ECEN 222

Maxx Seminario

Electronic Circuits

Lecture 0: Course Introduction and Overview

Maxx Seminario

University of Nebraska-Lincoln
Department of Electrical and Computer Engineering

January 2026

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Outline

Teaching Staff

Instructor

Maxx Seminario
Office hours: Mondays 1:30 – 2:30 PM, SEC C215, or by appointment
e-mail: mseminario2@huskers.unl.edu

Teaching Assistant

Thomas Gokie
Office hours: TBD
e-mail: tgokie2@huskers.unl.edu

Course Resources

- Canvas: canvas.unl.edu
- All materials, assignments, and announcements posted on Canvas

Class Meetings

Lecture

- Mondays, Wednesdays, Fridays: 12:30 – 1:20 PM
- Location: NH W131

Laboratory

- Weekly 3-hour lab sessions (Date TBD)
- Work in groups of two students
- Hands-on experience with electronic circuits
- Lab reports due one week after session

Inclement Weather

If in-person classes are canceled, you will be notified of the instructional continuity plan via Canvas

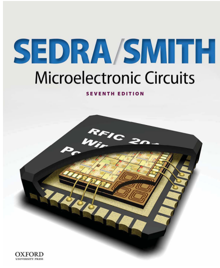
Textbook and Resources

Course Textbook

- *Microelectronic Circuits*, 7th Edition
- Authors: Adel S. Sedra and Kenneth C. Smith
- Oxford University Press, 2015
- ISBN: 978-0-19-93913-6

Additional Materials

- Lecture notes (comprehensive, posted on Canvas)
- SPICE simulation files (Multisim)
- Laboratory manuals



Course Evaluation

Grading Breakdown

- In-Class Quizzes: 10%
- Homework Assignments: 30%
- Laboratory Reports: 30%
- Exams: 30%

Homework Policy

- Assigned Friday, due following Friday at 11:59 PM
- Submit single PDF on Canvas
- Discussion encouraged, but individual work required
- Late penalty: 20% per day, unless previously approved by instructor

Laboratory Component

Lab Format

- 10 laboratories throughout semester
- Groups of two students, individual lab reports required
- Reports due one week after lab session
- Late penalty: 20% per day

What to Expect

- Hands-on circuit construction on breadboards
- Measurement using oscilloscopes, multimeters, function generators
- Comparison of theoretical predictions with experimental results
- Development of practical circuit design skills

From Circuits to Electronics

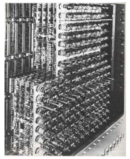
What you learned in Circuits I (ECEN 213/218)

- Linear circuit elements: resistors, capacitors, inductors
- Ideal sources (voltage and current)

What we'll learn in Electronic Circuits

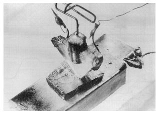
- **Active, nonlinear** semiconductor devices
- Diodes, transistors (BJT and MOSFET)
- Signal amplification and switching
- Digital logic circuits
- Practical circuit design and implementation

The Semiconductor Revolution



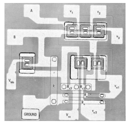
Vacuum Tube

(1900s-1950s)



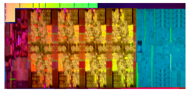
First Transistor

(Bell Labs, 1948)



First IC

(Moterola ECL 3-input Gate, 1960)



Modern CPU - Intel Core i9-9900K Microprocessor

(2018, 1 Billion Transistors, 3.6 GHz Operation, 14nm)

Impact

- Enabled modern computing, communications, and information age
- Foundation of all modern integrated electronic systems

Why Study Electronics?

