

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous) Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

ELECTRONIC DEVICES AND CIRCUITS LABORATORY								
III Semester: ECE								
Course Code	Category	Hours / Week			Credits	Maximum Marks		
AECD06	Core	L	Т	Р	С	CIA	SEE	Total
		-	-	2	1	40	60	100
Contact Classes: Nil	Tutorial Classes: Nil	Practical Classes: 45				Total Classes: 45		
Prerequisite: Applied Pl	nysics							

I. COURSE OVERVIEW:

This course provides the hands-on experience on designing circuits using Diodes, Bipolar Junction Transistors, and Field Effect Transistors. Measure the gain, bandwidth and input output impedances of BJT and FET amplifiers. Provides the capability to extract the characteristics of semi conductor devices and circuits with simulation tools (Multisim).

II. COURSES OBJECTIVES:

The students will try to learn

- I. The behavior and characteristics of semiconductor devices for designing the semiconductor circuits such as amplifier and rectifiers.
- II. Estimation of device characteristics like gain, bandwidth, input and output resistance of bipolar junction transistors and field effect transistors amplifiers to derive appropriate small-signal model analysis of basicamplifier circuits.
- III. The analytical skills to model analog and digital integrated circuits at discrete and micro circuit level.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

- CO 1 Demonstrate the electronic instruments for measuring voltage, current and phase parameters
- CO 2 Determine the parameters of rectifiers and voltage regulators using the diode characteristics.
- CO 3 Examine the input and output characteristics of transistor (B JT and FET) configurations for determining input output resistances
- CO 4 Characterize BJT and FET amplifiers for estimating the voltage gain and Current gain.
- CO 5 Analyze the transistor biasing circuits for a proper operation of transistors in electronic circuits
- CO 6 Develop the design of a regulated power supply circuit for the specified voltage and current requirements.

DO's

- 1. Once the operation is completed pull the plug itself rather chord attached to it.
- 2. Repair the equipments witch-off the supply and goon.
- 3. Operate the equipment on supply; see that hands are dry, if that is not possible, hide the hand in the pockets.
- 4. If a person comes in contact with current unexpectedly don't touch the person with hands but immediately use any insulator material and shut down the power (like leather belts, wood and plastic bars etc).
- 5. If water is nozzles on the equipment, immediately shutdown the power using circuit breaker or pull out the plug.
- 6. Use the connecting wires of good continuity, short circuit of connecting wire leads damage of circuit parameters.

DON'Ts

- 1. Do not wear loose clothing and do not hold any conducting materials in contact with skin when the power is on.
- 2. Do not pull out the connections until unless all the currents are dead.
- 3. Do not over load the circuit by plugging in too many appliances.
- 4. If you are mentally and physically stressed don't operate the power equipment.
- 5. Never operate the equipment under wet conditions.
- 6. Do not inter connect two or more wires, take appropriate length of wire.

SAFETY NORMS

- 1. The lab must be equipped with fire extinguisher.
- 2. See that the connections are made tight.
- 3. Use single plug for each equipment.
- 4. Cover the body completely to avoid arc effect.
- 5. To change the connections during the experiment, switch off the supply and carry on.
- 6. Used equipment may get heated, so take care handling the equipment after it is used.
- 7. Do the wiring, all setups and check the circuit connections before the supply is on

IV. LIST OF EXPERIMENTS:

EXERCISES FOR ELECTRONIC DEVICES AND CIRCUITS LABORATORY

Note: Students are encouraged to bring their own laptops for laboratory practice session

1. Getting Started Exercises

1.1 Introduction to MULTISIM

Step 1: Open				
Multisim. Step2:				
Place				
components.				
Step 3: Wire				
components.				

Step4: Place a simulation source. Step5: Place measurement instruments. Step 6: Run a simulation

1.2 V-I characteristics of p-n junction diode

A p-n junction diode conducts only in one direction. The *V-I* characteristic of the p-n diode is a curve plot between voltage measured across the diode and current flowing through the diode. When external voltage is zero, circuit is open and the potential barrier does not allow the current to flow.

1.2.1 V-I characteristics of p-n junction diode under forward bias

When p-type (Anode) is connected to +ve terminal and n-type (cathode) is connected to –ve terminal of the supply voltage is known as forward bias.

Plot the V-I characteristics curve of p-n junction diode under forward bias and calculate the forward static and dynamic resistances of a p-n junction diode as shown in Figure 1.2.1.



