
Digital Electronics Detailed Outline

Unit 1: Fundamentals of Analog and Digital Electronics (32 Total Days)

Lesson 1.1: Foundations and the Board Game Counter (9 days)

Concepts Addressed in Lesson:

1. Safety is an important concept that must be considered for the safety of the individual, class, and overall environment of the classroom/laboratory.
2. Electricity, even at the nominal levels used in this curriculum, can cause bodily harm or even death.
3. Engineers and technicians use scientific notation, engineering notation, and Systems International (SI) notation to conveniently write very large or very small numbers frequently encountered when working with electronics.
4. Manufacturers of resistors and capacitors use an accepted industry standard to label the nominal value of resistors and capacitors.
5. Soldering is the process of joining two metal surfaces together to form an electrical connection. Soldering is used extensively in the assembly of electronic components.
6. The ability to properly solder electronic components and recognition of improper solder connections is an important skill for engineers and technicians.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Know and practice proper safety while working with electronics.
- Be able to express numbers in scientific notation, engineering notation, and System International (SI) notation.
- Identify many of the common components used in electronics.
- Be able to determine a resistor's nominal value by reading its color code.
- Be able to determine a resistor's actual value by reading its resistance with a Digital Multimeter (DMM).
- Be able to determine a capacitor's nominal value by reading its labeled nomenclature.
- Be able to properly tin the tip of a soldering iron.
- Use proper soldering/de-soldering techniques to solder and de-solder components on a printed circuit boards.

Lesson 1.2: Introduction to Analog (11 days)

Concepts Addressed in Lesson:

1. Analog and digital signals have different waveforms with distinctive characteristics.
2. Digital signals have two well-defined voltage levels, one for a logic high and one for a logic low.
3. Analog signals have an infinite number of voltage levels that vary continuously over the voltage range for that particular system.
4. The atomic structure of a material determines whether it is a conductor, an insulator, or a semiconductor.
5. An understanding of the basics of electricity requires the understanding of three fundamental concepts of voltage, current, and resistance
6. Engineers and technicians use Circuit Design Software as a tool to verify functionality of their analog and digital designs.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Be able to identify the parts of an atom and determine if an element would make a good conductor, insulator, or semiconductor.
- Use Ohm's Law, Kirchhoff's Voltage Law, and Kirchhoff's Current Law to solve for simple series and parallel circuit.
- Be able to use a Circuit Design Software to analyze simple analog circuits.
- Be able to use a breadboard and digital multimeter to analyze simple analog circuits.
- Be able to determine the amplitude, period, frequency, and duty cycle analog and digital signals.
- Be able to analyze and design simple digital oscillators using the 555 Timer chip.
- Utilize the Circuit Design Software (CDS) to simulate and test a complete analog design.

Lesson 1.3: Introduction to Digital (12 days)

Concepts Addressed in Lesson:

1. The manufacturer datasheet contains a logic gate's general description, connection diagram, and function table.
2. Integrated circuits are categorized by their underlying circuitry, scale of integration, and packaging style.

3. Transistor-Transistor Logic (TTL) gates are available in a series of sub-families, each having their own advantages and disadvantages related to speed and power.
4. Logic gates are depicted by their schematic symbol, logic expression, and truth table.
5. The input and output values of combinational and sequential logic function differently.
6. Combinational logic designs implemented with AND gates, OR gates, and INVERTER gates are referred to as AOI designs.
7. The flip-flop is the fundamental building block of sequential logic.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Be able to obtain and extract information from the manufacturer datasheets for components commonly used in digital electronics.
- Know how to identify commonly used electronic components given their part number or schematic symbol.
- Be able to identify various integrated circuit (IC) package styles.
- Know the fundamental differences between combinational and sequential logic.
- Identify and describe the function of AND, OR, & Inverter gates.
- Be able to use Circuit Design Software (CDS) to simulate and test a simple combinational logic circuit designed with AND, OR, & Inverter gates.
- Identify and describe the function of a D flip-flop.
- Be able to use Circuit Design Software (CDS) to simulate and test a simple sequential logic circuit design with D flip-flops.
- Utilize the Circuit Design Software (CDS) to simulate and test a complete design containing both combinational and sequential logic.

