin7 is +9V and pin4 is -9V

OBSERVATION:

Table 1. Observation Table for Non- Inverting Amplifier

Positive Input (Vin)	Output (Vo)	Gain (Vo/Vin)	Negative Input (Vin)	Output (Vo)	Gain (Vo/Vin)
1			-1		
2			-2		
3			-3		
4			-4		
5			-5		
6			-6		

RESULTS:

1. Theoretical Gain (as per the gain Formula): ______________________
2. Practical gain (as per the observation table readings): ________________________
3. Phase difference between Input and Output signals: ________________________

PRECUATIONS:

1. Do not Short circuit the connections.
2. Do not exceed the input beyond set limit.
3. Keep all the instruments control knob to the minimum position before switching it ON.
4. Do not fiddle with the instruments.
5. Switch OFF all the instruments when not in use.

GRAPH OF INPUT VS OUTPUT:

Draw the V_0 vs V_{in} for the positive Vin and negative vin. Refer the readings

Draw the V0 vs Vin for the positive V_{in} and negative vin. Refer the readings

CONCLUSION:

The Inverting amplifier circuit was constructed on the breadboard. The readings indicated that the output is of opposite polarity w.r.t input and is amplified by the gain.

QUESTIONS/ASSIGNMENT QUESTIONS:

1. Explain the bandwidth of an OPAMP?
2. What are the different grades of ICs available in the market? Explain?
3. IF R1= 10 ohms and Rf = 250 ohms calculate the gain of Non-inverting amplifier?
4. Explain the working of Inverting and NON-inverting Inputs of an OPAMP?
5. Design the Inverting Amplifier having gain of 35?

Evaluation	Circuit(10M)	Readings(10M)	Output(5M)	Total (25M)
Remarks				

EXPERIMENT NO. 3: TO OBTAIN THE FREQUENCY RESPONSE AND CALCULATE THE BANDWIDTH OF NON-INVERTING AMPLIFIER USING OPAMP IC-741. (CO 303.1)

AIM: To obtain the Frequency response and Practical Gain of Non-Inverting Amplifiers using OPAMP IC-741.

EXPERIENTIAL OBJECTIVES:

1. To build the Non-Inverting Amplifier Circuit using OPAMP IC-741 on the breadboard.
2. To provide correct power supply to the circuit and connecting required output measuring instruments.
3. To record the readings in the observation table and calculate the Practical Gain.
4. To measure the Bandwidth using the Gain Equation of Non-Inverting Amplifier.
5. To observe Inverted signal and draw the output of Inverting Amplifier.
6. To plot the frequency response Graph output (V_0) VS AC Input (V_{IN}).

RESOURCES REQUIRED:

1. Signal Generator(1MHz)
2. CRO/DSO (15 MHz)
3. Following Components are required
4. Resistors: Feedback resistor 10kΩ, Input resistor 1kΩ, Load resistor 25kΩ
5. Breadboard
6. OPAMP IC-741
7. Connecting Wires

EXPERIMENT OUTCOME:

1. Operate the Signal Generator.
2. Operate the CRO/DSO.
3. Determine the Bandwidth of a Non- Inverting Amplifier
4. Plot the Frequency response of the Non- Inverting Amplifier.
5. Observe the Phase reversal of the Inverting Amplifier.
6. Calculate Theoretical gain and Practical Gain.

LLO:

LLO1: Build the circuit on the breadboard

LLO1: Measure output voltage of a differential circuit made of IC 741.

CIRCUIT DIAGRAM:

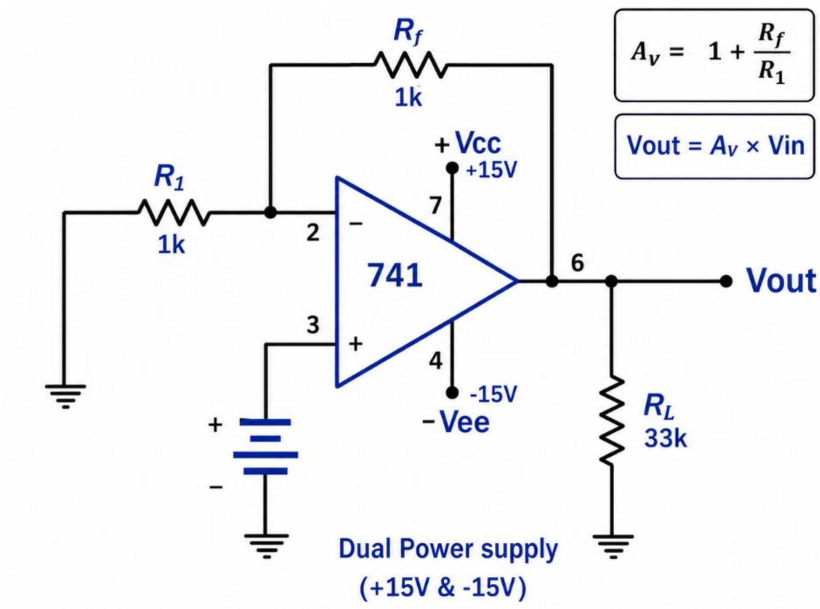


Fig. 1 Circuit Diagram of Non- Inverting Amplifier gain is set to 11

THEORY:

A non-inverting amplifier provides an amplified output that is **in phase** with the input. Its gain remains constant at low and mid frequencies, but decreases at high frequencies due to the op-amp's limited bandwidth. The gain is given by:

$$\boxed{\mathbf{A_v = 1 + \frac{R_f}{R_1}}}$$

and the frequency response is characterized by a flat gain up to the cut-off frequency, followed by a roll-off of approximately −20 dB per decade. This behaviour is important when designing amplifier circuits for high-frequency applications.

- Output is in phase (0° phase shift) with the input.
- Very high input impedance.
- Low output impedance.
- Gain is always greater than or equal to 1.
- Gain is determined by the resistor ratio.
- Stable operation due to negative feedback

Bandwidth: The bandwidth (BW) is the range of frequencies over which the amplifier maintains its specified gain. The cutoff frequency (fc) is the frequency at which the gain falls to 70.7% (−3 dB) of its low-frequency value.

Gain-Bandwidth Product (GBW) for most op-amps, Higher closed-loop gain results in lower bandwidth. Lower closed-loop gain results in higher bandwidth.

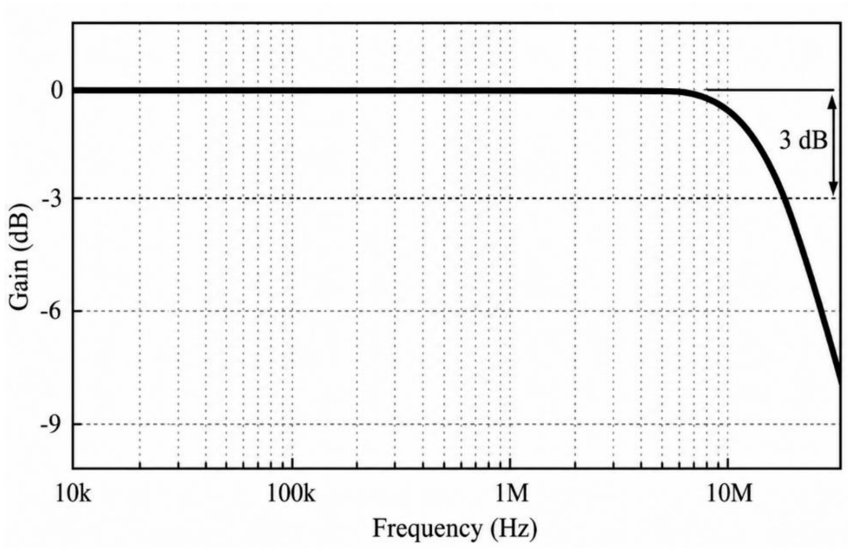


Fig. 2. Frequency response graph of non-inverting amplifier

Advantages:

1. High input impedance.
2. Low output impedance.
3. Output is in phase with the input.
4. Stable voltage gain.
5. Wide bandwidth (depending on the op-amp used).
6. Suitable for amplifying weak signals.

Applications:

1. Audio amplifiers
2. Voltage followers (buffer amplifiers)
3. Sensor signal conditioning
4. Active filters
5. Data acquisition systems
6. Instrumentation amplifier

PROCEDURE:

1. Build the Amplifier circuit on the bread board as per the circuit diagram.
2. Connect Signal generator input (1Vpeak-peak) to Non-inverting input.
3. Connect the output to CRO/DSO through Probes.
4. Record the readings as per the observation table.
5. Connect the Dual power supply to IC 741 as per the diagram.

OBSERVATIONS:

Table1. Frequency response of non-inverting amplifier

Sr. No.	Input Voltage (Vin)	Input Frequency (Hz)	Output Voltage (Vo)	Voltage Gain A=(V0/Vin)	Gain in dB 20log (V0/Vin)
1	1 Vp-p	500 Hz			
2	1 Vp-p	1 KHz			
3	1 Vp-p	5 KHz			
4	1 Vp-p	10 KHz			
5	1 Vp-p	15 KHz			
6	1 Vp-p	20 KHz			
7	1 Vp-p	25 KHz			
8	1 Vp-p	50 KHz			
9	1 Vp-p	100 KHz			
10	1 Vp-p	150 KHz			
11	1 Vp-p	200 KHz			
12	1 Vp-p	300 KHz			
13	1Vp-p	500 KHz			
14	1Vp-p	1 MHz			

RESULTS:

1. Theoretical Gain (as per the gain Formula): ________________________
2. Practical gain (as per the observation table readings): _________________________
3. Phase difference between Input and Output signals: _________________________

PRECUATIONS:

1. Do not Short circuit the connections.
2. Keep all the instrument's control knob to the minimum position before switching it ON.
3. Do not fiddle with the instruments.
4. Switch OFF all the instruments when not in use.

GRAPH OF FREQUENCY RESPONSE (SEMILOG GRAPH PAPER)

CONCLUSION:

QUESTIONS/ASSIGNMENT QUESTIONS:

1. Draw and explain the block diagram of an OPAMP.
2. What is the Gain formula of Non-Inverting Amplifier? Derive the Gain?
3. IF R1= 10 ohms and Rf = 250 ohms calculate the gain of non-inverting amplifier?
4. Explain any Six OPAMP Parameters?

Evaluation	Circuit(10M)	Readings(10M)	Output(5M)	Total (25M)
Remarks				

EXPERIMENT NO. 4: TO DESIGN SUBTRACTOR FROM DIFFERENTIAL AMPLIFIER USING OPAMP IC-741. (CO 303.2)

AIM: To design a subtractor from Differential Amplifier using OPAMP IC-741.

EXPERIENTIAL OBJECTIVES:

1. To build the Subtractor using Differential Amplifier Circuit using OPAMP IC-741 on the breadboard.
2. To provide correct power supply to the circuit and connect required output measuring instruments.
3. To record the readings in the observation table and calculate the Practical Gain.

RESOURCES REQUIRED:

1. Fixed Dual Power supply +15V & -15V
2. Regulated power supply 0-12V
3. Multi-meter
4. Resistors: - Feedback resistor 10kΩ, Input resistor 1kΩ, Load resistor 25kΩ
5. Breadboard
6. OPAMP IC-741
7. Connecting Wires

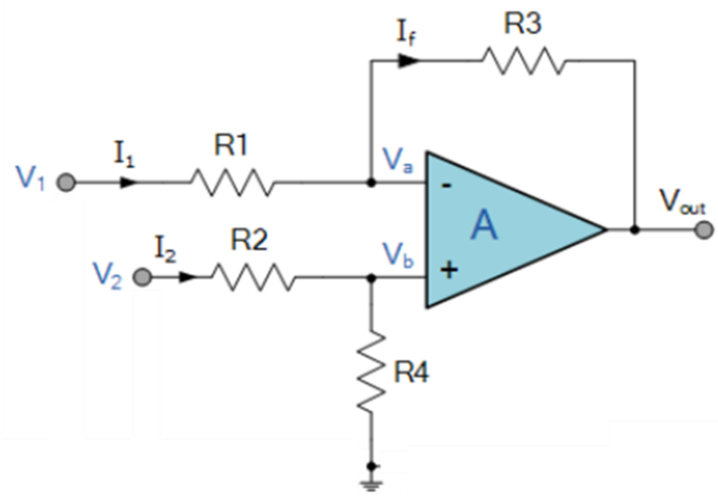
EXPERIMENT OUTCOME:

1. Operate the power supply and test IC 741.
2. Build the Inverting Amplifier circuit on the breadboard
3. Obtain the readings and record the readings in the manual.
4. Calculate Theoretical gain and Practical Gain.

LLO:

LLO1: Build the circuit on the breadboard
LLO1: Measure output voltage of a differential circuit made of IC 741.
LLO3: To use differential configuration as a subtractor

CIRCUIT DIAGRAM:



V1 = Variable Voltage (0V to 15V)

V2 = Fixed voltage +15V

R1=R2=R3=R4 = 1Kohm

Fig. 1 Circuit Diagram of a subtractor

OBSERVATIONS:

Table 1. Observation table

SR. NO.	NON-INVERTING INPUT (VOLTAGE)	INVERTING INPUT (VOLTAGE)	OUTPUT (VOLTAGE)
1	+9V	1V	
2	+9V	2V	
3	+9V	3V	
4	+9V	4V	
5	+9V	5V	
6	+9V	6V	
7	+9V	7V	
8	+9V	8V	
9	+9V	9V	

THEORY:

Differential Amplifier is designed using IC 741. When the input signal is given to the non-Inverting pin and as well as inverting input of IC 741 then the OPAMP calculates the difference between them.

$$V_{out} = -V_1\left(\frac{R_3}{R_1}\right) + V_2\left(\frac{R_4}{R_2+R_4}\right)\left(\frac{R_1+R_3}{R_1}\right)$$

$$If\ R_1 = R_2\ \&\ R_3 = R_4$$

$$V_{out} = -\frac{R_3}{R_1}(V_2 - V_1)$$

$$If\ Gain = \frac{R_f}{R_1} = 1$$

$$V_{out} = (V_2 - V_1)$$

PROCEDURE:

1. Build the Inverting Amplifier circuit on the breadboard as per the circuit diagram.
2. Connect the Dual power supply to IC 741 as per the diagram.
3. Provide the Input voltage as per the observation table and observe the reading on the multimeter.

RESULTS:

1. Theoretical Gain (as per the gain Formula): ____________________
2. Practical gain (as per the observation table readings): ____________________
3. Phase difference between Input and Output signals: ____________________

PRECAUTIONS:

1. Do not Short circuit the connections.
2. Keep all the instrument's control knob to the minimum position before switching it ON.
3. Do not fiddle with the instruments.
4. Switch OFF all the instruments when not in use.

QUESTIONS:

1. Draw the circuit diagram of the differential amplifier and derive its gain formula?
2. Draw the subtractor circuit?
3. Distinguish between Differential amplifier and Inverting amplifier?

Evaluation	Circuit(10M)	Readings(10M)	Output(5M)	Total (25M)
Remarks				

EXPERIMENT NO. 5: TO BUILD/TEST INTEGRATOR CIRCUIT IN INVERTING MODE USING OPAMP IC-741. (CO 303.2)

AIM: To obtain the Output waveform of Integrator circuit in Inverting mode using OPAMP IC-741.

