Solid State Devices: Course Materials

This page contains **Syst** Solid State devices course materials and relevant information. Toggle the tabs below to view all the content of this course area.

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Traditional View

Most AAS degree curricula in electronics technology contain a course called Solid State Electronics or Solid State Circuits. Alternate names are Semiconductor Devices or Linear Circuits. Whatever the name, most of these courses teach the basics of semiconductor materials and semiconductor devices like diodes and transistors. The courses go on to introduce basic electronic circuit such as power supplies, amplifiers and other related analog or linear circuits. Integrated circuits are introduced. The course usually concludes with an introduction to SCRs and thyristors of various types.

In these courses, the emphasis has always been on bipolar junction transistors (BJTs) and their circuits. FETs are introduced but with less circuit coverage. There is extensive coverage of BJT circuit biasing as well as in-depth circuit analysis of basic amplifier circuits using BJTs. Less coverage is given to FET circuits.

Most IC coverage is directed at op amps. While some courses only mention op amps in preparation for a later more advanced linear circuits course, most do a good job of covering the basic op amp circuits. Some coverage is given to IC audio power amps and well as 3-terminal linear regulators. With today's electronic technician doing more troubleshooting, maintenance and repair at the systems level, there is actually little need for much of the material covered in these courses. Most courses were developed in the 1970s and 1980s so they are severely dated and skewed from current needs. While some of the material, especially the fundamentals, can be retained most of it can be greatly minimized and replaced with more current relevant material.

New Systems View

The technician of today works more with PC boards, ICs, modules, sub-assemblies, equipment and complete systems there is little need to teach in-depth circuit analysis. While it is essential that the technician understand basic semiconductor principles, there is little need to learn of the detailed particle physics some courses still teach. Some elementary principles are usually sufficient.

There is also a need to shift emphasis from a BJT emphasis to a more FET centric approach. While BJTs must still be taught, today most transistors in use today, inside ICs as well as discrete are MOSFETs. Better than 90 % of all transistor usage is MOSFET. There must be more FET coverage and related FET circuits. And even that coverage can be minimal since so much of that circuitry is in IC form that can never be accessed by a tech anyway.

Another area that needs updating is power supplies. Most power supplies are of the bus oriented type with switching regulators, DC-DC converters and other switch mode devices. A more up to date system approach is needed with some details about how switch mode devices work and why they are preferred. Coverage should favor ICs and larger systems. Complete circuits and a block diagram analysis with a troubleshooting flavor should be included.

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Solid State Devices Instructional Materials List
Last Update: June 27, 2013

Click on the desired materials to download. By downloading, you agree to the terms of use of eSyst.

1. Student Guide: Power Amplifier Class Comparison Lab
   In this lab, the student will analyze four different classes of amplifiers and compare their efficiencies.

2. Student Guide: Device Pathology
   When an electronic component fails, a process like a crime scene investigation is carried out. In most cases, the cause is simple, obvious and fixable but in others it is more challenging and potentially expensive. Attribution of cause is a job for experts but their task is made easier if the first responders understand the basics of device pathology and the need for accurate documentation.

3. Student Guide: The Role of Devices in Systems Lab
   Electronic devices provide the critical enabling technology for today's advanced systems. Their performance and limitations depend on a long and complex chain of features that stretch from materials to systems architectures. The purpose of this module is to demonstrate some of these features through reverse engineering.

4. Instructor Guide: The Role of Devices in Systems Lab
   Electronic devices provide the critical enabling technology for today's advanced systems. Their performance and limitations depend on a long and complex chain of

features that stretch from materials to system architectures. The purpose of this module is to demonstrate some of these features through reverse engineering.

5. Student Guide: DC to DC Up Converter
The purpose of this lab is to introduce the student to Switch mode power supplies.

6. Instructor and Student Resource: WRE MOSFET Module
This module is designed to provide the student with a contemporary look at modern MOSFET circuits and applications. The following topics are covered: operation of the most commonly used types of MOSFETs, MOSFET biasing, basic MOSFET linear circuits including current sources and differential amplifiers, basic MOSFET switching circuits with an emphasis on complementary MOS (CMOS), and how to safely handle MOSFETs.

* Instructors should contactmike.lesiecki@domail.maricopa.edu , eSyst Director, for an answer key.