Unit 2: Combinational Logic (60 Total Days)

Lesson 2.1: Introduction to AOI Logic (20 days)

Concepts Addressed in Lesson:

1. An understanding of the binary number system and its relationship to the decimal number system is essential in the combinational logic design process.
2. The first step in designing a combinational logic circuit is to translate a set of design specifications into a truth table.
3. A truth table describes the behavior of a combinational logic design by listing all possible input combinations and the desired output for each.
4. Logic expressions can be derived from a given truth table; likewise, a truth table can be constructed from a given logic expression.

5. All logic expressions can be expressed in one of two forms: sum-of-products (SOP) or products of sum (POS).
6. All logic expressions, whether simplified or not, can be implemented using AND, OR, & Inverter Gates.
7. There is a formal design process for translating a set of design specifications into a functional combinational logic circuit.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Convert numbers between the binary and decimal number systems.
- Translate design specifications into truth tables.
- Extract un-simplified logic expressions from truth tables.
- Construct truth tables from logic expressions.
- Use the rules and laws of Boolean algebra, including DeMorgan's, to simplify logic expressions.
- Analyze AOI (AND/OR/Invert) combinational logic circuits to determine their equivalent logic expressions and truth tables.
- Design combinational logic circuits using AOI logic gates.
- Translate a set of design specifications into a functional AOI combinational logic circuit following a formal design process.
- Use Circuit Design Software (CDS) and a Digital Logic Board (DLB) to simulate and prototype AOI logic circuits.

Lesson 2.2: Introduction to NAND and NOR Logic (14 days)

Concepts Addressed in Lesson:

1. Karnaugh Mapping is a graphical technique for simplifying logic expressions containing two, three, and four variables.
2. A don't care condition is a situations where the design specifications "don't care" what the output is for one or more input conditions. Don't care conditions in K-Maps can lead to significantly simpler logic expressions and circuit implementations.
3. A NAND gate is considered a universal gate because it can be used to implement an AND gate, OR gate, and an inverter gate. Any combinational logic expression can be implemented using only NAND gates.
4. A NOR gate is considered a universal gate because it can be used to implement an AND gate, OR gate, and an inverter gate. Any combinational logic expression can be implemented using only NOR gates.

5. There is a formal design process for translating a set of design specifications into a functional combinational logic circuit implement with NAND or NOR gates.
6. Combinational logic designs implemented with NAND gates or NOR gates will typically required fewer Integrated Circuits (IC) than AOI equivalent implementations.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Use the K-Mapping technique to simplify combinational logic problems containing two, three, and four variables.
- Be able to solve K-Maps that contain one or more *don't care* conditions.
- Design combinational logic circuit using NAND and NOR logic gates.
- Translate a set of design specifications into a functional NAND or NOR combinational logic circuit following a formal design process.
- Be able to compare and contrast the quality of combinational logic designs implemented with AOI, NAND, and NOR logic gates.
- Use Circuit Design Software (CDS) and a Digital Logic Board (DLB) to simulate and prototype NAND and NOR logic circuits.

Lesson 2.3: Date of Birth Design (9 days)

Concepts Addressed in Lesson:

1. Seven-segment displays are used to display the digits 0-9 as well as some alpha characters.
2. The two varieties of seven-segment displays are common cathode and common anode.
3. Any combinational logic expression can be implemented with AOI, NAND, or NOR logic.
4. A formal design process exists for translating a set of design specifications into a functional combinational logic circuit.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Use a seven-segment display in a combinational logic design to display alpha/numeric values.
- Select the correct current limiting resistor and properly wire both common cathode and common anode seven-segment displays.

- Follow a formal design process to translate a set of design specifications for a design containing multiple outputs into a functional combinational logic circuit.
- Design AOI, NAND, & NOR solutions for a logic expression and select the solution that uses the least number of ICs to implement.
- Use Circuit Design Software (CDS) and Digital Logic Board (DLB) to simulate and prototype AOI, NAND, & NOR logic circuits.