Figure 1.2.1pn junction diode under Forward Bias

1.2.2 *V-I* characteristics of p-n junction diode under reverse bias

Whenn-type(cathode)isconnectedto+veterminalandp-type(Anode)isconnected–veterminalofthe supply voltage is known as reverse bias and the potential barrier across the junction increases.

Plot the V-I characteristics curve of p-n junction diode under reverse bias and calculate the reverse static and dynamic resistances of a p-n junction diode as shown in Figure 1.2.2



Figure 1.2.2 p-n junction diode under Reverse Bias

Try

- 1. The reverse saturation current of a silicon p-n junction diode is10mA.Calculate the diode current for the forward bias voltage of 0.6 V at 25 °C.
- 2. From the characteristics obtained in the Figure 1.2.2
 - (a) Determine the ac resistance at ID=2 mA.
 - (b) Determine the ac resistance at ID= 25 mA.
 - (c) Compare the results of parts (a) and (b) to the dc resistances at each current level.
- 3. Plot volt-ampere characteristics of germanium p-n junction diode. Find cut- in voltage, static and dynamic resistances in forward and reverse biased conditions using Hardware.
- 4. Compare silicon and germanium diodes for cut-in voltage and magnitudes of diode currents from V-I characteristics using digital simulation.

2. Exercises on Zener Diode Characteristics and Voltage Regulator

A Zener diode is heavily doped p-n junction diode, specially made to operate in the break down region. A p-n junction diode normally does not conduct when reverse biased. But if the reverse bias is increased, at a particular voltage it starts conducting heavily. This voltage is called Break down Voltage. High current through the diode can permanently damage the device. To avoid high current, we connect a resistor in series with Zener diode.

2.1 Zener diode under forward bias

The forward bias characteristic of Zener diode is same as the normal p-n junction diode. Plot the V-I characteristics curve of Zener diode under forward bias and calculate the forward static and dynamic resistances of a Zener diode as shown in the Figure 2.1.



Figure 2.1 Zener diode under forward bias

2.2 Zener diode under reverse bias

Plot the V-I characteristics curve of Zener diode under reverse bias and calculate the reverse static and dynamic resistances of a Zener diode as shown the Figure 2.2.



Figure 2.2 Zener diode under reverse bias

2.3 Zener diode as voltage regulator

Examine the Zener diode as a Voltage Regulator and determine the line and load regulations from the Figure 2.3.



Figure 2.3 Zener diode as line and load regulation

Try

- 1. Design a zener voltage regulator circuit to drive aload of 6V,100Mw from an unregulated input supply of Vmin = 8V, Vmax = 12V using a 6V zener diode.
- 2. Find the maximum zener current for the zener diode which is connected in voltage regulator to protect the load. Given $V_Z=6V$, $R_Z=1.5\Omega$, $R=400\Omega$.
- 3. The potential of the battery is varied from 10V to 16V.If by zener diode breakdown voltageis 6V, find maximum current through zener diode.
- 4. Design zener voltage regulator circuit with 6V output voltage using digital simulation. Choose the current limiting resistor and load resistor considering minimum break down current.

3. Exercises on Half wave and full wave rectifier with and without filter

Rectifier is an electronic circuit, which offers low resistance in one direction and high resistance in opposite direction. Rectifiers are used to convert AC voltages and DC voltages and currents.

A half-wave rectifier converts an AC signal to DC by passing either the negative or positive half-cycle of the waveform and blocking the other. Half-wave rectifiers can be easily constructed using only one diode, but are less efficient than full-wave rectifiers.

The full-wave rectifier consists of a center-tapped transformer, which results in equal voltages above and below the center-tap. During the positive half cycle, a positive voltage appears at the anode of D1 while a negative voltage appears at the anode of D2. Due to this diode D1 is forward biased. It results a current Id1 through the load R.

3.1 Half wave rectifier without filter

Design a half-wave rectifier circuit and determine the output waveform for the network of Figure 3.1 also analyze the rectifier output without a filter.



Figure 3.1 Half wave rectifier without filter

3.2 Half wave rectifier with filter

Design a half-wave rectifier circuit and determine the output wave form for the network of Figure 3.2 also analyze the rectifier output with a filter



Figure 3.2 Half wave rectifier with filter

3.3 Full wave rectifier without filter

Design a full-wave rectifier circuit and determine the output waveform for the network of Figure 3.3 also analyzes the rectifier output without a filter.



