# Digital Electronics

# Project Lead the Way

# Curriculum

| Unit 1 Overview |
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| **Content Area:** Digital Electronics - **Project Lead the Way**<br>Digital electronics is the study of electronic circuits that are used to process and control digital signals. In contrast |

to analog electronics, where information is represented by a continuously varying voltage, digital signals are represented by two discrete voltages or logic levels. This distinction allows for greater signal speed and storage capabilities and has revolutionized the world of electronics.

**Unit Title: Unit 1:** Foundations in Electronics**– 45 Days**

Target Course/Grade Levels: Digital Electronics
**- Project Lead the Way / 9-12**

**Unit Summary:** In Unit 1 Foundations in Electronics, students will explore the fundamental components, concepts, equipment, and skill sets associated with circuit design. They will learn an engineering design process that can be used to guide the creation of circuits based on a set of design requirements. PLTW Unit 1 provide an overview of the levels of understanding that each build upon the higher level: Knowledge and Skills, Objectives, Domains, and Competencies. The most fundamental level of learning is defined by course Knowledge and Skills statements. Each Knowledge and Skills statement reflects specifically what students will know and be able to do after they've had the opportunity to learn the course content. Students apply Knowledge and Skills to achieve learning Objectives, which are skills that directly relate to the workplace or applied academic settings. Objectives are organized by higher-level Domains.

**Essential Questions**

1. Why are the safety practices important?
2. Why are hand calculations important when a software can perform the same calculations?
3. How are analog and digital components used in products that you use?
4. How can you use your soldering skills beyond this course?
5. Can a digital and analog circuit be designed to accomplish the same tasks?
6. Why is the understanding of binary and decimal number systems essential to your ability to design combinational logic circuits?
7. How can the engineering design process be adapted to produce a circuit?
8. How can a computer software design (CSD) and measurement tools be applied to an engineering design process?

**21st-Century Life & Career Skills:** All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures.

**Learning Targets**

**Standards:** 8.2 Technology Education, Engineering, and Design All students will develop an understanding of the nature and impact of technology, engineering, technological design, and the designed world, as they relate to the individual, global society, and the environment.

**Content Statements:**

A. Nature of Technology: Creativity and Innovation: Technology products and systems impact every aspect of the world in which we live.
B. Design: Critical Thinking, Problem Solving, and Decision-Making: The design process is a systematic approach to solving problems.
C. Technological Citizenship, Ethics, and Society: Knowledge and understanding of human, cultural, and societal values are fundamental when designing technology systems and products in the global society
E. Communication and Collaboration: Digital tools facilitate local and global communication and collaboration in designing products and systems.
F. Resources for a Technological World: Technological products and systems are created through the application and appropriate use of technological resources.
G. The Designed World: The designed world is the product of a design process that provides the means to convert resources into products and systems.

**Goals:**

- Identify analog circuit components.
- Practice binary and decimal number equivalents.
- Investigate Basic Circuits and predict potential student questions and responses.

- Prototype a physical analog circuit.
- Practice stripping wires.
- Operate a digital multimeter.
- Explore direct instruction about circuit theory, including:
- Calculating circuit values using the appropriate formula.
- Selecting the proper formula for the given information.
- Discovering the similarities in calculations and simulation.
- Analyze similarities and differences between Circuit Theory in a classroom environment.
- Identify digital circuit components.
- Explore combinational logic design.
- Prototype a physical digital circuit.
- Explore proper use of the Oscilloscope function of Multisim.
- Explore sequential logic design.
- Explore clock signals.

**Students will be able exhibit the following professional skills:**

- Team collaboration
- Project management
- Problem-solving
- Communication skills
- Presentation skills
- Technical writing
- Ethical practice
- Global perspective

## Unit 1 Framework

**Transportable Knowledge and Skills**

Core workplace skills that students and workers need to acquire, that can be used across all stages of a career, and that, because of their universal utility, are transportable from job to job, from employer to employer, across the economy.

**Career Readiness (CAR):**

Today electronics technology impacts almost all careers. There are career specializations within digital electronics such as circuit developer, electronic engineer, designer and analyzer.

CAR1-B Explain how electronics technology has impacted innovation in other fields.

CAR1-B.2 Describe how electronics technology enables innovation by providing the ability to access and share information.

**Communication (COM):**

Engineering practice requires effective communication with a variety of audiences using multiple modalities.

1. COM-A. Communicate effectively with an audience based on audience characteristics.
2. COM-A.1 Adhere to established conventions of written, oral, and electronic communications (grammar, spelling, usage, and mechanics).
3. COM-A.2 Follow acceptable formats for technical writing and professional presentations.

