**CSE251- Handout Spring 2024**

1. **Course General Information:**

| **Course Code:** | CSE251  CSE251L |
| --- | --- |
| **Course Title:** | Electronic Devices and Circuits |
| **Credit Hours** (Theory+Lab): | 3 + 0 |
| **Contact Hours** (Theory+Lab): | 3 + 3 |
| **Category:** | Program Core |
| **Type:** | Required, Engineering, Lecture + Laboratory |
| **Prerequisites:** | CSE250 |
| **Co-requisites:** | None |

1. **Course Catalog Description (Content):**

Introduction to semiconductors, p-type and n-type semiconductors; I-V characteristics of Non-linear devices; p-n junction diode characteristics; Diode applications: half and full wave rectifiers, regulated power supply using zener diode, diode-logic circuits. Bipolar Junction Transistor (BJT): principle of operation, I-V characteristics; Operational Amplifiers (OPAMP): linear applications of OPAMPs – summer, subtractor, differentiator, integrator; gain, input and output impedances; Application of OPAMPs as comparator; Transistor circuit configurations (CE), BJT biasing, load lines; Switching circuits using BJTs; Small-signal analysis of single-stage amplifiers. Field Effect Transistors (FET): principle of operation of MOSFET; Depletion and enhancement type NMOS and PMOS; biasing of FETs; Switching circuits using FETs; Mathematical analysis of BJT and MOSFET based circuits; The course includes a compulsory 3 hour laboratory work each week.

1. **Course Objective:**

The objectives of this course are to:

1. Introduce Electronic Devices such as Diodes and Transistors, and, semiconductor physics principles used to make them
2. Introduce the Piece-Wise Linear modeling technique to analyze circuits with non-linear devices
3. Show the application of diodes in constructing various circuits, such as, rectifiers, regulators, etc.
4. Show the application of transistors in building switching circuits and amplifiers with appropriate biasing methods.
5. Introduce students to the Operational Amplifier, it’s application as a comparator and also in different circuits to perform analog signal-processing tasks, such as, Summing, Subtracting, Exponentiating, etc.
6. Training students to prototype circuits in hardware and analyzing their behavior
7. Exposing students to Circuit simulation tools to aid them in analyzing circuit behavior before implementing them in real life.
8. Guiding students to complete a project using transistors, Op-Amps to implement their knowledge of Non-linear devices.
9. **Course Outcomes (COs):**

Upon successful completion of this course, students will be able to

| **Sl.** | **CO Description** | **Weightage (%)** |
| --- | --- | --- |
| CO1 | **Understand** and **compare** the characteristics and operation of electronic devices such as Diode, BJT, MOSFET and Op-Amps. | 10% |
| CO2 | **Analyze** the behavior ofelectronic circuits consisting of different non-linear electronic devices such as Diodes,BJT, MOSFETs using tools such as piece-wise linear modeling and method of assumed states | 25% |
| CO3 | **Design** various electronic circuits for power-generation and analog signal-processing applications such as rectifiers, regulators, switching, analog-to-digital and digital-to-analog conversion, amplification, performing arithmetic operations on analog Signals, e.g, summing, subtracting, exponentiation and generating voltage waveforms of different shapes. | 35% |
| CO4 | **Demonstrate** competence in using electronic laboratory equipment to build, test, and troubleshoot electronic circuits. | 15% |
| CO5 | Collaborate effectively in a group to design, build and **execute** a project that demonstrates the application of electronic devices and circuits to a real-world problem. | 10% |