Figure 3.3 Full wave rectifier without filter

3.4 Full wave rectifier with filter

Design a full-wave rectifier circuit and determine the output waveform for the network of Figure 3.4 also analyzes the rectifier output without a filter.



Figure 3.4 Full wave rectifier with filter

Try

- An ac supply of 230 V is applied to a half-wave rectifier circuit through transformer of turn's ratio 5:1. Assume the diode is an ideal one. The load resistance is 300V. Find (a)d.c. output voltage (b) PIV (c) maximum (d) average values of power delivered to the load using multisim.
- 2. Design half wave rectifier with an a.c. supply of 230V is applied through a transformer of turn ratio 10:1. Observe the output d.c. voltage, peak inverse voltage and identify d.c. output voltage if transformer turns ratio changed to 20:1.
- 3. Examine how negative DC voltage can be obtained with HWR in power supply circuits?
- 4. With capacitor and inductor filters observe the variation in ripple voltage for small, medium & amp; high load currents for half wave rectifier using digital simulation.
- 5. A half-wave rectifier issued to supply 50V d.c. to a resistive load of 800Ω. The diode has a resistance of 25Ω. Calculate a.c. voltage required.
- 6. A half wave rectifier has a load of 3.5k. If the diode resistance and secondary coil resistance

together have a resistance of 800 and the input voltage has a signal voltage of peak value 240 V, calculate (i) Peak, average and rms value of current flowing (ii) d.c. power output (iii) a.c. power input (iv) Efficiency of the rectifier.

- Design a bridge rectifier using four identical diodes having forward resistance of 5 V and the secondary voltage is 30 V_{rms}. Determine the dc output voltage for I_{dc}200 mA and value of the output ripple voltage.
- 8. Design a $12V_{dc}$ power supply out of an a.c. line source (120 V_{ac}), a transformer with $N_p / N_s = 10$, some diodes, and a low pass filter. Calculate the ripple voltage at the output of your supply when it has a 50 Ohms load.
- Design the circuit of a full-wave rectifier using center tapped transformer to obtain an output d.c.voltage of V_{dc}= 18 at 200mA and V_{dc}no load equals to 20V. Assume suitable value of rf and transformer resistance and mention transformer rating and sketch the input and output waveforms.

4. Exercises on Bridge Rectifier

A Bridge Rectifier is a device used to convert AC into DC. Its main purpose is rectification ensuring that electric current flows in one direction. It is composed of diodes arranged in a bridge structure. It can rectify both the negative and positive halves of an AC waveform. Bridge Rectifiers use four diodes that are arranged cleverly to convert the AC supply voltage to a DC supply voltage. The output signal of such a circuit is always of the same polarity regardless of the polarities of the input AC signal. Design a bridge rectifier circuit and analyze the rectifier output with and without filter.

4.1 Bridge rectifier without filter

Design a full-wave bridge rectifier circuit and determine the output waveform for the network of Figure 4.1 also analyze the rectifier output without a filter.



Figure 4.1 Bridge rectifiers without filter

4.2 Bridge rectifier with filter

Design a full-wave bridge rectifier circuit and determine the output waveform for the network of Figure 4.2 also analyze the rectifier output with a filter.



Figure 4.2 Bridge rectifier with filter

Try

- 1. Design a full wave bridge rectifier circuit to deliver 10V dc with less than 0.1V(pp) ripple factor into a load drawing up to 10mA. Choose the appropriate ac input, assuming 0.6V diode drops.
- 2. Design a bridge rectifier with 1000uf capacitor filter, 24V AC input , load current 2A.

5. Exercises on Clippers and Clampers

A clipper circuit in which the diode is connected in series or shunt to the input signal and biased with positive or negative reference voltage V_r and that attenuates the positive or negative portions of the waveform Series Clipper with positive V_r .

A clamper circuit can be defined as the circuit that consists of a diode, a resistor and a capacitor that shifts the waveform to a desired DC level without changing the actual appearance of the applied signal. Clamping circuit restores the DC level. When a negative peak of the signal is raised above to the zero level, then the signal is said to be positively clamped.

5.1 Positive clippers with and without biasing

Design non-linear wave shaping circuits as positive clippers shown in Figure 5.1.1, Figure 5.1.2 and Figure 5.1.3.