**Ethical Reasoning and Mindset Critical and Creative Problem-Solving (CCP):**

The skills necessary for students to generate ideas and solutions to problems.

1. CCP-A. Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal.
2. CCP-A.1 Plan and use time in pursuit of accomplishing a goal without direct oversight.
3. CCP-A.2 Plan how to gain additional knowledge and learning to accomplish a goal.
4. CCP-C. Persevere to solve a problem or achieve a goal.
5. CCP-C.1 Describe why persistence is important when identifying a problem and/or pursuing solutions.
6. CCP-C.2 Accept failure as part of an evolution of individual growth and necessary to the expansion of the engineering profession.
7. CCP-A. Explain and justify an engineering design process.
8. CCP-A.5 Document a design process in an engineering notebook according to best practices.
9. CCP-G. Make judgements and decisions based on evidence.
10. CCP-G. Explain that a conclusion is valid if the evidence supports the conclusion while acknowledging the limitations, opposing views, and biases
11. CCP-G. Evaluate evidence and arguments to identify deficiencies, limitations, and biases or appropriate next steps in the pursuit of a better solution.

**Technical Knowledge and Skills**

Every career field requires technical literacy and career-specific knowledge and skills to support professional practice.

Sequential Logic (SLO):

The foundation of digital circuits based on the use of memory.

1. SLO-A. Design, interpret, and/or modify common sequential logic circuits, such as counters, event detectors, and shift registers, using flip-flops based on given design requirements.
2. SLO-A.1 Draw or analyze 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.
3. SLO-A.2 Analyze and/or design introductory flip-flop applications, such as latches, event detection circuits, data synchronizers, shift registers, and frequency dividers.
4. SLO-A.3 Describe the advantages and disadvantages of counters using an asynchronous counter design or synchronous counter design.
5. SLO-B. Design, interpret, and/or modify asynchronous counter circuits based on specific design requirements using SSI and/or MSI to count up/down, hold/rest, and start/stop counts according to any desired range.
6. SLO-B.1 Describe the ripple effect of an asynchronous counter.
7. SLO-B.2 Analyze and/or design up, down, and modulus asynchronous counters using discrete D and J/K flip-flops.

SLO-B.4 Describe where a count starts and where a count stops/repeats on a modulus asynchronous counter.

Combinational Logic (CLO):

1. Create specific outputs in a circuit based on specific inputs.
2. CLO-A. Create, interpret, and/or modify an AOI combinational logic circuit based on design requirements according to a systematic process for designing a combinational logic circuit.
3. CLO-A.1 Translate design requirements into Boolean expressions and/or a truth table.
4. CLO-A.2 Translate Boolean expressions into truth tables and truth tables into un-simplified Boolean expressions.
5. CLO-A.3 Translate circuit schematics into Boolean expressions or truth tables and Boolean expressions or truth tables into circuit schematics.
6. CLO-A.4 Interpret and/or modify an AOI circuit based on design requirements.

Engineering Tools and Technology (ETT):

The practice of engineering requires the application of mathematical principles and common engineering tools, techniques, and technologies.

1. ETT-A. Using a variety of measuring devices, measure and report quantities accurately and to a precision appropriate for the purpose.
2. ETT-A.1 Explain and differentiate between the accuracy and precision of a measurement or measuring device.
3. ETT-B. Construct physical objects using hand tools and shop tools.
4. ETT-B.1dentify basic hand tools and shop tools and des
5. ETT-B.2 Describe a process to build a physical object based on a conceptual communication such as a drawing or description.
6. ETT-B.3 Demonstrate use of hand tools and shop tools.
7. ETT-B.4 Produce a physical model using electronic components.
8. ETT-C. Apply computational thinking to generalize and solve a problem using a computer.
9. ETT-C.1 Interact with content-specific models and simulation to support learning and research.
10. ETT-C.2 Use model in and simulation to represent and understand natural phenomena.
11. ETT-C.3 Analyze data and identify patterns through modeling and simulation.

Foundations in Mathematics and Science (FMS):

Engineering practice requires an understanding of mathematical principles and scientific phenomena to solve problems.

1. FMS-A. Solve complex calculations using appropriate notation.
2. FMS-A.1 Select the most appropriate notation.
3. FMS-A.2 Convert any number to/from engineering notation.
4. FMS-A.3 Convert any number between the International System of Units, SI, prefixes.
5. FMS-B. Use mathematical processes to convert any value between any two number systems.
6. FMS-B.1 Count from 0 to15inbinary.
7. FMS-B.2 Convert numbers between the binary and decimal number systems.
8. FMS-C. Calculate voltage, current, and/or resistance for components in a circuit.
9. FMS-C.1 Identify parts and distinguish between characteristics of a circuit that are in series.
10. FMS-C.2 Identify parts and characteristics of a circuit that are in parallel.
11. FMS-C.3 Calculate total resistance for a circuit by applying Kirchhoff’s Voltage Law and Kirchhoff’s Current Laws.
12. FMS-C.4 Solve for unknown values in a circuit by applying Ohm’s law.