EXPERIENTIAL OBJECTIVES:

1. To build the Integrator circuit in Inverting mode using OPAMP IC-741 on the breadboard.
2. To provide correct power supply to the circuit and connecting required output measuring instruments.
3. To observe and draw the output waveform of an Integrator circuit from CRO.
4. To observe the output when the input applied is a) Sine wave b) Square wave.
5. To record the Amplitude, frequency of the above inputs.
6. To plot the Graph (V_0) VS (V_{IN}).

RESOURCES REQUIRED:

1. Signal Generator(1MHz)
2. CRO/DSO (15 MHz)
3. Following Components are required
4. Resistors: - input resistor 1kΩ.
5. Capacitor: - 1 μF
6. Breadboard
7. OPAMP IC-741
8. Connecting Wires

EXPERIMENT OUTCOME:

1. Build and Test the Integrator circuit and observe output waveform on CRO.
2. Apply Square wave and Sine wave and observe the output on the CRO
3. Observe and draw the input and output waveforms of an Integrator Circuit in Inverting mode. Observe and draw the input and output waveforms of an Integrator Circuit in Non -Inverting mode. Record the readings in the manual

LLO

LLO1: Build the circuit on the breadboard
LLO1: Measure output voltage of integrator circuit made of IC 741.
LLO3: To plot the waveforms on the graph paper

CIRCUIT DIAGRAM:

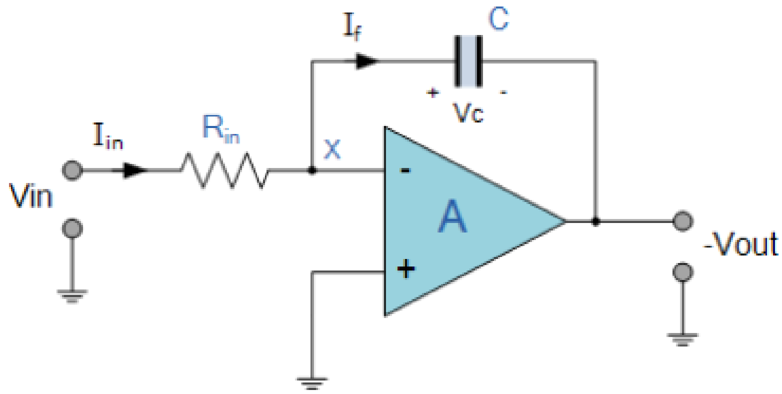


Fig. 1 Integrator Circuit using OPAMP

Rf = 1 kΩ
C = 1 μF
Input = AC input 1V, 200Hz

The Output is given by:

$$\boldsymbol{V_{out} = -\frac{1}{R_{in}C}\int_0^t V_{in}\, dt}$$

THEORY:

An OP-Amp Integrator is an operational amplifier circuit that performs the mathematical operation of integration on the input signal. It is formed by connecting a resistor (R) at the input and a capacitor (C) in the feedback path of an operational amplifier. The input signal is applied to the inverting terminal, while the non-inverting terminal is grounded. Due to negative feedback, the inverting terminal remains at virtual ground, and the current flowing through the input resistor charges or discharges the feedback capacitor. As a result, the output voltage is proportional to the integral of the input voltage with respect to time. The output waveform is 180° out of phase with the input because the signal is applied to the inverting terminal. The output voltage is given by

$$\boldsymbol{V_{out} = -\frac{1}{RC}\int V_{in} dt}$$

where R is the input resistance and C is the feedback capacitance. An op-amp integrator is widely used in analog computers, waveform generators, active filters, signal processing, and control systems. For practical applications, a resistor is often connected in parallel with the feedback capacitor to improve stability and prevent output saturation due to input offset voltages.

OBSERVATION:

INPUT	SQUARE	SINE
OUTPUT	INVERTED TRANGLE	NEGATIVE INVERTED COSINE

WAVEFORMS:

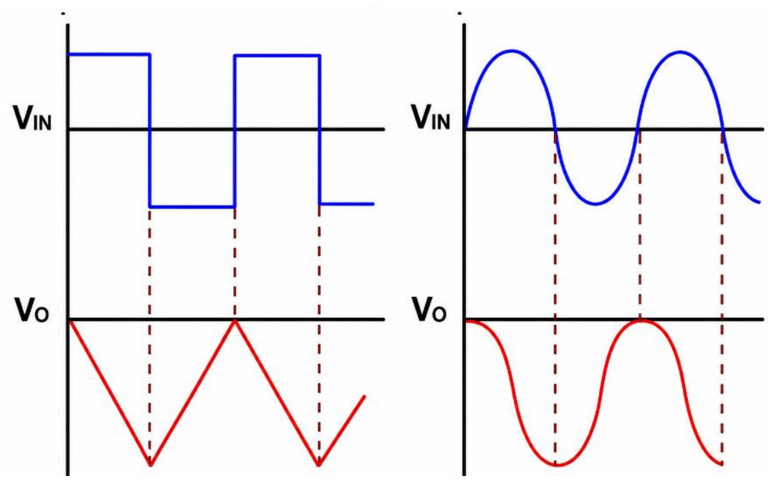


Fig. 2 Waveforms of Integrator

PROCEDURE:

1. Build the Inverting Amplifier circuit on the bread board as per the circuit diagram.
2. Connect the Dual power supply to IC 741 as per the diagram.
3. Provide the Input voltage as per the observation table and observe the waveform on the CRO
4. Connect the input signal to channel 1 of the CRO and output to channel 2
5. Switch on both the channel and position them such that channel 1 – input is on the upper side and the output channel 2 is at the lower side exactly it should look like above fig. 2

PRECAUTIONS:

1. Do not Short circuit the connections.
2. Keep all the instrument's control knob to the minimum position before switching it ON.
3. Do not fiddle with the instruments.
4. Switch OFF all the instruments when not in use.

QUESTIONS:

1. Draw circuit diagrams of Integrator?
2. Draw the waveforms of Integrator output for Sine and square inputs?
3. Derive the Integrator output equation?

Evaluation	Circuit(10M)	Readings(10M)	Output(5M)	Total (25M)
Remarks				

EXPERIMENT NO. 6: TO BUILD/TEST DIFFERENTIATOR CIRCUIT IN INVERTING MODE USING OPAMP IC-741. (CO 303.2)

AIM: To obtain the Output waveform of DIFFRENTATOR circuit in Inverting mode using OPAMP IC-741.

EXPERIENTIAL OBJECTIVES:

1. To build the differentiator circuit in Inverting mode using OPAMP IC-741 on the breadboard.
2. To provide correct power supply to the circuit and connecting required output measuring instruments.
3. To observe and draw the output waveform of an Integrator circuit from CRO.
4. To observe the output when the input applied is a) Sine wave b) Square wave.
5. To record the Amplitude, frequency of the above inputs.
6. To plot the Graph (V_0) VS (V_{IN}).

RESOURCES REQUIRED:

1. Signal Generator (1 MHz)
2. CRO/DSO (15 MHz)
3. Resistors: - input resistor 1 kΩ.
4. Capacitor: - 1 μF
5. Breadboard
6. OPAMP IC-741
7. Connecting Wires

EXPERIMENT OUTCOME:

1. Build and test the differentiator circuit and observe output waveform on CRO.
2. Apply Square wave and Sine wave and observe the output on the CRO.
3. Observe and draw the input and output waveforms of an Integrator Circuit in Inverting mode.
4. Observe and draw the input and output waveforms of an Integrator Circuit in Non -Inverting mode.
5. Record the readings in the manual

LLO:

LLO1: Build the circuit on the breadboard
LLO1: Measure output voltage of integrator circuit made of IC 741.
LLO3: To plot the waveforms on the graph paper

CIRCUIT DIAGRAM:

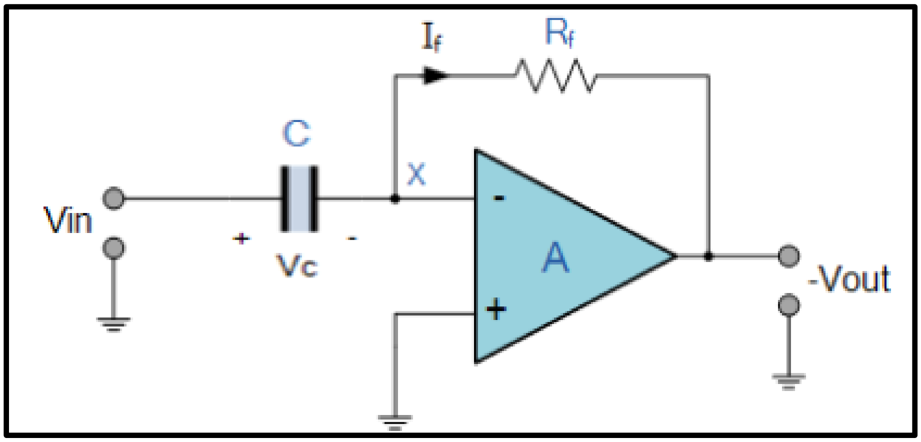


Fig. 1 Differentiator circuit

Rf = 1kΩ, C = 1 µF
Input = 1V, 200Hz

The Output is given by:

$$\boxed{I_{in} = I_{IN} = I_F}$$

Where $\boxed{I_F = -\frac{V_{OUT}}{R_F}}$ & $\boxed{I_{IN} = C\frac{dV_{IN}}{dt}}$

$$\boxed{-\frac{V_{OUT}}{R_F} = C\frac{dV_{IN}}{dt}}$$

$$\boxed{V_{OUT} = -R_F C\frac{dV_{IN}}{dt}}$$

THEORY:

In the differentiator amplifier circuit, the position of the capacitor and resistor have been reversed and now the reactance, XC is connected to the input terminal of the inverting amplifier while the resistor, R_F forms the negative feedback element across the operational amplifier as This operational amplifier circuit performs the mathematical operation of Differentiation, that is it "produces a voltage output which is directly proportional to the input voltage's rate-of-change with respect to time".

OBSERVATION:

INPUT	SQUARE	SINE
OUTPUT	INVERTED SPIKES	INVERTED COSINE

WAVEFORMS:

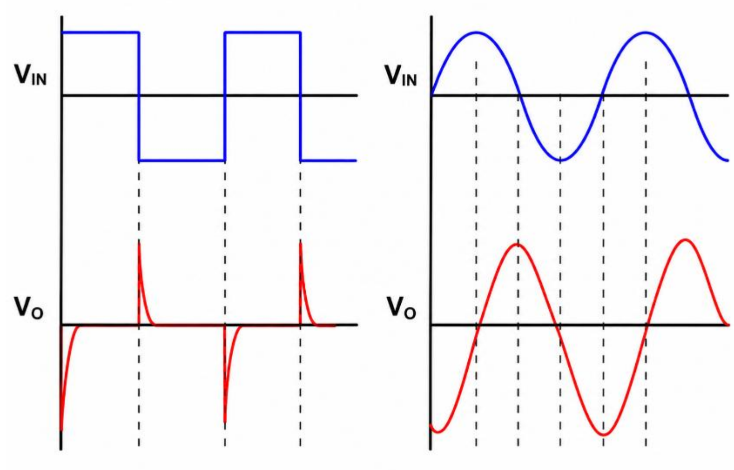


Fig. 2 Waveforms of differentiator

PROCEDURE:

1. Build the Inverting Amplifier circuit on the breadboard as per the circuit diagram.
2. Connect the Dual power supply to IC 741 as per the diagram.
3. Provide the Input voltage as per the observation table and observe the waveform on the CRO.
4. Connect the input signal to channel 1 of the CRO and output to channel 2
5. Switch on both the channel and position them such that channel 1 – input is on the upper side and the output channel 2 is at the lower side exactly it should look like above fig.2

PRECAUTIONS:

1. Do not Short circuit the connections.
2. Keep all the instrument's control knob to the minimum position before switching it ON.
3. Do not fiddle with the instruments.
4. Switch OFF all the instruments when not in use.

QUESTIONS:

1. Draw circuit diagrams of differentiators?
2. Draw the waveforms of differentiator output for Sine and square inputs?
3. Derive the differentiators output equation?

Evaluation	Circuit(10M)	Readings(10M)	Output(5M)	Total (25M)
Remarks				

EXPERIMENT NO. 7: MEASURE THE BANDWIDTH AND CUTOFF FREQUENCY OF THE GIVEN FIRST ORDER LOW PASS (LPF) BUTTERWORTH FILTER. (CO 303.2)

AIM: Measure the bandwidth and cutoff frequency of the given first order low pass (LPF) Butterworth filter using OPAMP IC-741.

EXPERIENTIAL OBJECTIVES:

1. To build the LPF using OPAMP IC-741 on the breadboard.
2. To provide correct power supply to the circuit and connecting required output measuring instruments.
3. To record the readings in the observation table and calculate the Practical Gain.
4. To measure the bandwidth and cutoff frequency of the given first order low pass (LPF) Butterworth filter and Gain Equation and phase equation
5. To plot the Frequency response

RESOURCES REQUIRED:

1. Fixed Dual Power supply +15V & -15V
2. Regulated power supply 0-12V
3. Multi-meter
4. Resistors: Feedback resistor 10kΩ, LPF resistor 10Ωk, LPF capacitor 1μF and Load resistor 25kΩ
5. Breadboard
6. OPAMP IC-741
7. Connecting Wires

EXPERIMENT OUTCOME:

1. Operate the power supply.
2. Test IC 741.
3. Determine the values of resistors using color code
4. measure the bandwidth of LPF
5. Obtain the readings and record the readings in the manual.
6. Calculate cutoff frequency of the given first order low pass (LPF) Butterworth filter.

LLO:

LLO1: Build the First order and second order LPF and measure the output on the CRO.