Ubiquity

- Smartphones
- Computers
- Automotive systems
- Medical devices
- Power systems
- Communications
- IoT devices
- Renewable energy

Career Relevance

- IC design
- Embedded systems
- Power electronics
- RF/wireless design
- Analog/mixed-signal
- Test engineering
- Research & development

Electronics is foundational to modern electrical and computer engineering

Course Objectives

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By the end of this course, you will be able to:

1. Understand the **physics and operation** of semiconductor devices:
   - Diodes, BJTs, MOSFETs
2. Analyze the **nonlinear I-V characteristics** of these devices
3. Design and analyze **DC bias circuits** for transistors
4. Perform **small-signal analysis** for amplifier applications
5. Design **single-stage amplifiers** with specified gain and impedance
6. Understand **transistor switching** and digital logic circuits
7. Build and test circuits in the laboratory
8. Use **SPICE simulation** tools for circuit analysis

Unit 1: Signals and Amplifiers

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Topics

- Signal classification: analog vs. digital
- Frequency spectra and bandwidth
- Introduction to amplifiers as circuit building blocks
- Amplifier models and parameters: gain, input/output impedance

Why Start Here?

- Establishes terminology and fundamental concepts
- Introduces the *purpose* of electronic circuits: signal processing
- Provides context before diving into device physics

Reading: Sedra & Smith Chapter 1

Unit 2: Operational Amplifiers

Topics

- Ideal op-amp model
- Inverting and non-inverting configurations
- Op-amp applications: summing, difference, integrator, differentiator
- Non-ideal characteristics: finite gain, bandwidth, slew rate

Note

- Op-amps are *complex* circuits made from transistors
- We treat them as "black boxes" first
- Later, we'll understand their internal design using transistors
- Immediate practical applications

Reading: Sedra & Smith Chapter 2

Unit 3: Semiconductors

Topics

- Intrinsic and extrinsic semiconductors
- n-type and p-type doping
- Current flow: drift and diffusion
- The pn junction and depletion region under bias: forward and reverse
- I-V characteristics of pn junction

Foundation for Integrated Circuits

- Understanding semiconductor physics is crucial
- Explains *why* devices behave as they do
- Necessary for diodes and transistors

Reading: Sedra & Smith Chapter 3 (Sections 3.1-3.2)

Unit 4: Diodes

Topics

- Ideal diode model
- Diode equation and terminal characteristics
- Circuit models: ideal, constant voltage drop, small-signal
- Rectifier circuits: half-wave, full-wave, bridge
- Limiting and clamping circuits

First Real Semiconductor Device

- Simplest nonlinear device
- Foundation for understanding transistor junctions
- Important practical applications

Reading: Sedra & Smith Chapter 3

Unit 5: MOSFETs (The Best)

Topics

- Device structure and physical operation
- I-V characteristics: cutoff, triode, saturation
- DC circuit analysis and biasing
- MOSFET as amplifier and switch
- Small-signal model and parameters (g_m, r_o)
- Single-stage amplifiers: common-source, source follower

Why MOSFETs First?

- Dominant in modern digital ICs
- Foundation for CMOS technology

Reading: Sedra & Smith Chapter 4

Unit 6: Bipolar Junction Transistors

Topics

- Device structure and physical operation
- Modes of operation: cutoff, active, saturation
- I-V characteristics and Ebers-Moll equations
- DC circuit analysis and biasing techniques
- Small-signal model and parameters (β, g_m, r_π)
- Single-stage amplifiers: common-emitter, emitter follower

Complementary to MOSFETs

- Current-controlled device
- Lost the IC design battle to MOSFETs but important for discrete electronics

Reading: Sedra & Smith Chapter 5

Unit 7: Transistor Amplifiers

Topics

- Common-source (CS) and common-emitter (CE) with loads
- Common-gate (CG) and common-base (CB) amplifiers
- Source/emitter degeneration for linearity
- Source/emitter followers as buffers
- Current mirrors and active loads
- High-frequency response and Miller effect

Synthesis and Design

- Practical amplifier design techniques
- SPICE simulation exercises

Reading: Sedra & Smith Chapters 6-7

Unit 8: Digital Circuits

Topics

- CMOS inverter: static and dynamic characteristics
- Voltage transfer characteristics (VTC)
- Noise margins and logic levels
- Power dissipation: static and dynamic
- Propagation delay
- NAND, NOR, and complex logic gates
- CMOS transmission gates

Design and Simulation

- Emphasis on practical design techniques
- Use of SPICE for performance analysis