Foundations in Electronics (FIE):

Electronics requires specific knowledge related to working safely, the tools, and the electrical components used within the field.

1. FIE-A. Demonstrate and apply appropriate safety procedures when working with electronics in a classroom.
2. FIE-A.1 Identify potential electrical hazards that might cause damage to the human body.
3. FIE-B. Identify and describe the characteristics of common components and logic gates. FIE-B.1 Explain that the transistor is the most fundamental
4. FIE-B.2 Demonstrate that digital components, such as transistors, and analog components, such as resistors and capacitors, can be used to create logic gates.
5. FIE-B.3 Identify resistor component values from color codes.
6. FIE-B.4 Identify a capacitor’s nominal value by reading its labeled nomenclature.
7. FIE-B.5 Know that common logic gates are designed to fit in Integrated Circuits (ICs) for easier use in design. These ICs are most often found in two styles: Small Scale Integration (SSI) and Medium Scale In
8. FIE-B.6 Identify, implement, and/or describe integrated circuits’ properties from their part number, schematic symbol, and/or data sheet.
9. FIE-B.7 Identify integrated circuits wiring diagram from a datasheet.
10. FIE-B.8 Identify a logic gate from a truth table or write a truth table representing a logic gate.
11. FIE-C. Select and apply the appropriate components, tools, and technology when creating or characterizing a design.
12. FIE-C.1 Troubleshoot circuits (mechanics of circuit and logic of circuit).

13. FIE-C.3 Measure current, voltage, and/or resistance within a circuit or across a component using a digital multimeter (DMM).
14. FIE-C.4 Measure frequency, period, and duty cycle of a clock signal using an oscilloscope.
15. FIE-C.5 Design a circuit, simulate a circuit, and verify a measurement and/or hand calculation using circuit design software (CDS).
16. FIE-D. Clock signals trigger events in circuits.
17. FIE-D.1 Select and apply components in a design to produce a desired waveform, frequency, period, and/or duty cycle.
18. FIE-D.2 Analyze and interpret the amplitude, period, frequency, and duty cycle of analog and digital signals based on instrumentation and calculations.
19. FIE-D.3 Interpret and/or modify the analog components of a 555 timer oscillator circuit to affect the wave generated.

| Unit 1 Lessons | | |
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| **Lesson Title:** | **Timeframe (Periods)** | **Knowledge & Skills** |
| **Lesson 1.1** Introduction to Electronics<br><br>In Lesson 1.1 Introduction to Electronics, students will learn to distinguish between analog and digital components. They will begin by exploring basic circuits and the measurement tools used to characterize and validate calculations that predict a circuit's behavior. Students will be able to clearly describe electrical circuits, voltage, current, resistance, series and parallel circuits, Ohm's law, and how to use a digital multimeter to measure voltage. Students will be introduced to common components such as resistors, capacitors, light emitting diodes (LEDs),seven-segment displays, combinational logic gates, and sequential logic gates. | 19 days | KS 1.1.2, KS 1.2.2, KS 1.3.1, KS 1.4.2, KS 2.1.2, KS 2.1.3, KS 2.1.4, KS 2.1.5, KS 2.1.6, KS 2.1.7, KS 3.1.2, KS 3.2.1, KS 3.2.2, KS 3.2.3, KS 3.2.4, KS 4.1.1, KS 4.1.2, KS 4.2.1, KS 4.2.2, KS 4.1.2, KS 6.2.1, KS 7.1.3, KS 7.2.4, KS 7.3.1, KS 7.3.2, KS 8.1.1, KS 8.1.2, KS 8.1.3, KS 8.1.4, KS 10.1.1, KS 10.1.2, KS 10.1.3, KS 12.2.1, KS 12.4.1, KS 12.4.2, KS 13.1.2, KS 13.2.1 |
| **Lesson 1.2** Introduction to Circuit Design<br><br>In Lesson 1.2 Introduction to Circuit Design, students will explore fundamental circuit designs, manipulate circuits to understand their function, and explore the examples that combine analog, digital combinational logic, and digital sequential logic. This lesson is meant to serve as a broad overview of circuit design and to expose students to basic designs they will be exploring and incorporating into their own future designs. | 17 days | KS 1.2.2, KS 2.1.3, KS 2.1.5, KS 7.3.2, KS 8.1.3, KS 12.5.1, KS 13.1.1, KS 13.1.2, KS 13.3.2, KS 13.3.3, KS 13.3.4, KS 13.3.6, KS 13.5.1, KS 13.5.2, KS 13.6.1, KS 13.6.2 |