CIRCUIT DIAGRAM:

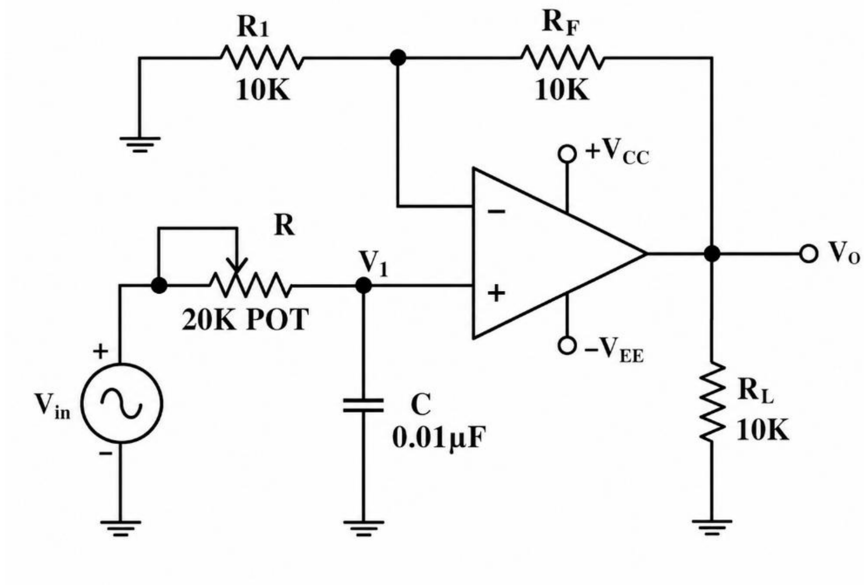


Fig. 1 Circuit diagram of Active Low pass filter

WAVE FORMS:

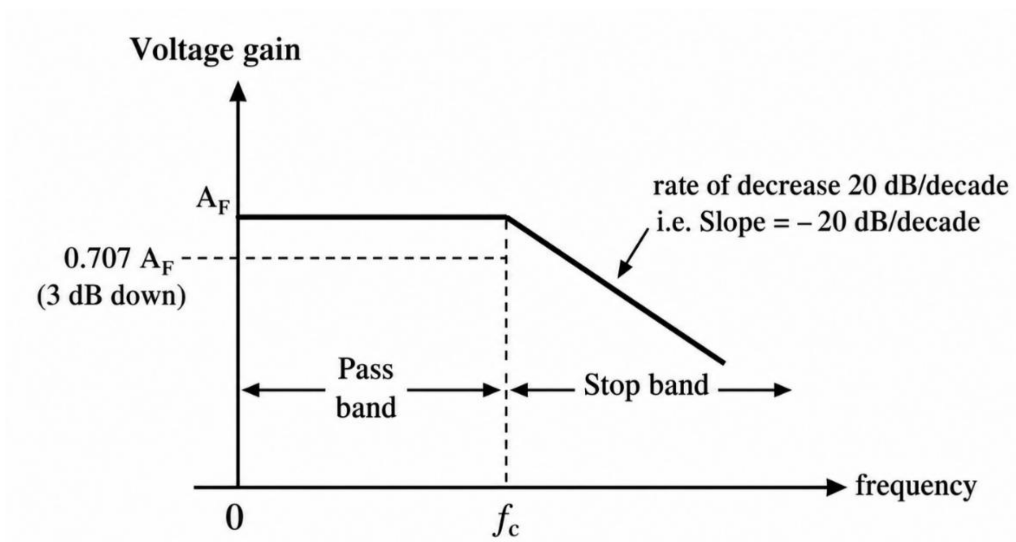


Fig. 2 Frequency response graph of LPF

THEORY:

A low-pass filter is a filter that allows signals with a frequency lower than the cut-off frequency (the frequency at which the output voltage is 70.7% of the source voltage) to pass through it. It also attenuates those signals whose frequency is higher than the cut-off frequency. Low-pass filters help in removing short-term fluctuations, and provide a smoother form of signal. Low pass

Butterworth filter is designed to have a flat frequency response in pass band and stop band. Hence called as flat-flat filter.

Depending on the Roll of Rate of the LPF it is classified as first order, second order filters and so on. Roll of rate is defined as the rate at which the gain of the filter changes with frequency in stop band. In First order Low pass Butterworth filter gain roll of at.

Cut-off frequency is given by:

$$\boxed{Fc = \frac{1}{2\pi RC}}$$

Gain is given by:

$$\boxed{Gain\ in\ dB = 20\ log_{10}\left[\frac{V_o}{V_{in}}\right]}$$

PROCEDURE:

1. Test and mount the IC741 on breadboard.
2. Connect the circuit as per the circuit diagram show in fig
3. Apply voltage and using DC power supply to pin no 7 and pin no. 4 respectively.
4. Connect the (1volt peak to peak, 100Hz) sine wave input from function generator and observe the corresponding output of pin number 6 on CRO.
5. Measure the output voltage of LPF on CRO for the applied signal as in step 4.
6. Vary input signal frequency step by step as shown in observation table and note down the corresponding output voltage.
7. Repeat step 4 to 6 up to frequency 1MHz. 8. Calculate gain in decibels using formula:
8. Calculate the cutoff frequency theoretically using formula:
9. Plot the frequency response on semi log paper for frequency on x axis and gain in dB on y axis.

OBSERVATION:

Table 1. Observation Table

Input Frequency (Hz)	**Output Voltage, Vo (Volts)**	**Voltage Gain (A= Vo/Vi)**	**Gain in dB 20 log (Vo/Vi)**
100Hz			
200Hz			
500Hz			
1000Hz			

Input Frequency (Hz)	Output Voltage, Vo (Volts)	Voltage Gain (A= Vo/Vi)	Gain in dB 20 log (Vo/Vi)
2000Hz			
3000Hz			
4000Hz			
5000Hz			
7000Hz			
10kHz			
12kHZ			
15kHz			
20kHz			
25kHz			
50kHz			

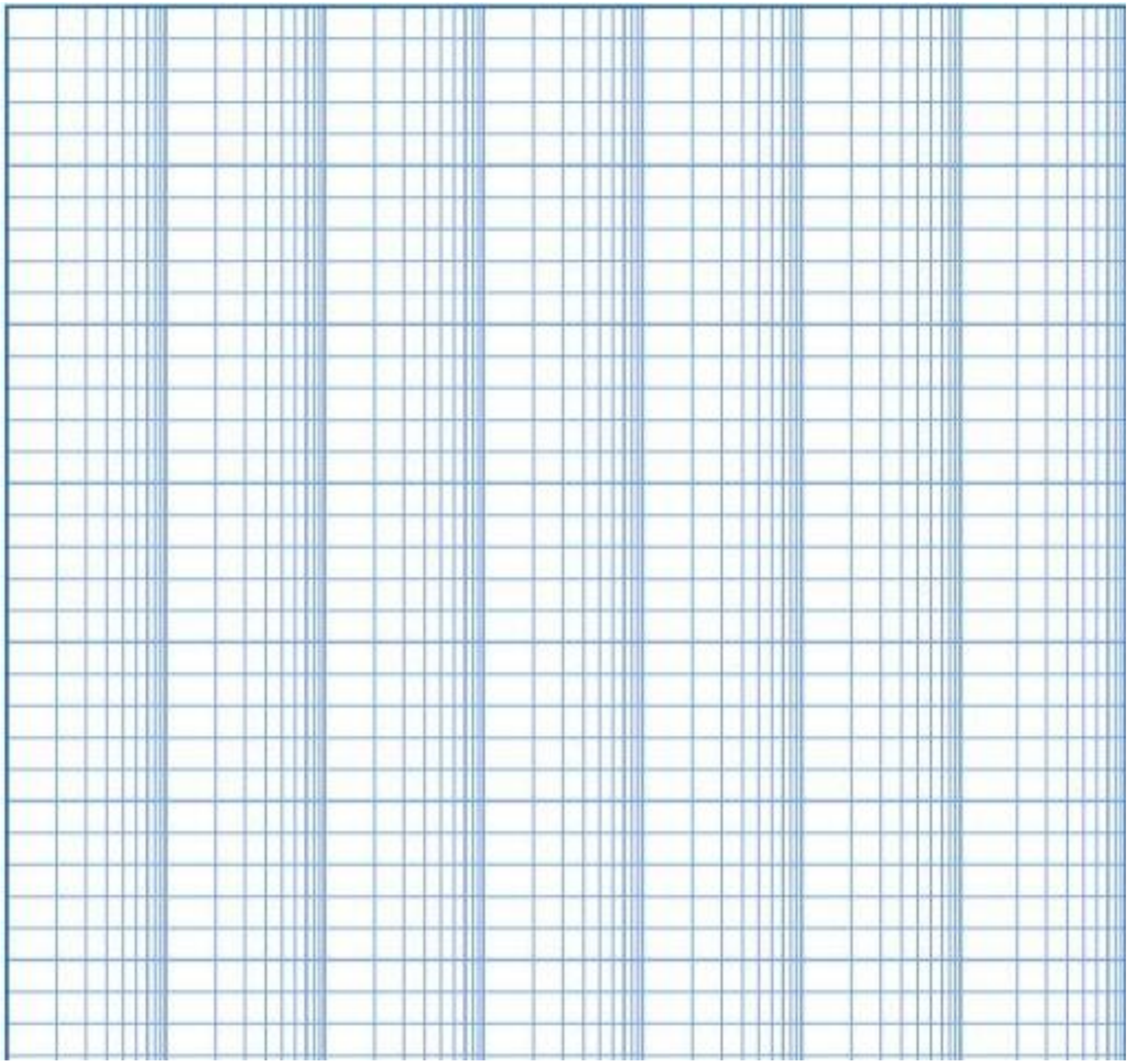
RESULT:

1. Cutoff Frequency =________________
2. Roll of rate =______________________
3. Bandwidth=_______________________

PRECUATIONS:

1. Do not Short circuit the connections.
2. Keep all the instruments control knob to the minimum position before switching it ON.
3. Do not fiddle with the instruments.
4. Switch OFF all the instruments when not in use.

GRAPH OF FREQUENCY RESPONSE:



QUESTIONS:

1. Draw the circuit diagram and frequency response of first order low pass Butterworth filter.
2. Draw the circuit diagram and frequency response of second order low pass Butterworth filter?
3. Derive the gain formula of first order LPF?
4. Derive the gain formula of second order LPF?

<table>
<tr><td rowspan="2">Evaluation</td><td>Circuit(10M)</td><td>Readings(10M)</td><td>Output(5M)</td><td>Total (25M)</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Remarks</td><td colspan="4"></td></tr>
</table>

EXPERIMENT NO. 8: MEASURE THE BANDWIDTH AND CUTOFF FREQUENCY OF THE GIVEN FIRST ORDER HIGH PASS (HPF) BUTTERWORTH FILTER. (CO 303.2)

AIM: Measure the bandwidth and cutoff frequency of the given first order High pass (HPF) Butterworth filter

EXPERIENTIAL OBJECTIVES:

1. To build the HPF Butterworth using OPAMP IC-741 on the breadboard.
2. To provide correct power supply to the circuit and connecting required output measuring instruments.
3. To record the readings in the observation table and calculate the Gain and Phase magnitude.
4. To measure the cutoff frequency of the given first order High pass (HPF) Butterworth filter
5. To plot the Graph of frequency response

RESOURCES REQUIRED:

1. Fixed Dual Power supply +15V & -15V
2. Regulated power supply 0-12V
3. Multi-meter
4. Resistors Feedback resistor 10kΩ, HPF Resistor 10kΩ, HPF capacitor 0.1μF, Load resistor 25kΩ
5. Breadboard
6. OPAMP IC-741
7. Connecting Wires

EXPERIMENT OUTCOME:

1. Operate the power supply.
2. Test IC 741.
3. Determine the values of resistors using colour code.
4. Build the HPF circuit on the breadboard.
5. Obtain the readings and record the readings in the manual.
6. Measure the bandwidth.
7. Determine cutoff frequency of the given first order High pass (HPF) Butterworth filter.

LLO:

LLO1: Build the First order and second order HPF and measure the output on the CRO

CIRCUIT DIAGRAM:

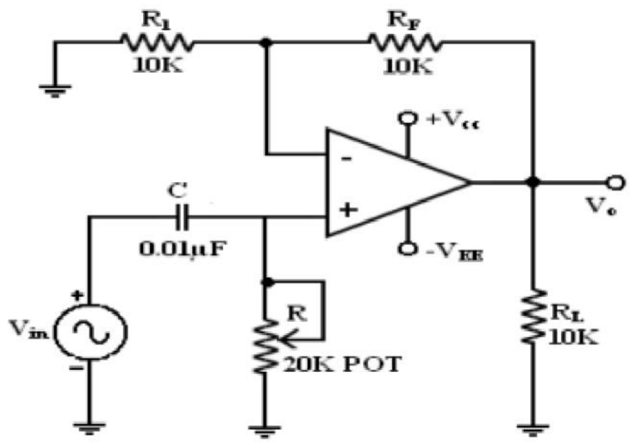


Fig. 1 Circuit diagram of First order Active High Pass filter

WAVEFORM:

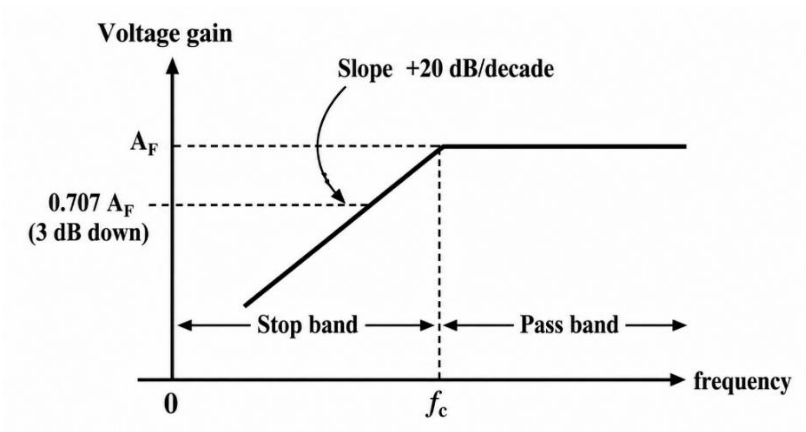


Fig. 2 Frequency response of First order high pass filter

THEORY:

A high-pass filter is a filter that allows signals with a frequency higher than the cut-off frequency (the frequency at which the output voltage is 70.7% of the source voltage) to pass through it. It also attenuates those signals whose frequency is lower than the cut-off frequency. High-pass filters are used for AC coupling at the inputs of many audio power amplifiers, for preventing the amplification of DC currents which may harm the amplifier, rob the amplifier of headroom, and generate waste heat at the loudspeakers voice coil.

A High-Pass Filter is widely used wherever low-frequency components or DC signals need to be removed while preserving useful high-frequency information. Its simplicity, effectiveness, and wide range of applications make it an essential circuit in electronics, communication, audio, biomedical, and instrumentation systems.

Advantages:

1. Removes low-frequency noise and unwanted signals.
2. Blocks DC components while allowing AC signals to pass.
3. Improves the quality of high-frequency signals.
4. Enhances signal clarity by reducing low-frequency interference.
5. Simple circuit design with low cost.
6. Can be designed using passive or active components.
7. Provides good frequency selectivity.
8. Useful for eliminating baseline drift in electronic circuits.

Applications:

1. Audio Systems: Removes low-frequency hum and rumble from audio signals.
2. Communication Systems: Eliminates low-frequency interference before signal transmission or reception.
3. Amplifier Circuits: Blocks DC voltage between amplifier stages (AC coupling).
4. Radio and Television Receivers: Filters unwanted low-frequency signals.
5. Biomedical Instruments: Removes baseline drift in ECG and EEG signals.
6. Image Processing: Enhances edges by emphasizing high-frequency components.
7. Instrumentation Systems: Eliminates slow-varying noise from sensor outputs.
8. Digital Signal Processing (DSP): Used for high-frequency signal extraction and noise reduction.
9. Microphone and Audio Recording Systems: Reduces wind noise and low-frequency vibrations.
10. Control Systems: Removes low-frequency disturbances to improve system response.