1. **Mapping of CO-PO-Taxonomy Domain & Level- Delivery-Assessment Tool:**

| **Sl.** | **CO Description** | **POs** | **Bloom’s taxonomy**  **domain/level** | **Delivery methods**  **and activities** | **Assessment**  **tools** |
| --- | --- | --- | --- | --- | --- |
| CO1 | **Understand** and **compare** the characteristics and operation of electronic devices such as Diode, BJT, MOSFET and Op-Amps | **PO1** | Cognitive/Analyze, Understand | Lectures, Notes/Handouts, Simulation Demo | Quiz, Exam, Assignment |
| CO2 | **Analyze** the behavior ofelectronic circuits consisting of different non-linear electronic devices i.e. Diodes,BJT, MOSFETs using appropriate models and methods such as piece-wise linear models and Method of assumed states | **PO2** | Cognitive/Analyze, Apply | Lectures, Notes/Handouts, Simulation Demo | Quiz, Exam, Assignment |
| CO3 | **Design** various electronic circuits for power-generation and analog signal-processing applications such as rectifiers, regulators with diodes, switching and amplification using transistors and perform arithmetic operations on Analog Signals, e.g, Summing, Subtracting, Exponentiation using Op-Amps. | **PO3,PO5** | Cognitive/Evaluate, Apply,Analyze | Lectures, Notes/Handouts, Simulation Demo | Quiz, Exam, Assignment |
| CO4 | **Demonstrate** competence in using laboratory equipments to build, test, and troubleshoot electronic circuits | **PO3,PO9** | Cognitive/ Analyze, Apply, Psychomotor/Precision, Manipulation | Lab Class | Lab Work, Lab Test |
| CO5 | Collaborate effectively in a group to design, build and **execute** an electronic project that demonstrates the application of electronic devices and circuits to a real-world problem. | **PO3,PO9** | Cognitive/Create, Analyze, Apply, Psychomotor/Precision, Manipulation | Lab Class | Lab Work, Q/A, Presentation |

1. **Course Materials:**
2. **Text and Reference Books:**

| **Sl.** | **Title** | **Author(s)** | **Publication Year** | **Edition** | **Publisher** | **ISBN** |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | Foundations of Analog and Digital Electronic Circuits | Anant Agarwal, Jeffrey H. Lang | 2005 | 1st ed. | Morgan Kaufmann Publishers | 978–1–55–860735–4 |
| 2 | Microelectronic Circuits | Adel S. Sedra, Kenneth C. Smith | 2015 | 7th ed. | Oxford University Press | 978–0–19–933913–6 |
| 3 | The Art of Electronics | Paul Horowitz, Winfield Hill | 2016 | 3rd ed. | Cambridge University Press | 978–0–521–80926–9 |
| 4 | Operational Amplifiers and Linear Integrated Circuits | Robert F. Coughlin, Frederick F. Driscoll | 2001 | 6th ed. | Prentice Hall | 978–0–130–14991–6 |

1. **Other materials**
2. Lecture Notes/Handouts
3. Video Lectures (buX Course – Circuits and Electronics)
4. Lab Sheets
5. **Lesson Plan:**