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Student Learning Outcomes

Toggle the arrows to view the SLOs. New student learning outcomes (SLOs) are listed in red.

Solid State Devices And Circuits

1. Explain semiconductor material structure and how it can be doped to produce P and N-type materials.

2. Name the most common semiconductor materials and compound semiconductors.

3. Show how a diode is formed with a PN junction.

4. Explain the operation of a diode.

5. Explain the characteristics, operation and applications of the LED, zener, varactor, PIN and Schottky diodes.

6. Identify half wave, full wave and bridge rectifier circuits and trace current through them.

7. Draw the output waveforms of half wave and full wave rectifier circuits and state the ripple frequency based on the input AC frequency.

8. Explain the operation of a power supply filter capacitor and calculate the size of a capacitor for a given load current and desired ripple output level.

9. Draw a generic block diagram of a power supply identifying all the major circuits and explaining the basic function and operation of each. Calculate output voltage from inputs and component values and configuration.

10. Define voltage regulation as it applies to power supplies, state the factors influencing regulation, and calculate the value of regulation given input and output voltage levels and load values.

11. Explain the operation of a zener diode as a regulator and calculate the value of series dropping resistor for a given zener and load current and voltage.

12. Explain the concept of a 3-terminal device called a transistor and show how current is controlled between two of the terminals by a signal on the third terminal.

13. State the two main functions of a transistor.

14. Explain the composition of a MOSFET and how it works as an amplifier and switch.

15. Identify basic methods for biasing MOSFETs as amplifiers and switches.

16. Explain the composition of a bipolar junction transistor (BJT) and how it works.

17. Identify the basic methods for biasing a BJT as an amplifier and a switch.

18. Identify basic transistor amplifier circuits such as common emitter/source, common base/gate, and common collector/drain.

19. Draw the circuit of an emitter/source follower; explain its characteristics, purpose and operation.

20. Name the basic characteristics of an amplifier (gain, input and output impedance, frequency response, voltage/power output limits, etc) and state how each is expressed.

21. Calculate the gain of an amplifier from input and output voltages (or powers) and calculate the gain of cascade amplifiers.

22. Express voltage and power gain in decibels (dB).

23. Explain the relationship between amplifier bandwidth and speed of binary pulse rate.

24. Identify a differential amplifier by its schematic, state its purpose, and explain its operation and benefits.

25. Define op amp and draw the basic circuits for an op amp inverter, non-inverting amplifier, differential amplifier, follower, instrumentation amplifier and active filter.

26. State the basic specifications of an op amp and explain the importance of each.

27. Describe the purpose, operation, specifications and applications of the following IC amplifiers: programmable gain, power amplifier, video amplifier, and RF amplifier.

28. Explain how BJTs and MOSFETs are used as switches, define the basic switching characteristics of each and name three common switching applications.

29. Identify the block diagram of a 555 timer IC and explain its operation as an astable (clock) oscillator and as a one shot multivibrator. Name three common applications of each mode.

30. Explain the operation of an amplifier connected as an oscillator and calculate oscillation frequency.

31. Explain the operation of a switching oscillator and calculate frequency of operation.

32. Name three common types of oscillators, identify their circuits from schematics and state the primary applications.

33. Draw the equivalent circuits of a quartz crystal used as a frequency-determining element in an oscillator. State the major benefits of crystal oscillators over all other types.

34. Name another application for quartz crystals besides oscillator frequency setting.

35. Explain the operation of a series pass transistor type voltage regulator using a zener reference and feedback.

36. List the benefits of regulation to an electronic circuit.

37. Explain the operation of both conventional linear and LDO IC regulators.

38. Calculate the output voltage and current in a circuit using a 3-terminal regulator.

39. Describe the principles of switching regulators and state the primary technique to achieve feedback regulation.

40. Name, identify and explain the operation of the three most common types of IC switching regulators.

41. State the function of a DC-DC converter and inverter and explain how each works.

42. Draw a diagram of a bus architecture power supply and name the most common circuits.

43. Define power management and explain what a power management IC does.

44. Calculate the efficiency of any type of power supply given the necessary values. State the general efficiency range of linear and switching power supplies.

45. Explain the operation of a switching amplifier and state its benefits.

46. Name the basic classes of amplifiers, state the approximate efficiency of each and indicate where each type is generally used.