PROCEDURE:

1. Test and mount the IC741 on breadboard.
2. Connect the circuit as per the circuit diagram show in fig
3. Apply voltage and using DC power supply to pin no 7 and pin no. 4 respectively.
4. Connect the (1volt peak to peak, 100Hz) sine wave input from function generator and observe the corresponding output of pin number 6 on CRO.
5. Measure the output voltage of HPF on CRO for the applied signal as in step 4.
6. Vary input signal frequency step by step as shown in observation table and note down the corresponding output voltage.
7. Repeat step 4 to 6 up to frequency 1MHz. 8. Calculate gain in decibels using formula:
8. Calculate the cutoff frequency theoretically using formula:

OBSERVATIONS:

Table 1. Observation Table

Input Frequency (Hz)	Output Voltage, Vo (Volts)	Voltage Gain (A= Vo/Vi)	Gain in dB = 20 log (Vo/Vi)
100Hz			
500Hz			
1000Hz			
2000Hz			
5000Hz			
10kHz			
12kHZ			
15kHz			
20kHz			
25kHz			
50kHz			
100kHz			

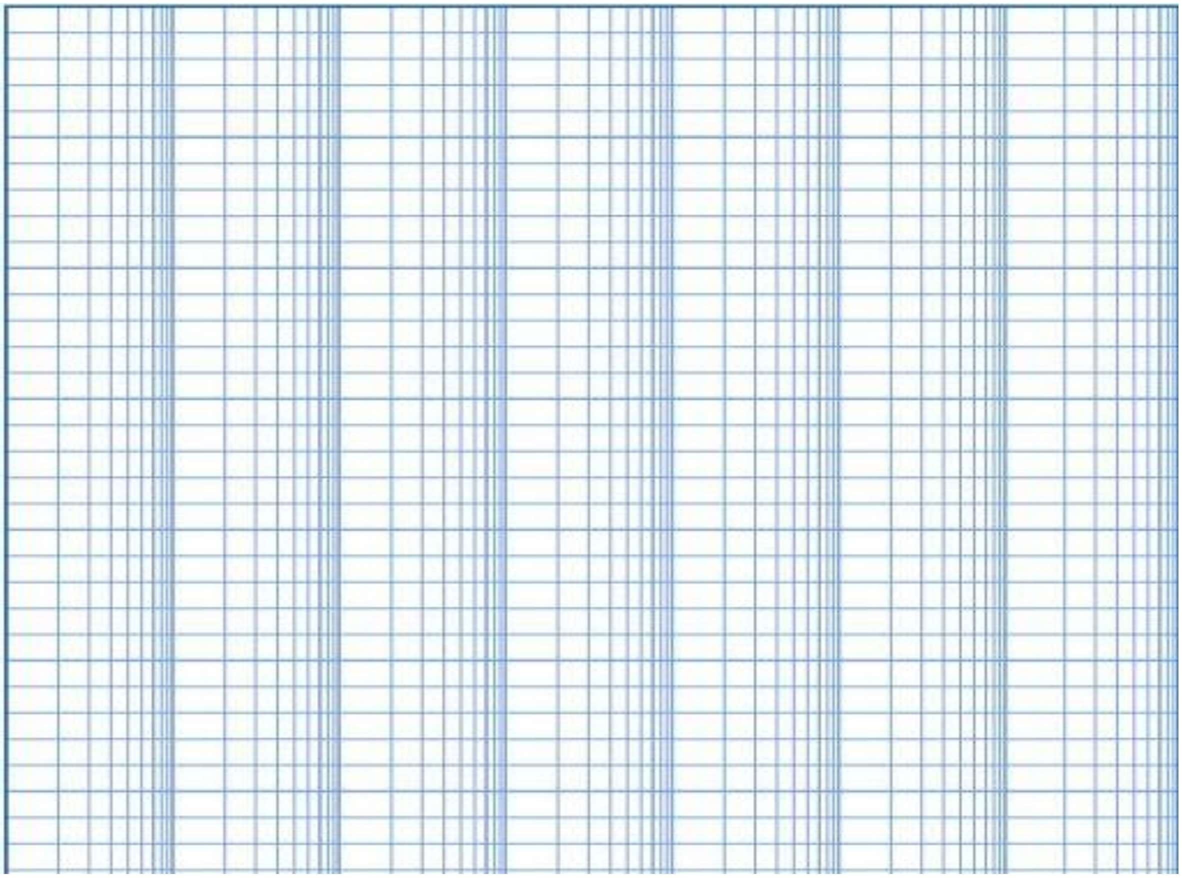
RESULT:

1. Cutoff Frequency =________________
2. Roll of rate =______________________
3. Bandwidth=_______________________

PRECUATIONS:

1. Do not Short circuit the connections.
2. Keep all the instruments control knob to the minimum position before switching it ON.
3. Do not fiddle with the instruments.
4. Switch OFF all the instruments when not in use.

GRAPH OF FREQUENCY RESPONSE:



QUESTIONS:

1. Draw the circuit diagram and frequency response of first order high pass Butterworth filter.
2. Draw the circuit diagram and frequency response of second order high pass Butterworth filter?
3. Derive the gain formula of first order HPF?
4. Derive the gain formula of second order HPF?

Evaluation	Circuit(10M)	Readings(10M)	Output(5M)	Total (25M)
Remarks				

EXPERIMENT NO. 9: BUILD THE MONOSTABLE MULTIVIBRATOR CIRCUIT AND PLOT THE WAVEFORMS USING IC-555. (CO 303.5)

AIM: To Build the Monostable Multivibrator Circuit and plot the waveforms using IC-555

EXPERIENTIAL OBJECTIVES:

1. To build the Monostable multivibrator using IC-555 on the breadboard.
2. To provide correct power supply to the circuit and connecting required output measuring instruments.
3. To observe the output waveform and capacitor waveform on CRO and calculate the Ton time of the output wave.
4. To draw the waveforms in the observation table.
5. To plot the Graph output (V_0) VS Input (V_{IN}).

RESOURCES REQUIRED:

1. 5V Power supply.
2. CRO & probes
3. Function generator.
4. Multi-meter
5. Following Components are required: Resistors: Resistor R1 = 10kΩ, Capacitor 0.1μf, Breadboard. TIMER IC-555 & Connecting Wires

EXPERIMENT OUTCOME:

1. Build the Monostable multivibrator circuit on the breadboard
2. Obtain the Output waveform and calculate the Ton Time.
3. Calculate Theoretical Ton time and Practical Ton time.
4. Draw the waveforms on the graph.

LLO:

LLO1: Build the Monostable Multivibrator using IC 555 on the breadboard
LLO2: Observe and measure the output voltage of Monostable Multivibrator using IC 555 the CRO
LLO3: Draw the waveforms of Monostable Multivibrator.

THEORY:

A monostable multivibrator using the 555 Timer IC is a pulse-generating circuit that has one stable state and one quasi-stable (temporary) state. It is also known as a one-shot multivibrator because it produces a single output pulse of fixed duration for each trigger input.

PIN-LAYOUT DIAGRAM

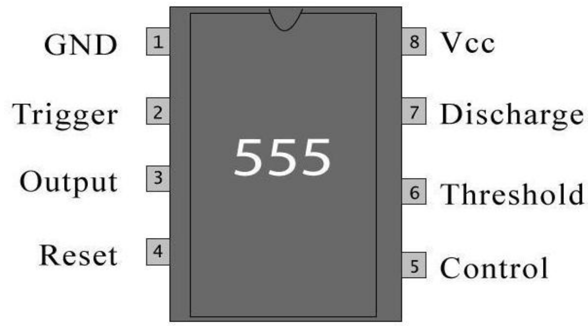


Fig. 1 IC layout of 555 IC

Pin Functions of the 555 Timer IC

Pin No.	Pin Name	Function
1	Ground (GND)	Connected to the 0 V (negative) supply. It is the reference ground for the IC.
2	Trigger (TRIG)	Starts the timing cycle when the voltage falls below 1/3 of the supply voltage (VCC).
3	Output (OUT)	Provides the output signal. It can source or sink current to drive LEDs, relays (with a driver), and other loads.
4	Reset (RESET)	Active-low reset input. Bringing this pin low resets the output. If unused, it is normally connected to VCC.
5	Control Voltage (CV)	Allows external adjustment of the internal threshold levels. Usually connected to ground through a 0.01 μF capacitor to reduce noise if not used.
6	Threshold (THRESH)	Ends the timing cycle when the voltage exceeds 2/3 of VCC.
7	Discharge (DISCH)	Connected to an internal transistor that discharges the external timing capacitor during the timing cycle.
8	VCC	Positive power supply input, typically 4.5 V to 15 V for the standard NE555.

Principle of Operation:

In the stable state:

- The output (Pin 3) remains LOW.
- The discharge transistor (Pin 7) is ON, keeping the timing capacitor C fully discharged.
- When a negative trigger pulse is applied to Pin 2 (Trigger) and its voltage falls below 1/3 VCC:
- The trigger comparator sets the internal flip-flop.
- The output at Pin 3 changes from LOW to HIGH.
- The discharge transistor at Pin 7 turns OFF.

- The timing capacitor C starts charging through the resistor R.
- As the capacitor charges exponentially, its voltage increases from 0 V toward VCC.
- When the capacitor voltage reaches 2/3 VCC:
- The threshold comparator resets the flip-flop.
- The output returns to LOW.
- The discharge transistor turns ON again.
- The capacitor rapidly discharges through Pin 7, returning the circuit to its stable state. The circuit now waits for the next trigger pulse.

Pulse Width:

The duration for which the output remains HIGH is called the pulse width or time period, and is given by:

$$\boxed{(T) = (1.1\, RC)}$$

where:
T = Output pulse width (seconds)
R = Timing resistor (Ω)
C = Timing capacitor (F)
Thus, the pulse width can be adjusted by changing the values of R or C

CIRCUIT DIAGRAM:

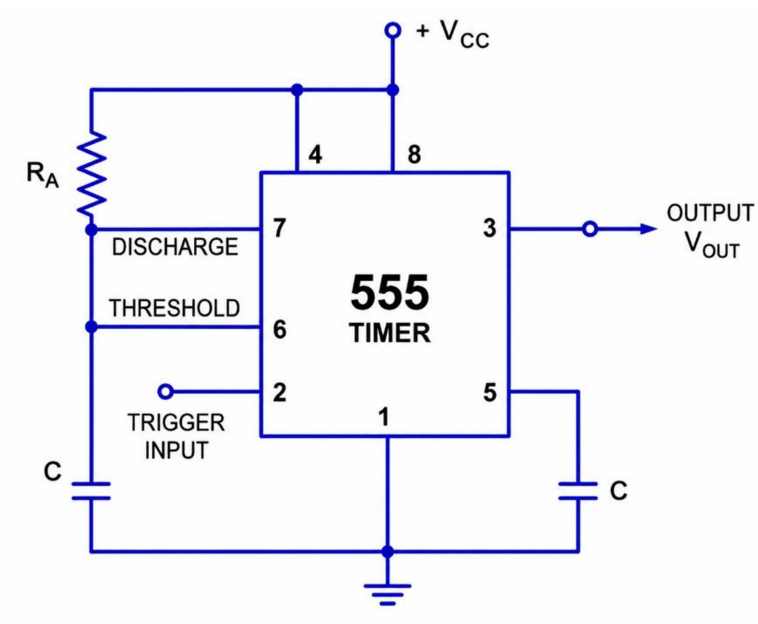


Fig. 2 Circuit Diagram of monostable multivibrator

WAVEFORMS:

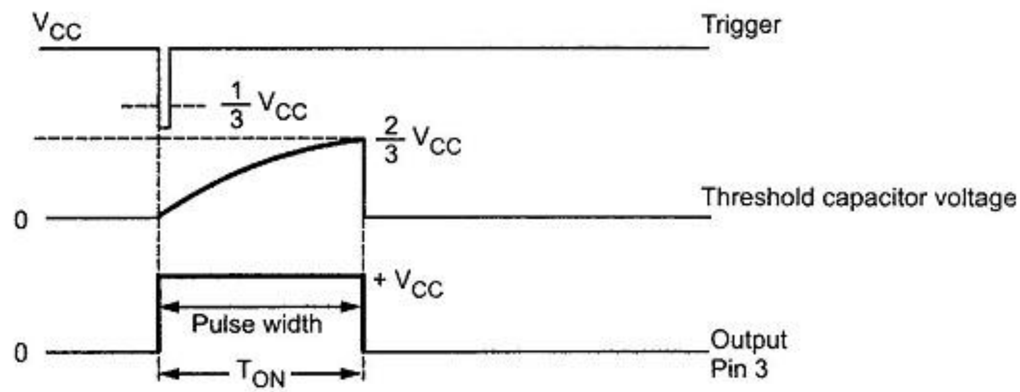


Fig. 3 Waveform of monostable multivibrator

PROCEDURE:

1. Build the above circuit on the bread board.
2. Supply 5V supply to the 555
3. Provide Square wave signal as a trigger input to pin 2 of 555. Square wave can be provided by Signal generator. Keep Voltage 5V & Frequency around 300Hz
4. Connect probe to Pin 3 and capacitor. Observe the waveforms on the CRO.
5. Calculate the Theoretical Ton Time or Pulse width by the formula
6. $T = 1.1 R_A C$
7. Compare the Output voltage and Capacitor voltage.

OBSERVATION:

Table 1. Observation table

Sr. No.	Theoretical	Practical
1	T_{ON}____________ for (RT = 1K, CT = 0.1uf)	T_{ON}____________ for (RT = 1K, CT = 0.1uf)
2	T_{ON}____________ for (RT = 10K, CT = 0.1uf)	T_{ON}____________ for (RT = 10K, CT = 0.1uf)
3	T_{ON}____________ for (RT = 10K, CT = 1uf)	T_{ON}____________ for (RT = 10K, CT = 1uf)

RESULT: The T_{ON} Pulse is ________________

PRECUATIONS:

1. Do not Short circuit the connections.
2. Keep all the instruments control knob to the minimum position before switching it ON.
3. Do not fiddle with the instruments.
4. Switch OFF all the instruments when not in use.

CONCLUSION:

QUESTIONS:

1. Explain the working of the Monostable multivibrator?
2. State the equation for T_{ON} time of Monostable multivibrator?
3. State any two applications of Monostable multivibrator?
4. Draw and explain the internal Block diagram of 555 IC?

<table>
<tr><td rowspan="2">Evaluation</td><td>Circuit(10M)</td><td>Readings(10M)</td><td>Output(5M)</td><td>Total (25M)</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Remarks:</td><td colspan="4"></td></tr>
</table>

EXPERIMENT NO. 10: BUILD THE ASTABLE MULTIVIBRATOR CIRCUIT AND PLOT THE WAVEFORMS USING IC-555. (CO 303.5)

AIM: To Build the Astable Multi vibrator Circuit and plot the waveforms using IC-555.

EXPERIENTIAL OBJECTIVES:

1. To build the Astable multivibrator using IC-555 on the breadboard.
2. To provide correct power supply to the circuit and connecting required output measuring instruments.
3. To observe the output waveform and capacitor waveform on CRO and calculate the Ton, Toff, Duty cycle, Time period and Frequency of the output wave.
4. To draw the waveforms in the observation table.
5. To plot the Graph.

RESOURCES REQUIRED:

1. 5V Power supply.
2. CRO & probes
3. Multi-meter
4. Resistor R1 = 10kΩ, Resistor R2 = 1kΩ, Capacitor 0.1μf , Capacitor 10nf
5. TIMER IC-555
6. Breadboard & Connecting Wires

EXPERIMENT OUTCOME:

1. Build the Monostable multivibrator circuit on the breadboard.
2. Obtain the Output waveform and calculate the Ton Time.
3. Calculate Theoretical Ton time and Practical Ton time.
4. Draw the waveforms on the graph.

