## ELECTRONIC DEVICES AND CIRCUITS LABORATORY

| III Semester: ECE |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Course Code | Category | Hours / Week |  |  | Credits | Maximum Marks |  |  |
| AECC05 | Core | L | T | P | C | CIA | SEE | Total |
|  |  | 0 | 0 | 3 | 1.5 | 30 | 70 | 100 |
| Contact Classes: Nil | Tutorial Classes: Nil | Practical Classes: 36 |  |  |  | Total Classes:36 |  |  |
| Prerequisite: There are no prerequisites to take this course. |  |  |  |  |  |  |  |  |

## I. COURSE OVERVIEW:

This course provides the hands-on experience on designing circuits using Diodes, Bipolar Junction Transistors, Field Effect Transistors, UJTs and SCRs. Determine the gain, bandwidth and input output impedances of BJT and FET amplifiers. Provides the capability to extract the characteristics of semiconductor devices with simulation tools.

## 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 basic amplifier 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:

CO1 Demonstrate the electronic instruments for measuring voltage, current and phase parameters.
CO2 Experiment and determine the parameters of rectifiers and voltage regulators using the diode characteristics.
CO3 Examine the input and output characteristics of transistor (BJT and FET) configurations for determining input - output resistances.
CO4 Characterize BJT and FET amplifiers for estimating the voltage gain and Current gain.
CO5 Demonstrate the intrinsic stand-off ratio of the uni-junction transistor using volt ampere characteristics
CO6 Build and determine holding, latching current and break over voltage of silicon-controlled rectifier using volt - ampere characteristics.

## DO's

1. Once the operation is completed pull the plug itself rather chord attached to it.
2. Repair the equipment switch-off the supply and go on
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 overload 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 interconnect 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. COURSE CONTENT

## 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.
Step 2: Place components.
Step 3: Wire components.
Step 4: Place a simulation source.
Step 5: 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.

Draw the $V-I$ characteristics curve of $p-n$ junction diode under forward bias as shown in Figure 1.2.1.


Figure 1.2.1: p-n junction diode forward bias
1.2.2 V-I characteristics of $p-n$ junction diode under reverse bias
When n-type (cathode) is connected to +ve terminal and p-type (Anode) is connected - ve terminal of the supply voltage is known as reverse bias and the potential barrier across the junction increases.

Draw the $V-I$ characteristics curve of $\mathrm{p}-\mathrm{n}$ junction diode under reverse bias as in Figure 1.2.2.


Figure 1.2.2: p-n junction diodes reverse bias
Try

1. The reverse saturation current of a silicon $p-n$ junction diode is 10 mA . Calculate the diode current for the forward bias voltage of 0.6 V at $25^{\circ} \mathrm{C}$.
2. A diode connected to an external resistance and an e.m.f assuming that the barrier potential developed in diode is 0.5 V . Obtain the value of current shown in Figure 1.2.3 in milli-ampere.


Figure 1.2.3
3. The diode used in the Figure 1.2.4 has a constant voltage drop of 0.5 V at all current and a maximum power rating of 100 mill watts. What should be the value of the resistor $R$, connected in series with the diode for obtaining maximum current?


Figure 1.2.4

## 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.
Examine the Zener diode characteristics under forward bias from the Figure 2.1.


Figure 2.1: Zener diode forward bias

### 2.2 Zener diode under reverse bias

Examine the Zener diode characteristics under reverse bias from the Figure 2.2.


Figure 2.2: Zener diode reverse bias

### 2.3 Zener diode as voltage regulator

Examine the Zener diode as a Voltage Regulator from the Figure 2.3.


Figure 2.3: Zener diode as voltage regulator

Try

1. Design a zener voltage regulator circuit to drive a load of $6 \mathrm{~V}, 100 \mathrm{~mW}$ from an unregulated input supply of $\mathrm{Vmin}=8 \mathrm{~V}$, $\mathrm{Vmax}=12 \mathrm{~V}$ using a 6 V zener diode.
2. Find the maximum zener current for the zener diode which is connected in voltage regulator to protect the load. Given $\mathrm{V}_{\mathrm{z}}=6 \mathrm{~V}, \mathrm{R}_{\mathrm{z}}=1.5 \Omega, \mathrm{R}=400 \Omega$.
3. The potential of the battery is varied from 10 V to 16 V . If by zener diode breakdown voltage is 6 V , find maximum current through zener diode.

## 3. Exercises on Half 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.

### 3.1 Half wave rectifier without filter

Design a half-wave rectifier circuit and analyze the rectifier output without a filter in Figure 3.1


Figure 3.1: Half wave rectifier without filter

### 3.2 Half wave rectifier with filter

Design a half-wave rectifier circuit and analyze the rectifier output with filter as in Figure 3.2.