Theory

| No | Topic | Week/Lecture# | Related CO (if any) |
| --- | --- | --- | --- |
|  |  |  |  |
|  | History and Importance of Electronic Devices – Diodes, Electronic Switches and Amplifiers, Transition from Mechanical Switches to Vacuum Tubes to Solid State Devices, Current State-of-the-Art in Electronics/Semiconductor Technology | Lecture-1 | CO1 |
|  | Alternative circuit representation; Review of KCL,KVL, Nodal analysis | Lecture-2 | CO3 |
|  | Introduction to Operational Amplifiers – Differential Amplifiers; Solving Op-Amp based circuits using KCL,KVL and Nodal Analysis; Op-Amp Circuits in Open-Loop Configuration – Square Wave Generator, Characteristics of Infinite Gain. | Lecture-3 | CO1, CO2 |
|  | Op-Amp Circuits in Closed Loop Configuration - Controlling Gain through Negative Feedback, Virtual Ground  Op-Amp Circuits in Closed Loop Configuration – Inverting Amplifier, Non-Inverting Amplifier, | Lecture-4 | CO2,CO3 |
|  | Op-Amp applications in Follower, Buffer, Inverting Weighted Summer, Weighted Subtractor, Exponential Converter, Logarithmic Converter, Multiplier, Divider, Differentiator, Integrator | Lecture-5 | CO2,CO3 |
|  | Introduction to I-V Characteristics. I-V Characteristics of:  Simple Linear Elements – Resistors, Voltage Source and Current Source; Hybrid Linear Elements – Voltage Source in series with Resistor, Current Source in parallel with Resistor;  Source-Conversion; I-V Characteristics of: Degenerate Elements – Open-Circuit and Short-Circuit; Finding I-V of Series/Parallel Combination; | Lecture-6 | CO2 |
|  | I-V Characteristics of Piecewise Linear Elements. Finding Device Parameters from I-V Graphs, Problem-Solving; Introduction to Non-Linear Elements: Ideal Diodes | Lecture-7 | CO1,CO2 |
|  | Constructing a Real Diode – Introduction to Semiconductors, n-type and p-type doping, P-N junction, Schokley Diode Equation and , Diode Logic Gates. | Lecture-8 | CO1,CO3 |
|  | Real diode equation and Characteristics, PWL Model of Diodes, Solving Diode Circuits | Lecture-9 | CO1,CO2 |
|  | Solving Diode Circuits, Introduction to Rectifiers, Half-Wave Rectifiers and Transfer Characteristics, Full-Wave Rectifiers and Transfer Characteristics | Lecture-10 | CO2,CO3 |
|  | Rectifiers Revisited – Average Value of Output, Smoothing Capacitor, Peak-to-Peak Ripple, Ripple Factor | Lecture-11 | CO3 |
| **Mid-Term Exam** | | | |
|  | Introduction to Voltage Regulators, Drawbacks of Voltage Regulation using Diodes, Zener Diodes, Breakdown Voltage. Finding Vin(min) and Iout(max) of an \*ideal\* Zener Regulator, Regulators Revisited, Line-Regulation, Load Regulation, Knee Current, Problem-Solving | Lecture-12 | CO3 |
|  | Introduction to Electronic Switches, Basic Inverter, Introduction to Controlled Sources, Introduction to MOSFET, Designing Logic gates with MOSFETs | Lecture-12 | CO1,CO3 |
|  | Constructing a \*real\* MOSFET – n/p-channel, enhancement/depletion-type MOSFETs. Operation of an Ideal FET- Cut-Off, Saturation and Triode Mode, Output Characteristics,PWL Model and Non-ideal Analysis, Static Analysis | Lecture-13 | CO1 |
|  | Solving MOSFET Circuits using Method of Assumed States | Lecture-14 | CO2 |
|  | Solving MOSFET Circuits using Method of Assumed States, | Lecture-15 | CO2 |
|  | Introduction to BJT, Voltage-Current Conversion using Resistors, Constructing a \*real\* BJT – npn and pnp transistors,Ebers-Moll Equation, Current and Voltage controlled logic gates | Lecture-16 | CO1 |
|  | Operation of an Ideal BJT- Cut-Off, Active and Saturation Mode, Ideal Output Characteristics, PWL Model & Non-ideal Analysis, Solving Transistor Circuits using Method of Assumed States, Problem-Solving | Lecture-17 | CO1,CO2 |
|  | Introduction to Amplifiers ,Common Emitter Amplifiers, Small Signal amplifier | Lecture-18 | CO3 |
|  | Small Signal amplifier Mathematical examples | Lecture-19 | CO3 |
|  | Introduction to DTL, RTL | Lecture-20 |  |
| **Final Exam** | | | |

| **Important dates:**   * **Jan 20th** (Saturday) Classes of Spring 2024 begin * **TBA**: Midterm exam (TBA) * **April 30th** (Tuesday) Last class of Spring 2024 * **2/05/2024 (4:30 PM-6:30 PM)** |
| --- |

# Marks Distribution

| **Assessment** | **Percentage** | **Total number of assessments** | **Number of assessment to be graded** |
| --- | --- | --- | --- |
| Attendance | 7% | - | - |
| Assignment | 12% | 6 | Best 5 |
| Quiz | 14% | 4 | Best 3 |
| Midterm | 22% | 1 | 1 |
| Final | 20% | 1 | 1 |
| Lab | 25% | - | - |