LLO:

LLO1: Build and determine the Ton and Toff of Astable Multivibrator using IC 555.

THEORY:

An astable multivibrator using the 555 Timer IC is a free-running oscillator that continuously generates a square wave without requiring any external triggering. It has no stable state; the output alternates continuously between HIGH and LOW.

- Initially, the timing capacitor C is discharged, and the output at Pin 3 is HIGH.
- The capacitor begins charging through RA and RB.
- When the capacitor voltage reaches 2/3 VCC, the threshold comparator resets the flip-flop.
- The output becomes LOW, and the discharge transistor (Pin 7) turns ON.

- The capacitor discharges through RB and Pin 7.
- When the capacitor voltage falls below 1/3 VCC, the trigger comparator sets the flip-flop.
- The output becomes HIGH again, the discharge transistor turns OFF, and the capacitor starts charging once more.
- This charging and discharging cycle repeat continuously, producing a rectangular (square) wave at the output.

CIRCUIT DIAGRAM:

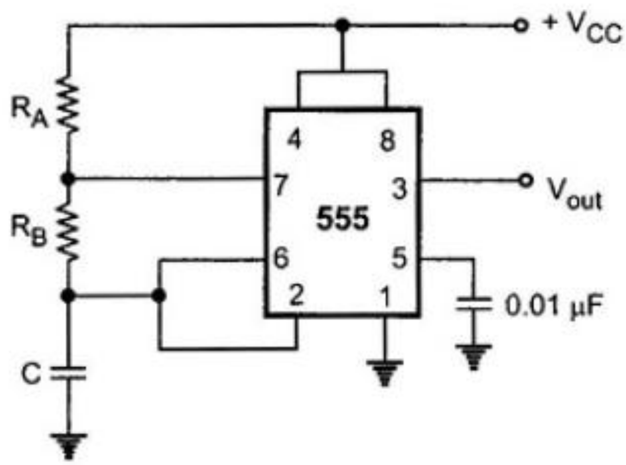


Fig. 1 Circuit Diagram of Astable Multivibrator

WAVEFORMS:

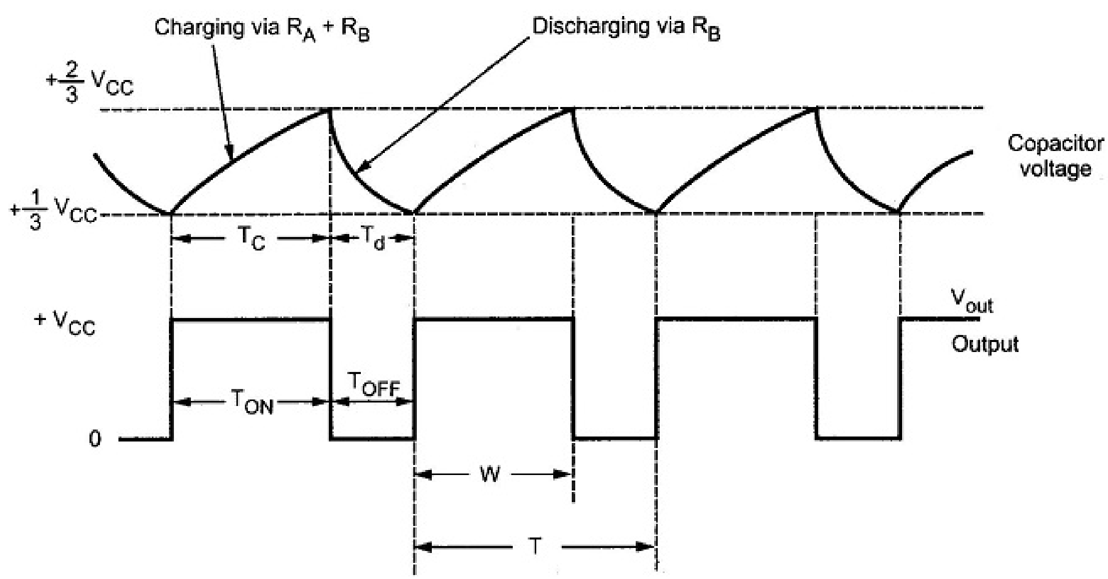


Fig. 2 Waveform of Astable Multivibrator

PROCEDURE:

1. Build the circuit as shown in the circuit diagram on the breadboard.
2. Supply 5V and obtain output from pin 3 and capacitor on two different channels.
3. No need of any input signal, obtain output on the CRO.
4. Calculate T_{ON}, T_{OFF} :

$$\boxed{T_{ON} = \big(0.693(R_A + R_B)\big)C}$$

$$\boxed{(T_{OFF}) = (0.693)R_B C}$$

5. Time period of one cycle (T):

$$\boxed{T = T_{ON} + T_{OFF} = T_C + T_D} \approx \boxed{T = \big(0.693(R_A + 2R_B)\big)C}$$

6. Duty cycle is the ratio of the time TON during which the output is high to the total time period T. The duty cycle % D is given by:

$$\boxed{\%D = \frac{T_{ON}}{T}(100)} \approx \boxed{\%D = \frac{R_A + R_B}{R_A + 2R_B}(100)}$$

7. The frequency F is given by:

$$\boxed{f = \frac{1.45}{(R_A + 2R_B)\ C}}$$

OBSERVATION:

R_A = 10kΩ, R_B = 1kΩ & C= 0.1 μF

Sr. No.	Theoretical	Practical
1	T_{ON} = ____________________	T_{ON} = ____________________
2	T_{OFF} = ____________________	T_{OFF} = ____________________
3	Time Period for 1 Cycle, T =__________	Time Period for 1 Cycle, T =__________
4	Duty Cycle %D = ___________	Duty Cycle %D = ___________
5.	Frequency =_________________	Frequency =_________________

RESULTS:

1. Percentage Duty Cycle =______________
2. Output frequency =_______________

PRECUATIONS:

CONCLUSION:

QUESTIONS:

1. Explain the working of the Astable multivibrator?
2. State the equation for TON time and TOFF of Astable multivibrator?
3. State any two applications of Astable multivibrator?

Evaluation	Circuit(10M)	Readings(10M)	Output(5M)	Total (25M)
Remarks:				

ST. XAVIER'S TECHNICAL INSTITUTE

To Nurture the Joy of Excellence in the World of High Technology

DIPLOMA IN ELECTRONICS AND TELECOMMUNICATION ENGINEERING (DETE)
FIRST YEAR SEMESTER-II
ENGINEERING GRAPHICS LABORATORY MANUAL

Document Number: 2526-DEC 25-DETE-03

00	5th Dec 2025	Laboratory Manual for EG (23206)	MMM	VRR	SBG
REV. NO.	**DATE**	**DESCRIPTION**	**PREPARED BY**	**CHECKED BY**	**APPROVED BY**

REVISION HISTORY

Rev. No.	Date	Pages	Description
00	5th Dec 2025	36	Laboratory Manual: Engineering Graphics

HOLD LIST

Hold No.	Pages	Description
NIL	NA	--

EXECUTIVE SUMMARY

- Laboratory Manual is prepared by Dr. Mahesh Munde, reviewed by Dr. Vijay Rathod and approved by Dr. Shivaji Ghungrad consisting Ten (10) laboratory experiments covering Six course outcomes (CO 206.1 to CO206.6).
- Engineering Graphics is a foundational course designed to develop technical drawing and visualization skills essential for engineering practice. The course introduces students to the principles of graphical communication, enabling them to represent three-dimensional objects accurately on two-dimensional media using standardized drawing conventions.
- The curriculum covers freehand sketching, engineering lettering, geometric constructions, orthographic projections, isometric projections, and basic 2D drafting using AutoCAD. Emphasis is placed on understanding projection theory, dimensioning practices, scale usage, and adherence to engineering drawing standards. Students progressively build spatial visualization abilities and precision in manual as well as computer-aided drafting.
- Through structured laboratory experiments and practical exercises, learners gain competence in interpreting and creating technical drawings, which form the basis for design, manufacturing, and engineering analysis. The course equips students with the graphical literacy and drafting proficiency required across core engineering disciplines.

Dr. Mahesh Munde Lecturer (Selection Grade), DETE	Dr. Vijay Rathod HOD, DETE	Dr. Shivaji Ghungrad Principal

St. Xavier's Technical Institute

Department of Electronics and Telecommunication Engineering

VISION

To become a center of excellence and to produce high quality, self-motivated creative and ethical diploma engineers and technologists, contributing effectively to universal engineering and contemporary education.

MISSION

- To prepare the students of the Department of Electronics and Telecommunication Engineering for a brilliant career / entrepreneurship along with the development of knowledge, skills, attitude and teamwork ideal for a professional through the designed programme.

- The faculty of the department continually seeks to enhance their knowledge to competently lead and empower students.

- To impart high quality engineering education and ethics to the students & to provide the best facilities, infrastructure, environment to the students and faculty members, creating an ambience conducive for excellence in technical education and research.

St. Xavier's Technical Institute

TECH

Institute Vision

To nurture the joy of excellence in a world of high technology

Institute Mission

To strive to match global standards in technical education by

- **Interaction with Industry**
- **Continuous Staff training**
- **Development of quality of life**

St. Xavier's Technical Institute

Mahim, Mumbai 400016

Department of Electronics and Telecommunication Engineering

Program Educational Objectives (PEOs)

PEO1: To produce diploma holders who have the ability to demonstrate technical competence in the fields of Electronics and Telecommunication engineering and develop solutions to the problems.

PEO2: To produce diploma holders who would be able to take individual responsibility and to work as a part of a team towards the fulfilment of both individual and organizational goals.

PEO3: To prepare the students to engage in professional development through self-study, graduate and professional studies in engineering, management and research.

Program Specific Outcomes (PSOs)

The students will have the ability to:

PSO1: Design, verify and validate electronic functional elements for a variety of applications, with skills to interpret and communicate results.

PSO2: Exercise good programming practices employing low or high level languages on appropriate platforms.

St. Xavier's Technical Institute

Mahim, Mumbai 400016

Department of Electronics and Telecommunication Engineering

Program Outcomes (POs)

1. **Basic and Discipline specific knowledge:** Apply knowledge of basic mathematics, science and engineering fundamentals and engineering specialization to solve the engineering problems.

2. **Problem analysis:** Identify and analyse well-defined engineering problems using codified standard methods.

3. **Design/ development of solutions:** Design solutions for well-defined technical problems and assist with the design of systems components or processes to meet specified needs.

4. **Engineering Tools, Experimentation and Testing:** Apply modern engineering tools and appropriate technique to conduct standard tests and measurements.

5. **Engineering practices for society, sustainability and environment:** Apply appropriate technology in context of society, sustainability, environment and ethical practices.

6. **Project Management:** Use engineering management principles individually, as a team member or a leader to manage projects and effectively communicate about well-defined engineering activities.

7. **Life-long learning:** Ability to analyse individual needs and engage in updating in the context of technological changes.

Program Title	Diploma in Electronics & Telecommunication Engineering			
Course Code	Course Title	ENGINEERING GRAPHICS	Course Type	Semester
23206			SEC	2

Learning Scheme						Assessment Scheme										
Actual Contact Hrs./Week			SLH	NLH	CREDITS	THEORY				PRACTICAL				SLA		Total
								Total		FA		SA				
CL	TL	LL				FA	SA	Max	Min	Max	Min	Max	Min	Max	Min	
0	0	2	2	4	2	---	---	---	---	25	10	---	---	---	---	25

1) IKS of 0 hrs.
2) Theory paper duration 3 hrs.
3) Theory paper assessment is Internal and External.
4) The assessment of Practical is Internal and External.
5) Formative Assessment out of 30 marks is average of 2 periodical tests (PT).
6) The assessment of Self Learning is Internal.

RATIONALE:

This subject comes under the Core Technology group and will enable the students to comprehend the theory, concepts, characteristics and working principles of basic electronic devices and their applications in electronic circuits. The knowledge of various devices acquired by the students will help them to design, test, troubleshoot basic electronic circuits. The course will help the diploma engineers to apply the basic concepts and principles to understand different technology-based application.

COURSE OUTCOMES ::--

Course practical skills, experience help student to understand basic terms, tools of drawing & design , thus student should able to

Semester 2	Subject: ENGINEERING GRAPHICS
CO 206	15th COURSE IN FIRST YEAR
CO 206.1	**Understand & Learn basic elements of drawing**
CO 206.2	**Identify & draw Orthographic projections off given object**
CO 206.3	**Draw Isometric view of given component or orthographic projection**
CO 206.4	**Draw free hand sketches of engineering components**
CO 206.5	**Demonstrate the use of computer aided drafting approach to create engineering drawing**
CO 206.6	**Enhance the drawing skills by basic methods & computer based tools**

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Mapping of Course outcomes (COs) to Program outcomes (POs)

SEM II	ENGINEERING GRAPHICS						
CO 206	(15th COURSE IN FIRST YEAR)PREPARED BY : RS						
CO 206	PO1	PO2	PO3	PO4	PO5	PO6	PO7
CO 206.1	3						
CO 206.2	3	1	2	2			
CO 206.3	2	2	2	2	1	1	
CO 206.4	2	2	2		2	1	1
CO 206.5	3	2	2	2	2	1	1
CO 206.6	3	1	2	1	1	1	
CO 206 TOTAL	16	08	10	07	06	04	02
CORRELATION LEVEL	3	1	2	1	1	1	0

TABLE TO DECIDE CORRELATION LEVELS

CO SUM TOTAL	06	12	18
CORRELATION LEVEL	1	2	3

CO SUM TOTAL	0, 1, 2	3, 4, 5, 6, 7, 8	9, 10, 11, 12, 13, 14	15, 16, 17, 18
CORRELATION LEVEL	0	1	2	3

Subject Expert

Mr. Rakeshkumar Saroj

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	Section -- 1						
Chapter No	**Topics**	**Periods**	**Marks**				**COs**
		Hrs.	**R**	**U**	**A**	**Total**	
1	**BASIC ELEMENTS OF DRAWING**						**C110. 1**
	1.1 Drawing Instruments and supporting materials: method to use them with applications. 1.2 Convention of lines and their applications. 1.3 Representative Fractions – reduced, enlarged and full-size scales; Engineering Scales such as plain and diagonal scale. 1.4 Dimensioning techniques as per SP-46:2003 – types and applications of chain, parallel and coordinate dimensioning. Geometrical and Tangency constructions. (Redraw the figure)	----	---	--	---	---	**CO 206.1**
2	**ORTHOGRAPHIC PROJECTIONS**						
	2.1. Introduction of projections- orthographic, perspective, isometric and oblique: concept and applications. (No question to be asked in examination). 2.2 Introduction to orthographic projection, First angle and Third angle method, their symbols. 2.3 Conversion of pictorial view into Orthographic Views – object containing plain surfaces, slanting surfaces, slots, ribs, cylindrical surfaces. (use First Angle Projection method only)	-----	----	---	---	----	**CO 206.2**
3	**ISOMETRIC PROJECTIONS**						
	3.1 Introduction to isometric projections. 3.2 Isometric scale and Natural scale. 3.3 Isometric view and isometric projection. 3.4 Illustrative problems related to objects containing lines, circles and arcs shape only. Conversion of orthographic views into isometric view/projection.	---	---	---	---	---	**CO 206.3**