47. State the concept of a push pull amplifier.

48. Identify a complementary symmetry class AB amplifier and explain its operation.

49. Show how BJTs and MOSFETs are used in power amplifiers.

50. State the three main types of thyristors, explain how each operates and show an application for each.

51. Troubleshoot transistor and IC amplifiers and power supply circuits using common test equipment.

52. Install, connect, test, explain the operation of and operate at least one complete analog/linear electronic system. Examples: Audio PA system, music/instruments system, consumer stereo/surround sound system, home solar power system, and auto sound system.

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Detailed Course Outline

Toggle the arrows to view the outlines. New topics are listed below in red.

Solid State Devices and Circuits

1. Semiconductor Fundamentals
   a. Semiconductor materials
   b. Structure of semiconductors
   c. Compound semiconductors
   d. Doping, P and N-type semiconductors
   e. Current flow in semiconductors

2. PN Junctions and Diodes
   a. Depletion region
   b. Forward and reverse bias and current flow
   c. The ideal diode and practical models

3. Special Diodes
   a. Light emitting diodes (LEDs)
   b. Zener diodes
   c. Schottky diodes
   d. Varactor diodes
   e. PIN diodes

4. Power Supply Fundamentals
   a. Definition and general block diagram of a power supply
   b. Rectifiers: half wave, full wave, bridge
   c. Transformers
   d. Capacitive filters and ripple
   e. Regulation, defined and measurement
   f. Zener regulator
   g. Three terminal regulators ICs

5. Introduction to Transistors
   a. Generic concepts, 3-terminal devices for controlling current flow
   b. Transistors functions: switching and amplification

6. Field Effect Transistors
   a. MOSFET structure and types: enhancement mode, depletion mode, N and P
   b. MOSFET biasing
   c. Basic MOSFET amplifiers
   d. Basic MOSFET switches. CMOS
   e. JFET structure and types: P and N-type
   f. Basic JFET biasing
   g. Basic JFET amplifiers

7. Bipolar Junction Transistors (BJTs)
   a. BJT structure and types: NPN and PNP
   b. BJT biasing
   c. Basic BJT amplifiers
   d. Basic BJT switches

8. Amplifier Fundamentals (block diagram level)
   a. Specifications (gain, input/output impedance), maximum power/voltage output, frequency response
   b. Amplifier Classifications (A, AB, B, C, etc.)
   c. Expressing amplifier gain and power in dB/dBm
   d. Relationship between amplifier bandwidth and pulse response

9. Power Amplifiers
   a. Emitter/source followers
   b. Push pull amplifier with transformers

c. Complementary symmetry amplifiers
d. Bridge amplifiers

10. Differential Amplifiers
    a. Configuration
    b. Characteristics, features and benefits (common mode rejection)
    c. Typical MOSFET and BJT circuits
    d. Constant current sources and mirrors and biasing

11. Operational Amplifiers
    a. Characteristics, specifications and features
    b. Common op amp circuits (inverter, non-inverting amplifier, follower, differential amplifier, integrator, and comparator)
    c. Active filters

12. Integrated Circuit Amplifiers
    a. Instrumentation amplifiers
    b. Programmable gain amplifiers
    c. Video amplifiers
    d. RF amplifiers
    e. Power amplifiers
    f. Class D switching amplifiers

13. Oscillators (emphasis on ICs)
    a. Basic feedback concepts
    b. LC and RC oscillators
    c. 555 timer IC and oscillator circuits
    d. Quartz crystals
    e. Crystal oscillators

14. Power Supply Circuits
    a. Linear regulators including low drop out (LDO)
    b. Switching regulators: types, configurations, circuits
    c. Switching regulator advantages and benefits
    d. DC-DC converters
    e. DC-AC inverters and UPS
    f. The power supply bus
    g. Power management

15. Power Switches and Thyristors
    a. Silicon controlled rectifiers
    b. Triacs and diacs
    c. Power MOSFETs
    d. IGBT
    e. PPower switch and thyristor applications

16. Examples of Linear Solid State Systems (some recommendations)
    a. Audio amplifiers for stereo, surround sound, public address, auto sound, music)
    b. Home solar power system
    c. Analog controller, industrial applications

17. Troubleshooting Linear Circuits
    a. General testing procedures
    b. Overview of test instrument options
    c. DC troubleshooting
    d. Signal tracing
    e. Physical repair, soldering/desoldering, IC handling