# Exams (subject to change)

| **Exam** | **Syllabus** |
| --- | --- |
| Quiz 1 | Lecture 1 - 5 |
| Quiz 2 | Lecture 7 - 11 |
| **Midterm** | **Lecture 1 - 10** |
| Quiz 3 | Lecture 13 - 17 |
| Quiz 4 | Lecture 16 - 20 |
| **Final** | **Lecture 11 - 20** |

# Course Policy

## Weekly Classes.

* Theory classes –[USIS Schedule]
* **Attendance policy – Mandatory [at max 3 attendance will be considered]**

# Quiz,Midterm and Final

* At least 4 quizzes will be taken.
* Marks of best (n-1) quizzes will be considered.
* Quiz questions should help prepare the students for the midterm and final exams.
* Quiz, midterm, and final may contain bonus questions, but that will be at most 10% of the total marks of the assessment.
* Questions for quiz, midterm, and final are often modified versions of assignments

# Assignments

The main point of the assignments is for the students to test their understanding and to get some practice materials for midterm and finals. Hence, all assignments should collectively cover the whole syllabus.

There will be **at least 4 to 6** assignments spread throughout the semester, and the marks of best **(n-1)** will be considered. We will try to make sure that the assignment submission deadlines do not overlap with quiz/mid/final dates.

## Collaboration policy

* Can discuss the assignment questions in **study groups**
* Have to understand and write solutions independently (no copying)
* **Collaboration ≠ Copying**, severe penalty for direct plagiarism

## Late Submission Policy for Assignments

* Up to 2 late days per assignment
* Up to 4 “free” late days
* After exhaustion of free late days, per day 25% penalty
* Medical emergencies (with documents) will be considered separately

**Example:** If the assignment is due on 16th October 5:00 PM, and a student turns in their assignment before 17th October 4:59 PM, it would be considered as one late day. A student can use up to 4 late days throughout the semester without any penalty. However, assignments submitted two days after the deadline will not be accepted even if the student has free late days available.

# Communication Platform

All communication will be done via **Discord only**

## Things \***NOT**\* to Do

Any form of plagiarism/cheating/copying may result in negative marking/grade capping/suspension from BracU.

Any type of bullying/harassment will not be tolerated

**Messaging/mentioning faculty in Discord outside of office hours (8 AM - 5 PM)**

# Attendance:

In a tri-semester system, we get about 20 ~ 22 lectures. Following rules should apply for attendance of these classes:

* Attendance will be recorded in a Google sheet and will be shared with the students
* Attendance will be counted in the following 4 categories: **Present (P) / Absent (A) / Late (L) / Excused absence (E) . 3 Lates = 1 Absent = 0.5 marks** penalty of total attendance marks
* **3 absences** should be excused without any penalty
* Excused absences must be backed by relevant documents (e.g. medical reports)
* Class performance marks might be offered based on student's participation, but should not be more than 10% of total attendance marks.
* Students having less than 70% attendance might be reported. In such a case, he/she will be eligible for Midterm and Final exam only if the faculty agrees to it.
* A student with class attendance **below 70%** must consult with the instructor in order to discuss the completion of the course.

# 

# Bonus Marks Policy:

Each exam may carry some bonus questions for exceptional students. Bonus marks might be offered within each category, but **will be capped to full marks** within that category. Bonus marks **will not exceed 10%** of the total marks of the exam.