Chapter No	Topics	Periods	Marks				COs
		Hrs.	R	U	A	Total	
4	**FREE HAND SKETCHES OF ENGINEERING ELEMENTS**						
	4.1 Free hand sketches of Electronic elements: Resistor, Capacitor, Integrated Circuit(IC), Small Circuit. 4.2 Free hand sketches of orthographic view (on squared graph paper) an isometric view (on Isometric grid aper)	-----	-----	---	---	----	**CO 206.4**
5	**COMPUTER AIDED DRAFTING INTERFACE**						
	5.1 Computer Aided Drafting: concept. 5.1.1 Hardware and various CAD software available. 5.1.2 System requirements and Understanding the interface. 5.2.1 Components of AutoCAD software window: Title bar, standard tool bar, menu bar, object properties tool bar, draw tool bar, modify tool bar, cursor cross hair. Command window, status bar, drawing area, UCS icon. 5.2.3 File features: New file, Saving the file, opening an existing drawing file, Creating templates ,Quit. 5.2.4 Setting up new drawing: Units, Limits, Grid, Snap. Undoing and redoing action.	----	-----	---	---	---	**CO 206.5**
6	**COMPUTER AIDED DRAFTING**						
	6.1 Draw basic entities like Line, Circle, Arc, Polygon, Ellipse, Rectangle, Multiline, Poly Line. 6.2 Method of Specifying points: Absolute coordinates, Relative Cartesian and Polar coordinates. 6.3 Modify and edit commands like trim, extend, delete, copy, offset, array, block, layers. 6.4 Dimensioning: Linear, Horizontal Vertical, Aligned, Rotated, Baseline, Continuous, Diameter, Radius, Angular Dimensions, Dim scale variable, Editing dimensions. 6.5 Text: Single line Text, Multiline text. Standard sizes of sheet. Selecting Various plotting						

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	6.6 Draw basic entities like Line, Circle, Arc, Polygon, Ellipse, Rectangle, Multiline, Poly Line. 6.7 Method of Specifying points: Absolute coordinates, Relative Cartesian and Polar coordinates. 6.8 Modify and edit commands like trim, extend, delete, copy, offset, array, block, layers. 6.9 Dimensioning: Linear, Horizontal Vertical, Aligned, Rotated, Baseline, Continuous, Diameter, Radius, Angular Dimensions, Dim scale variable, Editing dimensions. 6.10 Text: Single line Text, Multiline text. Standard sizes of sheet. Selecting Various plotting parameters such as Paper size, paper units, drawing orientation, plot scale, plot offset, plot area, print preview.	----	----	---	---	---	**CO 206.6**

LIST OF LABORATORY EXPERIENCES

EXP. NO	TITLE	COURSE OUTCOME MAPPING
1.	Draw horizontal, Vertical, 30-degree, 45-degree, 60 and 75-degrees lines, different types of lines, dimensioning styles using Tee and Set squares/ drafter. (do this exercise in sketch book)	**CO 206.1**
2.	Write alphabets and numerical (Vertical only) (do this exercise in sketchbook)	**CO 206.1**
3.	Draw regular geometric constructions and redraw the given figure (do this exercise in sketch book)	**CO 206.2**
4.	Draw a problem on orthographic projections using first angle method of projection having plain surfaces and slanting.	**CO 206.2**
5.	Draw two problems on orthographic projections using first angle method of projection having cylindrical surfaces, ribs.	**CO 206.2**
6.	Draw two problems on Isometric view of simple objects having plain and slanting surface by using natural scale.	**CO 206.3**
7.	Draw some problems on Isometric projection of simple objects having cylindrical surface by using isometric scale.	**CO 206.3**

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8.	Draw free hand sketches/ conventional representation of machine elements in sketch book of some electronic components	**CO 206.4**
9.	Problem based Learning: Given the orthographic views of at least three objects with few missing lines, the student will try to imagine the corresponding objects, complete the views and draw these views in sketchbook.	**CO 206.5**
10.	Draw basic 2D entities like: Rectangle, Rhombus, Polygon using AutoCAD (Print out should be a part of progressive assessment). Part I	**CO 206.6**
11.	Draw basic 2D entities like: Circles, Arcs, circular using AutoCAD(Printout should be a part of progressive assessment). Part II	**CO 206.6**
12.	Draw basic 2D entities like: Circular and rectangular array using AutoCAD (Printout should be a part of progressive assessment). Part III	**CO 206.6**

IMPLEMENTATION STRATEGY:

1) Use of PowerPoint presentations and Videos
2) References from the internet **(for teachers as well as students)**
3) Extensive use of examples
4) Group discussions and micro project
5) Assignments for writing skills, create awareness about selection /purchasing components

(Example : Market survey study of latest Diodes with ratings and applications,
Power supply ratings, applications etc)

REFERENCES

Sr. No.	Author	Title	Edition	Year of Publication	Publisher & Address
1	Bureau of Indian Standards	Engineering Drawing Practice for Schools and Colleges	3 rd	October 1998	Bureau of Indian Standards, Government of India
2	Bhatt, N. D	Engineering Drawing.	---	2010	Charotar Publishing House, Anand, Gujrat
3	Jain & Gautam	Engineering Graphics & Design	2nd	2010	Tata McGraw Hill Edu. New Delhi
4	Jolhe	Engineering Drawing	2nd	2010	Tata McGraw Hill Edu. New Delhi
5	Jeyapoovan	Essentials of Engineering Drawing and Graphics using AutoCAD	----	2011	Vikas Publishing HousePvt. Ltd, Noida

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LAB EXPERIMENT 1: LINES AND ANGLES (CO 206.1)

1 **Title:** Drawing Horizontal, Vertical Lines and Lines at Different Angles Using Geometrical Box

2 **Objectives:**

To study and practice the use of drawing instruments (geometrical box) for drawing horizontal lines, vertical lines, and lines at different standard angles accurately.

3 **Apparatus Required:**

- Drawing Book (A3 size)
- T–square
- Set squares (45° and 30°)
- Protractor
- Compass
- Scale
- Pencils (HB, 2H)
- Sharpener
- Eraser

4 **Theory:**

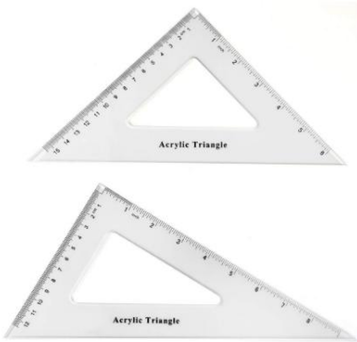
In Engineering Graphics, accurate line drawing forms the foundation of technical drawings.

- Horizontal lines are parallel to the horizontal edge of the drawing sheet.
- Vertical lines are perpendicular to horizontal lines.
- Inclined lines are drawn at specific angles (30°, 45°, 60°, 75°, 90°, etc.) using set squares or a protractor.

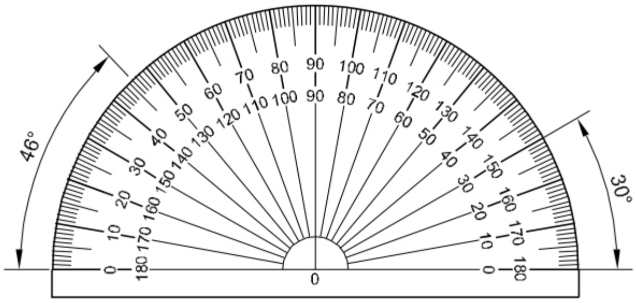
Set squares allow quick construction of standard angles (30°, 45°, 60°, 90°), while a protractor is used for non-standard angles.

Instrument Identification:

(a) Set Squares: Used to draw parallel horizontal and vertical lines and standard angles.



(b) Protractor: Used to measure and construct any required angle.



5 Procedure:

Part A: Drawing Horizontal Lines

1. Fix the drawing sheet on the drawing board using clips/tape.
2. Place the T-square firmly against the left edge of the board.
3. Hold the pencil properly and draw a straight horizontal line along the T-square edge.
4. Slide the T-square up or down to draw multiple parallel horizontal lines.

Part B: Drawing Vertical Lines

1. Place a set square on the T-square.
2. Hold the set square firmly.
3. Draw a vertical line along the vertical edge of the set square.
4. Ensure the line is perpendicular (90°) to the horizontal line.

Part C: Drawing Lines at Different Angles

(i) Using Set Squares

- 30° and 60°: Use 30°–60° set square.
- 45°: Use 45° set square.
- 90°: Use either set square vertically.

Steps:

1. Draw a base horizontal line.
2. Position the appropriate set square on the T-square.
3. Draw the inclined line along the required edge.

(ii) Using Protractor (Example: 75°)

1. Draw a base line AB.
2. Mark point A as the vertex.
3. Place the protractor center at point A.
4. Mark 75° on the scale.
5. Join point A to the marked point to obtain the inclined line.

6 Precautions

- Use sharp pencils (2H for construction lines, HB for final lines).
- Keep instruments clean and properly aligned.
- Do not tilt the T-square while drawing.
- Apply uniform pressure while drawing lines.

- Ensure all lines are thin and neat unless specified.

7 Conclusion:

Horizontal lines, vertical lines, and lines at different specified angles (30°, 45°, 60°, 75°, 90°) were drawn accurately using the geometrical box instruments.

8 Learning Outcomes:

By the end of this experiment, students will be able to:

- Draw accurate horizontal and vertical lines using T-square and set squares.
- Construct lines at standard angles (30°, 45°, 60°, 90°, etc.) with precision using a geometrical box.
- Develop proper line quality, uniform thickness, and neatness in engineering drawings.
- Understand the importance of accuracy and instrument handling in technical drafting.

LAB EXPERIMENT 2: ALPHABETS AND NUMERICALS (CO 206.1)

1 **Title:** Drawing of Alphabets and Numerals in Sketch Book (Engineering Lettering).

2 **Objectives:**

To practice and develop skill in drawing standard engineering alphabets (capital and small letters) and numerals neatly and uniformly in a sketch book.

3 **Apparatus Required:**

- Drawing Book (A3 size)
- T–square
- Set squares (45° and 30°)
- Protractor
- Compass
- Scale
- Pencils (HB, 2H)
- Sharpener
- Eraser

4 **Theory:**

Lettering in Engineering Graphics is essential for clear communication in technical drawings. Good lettering must be:

- Uniform in size
- Properly spaced
- Neat and legible
- Consistent in style

Types of Lettering:

- Single Stroke Vertical Lettering
- Single Stroke Inclined Lettering (75°)

Standard practice generally follows guidelines similar to those adopted by organizations like Bureau of Indian Standards (BIS) for engineering drawings.

Guidelines for Lettering

- Maintain uniform height (commonly 5 mm or 10 mm).
- Keep equal spacing between letters.
- Maintain uniform thickness of strokes.
- Use light guidelines which can be erased later.
- Inclined letters should be at 75° to the horizontal.

5 **Procedure:**

Part A: Drawing Guide Lines:

1. Draw two parallel horizontal guide lines using a scale.
2. Maintain consistent letter height (e.g., 5 mm).
3. Keep proper spacing between words.

Capital Alphabets (A–Z), Small Letters (a-z) and Numbers (0-9):

6 Precautions:

- Do not darken letters before checking alignment.
- Avoid overwriting or double lining.
- Maintain consistent inclination if using inclined lettering.
- Keep letters simple and clear.

7 Conclusion:

Standard single-stroke vertical (and inclined) alphabets and numerals were drawn neatly in the sketch book with uniform height, spacing, and proportion.

8 Learning Outcomes:

- Write capital letters, small letters, and numerals in standard engineering lettering style with correct proportions.
- Maintain uniform height, spacing, and alignment in free hand lettering.
- Apply single-stroke vertical and inclined lettering techniques as per drawing standards.
- Develop neatness and clarity in written communication for engineering drawings.

LAB EXPERIMENT 3: BASIC GEOMETRIC SHAPES IN 2D (CO 206.2)

1 Title: Construction of Basic Geometric Shapes in 2 and 3 Dimensions

2 Objectives:

To construct and draw basic two-dimensional geometric shapes such as circle, rectangle, square, parallelogram, and the 2D representations of cylinder and cone using standard drawing instruments.

3 Apparatus Required:

- Drawing Book (A3 size)
- T–square
- Set squares (45° and 30°)
- Protractor
- Compass
- Scale
- Pencils (HB, 2H)
- Sharpener
- Eraser

4 Theory:

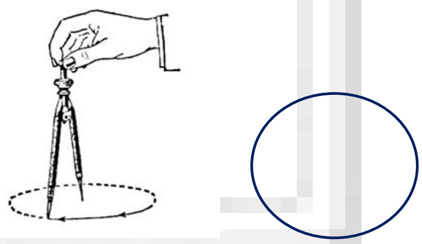
Basic geometric shapes form the foundation of engineering drawing and drafting. Accurate construction ensures dimensional correctness and proportional clarity.
Circle: Set of all points equidistant from a fixed point (center).
Rectangle: Quadrilateral with opposite sides equal and all angles 90°.
Square: Special rectangle with all sides equal.
Parallelogram: Quadrilateral with opposite sides parallel and equal.
Cylinder (2D view): Represented by a rectangle (side view) or circle (top view).
Cone (2D view): Represented by a triangle (side view) or circle (top view).

5 Constructions:

(A) Circle:

Steps:

1. Mark center point O.
2. Set compass to required radius.
3. Place needle at O and rotate to draw the circle.



(B) Rectangle:

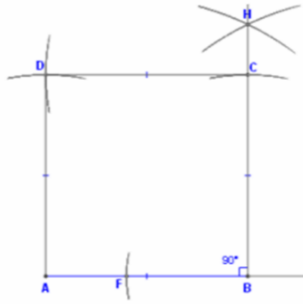
Steps:

1. Draw base AB of given length.
2. Construct perpendiculars at A and B.
3. Mark required height on both perpendiculars.
4. Join the top ends to complete rectangle ABCD.

(C) Square:

Steps:

1. Draw side AB of given length.
2. Construct perpendiculars at A and B.
3. Mark equal length on both sides.
4. Join endpoints to complete square.



(D) Parallelogram:

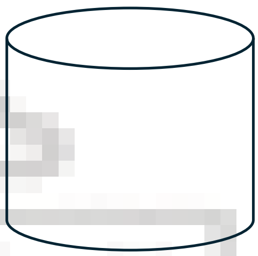
Steps:

1. Draw base AB.
2. At A, construct required angle.
3. Mark length AD.
4. Through D draw a line parallel to AB.
5. Through B draw a line parallel to AD to meet at C.

