Digital Fundamentals: Course Materials

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

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Traditional View

Every AAS degree program in electronics technology has a Digital fundamentals course. This course contains valuable concepts that students will use in later courses and on their jobs. These courses teach the binary number system and coding, logic gates and flip flops, and basic combinational and sequential logic circuits. Some courses also include an introduction to A/D and D/A conversion. Others provide an introduction to microcontrollers. Usually the Digital course is the prerequisite for a more comprehensive microcontrollers course.

Typically such Digital courses and the texts that support them take a very detailed approach to digital logic, which includes extensive coverage of Boolean algebra, truth tables, logic minimization with Boolean algebra, Karnaugh maps, and basic digital circuit design from state tables, truth tables, etc. Implementation focuses on TTL, or in some cases CMOS, logic gates, flip-flops and functional logic circuits like decoders, registers, counters and others.

Looking at this approach today reveals that it is less appropriate to modern equipment and jobs. First, many of the methods taught address how to design circuits. Since technicians rarely design circuits there is less need to spend time on methods of design.

Second, modern equipment is not implemented with discrete TTL or CMOS logic. Instead, virtually all-digital circuits are made with a microcontroller or a programmable logic device (PLD) like an FPGA.

Third, most technician work is at a higher systems level working with computers, boards, equipment, modules and in some cases ICs. The work is more related to testing and troubleshooting than to design. Techs trace signals and make measurements to insure compliance to some specification or standard. They use oscilloscopes, pulse generators, and logic analyzers to perform these jobs. Much of the work involves buses and interfaces between boards, modules and equipment. Typically most courses do not include coverage of these critical connections.

New Systems View

While the basic content of most Digital courses is sound, some of it can be eliminated to make room for new material on PLDs and microcontrollers as well as buses and interfaces. The emphasis can shift from a design approach to one more related to how circuits operate and how to test and troubleshoot them. It is still essential that the fundamentals of binary numbers and codes, logic circuit types and operation, and key combinational and sequential logic functions be taught. However, the approach should shift from a design orientation and more to a systems approach emphasizing test and troubleshooting.

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Digital Fundamentals 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. Instructor Presentation: Serial Digital Interface
   Basic electronics systems operations all contain the generation, transfer, and reception of electronic data. One of the most common but not usually covered interfaces is Serial Input and Output (I/O). This presentation covers the standard ways of getting data in and out of digital circuits, equipment, and computer systems.

2. Instructor Guide: Operation of Full Adder and Subtractor Using Xilinx ISE 9.2i Project Navigator and Spartan 3E FPGA Development Board with Schematic and VHDL
   The goal of this lab is to learn the use of Spartan 3E FPGA development board from Xilinx; how to program in VHDL and create the hardware connections between the development board and your PC.

3. Instructor and Student Resource: Getting to Know FPGA Spartan-3E Starter Board
   This guide helps instructor and students become familiar with the hardware interface of Spartan 3E FPGA board. The Spartan-3E Starter Kit board is more advanced and complex compared to other Spartan development boards. The advantage of this board is that it is programmed through USB port. JTAG port is used to program previous versions.

4. Student Guide: Wave Audio Player
   This lab introduces the student to data contained in computer files and hardware that can make use of the data contained in those files. This knowledge helps the student have a better understanding of how the digital world of computers is a world of 1s and 0s and hardware.

5. Instructor Guide: FPGA Beer Module - Lab Documents
The goal of this lab is to learn the use of Spartan 3E FPGA development board from Xilinx and how to create the hardware connections between the development board and your PC.

6. Instructor and Student Resource: Microprocessor Block Diagram Animation
Ever wonder how a computer works? Using the top-down approach, this block diagram takes you on a journey through the various stages of a microprocessor's architecture. At the system level, the details of each component are concealed, all emphasis being placed on the task that each device performs. For starters, every microprocessor has an arithmetic logic unit (ALU). As its name suggests, this component allows a computer to perform both arithmetic and logic operations. Therefore, it is important to take time to understand how this circuit works by following the animation.

* 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.

Digital and Microcomputer Fundamentals Course

1. Define the terms analog and digital and distinguish between digital and analog signals.

2. Represent quantities in binary codes, convert between the decimal and binary number systems. Convert between the hex and binary codes.

3. Represent characters with and perform conversions with the ASCII code.

4. Perform basic math operations such as add, subtract, multiply and divide in binary.

5. Explain how binary values are represented with electronic signals.

6. Explain the differences, benefits and differences between parallel and serial binary data transmissions methods.

7. Calculate serial data rates from binary bit times and vice versa.

8. Name and identify the basic logic operations such as AND, OR, NAND, NOR, XOR and inverter, show the logic symbol, write the Boolean expression, write the truth table and draw input and output signal diagrams.

9. Translate between truth table and Boolean expression. Write the Boolean expression from a logic diagram and draw the logic diagram from a Boolean expression.

10. Name and define the basic specifications (propagation delay, rise/fall time), fan in/out) for logic circuits.

11. Distinguish between bipolar and MOSFET logic circuits like TTL and CMOS, state the pros and cons of each.

12. Explain the operation and application of the most common combinational logic circuits such as decoders, encoders, multiplexers, demultiplexers, adders, and code converters.

13. Define bus three-state logic. Explain the difference between single ended and differential binary signals.

14. Name the three basic types of flip flops such as RS/latch, D type and JK, draw their logic symbol, and explain the operation of each with truth tables and logic signals. Name an application for each.