Figure 3.2: Half wave rectifier with filter

## Try

1. 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 300 V . 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 230 V 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. An AC supply of 230 V is applied to a half-wave rectifier circuit through a transformer of turn ratio 10:1. Find (i) the output d.c voltage and (ii) the peak inverse voltage. Assume the diode to be ideal.
4. A half-wave rectifier is used to supply 50 V d.c. to a resistive load of $800 \Omega$. The diode has a resistance of $25 \Omega$. Calculate a.c. voltage required.
5. A half wave rectifier has a load of 3.5 k . 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.

## 4. Exercises on Full wave rectifier with and without filter

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 $I_{d 1}$ through the load $R$.

### 4.1 Full wave rectifier without filter

Design a full-wave rectifier circuit and analyze the rectifier output without filter in Figure 4.1.


Figure 4.1: Full wave rectifier without filter

### 4.2 Full wave rectifier with filter

Design a full-wave rectifier circuit and analyze the rectifier output with filter in Figure 4.2.


Figure 4.2: Full wave rectifier with filter

## Try

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

## 5. Exercises on Transistor Common Base Characteristics

Common base (CB) configuration (or) Grounded base configuration. In this circuit arrangement, 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 and hence the name common base connection.

Plot the input and output characteristics of a transistor in common base configuration shown in Figure 5.1 and to compute the h - parameters.


Figure 5.1: Common base configuration

## Try

1. Plot the $I-V$ curves of n-p-n transistor based on observations. What collector-emitter voltage $\left(\boldsymbol{V}_{\boldsymbol{C E}}\right)$ does the transition from saturation to active region occur approximately?
2. Demonstrate the characteristics of common base using p-n-p transistor to determine the hparameters.
3. For the common base circuit, determine $\mathbf{I}_{\mathbf{c}}$ and $\mathbf{V}_{\mathbf{c b}}$. Assume the transistor to be of Germanium.

## 6. Exercises on Transistor Common Emitter Characteristics

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 ( $\mathrm{I}_{\mathrm{B}}$ ) with Base-emitter voltage ( $\mathrm{V}_{\mathrm{BE}}$ ), keeping Collector-emitter voltage ( $\mathrm{V}_{\mathrm{CE}}$ ) constant.

Plot the input and output characteristics of a transistor in common emitter configuration from the Figure 6.1 and compute the h - parameters.


Figure 6.1: Common emitter configuration

## Try

1. Design a circuit which acts as an electronic switch using common emitter configuration.
2. The output characteristics of a transistor connected in common emitter mode. Determine the value of $I_{C}$ when $\mathrm{V}_{C E}=15 \mathrm{~V}$. Also determine the value of $\mathrm{I}_{\mathrm{C}}$ when $\mathrm{V}_{\mathrm{CE}}$ is changed to 10 V .
3. Demonstrate the characteristics of Common Emitter using p-n-p transistor to determine the h parameters.

## 7. Exercises on Frequency Response of Common Emitter 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.

Obtain the frequency response curve of the below Figure 7.1 amplifier and determine the mid frequency gain, Amid, lower and higher cutoff frequency of the amplifier.


Figure 7.1: Common emitter amplifier

## Try

1. In a CE germanium transistor amplifier using self-bias circuit, $R_{C}=2.2 \mathrm{k} \Omega, \beta=50, \mathrm{VCC}=9 \mathrm{~V}$ and the operating point is required to be set at $\mathrm{I}_{\mathrm{C}}=2 \mathrm{~mA}$ and $\mathrm{V}_{\mathrm{CE}}=3 \mathrm{~V}$. Determine the values of $\mathrm{R} 1, \mathrm{R} 2$ and RE.
2. Compute the voltage gain from the Figure 7.2 by Assuming $\beta=150$.


Figure 7.2
3. Measure the voltage gain for the Figure 7.2. Adjust the input signal to approximately 10 mv 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 Figure7.3. Also determine $\mathrm{V}_{\text {load, }}$ if $\mathrm{V}_{\text {in }}=20 \mathrm{mV}$ peak. Assume $\beta=100$.


Figure 7.3

## 8. Exercises on Frequency Response of Common Collector Amplifier

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.

1. Design a common collector transistor ( $n-p-n$ ) amplifier circuit as shown in Figure 8.1.
2. Obtain the frequency response curve of the amplifier and determine the mid frequency gain, Amid, lower and higher cutoff frequency of the amplifier circuit as shown in Figure 8.1.