(E) Cylinder (3D Representation):

Front View: Rectangle

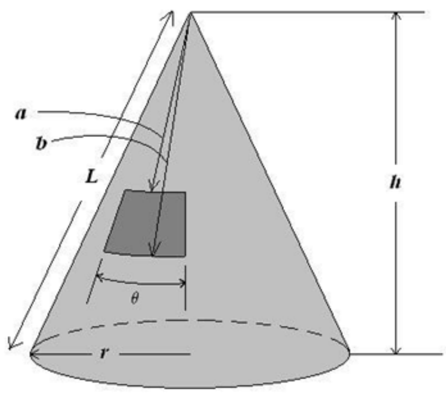
Top View: Circle



(F) Triangle 2D and Cone 3D:

Front View:

1. Draw base line equal to diameter.
2. Mark midpoint.
3. Draw vertical axis equal to height.
4. Join apex to base endpoints.



6 Precautions:

- Use light construction lines.
- Maintain perpendicularity and parallelism accurately.
- Check dimensions before darkening outlines.
- Keep compass radius fixed while drawing arcs.

7 Conclusion:

Basic 2D geometric shapes including circle, rectangle, square, parallelogram, and 2D views of cylinder and cone were constructed accurately using standard engineering drawing instruments.

8 Learning Outcomes:

By the end of this experiment, students will be able to:

- Construct accurate 2D geometric shapes such as square, rectangle, circle, cylinder, and polygon using drawing instruments.
- Apply standard geometric construction techniques and principles in drafting.
- Develop precision in measurement, alignment, and angular construction.
- Enhance understanding of geometric relationships used in engineering graphics.

LAB EXPERIMENT 4: ORTHOGRAPHIC PROJECTION (CO 206.3)

1 Title: Orthographic Projection of Points, Lines and rectangular Surfaces

2 Objective:

To draw the orthographic projections of points and straight lines in different quadrants using standard projection principles.

3 Apparatus Required:

- Drawing Book (A3 size)
- T–square
- Set squares (45° and 30°)
- Protractor
- Compass
- Scale
- Pencils (HB, 2H)
- Sharpener
- Eraser

4 Theory:

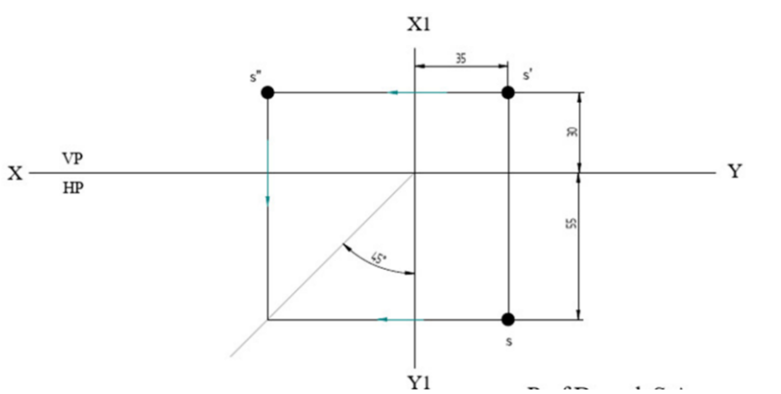
Orthographic projection is a method of representing three-dimensional objects in two dimensions using multiple views.
In India, engineering drawings generally follow the First Angle Projection Method as recommended by Bureau of Indian Standards.
Reference Planes:

- HP–Horizontal Plane
- VP–Vertical Plane
- XY Line–Reference line between HP and VP

Quadrants:

1. First Quadrant
2. Second Quadrant
3. Third Quadrant
4. Fourth Quadrant

Problem 2. Point S is 30mm above HP, 55mm infront of VP and also 35mm from left profile plane Draw the projections of the point S and state the quadrant in which it lies.



5 Constructions:

(A) Projection of a Point:

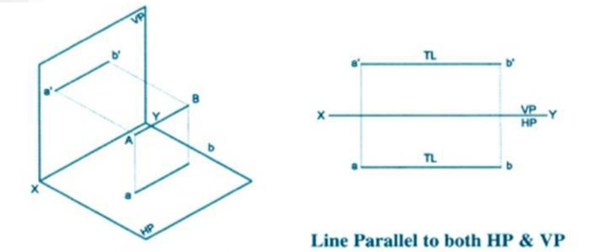
Steps:

1. Draw XY reference line.
2. Mark distances from HP and VP.
3. Project perpendiculars to obtain front view and top view.
4. Label views properly.

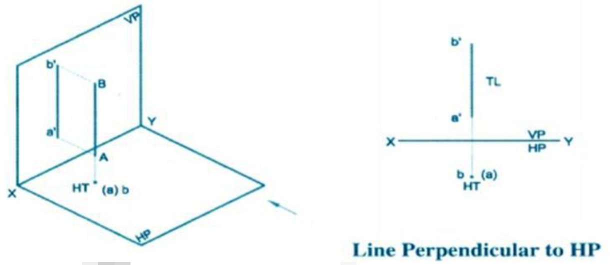
(B) Projection of a Line Parallel and Perpendicular to Both Planes:

Steps:

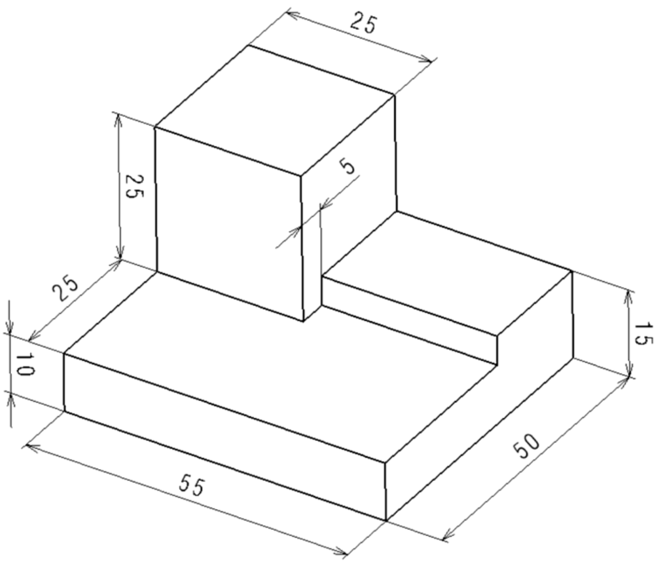
1. Draw XY line.
2. Draw given line in one view.
3. Project to obtain the corresponding second view.



Line Parallel to both HP & VP



Line Perpendicular to HP



6 Conclusion:

Orthographic projections of points and lines in different quadrants were drawn accurately using first angle projection method.

7. Learning Outcomes:

Upon completion of this experiment, the student will be able to:

- Apply principles of orthographic projection to represent objects composed of rectangular and flat surfaces.
- Draw accurate front, top, and side views using correct projection techniques and dimension transfer methods.
- Identify and represent visible and hidden edges in accordance with standard drawing conventions.
- Interpret multi-view drawings to visualize the three-dimensional shape of objects with plane surfaces.

LAB EXPERIMENT 5: ORTHOGRAPHIC PROJECTION (CO 206.2)

1 **Title:** Orthographic Projection for the object (Curved Surface).

2 **Objective:**

To draw the orthographic projections using first angle method.

3 **Apparatus Required:**

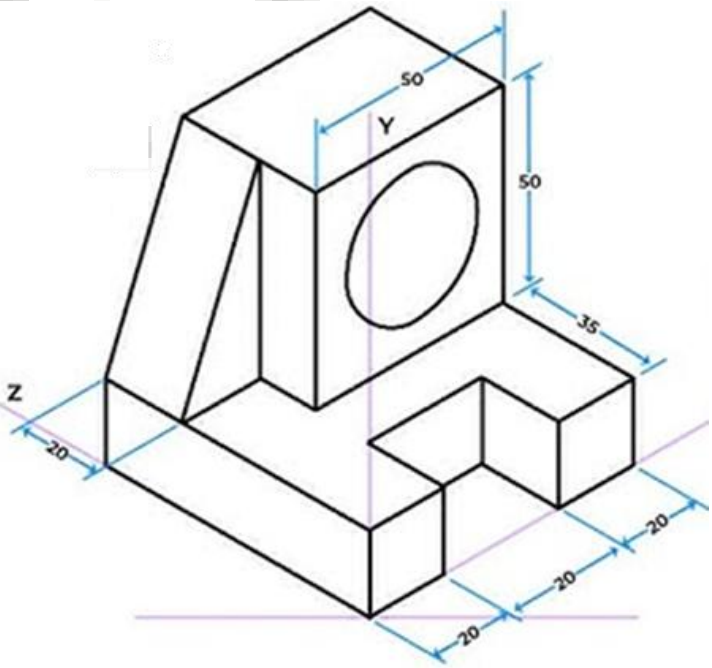
- Drawing Book (A3 size)
- T–square
- Set squares (45° and 30°)
- Protractor
- Compass
- Scale
- Pencils (HB, 2H)
- Sharpener
- Eraser

4 **Theory:**

Orthographic projection is a method of representing three-dimensional objects in two dimensions using multiple views.

5 **Constructions:**

(A) Orthographic Projection of the Object:



Steps:

1. Draw XY reference line.
2. Mark distances.
3. Project perpendiculars to obtain front view and top view.
4. Label views properly.
5. Get 45° inclined line in 4th quadrant
6. Transfer top view on inclined line
7. Transfer top and front views in first quadrant

6 **Precautions:**

- Maintain alignment of all views.
- Use thin projection lines.
- Darken only visible edges.
- Follow first angle projection symbol convention.

7 Conclusion:

Orthographic projections of simple solids were completed accurately showing front, top, and side views.

8 Learning Outcomes:

Upon completion of this experiment, the student will be able to:

- Apply principles of orthographic projection to represent objects containing curved surfaces such as circle/cylinder.
- Draw accurate front, top, and side views of curved objects, including correct representation of circular and elliptical shapes.
- Identify and represent visible and hidden edges using standard line conventions.
- Interpret multi-view drawings to visualize the three-dimensional form of objects with curved features.

LAB EXPERIMENT 6: ISOMETRIC VIEW (CO 206.3)

1 **Title:** Isometric Projection of Plane Figures

2 **Objective:**

To draw isometric projection from rectangular views (Front, Top and Side).

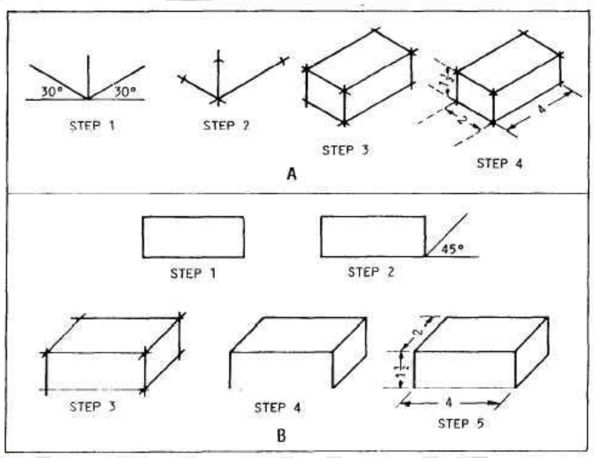
3 **Apparatus Required:**

- Drawing Book (A3 size)
- T–square
- Set squares (45° and 30°)
- Protractor
- Compass
- Scale
- Pencils (HB, 2H)
- Sharpener
- Eraser

4 **Theory:**

Isometric projection is a method of pictorial representation where the three axes are equally inclined at 120° to each other.
Key Features:

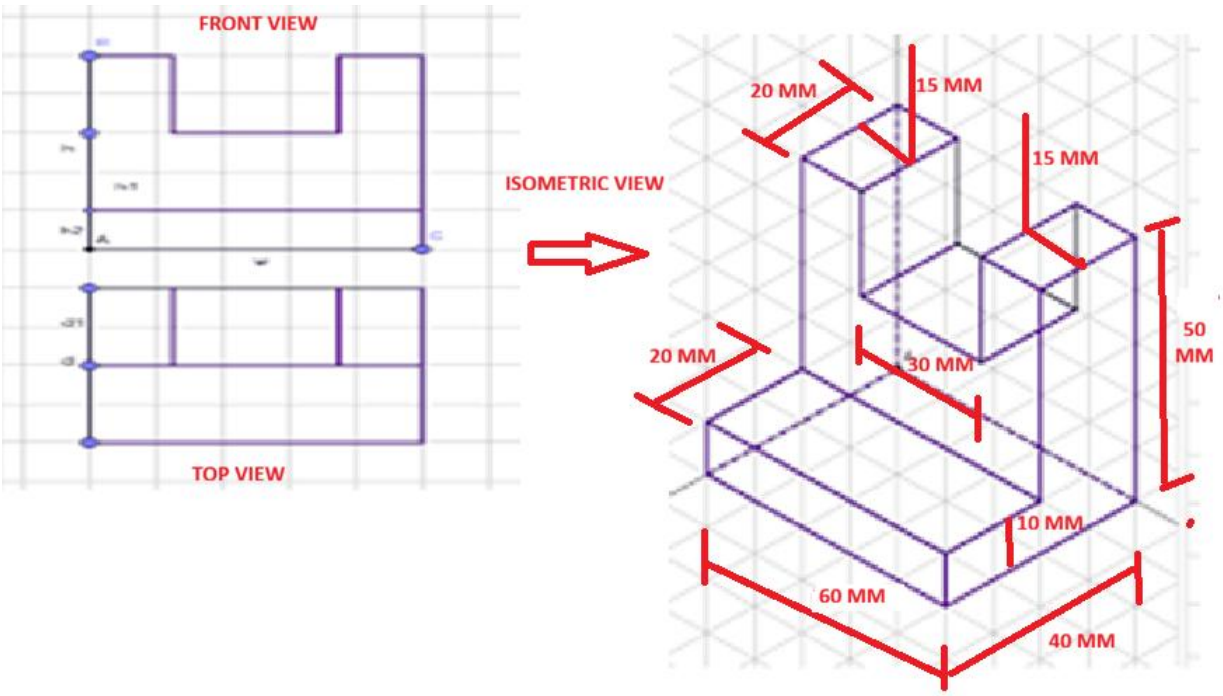
- Angles between axes: 120°
- True lengths along isometric axes
- Circles appear as ellipses in isometric view



5 **Constructions:**

(A) Isometric Projection of the Object:

Steps:
1. Draw vertical line (Height).
2. Draw two lines at 30° to horizontal (Isometric axes).
3. Mark Length on right 30° axis.
4. Mark Width on left 30° axis.
5. Complete base parallelogram.
6. Project vertical edges upward equal to height.
7. Join top edges to complete the solid.



6 Conclusion:

Isometric projections of plane figures were drawn accurately using isometric axes.

7 Learning Outcomes:

Upon completion of this experiment, students will be able to:

- Interpret given orthographic views (Front, Top, and Side) and visualize the three-dimensional form of the object.
- Construct accurate isometric projections using correct isometric axes and scale.
- Transfer dimensions precisely from rectangular views to isometric view without distortion.
- Develop spatial visualization skills and apply projection principles as per engineering graphics standards.

LAB EXPERIMENT 7: ISOMETRIC VIEW (CO 206.3)

1 **Title:** Isometric Projection of Solid Figures (Curved Surface)

2 **Objective:**

To draw isometric projections of simple solids such as cube, cylinder, and cone.