| Activity Timeframes | |
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| **Activity Title:** | **Timeframe (days)** |
| • Activity 1.1.4 Analog Component Identification | 2 days |
| • Activity 1.1.1 General Safety in the Electronics Classroom | 2 days |
| • Activity 1.1.5.c Circuit Theory Breadboarding | 2 days |
| • Activity 1.2.3 Binary System | 2 days |
| • Prepare for It’s Your Turn | 2 days |
| • Quiz 1.1.1 General Safety in the Electronics Classroom | 2 days |
| • Activity 1.1.4 Analog Component Identification | 2 days |
| • Circuit Theory Breadboarding Activity | 3 days |
| • Activity 1.2.3 Binary Systems | 3 days |
| • Activity 1.1.5a Circuit Theory Hand Calculations | 3 days |
| • Activity 1.1.6 Digital Component Identification | 3 days |
| • Activity 1.1.7 Datasheets | 3 days |
| • 1.2.1 Introduction to Combinational Logic Design: Seat Belt Circuit | 2 days |
| • Activity 1.1.5a Circuit Theory | 2 days |
| • Activity 1.1.5.b Circuit Theory Simulation | 2 days |
| • Activity 1.2.2 Analog and Digital Signals | 2 days |

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| • Activity 1.2.1 Introduction to Combinational Logic Design | 2 days |
| • Activity 1.2.4 Introduction to Sequential Logic Design: Counters | 2 days |
| • Activity 1.2.5 Clock Signals Using 555 Timer | 2 days |
| • Prepare for It's Your Turn | 2 days |

| CPI # | Cumulative Progress Indicator (CPI) |
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| 8.2.12.A.1 | Design and create a technology product or system that improves the quality of life and identify trade-offs, risks, and benefits. |
| 8.2.12.B.1 | Design and create a product that maximizes conservation and sustainability of a scarce resource, using the design process and entrepreneurial skills throughout the design process. |
| 8.2.12.B.2 | Design and create a prototype for solving a global problem, documenting how the proposed design features affect the feasibility of the prototype through the use of engineering, drawing, and other technical methods of illustration. |
| 8.2.12.B.3 | Analyze the full costs, benefits, trade-offs, and risks related to the use of technologies in a potential career path. |
| 8.2.12.C.1 | Analyze the ethical impact of a product, system, or environment, worldwide, and report findings in a web-based publication that elicits further comment and analysis. |
| 8.2.12.C.2 | Evaluate ethical considerations regarding the sustainability of resources that are used for the design, creation, and maintenance of a chosen product. |
| 8.2.12.C.3 | Evaluate the positive and negative impacts in a design by providing a digital overview of a chosen product and suggest potential modifications to address the negative impacts. |
| 8.2.12.E.1 | Use the design process to devise a technological product or system that addresses a global issue, and provide documentation through drawings, data, and materials, taking the relevant cultural perspectives into account throughout the design and development process. |
| 8.2.12.F.1 | Determine and use the appropriate application of resources in the design, development, and creation of a technological product or system. |
| 8.2.12.F.2 | Explain how material science impacts the quality of products. |
| 8.2.12.F.3 | Select and utilize resources that have been modified by digital tools (e.g., CNC equipment, CAD software) in the creation of a technological product or system. |
| 8.2.12.G.1 | Analyze the interactions among various technologies and collaborate to create a product or system demonstrating their interactivity. |

**Evidence of Learning**

**Formative Assessments:**

1. Daily question and response as we go along in the topic
2. Students will be asked to provide examples of certain ideas, or to apply ideas to samples of their own choosing.
3. Student work will be assessed according to the PLTW rubrics

4. Peer review ability
5. Ability to work together with other students

**Summative Assessment:**

1. Creative Expression App.
2. Students will be graded on their programming set up and different criteria deadlines.
3. Problem Solving App.

**Additional Materials**

**Digital Tools & Resources:**

- Microsoft Office (Excel, Word, PowerPoint)
  - • Multisim 14.1
  - • Tinker CAD

**Primary & Secondary Resources**

- • PLTW student website
- • PLTW resource package

**Unit 2 Overview**

**Content Area: Digital Electronics - Project Lead the Way**

**Unit Title: Unit 2: Combinational Logic– 45 Days**

**Target Course/Grade Levels:** Digital Electronics **Essentials - Project Lead the Way / 9-12**

**Unit Summary:** The most fundamental level of learning is defined by course Knowledge and Skills statements. Each Knowledge and Skills statement reflects specifically what students will know and be able to do after they've had the opportunity to learn the course content. Students apply Knowledge and Skills to achieve learning Objectives, which are skills that directly relate to the workplace or applied academic settings. Objectives are organized by higher-level Domains.