Figure 5.1.1 Positive clipper with zero biasing



Figure 5.1.2 Positive clipper with positive reference



Figure 5.1.3 Positive clipper with negative reference

5.2 Negative clippers with and without biasing

Design non-linear wave shaping circuits as negative clippers shown in Figure 5.2.1, Figure 5.2.2 and Figure 5.2.3.



Figure 5.2.1 Negative clipper with zero biasing



Figure 5.2.2 Negative clipper with positive reference



Figure 5.2.3 Negative clipper with negative reference

5.3 Positive clamper

Design non-linear wave shaping circuits as positive clampers shown in Figure 5.3.1, Figure 5.3.2 and Figure 5.3.3.



Figure 5.3.1 Positive clipper with zero biasing



Figure 5.3.2 Positive clamper with positive reference



Figure 5.3.3 Positive clamper with negative reference

5.4 Negative clamper

Design non-linear wave shaping circuits as negative clampers shown in Figure 5.4.1, Figure 5.4.2 and Figure 5.4.3



Figure 5.4.1 Negative clipper with zero biasing



Figure 5.4.2 Negative clipper with positive reference



Figure 5.4.3 Negative clipper with negative reference

Try

1. For the given circuit in Figure 5.4.4 for a $20V_{peak}$ s in usoidal input v_i, what is the value of v_i at which the clipping Begins?





2. For the given circuit in Figure 5.4.5, what is the minimum peak value of the output waveform if the input waveform is 10V square wave with switching time of 1 second?

Assume that the input switches between+10V and -10VDC levels.



Figure 5.4.5 Output waveform

3. For the given circuit in Figure 5.4.6 and input waveform, find the peak value of the output.



Figure 5.4.6 Waveorm circuit

6. Exercises on Transistor Characteristics

In common base (CB)configuration, input is applied between the emitter and base, and output is taken from the collector and base. Here, the base of the transistor is common to both input and output circuits. This configuration provides high current gain and high input impedance, and is commonly used in radio frequency amplifiers.

The configuration in which the emitter is connected between the collector and base is known as a common emitter configuration. The variation of emitter current (I_B) with Base-emitter voltage (V_{BE}), keeping Collector- emitter voltage (V_{CE}) constant.

6.1 Characteristics of a common base configuration

Plot the input and output characteristics of a transistor in common base configuration shown in Figure 6.1 and to compute the h – parameters



Figure 6.1:Common base configuration

6.2 Characteristics of common emitter configuration

Plot the input and output characteristics of a transistor in common emitter configuration from the Figure 6.2 and compute the h – parameters.



Figure 6.2 Common emitter configuration

Try

- 1. Demonstrate the characteristics of p-n-p transistor in CB configuration, identifying active, cutoff and saturation regions with digital simulation. Mark the collector-emitter voltage (VCE) when transition from saturation to active region occurs.
- 2. For the common base circuit, determine **IC** and **VCB**. Assume the transistor to be of Germanium.
- 3. Design a circuit which acts as an electronic switch using common emitter configuration.
- 4. The output characteristics of a transistor connected in common emitter mode. Determine the value of IC when VCE= 15V. Also determine the value of IC when VCEis changed to 10 V.
- 5. Model CE amplifier with voltage gain of -24 and current gain -50 using digital simulation.
- 6. Design a CC amplifier with current gain of 40 with suitable assumptions using digital simulation.
- 7. With appropriate selection of components, design a CB amplifier with voltage gain of 50 using digital simulation.

7. Exercises on Transistor Biasing

A transistor acts as an amplifier in active region. Biasing circuit is used in a transistor to keep in the activeregion. Following are the three common biasing circuits used in transistors.

- 1) **Fixed bias circuit:-**It provides a fixed value of base current for given values of VCC and Rb.
- 2) Collector to base bias circuit:- In this circuit the base bias is taken from the collector by connecting aresistor between base and collector.
- **3)** Self bias circuit:- In this circuit the base bias is obtained by using a voltage divider network. Anemitter resistor is used to limit the collector current and hence the Q-point is stable. Also the reverse saturation current doubles for every 100C rise in temperature, hence Q-point should be stable.

7.1 Fixed bias circuit

Design a fixed bias circuit and determine their stability factors



Figure 7.1: Circuit Diagram for Fixed bias.

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7.2 Collector to base bias circuit Design a Collector to base bias circuit and determine their stability factors



Figure 7.2: Circuit Diagram for Collector to base bias.