Lesson 2.4: Specific Comb Logic Circuits & Misc. Topics (8 days)

Concepts Addressed in Lesson:

1. An understanding of the hexadecimal and octal number systems and their relationship to the decimal number system is necessary for comprehension of digital electronics.
2. XOR and XNOR gates can be used to implement combinational logic circuits, but their primary intended purpose is for implementing binary adder circuits.
3. The addition of two binary numbers of any bit length can be accomplished by cascading one half-adder with one or more full adders.
4. Multiplexer/de-multiplexer pairs are most frequently used when a single connection must be shared between multiple inputs and multiple outputs.
5. Electronics displays that use multiple seven-segment display utilize de-multiplexers to significantly reduce the amount of power required to operate the display.
6. Two's complement arithmetic is the most commonly used method for handling negative numbers in digital electronics.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Convert numbers between the hexadecimal or octal number systems and the decimal number system.
- Use XOR and XNOR gates to design binary half-adders and full-adders.
- Use SSI and MSI gates to design and implement binary adders.
- Design electronics displays using seven-segment displays that utilize de-multiplexers.
- Use the two's complement process to add and subtract binary numbers.
- Use Circuit Design Software (CDS) and a Digital Logic Board (DLB) to simulate and prototype specific combinational logic circuits.

Lesson 2.5: Programmable Logic – Combinational (9 days)

Concepts Addressed in Lesson:

1. Engineers and technicians use Circuit Design Software to enter and synthesize digital designs into programmable logic devices.
2. Programmable logic devices can be used to implement combinational logic circuits.
3. Circuits implemented with programmable logic devices require significantly less wiring than discrete logic, but they typically require a dedicated printed circuit board to hold the device.
4. Programmable logic devices can be used to implement any combinational logic circuits but are best suited for larger, more complex designs.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Design combinational logic circuits using a programmable logic device.
- Be able to cite the advantages and disadvantages of programmable logic devices over discrete logic gates.
- Use Circuit Design Software (CDS) and a Digital Logic Board (DLB) to simulate and prototype combinational logic designs implemented with programmable logic.

Unit 3: Sequential Logic (56 Total Days)

Lesson 3.1: Latches & Flip-Flops (6 days)

Concepts Addressed in Lesson:

1. The flip-flop and transparent latch are logic devices that have the capability to store data and can act as a memory device.
2. Flip-flops and transparent latches have both synchronous and asynchronous inputs.
3. Flip-flops can be used to design single event detection circuits, data synchronizers, shift registers, and frequency dividers.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Know the schematic symbols and excitation tables for the D and J/K flip-flops.
- Describe the function of the D and J/K flip-flops.
- Describe the function of, and differences between, level sensitive and edge sensitive triggers.
- Describe the function of, and differences between, active high and active low signals.
- Describe the function of, and differences between, a flip-flop's synchronous and asynchronous inputs.

- Draw detailed timing diagrams for the D or J/K flip-flop's Q output in response to a variety of synchronous and asynchronous input conditions.
- Analyze and design introductory flip-flop applications such as event detection circuits, data synchronizers, shift registers, and frequency dividers.
- Use Circuit Design Software (CDS) and a Digital Logic Board (DLB) to simulate and prototype introductory flip-flop applications.
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Lesson 3.2: Asynchronous Counter (14 days)

Concepts Addressed in Lesson:

1. Asynchronous counters, also called ripple counters, are characterized by an external signal clocking the first flip-flop. All subsequent flip-flops are clocked by the output of the previous flip-flop.
2. Asynchronous counters can be implemented using small scale integrated (SSI) and medium scale integrated (MSI) logic gates.
3. Asynchronous counters can be implemented with either D or J/K flip-flops.
4. Up counters, down counters, and modulus counters all can be implemented using the asynchronous counter method.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Know the advantages and disadvantage of counters designed using the asynchronous counter method.
- Be able to describe the ripple effect of an asynchronous counter.
- Be able to analyze and design up, down and modulus asynchronous counters using discrete D and J/K flip-flops.
- Be able to analyze and design up, down and modulus asynchronous counters using medium scale integrated (MSI) circuit counters.
- Use Circuit Design Software (CDS) and Digital Logic Board (DLB) to simulate and prototype SSI and MSI asynchronous counters.