**Essential Questions**

1. How can a set of design specifications be transformed into a functional combinational logic circuit?
2. How do a truth table, logic expression, and circuit design interrelate?
3. How are all logic expressions, regardless of complexity, simply AND, OR, and INVERTER gates?
4. Why are NAND gates and NOR gates considered universal gates?
5. How can universal gates be used to create a combinational logic design?
6. How are K-mapping and Boolean algebra applied to logic expressions?
7. How can seven-segment displays be integrated into your design process?
8. How are common digital circuits such as binary adders, multiplexers, and de- multiplexers used in common electronic devices?
9. How can Circuit Design Software (CDS) and Programmable Logic Devices (PLDs) be used in an engineering design process?
10. How can a PLD be used to model a complex physical circuit?

**21st-Century Life & Career Skills:** All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures.

**Learning Targets**

**Standards:** 8.2 Technology Education, Engineering, and Design All students will develop an understanding of the nature and impact of technology, engineering, technological design, and the designed world, as they relate to the individual, global society, and the environment.

**Content Statements:**

A. Nature of Technology: Creativity and Innovation: Technology products and systems impact every aspect of the world in which we live.
B. Design: Critical Thinking, Problem Solving, and Decision-Making: The design process is a systematic approach to solving problems.
C. Technological Citizenship, Ethics, and Society: Knowledge and understanding of human, cultural, and societal values are fundamental when designing technology systems and products in the global society
D. Communication and Collaboration: Digital tools facilitate local and global communication and collaboration in designing products and systems.
E. Resources for a Technological World: Technological products and systems are created through the application and appropriate use of technological resources.
F. The Designed World: The designed world is the product of a design process that provides the means to convert resources into products and systems.

Goals

- Explore how fundamental circuits in Digital Electronics come together to make complex circuits.
- Explore analog and digital designs.
- Identify soldering resources for later use in the classroom.
- Produce digital logic expressions.
- Identify and explore processes of analysis.
- Explore and practice theorems.
- Discuss digital design and physical designing.
- Document a design in an engineering notebook.
- Discuss the Activity, Project, Problem approach.
- Examine the advantages and disadvantages of Boolean and K-mapping.
- Practice the design process of a logic circuit.
- Reflect on the PLTW PreK–12 career learning philosophy.
- Analyze the design process of a logic circuit.
- Analyze peer Date of Birth circuits.

**Students will be able exhibit the following professional skills:**

- Team collaboration
- Project management
- Problem-solving
- Communication skills
- Presentation skills
- Technical writing
- Ethical practice
- Global perspective

## Unit 2 Framework

**Transportable Knowledge and Skills**

Core workplace skills that students and workers need to acquire, that can be used across all stages of a career, and that, because of their universal utility, are transportable from job to job, from employer to employer, across the economy.

Critical and Creative Problem-Solving (CCP):

The skills necessary for students to generate ideas and solutions to problems.

1. CCP-A. Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal.
2. CCP-A.1 Plan and use time in pursuit of accomplishing a goal without direct oversight.
3. CCP-A.2 Plan how to gain additional knowledge and learning to accomplish a goal.
4. CCP-A. Explain and justify an engineering design process.
5. CCP-A.5 Document a design process in an engineering notebook according to best practices.

**Technical Knowledge and Skills**

Every career field requires technical literacy and career-specific knowledge and skills to support professional practice.

Combinational Logic (CLO):

Create specific outputs in a circuit based on specific inputs.

1. CLO-A. Create, interpret, and/or modify an AOI combinational logic circuit based on design requirements according to a systematic process for designing a combinational logic circuit.
2. CLO-A.1 Translate design requirements into Boolean expressions and/or a truth table.
3. CLO-A.2 Translate Boolean expressions into truth tables and truth tables into unsimplified Boolean expressions.
4. CLO-A.3 Translate circuit schematics into Boolean expressions or truth tables and Boolean expressions or truth tables into circuit schematics.
5. CLO-A.4 Interpret and/or modify an AOI circuit based on design requirements.
6. CLO-A.5 Create an AOI circuit on a breadboard from a schematic.
7. CLO-B. Simplify an AOI circuit design by applying mathematics, K-Mapping, and/or universal gates.
8. CLO-B.1 (same as KS4.4.1) Apply Boolean algebra theorems and De Morgan's theorems to simplify expressions.
9. CLO-B.2 (same as KS4.4.2) Apply the Karnaugh mapping technique to simplify Boolean expressions.
10. CLO-B.3 Translate a set of design specifications into a functional NAND or NOR combinational logic circuit, determine when NAND only or NOR only implementations are the most efficient design, and implement effectively into a circuit.