**Example**:If a student get 1.5 bonus marks in quiz but gets 14 out of 15 marks in Quiz, then s/he gets MIN(14+1.5, 15)=15

# Lecture Plan & Contents

**Lecture 1**:

* Intro to the course, Why CSE251
* Brief history of electronics

**Lecture 2**:

* Alternative circuit representation
* Review of CSE250 topics (KCL, KVL, nodal)

**Lecture 3**:

* Introduction to Operational Amplifiers – Differential Amplifiers
* Solving Op-Amp based circuits using KCL,KVL and Nodal Analysis
* Op-Amp Circuits in Open-Loop Configuration – Square Wave Generator
* Characteristics of Infinite Gain
* Intro to Op-Amp comparator

**Lecture 4**:

* Op-Amp Circuits in Closed Loop Configuration - Controlling Gain through Negative Feedback, Virtual Ground
* Op-Amp Circuits in Closed Loop Configuration – Inverting Amplifier, Non-Inverting Amplifier,
* Application of Op-Amp as comparator

**Lecture 5**:

* Mathematical applications: Using Op-Amp in Follower, Buffer, Inverting Weighted Summer, Weighted Subtractor, Differentiator, Integrator

**Lecture 6**:

* Introduction to IV characteristics
* I-V Characteristics of simple Linear Elements – Resistors, Voltage Source and Current Source & Hybrid Linear Elements – Voltage Source in series with Resistor, Current Source in parallel with Resistor
* Source-Conversion; I-V Characteristics of Degenerate Elements – Open-Circuit and Short-Circuit

**Lecture 7**:

* Intro to non-linear devices
* IV characteristics of non-linear devices: Introduction to Ideal diodes
* Diode Logic Gates
* Different input voltage analysis

**Lecture 8**:

* Introduction to diode [Review]: Constructing a Real Diode – Introduction to Semiconductors, n-type and p-type doping, P-N junction
* Shockley Diode Equation
* Piecewise linear approximation.

**Lecture 9**:

* Diode non-idealities : Real diode equation and characteristics graphs
* PWL Model of real Diodes : CVD model, CVD+R model
* Introduction to Method of assumed state

**Lecture 10**:

* Problem solving using Method of assumed states
* Examples
* Introduction to Rectifiers
* Halfwave rectifier design and transfer characteristics
* Full-wave rectifier design and transfer characteristics

**Lecture 11**:

* Half wave & Full-wave rectifier design and transfer characteristics with smoothing capacitor
* Ripple voltage, Average Value of Output, Peak-to-Peak Ripple, Ripple Factor, Input-Output graphs
* Mathematical problems

**Lecture 12**:

* Introduction to Voltage Regulators
* Drawbacks of Voltage Regulation using Diodes
* Zener Diodes : I-V characteristics, breakdown Voltage, voltage regulation using Zener diodes
* Problem-Solving : Conditions of using Zener diode as regulator

**Syllabus before midterm ends**

**Lecture 13**:

* Introduction to Electronic Switches
* Basic Inverter configuration
* Introduction to Controlled Sources
* Introduction to MOSFETs
* MOSFET as a digital switch (S-Model)
* Designing Logic gates with MOSFETs

**Lecture 14**:

* Constructing a \*real\* MOSFET – n/p-channel
* Operation of an Ideal FET- Cut-Off, Saturation and Triode Mode
* Output Characteristics
* PWL Model and Non-ideal Analysis: SR model
* Real MOSFET equations
* Introduction to Static analysis

**Lecture 15**:

* VTC of NAND gate and static analysis
* MOSFET in DC
* Introduction to Method of assumed state for MOSFET

**Lecture 16**:

* Method of assumed state for MOSFET

**Lecture 17**:

* Introduction to BJT, Constructing a \*real\* BJT – npn and pnp transistors, Ebers-Moll Equation
* Voltage-Current Conversion using Resistors
* S-model of BJT
* Current & voltage controlled logic gates

**Lecture 18**: **[QUIZ 3]**

**Lecture 19**:

* Operation of an Ideal BJT: Cut-Off, Active and Saturation Mode
* Ideal Output Characteristics
* PWL Model & Non-ideal Analysis
* Solving Transistor Circuits using Method of Assumed States

**Lecture 20**:

* Types of amplifiers
* Common-emitter configuration
* Introduction to BJT Small signal amplifier

**Lecture 21**:

* BJT Small Signal Amplifier Mathematical Examples
* RTL & DTL logic family (brief)

**Lecture 22**:

* **[QUIZ 4]**