Figure 8.1: Common collector amplifier

1. Design a common-collector amplifier using the 2 N 3904 transistor that meets the following specifications: $\mathrm{I}_{\mathrm{C}}=1 \mathrm{~mA}, \mathrm{VCC}=20 \mathrm{~V}, \mathrm{R}_{\text {in }}=70 \mathrm{k} \Omega, \mathrm{R}_{\mathrm{L}}=510 \Omega, \mathrm{~V}_{\text {in }}=10 \mathrm{mV} @ 10 \mathrm{kHz}$. Determine the value of $\mathrm{R}_{\mathrm{E}}$.
2. Design a Common emitter amplifier using PNP transistor.
3. For the Common Collector amplifier showed in Figure 8.2, find the voltage gain ( $\beta=120$ ).


Figure 8.2

## 9. Exercises on UJT Characteristics

The UJT consists of an n-type silicon semiconductor bar with an electrical on each end. The terminals of these connections are called Base terminals (B1 and B2). Near to base B2, a p-n junction is formed between a p-type emitter and the n-type silicon bar. The terminal of this junction is called emitter terminal (E). Since the device has three terminals and one $p-n$ junction, for this region this is called as a Uni junction Transistor (UJT).

Simulate and analyze the characteristics of a UJT (Uni-junction Transistor) from the given below Figure 9.1.


Figure 9.1: Uni-junction Transistor characteristics
Try

1. Design an UJT relaxation oscillator to generate a sawtooth waveform at a frequency of 600 Hz .

Assume the supply voltage $\mathrm{V}_{\mathrm{BB}}=18 \mathrm{~V}, \mathrm{~V}_{\mathrm{p}}=2.9 \mathrm{~V}$ and $\mathrm{V}_{\mathrm{V}}=1.118 \mathrm{~V}$.
2. Plot the volt-ampere characteristics of UJT 2 N 46 with $R_{E}=R B 2=1 \mathrm{~K} \Omega$ and $R B 1=500 \Omega$.
3. Design and observe the characteristics of relaxation oscillator using Uni-Junction Transistor.

## 10. Exercises on SCR Characteristics

The SCR has three $p-n$ junctions, and four layer of $p$ and $n$-type semiconductor joined alternatively to get p-n-p-n device. The three terminals are taken one from outer p-type layer called anode (A), second from the outer $n$ - type layer called cathode $(K)$ and the third from the internal $p$-type layer called gate (G).

To observe and analyze the $V$-I Characteristics of Silicon Control Rectifier (SCR) and determine holding, latching current and break over voltage of given SCR in Figure 10.1.


Figure 10.1: Silicon Control Rectifier characteristics
Try

1. The SCR has gate trigger voltage $V_{T}=0.7 \mathrm{v}$, gate trigger current $\mathrm{I}_{T}=7 \mathrm{~mA}$ and holding current $\mathrm{I}_{\mathrm{H}}=6 \mathrm{~mA}$. Find the input voltage that triggers the SCR?
2. If $220 \Omega$ resistor is connected in series with the gate of an $S C R$. The gate current required to fire the SCR is 7 mA . What is the input voltage $\left(V_{i n}\right)$ required to fire the SCR?
3. A SCR full wave rectifier is connected across a sinusoidal voltage of $400 \sin 314 t$, the RMS value of the current flowing through the device is 20 A . Find the power rating of the SCR.

## 11. 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 11.1


Figure 11.1: Field effect transistor characteristics

## Try

1. Plot the drain and transfer characteristics of $P$-channel JFET BFW11/10/BF245A with RL=50 $\Omega$.
2. A JFET has the following parameters: IDSS $=32 \mathrm{~mA} ; \mathrm{VGS}(\mathrm{off})=-8 \mathrm{~V} ; \mathrm{VGS}=-4.5 \mathrm{~V}$. Find the value of drain current.
3. An $N$-channel JFET having $V p=-4 V$ and $V_{D S S}=10 \mathrm{~mA}$ is used in the circuit of Figure 11.2. The parameter values are $\mathrm{V}_{\mathrm{DD}}=18 \mathrm{~V}, \mathrm{Rs}=2 \mathrm{k} \Omega, \mathrm{R} 1=450 \mathrm{k} \Omega$ and $\mathrm{R} 2=90 \mathrm{k} \Omega$. Determine $\mathrm{I}_{\mathrm{D}}$ and $\mathrm{V}_{\mathrm{DS}}$.


Figure 11.2

## 12. Exercises on frequency response of Common Source amplifier

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

Obtain the frequency response of common source FET amplifier and also measure the voltage gain and bandwidth from the Figure 12.1.