15. Explain the operation of a storage register and a shift register.

16. Explain the operation of a binary up counter, down counter, BCD counter, and frequency divider.

17. Define state machine and explain its application.

18. Name the basic solid state memory types such as RAM and ROM, identify the various types like SRAM, DRAM, PROM, EPROM, EEPROM, flash, explain how each works, give the basic specifications, and name an application for each,

19. Name and explain the specifications of basic parallel buses used in digital and computer systems including PCI, PCI-X, PCI Express, and LVDS.

20. Name and explain the specifications for the following serial interfaces used in digital and computer systems: RS-232/UART, RS-485/422/423, USB, SPI, SCI, CAN, I2C, LIN, Flex, MOST, Ethernet 10/100/1000.

21. Relate data rate to transmission path bandwidth.

22. Define PLD and name the basic types (like (PAL, GAL, CPLD, FPGA), show the internal organization of each, explain its operation, and state how each is programmed.

23. Identify the three basic ways digital functions are implemented (discrete logic, embedded controller and CPLD/FPGA) and explain the advantages and disadvantages of each.

24. Name the basic sections and components of a digital computer.

25. Explain the stored program concept of a computer showing data and address flows using a block diagram of a CPU.

26. Name the most common categories of computers (super, mainframe, server, PC, embedded controller)

27. Distinguish between and define the terms microprocessor, CPU, microcomputer, embedded controller, microcontroller, and PLC.

28. Explain the basic process of how a computer works showing data and address flows in the basic computer components.

29. Learn the basic commands and data formats for a common computer language such as BASIC and write simple programs to duplicate logic and math operations, control sequences, and I/O functions.

Laboratory

1. Breadboard basic logic circuits using TTL or CMOS ICs, validate their operation with truth tables, oscilloscope waveforms or other means.

2. Measure propagation delay and rise/fall time of a logic gate/circuit and flip flop.

3. Implement logic functions by programming a CPLD or FPGA.

4. Program a basic microcontroller using a higher level language like BASIC. Implement basic logic functions including interfaces for I/O operations.c

5. Generate a serial data signal and translate the pulses into data and determine the data rate.

6. Troubleshoot and test digital circuits with an oscilloscope and, if available, a logic analyzer.

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Detailed Course Outline

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

Digital Fundamentals

1. Basic Digital Concepts
   a. Distinguish between digital and analog signals
   b. Examples of analog/linear circuits and digital circuits

2. Introduction to Electricity (Voltage, Current, and Resistance)
   a. The decimal and binary number systems
   b. Representing quantities in binary
   c. Conversion between binary and decimal
   d. Maximum values of quantities and binary words
   e. Binary coded decimal (BCD)
   f. ACSII code
   g. Octal and hexadecimal representation

3. Data transmission principles
   a. Parallel transmission and buses
   b. Serial transmission, benefits, bit times, data rates

4. Concepts of data conversion.
   a. Analog-to-digital
   b. Nyquist theory
   c. Resolution
   d. Digital-to-analog
   e. Common applications

5. Basic Logic Elements
   a. Inverter
   b. AND gate
   c. OR gate
   d. Exclusive OR
   e. NAND/NOR gates
   f. Basic Boolean representation
   g. Basic truth tables

6. Logic circuit fundamentals
   a. TTL
   b. CMOS
   c. Specifications: propagation delay, rise/fall times, fan in/out, noise margin.

7. Combinational Logic Circuits
   a. Decoder
   b. Encoder
   c. Multiplexer
   d. Demultiplexer
   e. Adders
   d. Code conversion, parity.
   e. Three-state logic, wired OR and bus connections.

8. Basic Storage Circuits
   a. Set-Reset, Latch Flip Flop
   b. JK and T flip flops

c. D-flip flop
d. Basic storage registers.

9. Shift Registers and Counters
   a. Shift register basics
   b. Serial-parallel and parallel-serial conversion.
   c. Binary counters.
   c. Up/down counters.
   d. BCD counters
   e. Frequency division.
   f. Basic state machines.

10. Memory circuits
   a. Static memory basics
   b. Dynamic memory basics
   c. Memory specifications
   d. RAM chips organization and operation. IC decoding, storage and retrieval, refresh fundamentals
   e. ROM basics
   f. ROM types
   g. PROM
   h. EPROM
   i. EEPROM
   j. Flash, NAND and NOR types

11. Parallel Buses
   a. Concepts and data transmission limitations
   b. Common PC buses: PCI, PCI-X, PCI Express, CML, LVDS

12. Serial Buses
   a. Serial bus basics, data rates
   b. RS-232, RS-422/423, RS-485
   c. USP
   d. SPI
   e. I2C
   f. CAN, LIN and Flex
   g. Ethernet 10/100/1G/10G
   h. Optical fiber

13. Programmable Logic Devices
   a. PLD fundamentals, types and uses
   b. ROM-based and LUT
   c. PAL, GAL, PLA
   d. CPLD and FPGAs, organizations and types
   e. FPGA programming
   f. PLD applications

14. Introduction to Microcomputers and Embedded Controllers
   a. Basic stored program concept
   b. Definitions and basic architecture
   c. CPU organization and operation
   d. Introduction to a common microcontroller (8051, 68HC11, PIC, etc)
   e. Basic programming concepts
   f. Overview of I/O and interfacing