Foundations in Mathematics and Science (FMS):

Engineering practice requires an understanding of mathematical principles and scientific phenomena to solve problems.

FMS-B. Use mathematical processes to convert any value between any two number systems. FMS-B.1 Countfrom0to15inbinary.

1. FMS-B.2 Convert numbers between the binary and decimal number systems.
2. FMS-B.3 Convert numbers between the decimal, binary, octal, and hexadecimal number systems.
3. FMS-B.4 Convert numbers between the binary coded decimal and the decimal number systems.

FMS-D. Simplify algebraic expressions.

1. FMS-D.1 Apply Boolean algebra theorems and De Morgan's theorems to simplify expressions.
2. FMS-D.2 Apply the Karnaugh mapping technique to simplify Boolean expressions.
3. FMS-E. Add and subtract in the binary number system.
4. FMS-E.1 Describe and/or apply the two's complement arithmetic process and relate the process to decimal number systems without the use of negative numbers.

Foundations in Electronics (FIE):

Electronics requires specific knowledge related to working safely, the tools, and the electrical components used within the field.

1. FIE-B. Identify and describe the characteristics of common components and logic gates.
2. FIE-B.5 Know that common logic gates are designed to fit in Integrated Circuits (ICs) for easier use in design. These ICs are most often found in two styles: Small Scale Integration (SSI) and Medium Scale Integration (MSI).
3. FIE-B.6 Identify, implement, and/or describe integrated circuits' properties from their part number, schematic s
4. FIE-B.7 Identify integrated circuits wiring diagram from a datasheet.
5. FIE-B.9 Implement as even-segment display into a circuit design to display alphanumeric values using seven-segment display drivers.
6. FIE-B.10 Select the correct current-limiting resistor and/or properly wire both common cathode and common anode seven-segment displays.
7. FIE-C. Select and apply the appropriate components, tools, and technology when creating or characterizing a design.
8. FIE-C.1 Troubleshoot circuits (mechanics of circuit and logic of circuit).

9. FIE-E. Interpret and/or modify a full adder and half adder to predict outputs given specific inputs when adding or subtracting numbers.
10. FIE-E.1 (same as KS4.5.1) Describe and/or apply the two's complement arithmetic process and relate the process to decimal number systems without the use of negative numbers.
11. FIE-E.2 Predict outputs given specific inputs when adding or subtracting numbers.
12. FIE-E.3 Describe the design of an adder/subtractor circuit related to the carry out and use of XOR/XNOR gates.
13. FIE-F. Create, interpret, and/or modify a multiplexed or de-multiplexed circuit to make it more efficient.
14. FIE-F.1 Interpret and/or modify a multiplexed or de-multiplexed circuit to make it more efficient.