Figure 12.1: Common source amplifier

## Try

1. Plot the frequency response of FET BFW11 amplifier with $\mathrm{C} 2=5 \mu \mathrm{~F}$ with triangular/square $\mathrm{i} / \mathrm{p}$.
2. Plot frequency response of $P$-Channel JFET $R G 1=4.1 \mathrm{~K}, \mathrm{RG} 2=9.4 \mathrm{~K}$ with square $\mathrm{i} / \mathrm{p}$.
3. Design a FET amplifier in the common-source configuration uses a load resistance of 500 kV . The ac drain resistance of the device is 100 kV and the transconductance is $0.8 \mathrm{~mA} / \mathrm{V}$. Calculate the voltage gain.

## 13. Exercises on Frequency Response of Common Drain Amplifier

A common 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

To obtain frequency response of common drain FET amplifier and measure the voltage gain and bandwidth of CD amplifier from the Figure 13.1.


Figure 13.1: Common drain amplifier

Try

1. Design a MOSFET amplifier and plot frequency response based on the given specifications.

Both the input and the output should be AC coupled
Dual Supply Voltage is $\pm 5 \mathrm{~V}$
Load Resistance, RL = 100 ohms
0 to peak output swing is greater than or equal to 2 V
voltage gain is 50
input resistance is 10 k ohms.
2. For the source follower shown in Figure13.2. Determine the input impedance and output voltage. Assume $\mathrm{V}_{\text {in }}=100 \mathrm{mV}$, IDSS $=30 \mathrm{~mA}, \mathrm{~V}_{\mathrm{GS}}(\mathrm{off})=-2 \mathrm{~V}$.


Figure13.2
3. Consider the amplifier in Figure 13.3. Find the input resistance and voltage gain of the circuit, given $\mathrm{gm}=0.5 \mathrm{~m} \Omega-1$ and $\mathrm{Rds}=0.2 \mathrm{M} \Omega$.


Figure 13.3

## 14. Exercises on Clippers and Clampers

A clipper circuit in which the diode is connected in series to the input signal and biased with positive reference voltage $\mathrm{V}_{\mathrm{r}}$ and that attenuates the positive portions of the waveform, is termed as Positive Series Clipper with positive $\mathrm{V}_{\mathrm{r}}$.
14.1 Positive and negative clippers with and without biasing

A biased clipper comes in handy when a small portion of positive or negative half cycles of the signal voltage is to be removed. When a small portion of the negative half cycle is to be removed, it is called a biased negative clipper.

Design non-linear wave shaping circuits as clippers shown in Figure14.1.1 and Figure14.1.2


Negative clipper


Figure14.1.1: Positive and negative clippers without biasing


Figure 14.1.2: Positive and negative clippers with biasing

### 14.2 Positive clamper

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.

Design non-linear wave shaping circuits as positive clampers shown in Figure 14.2.


Figure 14.2: Positive clamper

### 14.3 Negative clamper

A negative clamper circuit is one that consists of a diode, a resistor and a capacitor and that shifts the output signal to the negative portion of the input signal. The figure below explains the construction of a negative clamper circuit.

Design non-linear wave shaping circuits as negative clampers shown in Figure 14.3.


Figure 14.3: Negative clamper

Try

1. For the given circuit in Figure 14.6 for a $20 \mathrm{~V}_{\text {peak }}$ sinusoidal input $\mathrm{v}_{\mathrm{i}}$, what is the value of $\mathrm{v}_{\mathrm{i}}$ at which the clipping begins?


Figure14.6
2. For the given circuit in Figure 14.7, what is the minimum peak value of the output waveform if the input waveform is 10 V square wave with switching time of 1 second?
Assume that the input switches between +10 V and -10 V DC levels.


Figure14.7
3. For the given circuit in Figure 14.8 and input waveform, find the peak value of the output.


Figure14.8

## 15. Final Notes

## Student can have any one of the following certifications:

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


## V. REFERENCE BOOKS:

1. J. Millman, C.C.Halkias, Millman's, "Integrated Electronics", Tata McGraw Hill, 2 ${ }^{\text {nd }}$ edition, 2001.
2. J. Millman, C.C.Halkias and Satyabrata Jit, "Millman's Electronic Devices and Circuits", Tata McGraw Hill, $2^{\text {nd }}$ edition, 1998.
3. Mohammad Rashid, "Electronic Devices and Circuits", Cengage learning, $1^{\text {st }}$ edition, 2014.
4. DavidA. Bell,"ElectronicDevicesandCircuits",OxfordUniversityPress, $5{ }^{\text {th }}$ edition, 2009.

## VI. WEB REFERENCES:

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