3 **Apparatus Required:**

- Drawing Book (A3 size)
- T–square
- Set squares (45° and 30°)
- Protractor
- Compass
- Scale
- Pencils (HB, 2H)
- Sharpener
- Eraser

4 **Theory:**

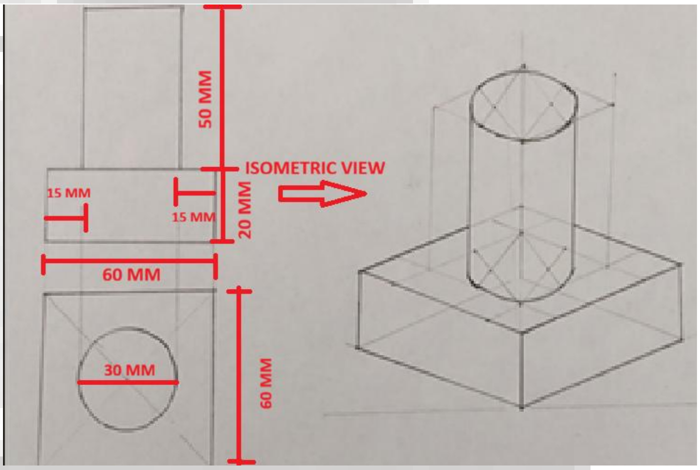
Isometric projection is a method of pictorial representation where the three axes are equally inclined at 120° to each other.
Key Features:

- Angles between axes: 120°
- True lengths along isometric axes
- Circles appear as ellipses in isometric view

5 **Constructions:**

(A) Isometric Projection of the Object:

Steps:
1. Draw isometric rectangle/square.
2. Construct isometric ellipse at top and bottom.
3. Join vertical edges.



6 **Conclusion:**

Isometric projections of Solid figure were drawn accurately using isometric axes.

7 **Learning Outcomes:**

After completing this experiment, students will be able to:

- Identify and interpret curved solid figures (cylinder, cone, sphere, etc.) from given views or dimensions.

- Construct accurate isometric projections of solids with curved surfaces using proper isometric scale.
- Draw isometric circles (ellipses) and curved profiles correctly using standard construction methods.
- Apply principles of projection and spatial visualization to represent curved surfaces clearly and proportionately.

LAB EXPERIMENT 8: FREE HAND SKETCHES (CO 206.4)

1 **Title:** Free Hand Sketching of Basic Electronic Components

2 **Aim:**

To develop free-hand sketching skills by drawing standard electronic components with correct proportions, symbols, and labelling as per basic engineering drawing practices.

3 **Objective:**

- To improve visualization and proportioning skills.
- To understand the physical shape and schematic symbol of electronic components.
- To practice neat lettering and component labelling.
- To correlate 2D symbolic representation with actual component geometry.

4 **Apparatus Required:**

- Drawing Book (A3 size)
- T–square
- Set squares (45° and 30°)
- Protractor
- Compass
- Scale
- Pencils (HB, 2H)
- Sharpener
- Eraser

5 **Theory:**

- Free-hand sketching is an essential skill in engineering graphics. In electronics, engineers frequently draw quick sketches of components, circuit layouts, and symbols during design discussions and troubleshooting.
- Electronic components are represented in two ways:
- Physical View – Shows the actual appearance of the component.
- Schematic Symbol – Standard electrical representation used in circuit diagrams.

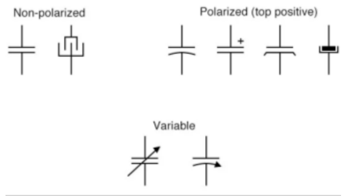
6 **Components to be Drawn:**

(A) Resistor:

1 Draw a small cylindrical body.
2 Add two thin leads on both sides.
3 Show colour bands.
4 Below it, draw the schematic zigzag symbol.
5 Label: Resistor (R)

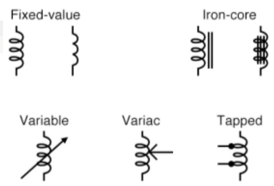
(B) Capacitor:

1 Draw disc type (ceramic capacitor).
2 Draw cylindrical type (electrolytic capacitor).
3 Draw both schematic symbols:
4 Two parallel lines (non-polarized)
5 One curved plate (polarized)
6 Label: Capacitor (C)



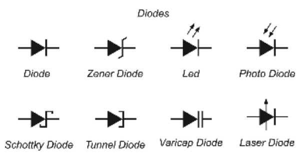
(C) Inductor:

1 Draw a small coil (semi-circular loops).
2 Add two leads.
3 Draw schematic coil symbol.
4 Label: Inductor (L)



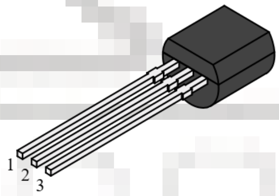
(D) Diodes:

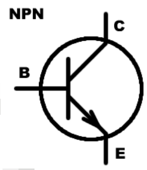
1 Draw cylindrical body with one band (cathode).
2 Add two leads.
3 Draw triangle with vertical line symbol.
4 Label: Diode (D)



(E) Transistor:

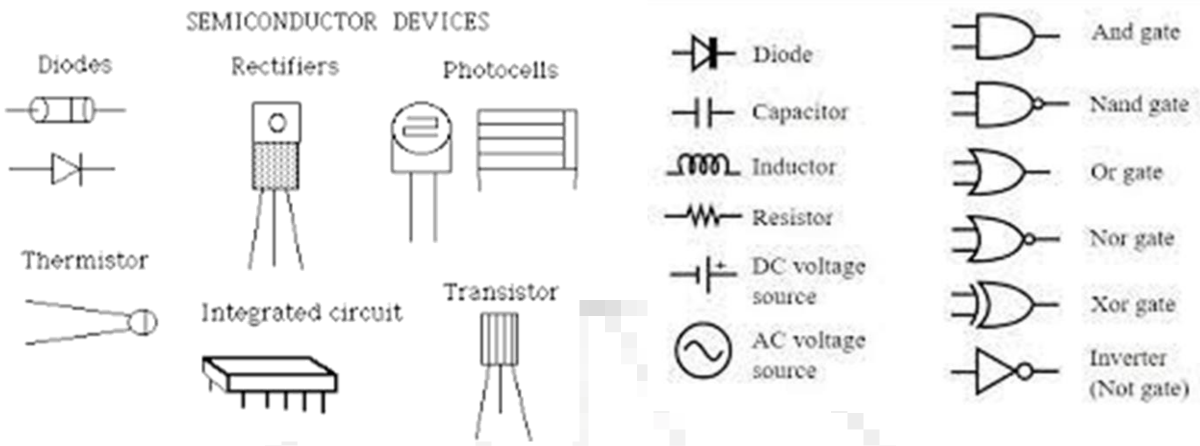
1 Draw TO-92 package (semi-circular top).
2 Show three leads.
3 Draw NPN symbol with arrow pointing outward.
4 Label terminals: Emitter (E), Base (B), Collector (C)





(F) Integrated Circuit:

1 Draw rectangular body.
2 Draw equal number of pins on both sides.
3 Mark pin 1 with a dot.
4 Draw schematic rectangular symbol.
5 Label: IC



7 Conclusion:

Free-hand sketches of basic electronic components were drawn successfully with proper proportion, labelling, and schematic symbols.

8 Learning Outcomes:

Upon completion of this experiment, students will be able to:

- Identify common electronic components (resistor, capacitor, diode, etc.) and understand their standard symbols.
- Develop freehand sketching skills with proper proportion, line quality, and clarity.
- Represent electronic components accurately without the use of drawing instruments.
- Enhance visualization and technical communication skills relevant to basic circuit representation.

LAB EXPERIMENT 9: DRAWING BASIC 2D ENTITIES IN AUTOCAD (CO 206.5 & 206.6)

1 **Title:** Draw basic entities: Shapes using AutoCAD tool

2 **Aim:**

To study and practice drawing fundamental 2D geometric entities such as rectangle, polygon, and rhombus using AutoCAD commands.

3 **Objective:**

- To understand coordinate input methods (absolute, relative, polar).
- To use basic drawing commands in AutoCAD.
- To create and modify standard 2D geometric shapes.
- To apply object snap (OSNAP) and grid settings effectively.

4 **Apparatus/ Software Required:**

- Computer system
- AutoCAD

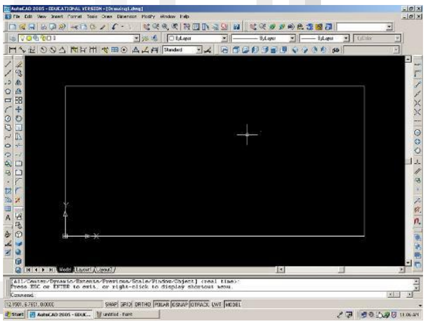
4 **Theory:**

AutoCAD is a computer-aided design (CAD) software used for 2D drafting and 3D modelling. Basic 2D entities are created using commands such as:

- LINE
- RECTANGLE
- POLYGON
- PLINE (Polyline)
- OFFSET
- TRIM
- DIM (Dimension)

Understanding these commands is fundamental for engineering drawing and drafting practices.

6 **Procedure:**

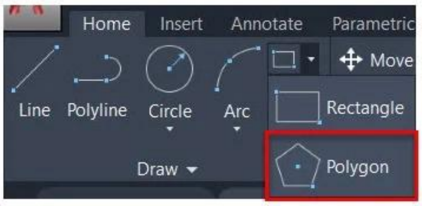


(A) Rectangle:

1 Open AutoCAD.
2 Type RECTANGLE in the command line → Press Enter.
3 Specify the first corner point (e.g., 0,0).
4 Specify the opposite corner point (e.g., 100,60).
5 Press Enter.

(B) Regular Polygon:

1 Type POLYGON→Press Enter.
2 Enter number of sides (e.g., 6 for hexagon).
3 Specify center point.

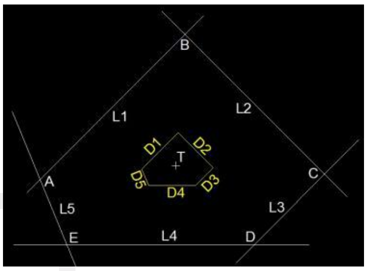


4 Choose:

I→Inscribed in circle

C→Circumscribed about circle 5

5 Enter radius (e.g., 50).



(C) Rhombus:

1 Type LINE→Enter.
2 Specify first point (0,0).
3 Draw first side: @60<0→Enter.
4 Draw second side: @60<60→Enter.
5 Draw third side: @60<180→Enter.
6 Type C to close.

7 Precautions:

- Set units properly using UNITS command.
- Turn ON OSNAP for accuracy.
- Use proper layers and line types.
- Save the drawing frequently.

8 Conclusion:

Basic 2D entities such as rectangle, polygon, and rhombus were successfully drawn using AutoCAD commands. The experiment helps in understanding coordinate systems and command-based drafting, which are fundamental skills in engineering graphics.

9. Learning Outcomes:

- After completing this experiment, students will be able to:
- Use fundamental AutoCAD drawing commands to create basic geometric entities such as line, rectangle, circle, polygon, and ellipse.
- Apply coordinate systems (absolute, relative, and polar) for precise drafting.
- Modify and edit shapes using tools like trim, extend, offset, move, copy, and rotate.
- Develop accuracy and efficiency in 2D drafting following standard engineering drawing practices.

LAB EXPERIMENT 10: DRAWING BASIC 2D ENTITIES IN AUTOCAD (CIRCLE, ARC, ELLIPSE) (CO 206.5 & 206.6)

1 **Title:** Draw basic entities: Circular Shapes using AutoCAD tool

2 **Aim:**

To study and practice drawing basic 2D entities such as circle, arc, and ellipse using AutoCAD commands.

3 **Objective:**

- To understand different methods of drawing circles and arcs.
- To learn ellipse construction techniques.
- To apply coordinate entry and object snap for accurate drafting.
- To develop command-line proficiency in AutoCAD.

4 **Apparatus/ Software Required:**

- Computer system
- AutoCAD

5 **Theory:**

AutoCAD provides multiple methods to construct circular and curved geometries. These entities are essential in engineering drawings for representing holes, shafts, fillets, cams, and curved profiles.
Basic commands used:

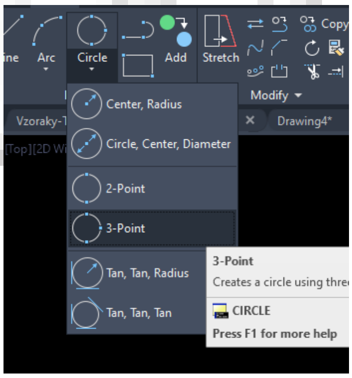
- CIRCLE
- ARC
- ELLIPSE
- OSNAP
- TRIM
- DIM

Understanding these commands is fundamental for engineering drawing and drafting practices.

6 **Procedure:**

(A) CIRCLE:

1 Type CIRCLE → Press Enter.
2 Specify center point (e.g., 0,0).
3 Enter radius (e.g., 50).
4 Press Enter.



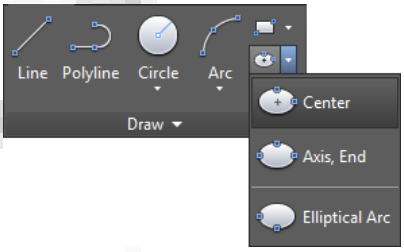
(B) ARC: COMMON ARC METHODS:

- 3-Point
- Start–Center–End
- Start–End–Angle
- Start–End–Radius

PROCEDURE (3-POINT METHOD):

1 Type ARC → Press Enter.
2 Specify first point.
3 Specify second point.
4 Specify third point.
5 Press Enter.

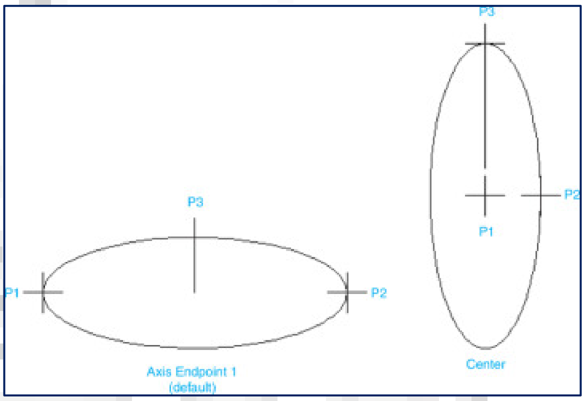
(C) ELLIPSE: METHODS AVAILABLE:



- Axis, End
- Center
- Isocircle (in isometric mode)

PROCEDURE (AXIS END METHOD):

1. Type ELLIPSE → Press Enter.
2. Specify first axis endpoint.
3. Specify second axis endpoint.
4. Specify distance for other axis.
5. Press Enter.



7 Precautions:

- Set units using UNITS command before starting.
- Use OSNAP for accurate point selection.
- Keep grid and ortho mode as required.

8 Conclusion:

Basic 2D entities such as circle, arc, and ellipse were successfully drawn using different AutoCAD methods. These commands form the foundation for advanced drafting and engineering design work.

9 Learning Outcomes:

- Create circular entities such as circle, arc, and ellipse using appropriate AutoCAD commands with accurate dimensions.
- Apply modification tools (trim, offset, fillet, extend) to edit and refine circular shapes as per drawing requirements.