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| **Lesson Title:** | **Timeframe (Periods)** | **Knowledge & Skills** |
| Lesson 2.1 AOI Combinational Logic Circuit Design<br>Focuses on AND, OR, Inverter (AOI) combinational logic circuit design. Students will reinforce concepts that were introduced in the previous units, including binary number systems, truth tables, and Boolean expressions. They will then expand on these concepts by exploring how mathematics can be used to reduce circuit size, cost, and complexity. Using the systematic approaches of AOI simplification, AOI logic analysis, and AOI implementation,<br><br>students will learn to take design specifications and translate them into the most efficient circuit possible. | 14 days | KS 2.1.1 KS 2.1.2 KS 2.1.3 KS 2.1.4 KS 4.1.1 KS 4.1.2 KS 4.2.1 KS 4.2.2 KS 8.1.1 KS 8.1.2<br>KS 8.1.3 KS 8.1.4 KS 8.1.5 KS 9.1.5 KS 9.1.6 KS 10.1.2 KS 10.1.4 KS 10.2.1 KS 13.1.2 KS 13.3.6<br>KS 13.4.1 KS 13.4.2 KS 13.4.3 KS 13.4.4 KS 13.5.1 KS 13.5.2 KS 13.6.1 KS 13.6.2 KS 13.6.3 |
| Lesson 2.2 Alternative Design: Universal Gates and K-Mapping<br>In the first lesson of this unit, students learned how to use a design process to transform design specifications into functional AOI combinational logic. Though the result of this work was a functioning circuit, this process does not address a few issues.<br>First, Boolean algebra was required to simplify the logic expressions. Though Boolean algebra is an important mathematical process, applying its numerous theorems and laws is not always the easiest task to undertake in simplifying circuits.<br>Second, AOI circuit implementations are rarely the most cost-effective solutions for combinational logic designs.<br>After completing a series of guided foundational activities on Karnaugh maps, NAND only logic design, and NOR only logic design, the students will apply the combinational logic design process to develop a Fireplace Control Circuit. This process will walk the students through the steps required to transform a set of written design<br><br>specifications into a functional combinational logic circuit implemented with either NAND only or NOR only logic. | 15 days | KS 1.1.2 KS 1.2.2 KS 1.2.3 KS 1.2.4 KS 1.4.1 KS 1.4.2 KS 1.4.3 KS 2.1.2 KS 2.1.3 KS 2.1.4 KS 2.1.5 KS 2.1.6 KS 4.1.2 KS 6.1.1 KS 6.2.1 KS 7.1.2<br>KS 7.2.3 KS 7.3.2 KS 8.1.1 KS 8.1.2 KS 8.1.3 KS 8.1.4 KS 9.1.1 KS 9.1.2 KS 9.1.3 KS 9.1.4 KS 9.1.5 KS 9.1.6 KS 9.2.1 KS 9.2.4 KS 11.1.1<br>KS 11.1.2 KS 12.1.1 KS 12.2.2 KS 12.5.1 KS 13.1.1 KS 13.1.2 KS 13.3.1 KS 13.4.2 KS 13.4.4 KS 13.5.1 KS 13.5.2 KS 13.5.3 KS 13.5.4 KS 13.6.2 KS 13.6.3 |
| Lesson 2.3 Specific Combinational Logic Designs<br>This lesson will address a few fundamental topics related to combinational logic. These topics include hexadecimal | 10 days | KS 1.4.4 KS 2.1.1 KS 2.1.3 KS 2.1.6<br>KS 6.2.1 KS 6.2.3 KS 8.1.1 KS 8.1.2<br>KS 10.1.3 KS 10.1.4 KS 10.3.1 KS 10.3.2 |

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| and octal number systems, XOR, XNOR, and binary adders, 2's complement arithmetic, and multiplexers/demultiplexers. These designs are commonly used in digital circuit designs related to adding/subtracting numbers, the use of seven segment displays in designs and carrying multiple signals through the same pathway in a circuit. | | KS 3.1.1 KS 8.1.3 KS 10.3.4<br>KS 3.1.2 KS 8.1.4 KS 10.3.5<br>KS 3.1.3 KS 8.1.6 KS 13.1.1<br>KS 3.1.4 KS 8.1.7 KS 13.1.2<br>KS 3.1.5 KS 9.2.4 KS 13.5.1<br>KS 4.1.1 KS 10.1.2 KS 13.5.2 |
| Lesson 2.4 Introduction to Programmable Logic Devices (PLDs)<br>In the first three lessons of this unit, students learned how to use a design process to transform design specifications into functional AOI, NAND, and NOR combinational logic circuits. In this lesson students apply all that they have learned to design a circuit in which they define some of the design specifications themselves for the first time.<br>Students will design, simulate, and breadboard a circuit that displays their unique birthdate. Circuit implementation is then demonstrated at the next level by utilizing a programmable logic device called a Field Programmable Gate Array (FPGA). FPGA is a state-of-the-art programmable device capable of implementing large, sophisticated designs.<br>In this course we have limited our designs to four inputs and circuits that are manageable for breadboarding. The PLD shows us the next evolution of circuit design, allowing us to design more complex circuits in a shorter period of time. Students quickly see the benefit of this new design tool and strategy over designing discrete logic gates. | **6 Days** | KS 1.4.4 KS 6.2.1 KS 10.1.3<br>KS 2.1.1 KS 6.2.3 KS 10.1.4<br>KS 2.1.3 KS 8.1.1 KS 10.3.1<br>KS 2.1.6 KS 8.1.2 KS 10.3.2<br>KS 3.1.1 KS 8.1.3 KS 10.3.4<br>KS 3.1.2 KS 8.1.4 KS 10.3.5<br>KS 3.1.3 KS 8.1.6 KS 13.1.1<br>KS 3.1.4 KS 8.1.7 KS 13.1.2<br>KS 3.1.5 KS 9.2.4 KS 13.5.1<br>KS 4.1.1 KS 10.1.2 KS 13.5.2 |

| **Activity Title:** | **Timeframe (days)** |
|---|---|
| Project 2.1.6 AOI Design Majority Vote | 3 days |
| Activity 2.1.1 AOI Design: Truth Tables to Logic Expressions | 3 days |
| Activity 2.1.2 AOI Logic Analysis: Circuit to Truth Table to Logic Expression | 3 days |
| Activity 2.1.3 AOI Logic Implementation | 3 days |
| Activity 2.1.4 Circuit Simplification: Boolean Algebra | 3days |
| Project 2.1.6 AOI Logic Design: Majority Vote | 3days |
| Activity 2.2.1 Circuit Simplification: Karnaugh Mapping | 4days |
| Activity 2.2.2 Universal Gates: NAND | 3days |