Lesson 3.3: Synchronous Counters (14 days)

Concepts Addressed in Lesson:

1. Synchronous counters, also called parallel counters, are characterized by an external signal clocking all flip-flops simultaneously.
2. Synchronous counters can be implemented using small scale integrated (SSI) and medium scale integrated (MSI) logic gates.
3. Synchronous counters can be implemented with either D or J/K flip-flops.

4. Up counters, down counters, and modulus counters all can be implemented using the synchronous counter method.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Know the advantages and disadvantage of counters designed using the synchronous counter method.
- Be able to analyze and design up, down and modulus synchronous counters using discrete D and J/K flip-flops.
- Be able to analyze and design up, down and modulus synchronous counters using medium scale integrated (MSI) circuit counters.
- Use Circuit Design Software (CDS) and Digital Logic Board (DLB) to simulate and prototype SSI and MSI synchronous counters.

Lesson 3.4: Introduction to State-Machine Design (20 days)

Concepts Addressed in Lesson:

1. A state machine is a circuit design that sequences through a set of predetermined states controlled by a clock and other input signals.
2. State machines are used to control common everyday devices such as elevator doors, traffic lights, and combinational (electronics) locks.
3. State machines can be implemented in one of two variations: Mealy or Moore.
4. State machines can be implemented using small and medium scale integrated gates and programmable logic devices.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Be able to describe the components of a state machine.
- Be able to draw a state graph and construct a state transition table for a state machine.
- Be able to derive a state machine's Boolean equations from its state transition table.
- Be able to implement Boolean equations into a functional state machine.
- Describe the two variations of state machines and list the advantages of each.
- Use Circuit Design Software (CDS) and a Digital Logic Board (DLB) to simulate and prototype state machines designs implemented with discrete and programmable logic.

Unit 4: Microcontrollers (29 Total Days)

Lesson 4.1: Introduction to Microcontrollers (9 days)

Concepts Addressed in Lesson:

1. Flowcharting is a powerful graphical organizer used by technicians, computer programmers, engineers, and professionals in a variety of roles and responsibilities.
2. Basic programming skills include variable declaration, loops, and debugging.
3. Programming languages have their own grammar, called syntax.
4. Many everyday products use microcontrollers.
5. Variables used in programming are declared and given a size that is expressed in binary.

Performance Objectives Addressed in Lesson

It is expected that students will:

- Create flowcharts to use in programming
- Use the Board of Education to write programs
- Create a program that utilizes the Debug screen
- Create programs that use variables
- Create programs that use various loops
- Create programs that use inputs and outputs

Lesson 4.2: Microcontroller: Hardware (11 days)

Concepts Addressed in Lesson:

1. Microcontrollers are used to control many everyday products like robots, garage door openers, traffic lights, and home thermostats.
2. A servo motor is one that delivers continuous motion at various speeds.
3. Microcontrollers can be programmed to sense and respond to outside stimuli

Performance Objectives Addressed in Lesson

It is expected that students will:

- Program a servo motor.
- Program and test an autonomous robot.
- Use mathematics to calculate programming values.

Lesson 4.3: Microcontroller: Process Control (9 days)

Concepts Addressed in Lesson:

1. Digital devices are only relevant if they can interact with the real world.
2. Digital control devices are increasingly necessary for mechanical systems.
3. Realistic problem solving with a control system requires the ability to interface analog inputs and outputs with a digital device.
4. Microcontrollers are a practical tool for controlling a mechanical system.

Performance Objectives

It is expected that students will:

- Design and build a maze course.
- Design and build a timing device with remote triggers.
- Program a microcontroller to guide a robot through a maze.