Reading: Sedra & Smith Chapters 10-11

Unit 9: Digital IC Design

Topics

- Logic gate design and optimization
- Pass-transistor logic
- Dynamic logic circuits
- Memory cells: SRAM and DRAM basics
- SPICE simulation of digital circuits

Note

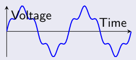
- There are advanced level complete courses on these topics, ECEN 470/870 (Digital VLSI Design)
- This unit provides an introduction to digital IC design concepts and techniques

Reading: Sedra & Smith Chapters 10-11

Signals: Analog vs. Digital

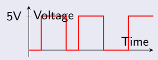
Analog Signals

- Continuous in time and amplitude
- Examples: audio, sensor outputs, RF
- Susceptible to noise
- Requires linear amplification



Digital Signals

- Discrete levels (typically 2: 0 and 1)
- Examples: computer data, logic signals
- Noise immunity
- Requires switching circuits

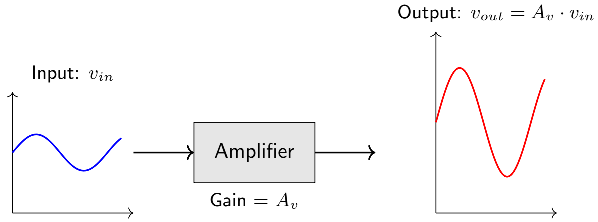


This course covers both: analog circuits (amplifiers) and digital circuits (logic gates)

What is an Amplifier?

Definition

A circuit that increases the amplitude of a signal while (ideally) preserving its shape



Why Do We Need Amplifiers?

Weak Signals Need Amplification

- Microphone output: 1-10 mV
- Antenna signal: μV to mV range
- Sensor outputs: often very small

Examples

- **Audio system:** Microphone → Amplifier → Speaker
- **Radio receiver:** Antenna → RF Amplifier → Demodulator
- **Communications:** Weak signal → Amplifier → Transmitter

Key Requirement

Amplification must preserve signal fidelity (minimize distortion)

The Transistor: Building Block of Electronics

What is a Transistor?

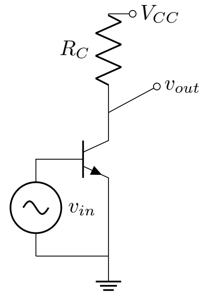
- Three-terminal semiconductor device
- Acts as electronically controlled switch or amplifier
- Small signal controls large current/voltage
- Nonlinear device

Two Main Types

- **BJT:** Current-controlled
- **MOSFET:** Voltage-controlled

Simple Amplifier Concept

Common-Emitter Amp



Small v_{in} controls large v_{out}

Linear vs. Nonlinear Devices

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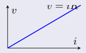
Linear Devices (Circuits I)

- Resistor: $v = iR$
- Capacitor: $i = C\frac{dv}{dt}$
- Inductor: $v = L\frac{di}{dt}$

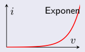
Property: Superposition applies



Nonlinear Devices (This Course)

- Diode: $i = I_s(e^{v/V_T} - 1)$
- MOSFET: $i_D \propto (v_{GS} - V_{th})^2$
- BJT: $i_C = I_s e^{v_{BE}/V_T}$

Property: Superposition does NOT apply



Challenge

Analysis of nonlinear circuits requires new techniques.

DC Analysis vs. AC Analysis

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Key concept for transistor circuits:

DC (Bias) Analysis

- Establish the operating point (Q-point)
- All capacitors open circuit, all inductors short circuit
- Determines DC voltages and currents
- Ensures transistor operates in desired region
- Uses large-signal models

AC (Small-Signal) Analysis

- Analyze behavior for small variations around Q-point
- All DC sources set to zero (AC ground)
- Capacitors short circuit (at signal frequency)
- Uses linearized small-signal models

SPICE Simulation

What is SPICE?

- **S**imulation **P**rogram with **I**ntegrated **C**ircuit **E**mphasis
- Industry-standard circuit simulator
- We'll use Multisim (National Instruments)

Why Use SPICE?

- Higher accuracy than pencil-and-paper calculations
- Explore parameter variations quickly
- Visualize waveforms and frequency response
- Test designs before building hardware
- Learn industry-standard tool