7.3 <u>Self-bias circuit</u>

Design a Self-bias circuit and determine their stability factors



Figure 7.3: Circuit Diagram for Self-bias

Try

- 1) Design a fixed bias circuit to establish the Q-point at $I_C = 1mA$, $V_{CE} = 6V$. Use a transistor with β = 200 and $V_{BE} = 0.65V$. Given $V_{CC} = 12V$.
- 2) Design a Collector to base bias circuit to establish the Q-point at $I_C = 1$ mA, $V_{CE} = 6$ V. Use a transistor with $\beta = 200$ and $V_{BE} = 0.65$ V. Given $V_{CC} = 12$ V.
- 3) Design a self-bias circuit for which the biasing conditions are as follows. $V_{CC} = 12V$, $I_C = 1mA$, $V_{CE} = 6V$ and Stability factor is S = 10. Use RC = 4.7K Ω . Use a transistor with $\beta = 200$ and $V_{BE} = 0.65V$

8. Exercises on Frequency Response of Common Emitter and Common Collector Amplifier

The voltage gain of a CE amplifier varies with signal frequency. It is because the reactance of the capacitors in the circuit changes with signal frequency and hence affects the output voltage. In common collector amplifier as the collector resistance is made to zero, the collector is at AC ground that is the reason for which the circuit is also called as grounded-collector amplifier or this configuration has voltage gain close to unity and hence a change in base voltage appears as an equal change across the load at the emitter.

8.1 Common Emitter Amplifier

Obtain the frequency response curve of the below Figure 8.1 Common Emitter amplifier and determine the mid frequency gain, Amid, lower and higher cutoff frequency of the amplifier.



Figure 8.1 Common Emitter amplifier

8.2 Common Collector Amplifier

Obtain the frequency response curve of the below Figure 8.2 common colloctor amplifier and determine the mid frequency gain, Amid, lower and higher cutoff frequency of the amplifier.



Figure 8.2 Common Collector amplifier

Try

- 1. In a CE germanium transistor amplifier using self-bias circuit, $R_C=2.2k\Omega$, $\beta=50$,VCC=9V and the operating point is required to be set at $I_C=2$ mA and $V_{CE}=3V$. Determine the values of R1, R2 and RE.
- 2. Compute the voltage gain from the Figure 8.1.1by Assuming β =150.



Figure 8.1.1 Voltage gain

- 3. Measure the voltage gain for the Figure 8.1.1. Adjust the input signal to approximately 10mv amplitude, with a frequency of 100 kHz. What is the voltage swing?
- 4. Determine the input impedance and voltage gain for the circuit shown in Figure 8.1.2.Also determine V_{load} , if V_{in} = 20 mV peak. Assume β =100.
- 5. Design a common-collector amplifier using the 2N3904 transistor that meets the following specifications: I_c = 1mA, VCC = 20V, R_{in} = 70k Ω , R_L = 510 Ω , V_{in} = 10mV @ 10kHz. Determine the value of R_E .
- 6. Design a Common emitter amplifier using PNP transistor. For the Common Collector amplifier showed in Figure 8.2.1, find the voltage gain (β =120).



Figure 8.2.1 Common emitter ampiier

9. Exercises on FET Characteristics

The functioning of Junction Field Effect Transistor depends upon the flow of majority carriers (electrons or holes) only. Basically, JFETs consist of an n type or p-type silicon bar containing p-n junctions at the sides.

To study the drain and transfer characteristics of FET and find the drain resistance, trans-conductance and

Amplification factor for the Figure 9.1.



Figure 9.1 FET Characteristics

Try

- 1. Plot the drain and transfer characteristics of P-channel JFET BFW11/10/BF245A with RL=50 Ω .
- 2. Demonstrate how FET can be used as voltage variable resistor (VVR) for small ac signals using digital simulation.
- 3. A JFET has the following parameters: IDSS=32mA;VGS(off)= -8V;VGS= -4.5V.Find the value of drain current.
- 4. An N-channel JFET having Vp=-4V and V_{DSS} =10mA is used in the circuit of Figure 9.2.The parameter values are V _{DD}= 18V, Rs=2k Ω , R1=450k Ω and R2=90k Ω . Determine I_D and V_{DS}.



Figure 9.2 JFET circuit

10. Exercises on frequency response of Common Source and Common Drain amplifier

When the input signal is applied at the gate terminal and source terminal, then the output voltage is a mplified and obtained across the resistor at the load in the drain terminal. This is called a common source amplifier.

Acommon drain amplifier is one in which the input signal is applied to the gate and the output is taken from the source, making the drain common to both. Because it is common, there is no need for a drain resistor

10.1 Common Source Amplifier

Obtain the frequency response of common source FET amplifier and also measure the voltage gain and band width from the Figure 10.1.



Figure 10.1 Common source Amplifier

10.2 Common drain Amplifier

To obtain frequency response of common drain FET amplifier and measure the voltage gain and bandwidth of CD amplifier from the Figure 10.2.



Figure 10.1Common Drain Amplifier

Try

- 1. Plot the frequency response of FET BFW11 amplifier with C2=5µF with triangular/square i/p.
- 2. Plot frequency response of P-Channel JFET RG1=4.1K, RG2=9.4K with square i/p.
- 3. Design a FET amplifier in the common-source configuration uses a load resistanceof500 kV. The ac drain resistance of the device is 100kV and the trans conductance is 0.8mA/V. Calculate the voltage gain.
- 4. Construct common source follower amplifier with output impedance of 300 k Ω . Measure phase difference between input and output using digital simulation.
- 5. Design common source amplifier with voltage gain -10 and output impedance of 7 k Ω using digital simulation.
- 6. Design common source follower amplifier with output impedance of 300 k Ω . Measure phase difference between input and output.



7. Consider the amplifier in Figure 13.3. Find the input resistance and voltage gain of the circuit, given $gm=0.5m\Omega-1andRds=0.2M\Omega$.





10. Exercises on Regulated Power Supply

An electronic circuit that produces a stable DC voltage of fixed value across the load terminals irrespective of changes in the load is known as regulated power supply. Thus, the primary function of a regulated power supply is to convert an AC power into a steady DC power. The regulated power supply is sometimes also called as a linear power supply.

The regulated power supply ensures that the output power at the load terminals should remain constant even if the input power varies. The regulated power supply receives an AC power as input and generates a constant DC power as output.

Design a DC regulated power supply and determine the load regulation and efficiency of the regulated power supply



Figure11: Regulated Power Supply

Try

1. Design a 5 V DC regulated power supply to deliver up to 1A of current to the load with 5% ripple. The input supply is 50Hz at 230 V AC.

11. Exercises on Public Addressing System

A public address system (PA system) is an electronic sound amplification and distribution system with a microphone, amplifier and loudspeakers, used to allow a person to address a large public. The term is also used for systems which may additionally have a mixing console, and amplifiers and loudspeakers suitable for music as well as speech, used to reinforce a sound source, such as recorded music or a person giving a speech or distributing the sound throughout a venue or building.

Design an experiment to set up a basic PA system. Include a microphone, amplifier, and speakers.



Figure12: Public Addressing System

- 1. If the power supply was $\pm 15V$, then the maximum output would be limited to around $\pm 13V$. If the same amplifier was then connected to a $\pm 5V$ supply, without making any changes to the circuit, the maximum output would then be limited to just $\pm 3V$. We call this effect saturation.
- 2. An amplifier is designed to operate with a $\pm 12V$ power supply, providing a maximum output of $\pm 10V$. If the power supply is reduced to $\pm 9V$, what will be the new maximum output voltage, and how will this affect the performance of the public address system.

12. Final Notes

Student can have any one of the following certifications:

- NPTEL–Semiconductor Devices and Circuits
- NPTEL–Basic Electronics

V. TEXT BOOKS:

- 1. J. Millman, C.C.Halkias, Millman's, "Integrated Electronics", Tata McGraw Hill, 2nd Edition, 2001.
- J. Millman, C.C.Halkias and Satyabrata Jit, "Electronic Devices and Circuits", Tata Mc Graw Hill, 2nd Edition, 1998.

VI. REFERENCE BOOKS:

- 1. Mohammad Rashid, "Electronic Devices and Circuits", Cengage learning, 1st Edition, 2014.
- 2. David A. Bell, "Electronic Devices and Circuits", Oxford University Press, 5th Edition, 2009.

VII. ELECTRONICS RESOURCES:

- 1. https://archive.org/details/ElectronicDevicesCircuits
- 2. http://www.tedpavlic.com/teaching/osu/ece327/

VIII. MATERIALS ONLINE

- 1. Course template
- 2. Lab Manual

Try