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| Activity 2.2.3 Universal Gates: NOR | 3 days |
| Project 2.2.5 Fireplace Control | 4 days |
| Activity 2.3.2 Seven-Segment Display | 3 days |
| Problem 2.4.1 Combinational Logic Circuit Design: Date of Birth | 6 days |
| Activity 2.2.4 Design Tool: Logic Converter | 4days |
| | |

| CPI # | Cumulative Progress Indicator (CPI) |
|---|---|
| 8.2.12. A.1 | Design and create a technology product or system that improves the quality of life and identify trade-offs, risks, and benefits. |
| 8.2.12. B.1 | Design and create a product that maximizes conservation and sustainability of a scarce resource, using the design process and entrepreneurial skills throughout the design process. |
| 8.2.12. B.2 | Design and create a prototype for solving a global problem, documenting how the proposed design features affect the feasibility of the prototype through the use of engineering, drawing, and other technical methods of illustration. |
| 8.2.12. B.3 | Analyze the full costs, benefits, trade-offs, and risks related to the use of technologies in a potential career path. |
| 8.2.12. C.1 | Analyze the ethical impact of a product, system, or environment, worldwide, and report findings in a web-based publication that elicits further comment and analysis. |
| 8.2.12. C.2 | Evaluate ethical considerations regarding the sustainability of resources that are used for the design, creation, and maintenance of a chosen product. |
| 8.2.12. C.3 | Evaluate the positive and negative impacts in a design by providing a digital overview of a chosen product and suggest potential modifications to address the negative impacts. |
| 8.2.12. E.1 | Use the design process to devise a technological product or system that addresses a global issue, and provide documentation through drawings, data, and materials, taking the relevant cultural perspectives into account throughout the design and development process. |
| 8.2.12. F.1 | Determine and use the appropriate application of resources in the design, development, and creation of a technological product or system. |
| 8.2.12. F.2 | Explain how material science impacts the quality of products. |
| 8.2.12. F.3 | Select and utilize resources that have been modified by digital tools (e.g., CNC equipment, CAD software) in the creation of a technological product or system. |
| 8.2.12. G.1 | Analyze the interactions among various technologies and collaborate to create a product or system demonstrating their interactivity. |

| Evidence of Learning |
|---|
| **Formative Assessments:**<br>1. Daily question and response as we go along in the topic, CSE notebook<br>2. Students will be asked to provide examples of certain ideas, or to apply ideas to samples of their own choosing.<br>3. Student work will be assessed according to the PLTW rubrics<br>4. Students skills<br>5. Peer review ability<br>6. Ability to work together with other students |
| |

| Additional Materials |
| --- |
| **Digital Tools & Resources:**<br>• Microsoft Office (Excel, Word, PowerPoint)<br>• Multisim 14.1<br>• TinkerCAD |
| **Primary & Secondary Resources**<br>• PLTW student website<br>• PLTW resource package |

## Unit 3 Overview

**Content Area: Digital electronics - Project Lead the Way**

**Unit Title: Unit 3: Sequential Logic – 55 Days**

**Target Course/Grade Levels: Digital Electronics - Project Lead the Way / 9-12**

**Unit Summary:** How do you get a circuit to do what you want it to do, when you want it to do it? Sequential logic introduces students to event detection and memory. Sequential logic has two characteristics that distinguish it from combinational logic. First, sequential logic must have a signal that controls the sequencing of events. Second, sequential logic must have the ability to remember past events.

A keypad on a garage door opener is a classic example of an everyday device that utilizes sequential logic. On the keypad, the sequencing signal controls when a key can be pressed. The need to enter the passcode in a specific order necessitates memory of past events.

These characteristics are made possible by a simple device called a flip-flop. The flip-flop is a logic device that is capable of storing a logic level and allowing this stored value to change only at a specific time. For this reason, the flip-flop is the fundamental building block for all sequential logic designs.

**Essential Questions**

1. How can sequential and differential logic circuits be used in a product that you use?
2. How would you explain the function and use of a flip-flop to someone with limited electronics background?
3. What are some of the common applications of flip-flops?
4. How can D flip-flops or J/K flip-flops be arranged to create a desired asynchronous clock signal?
5. How can a small-scale integration (SSI) and medium-scale integration (MSI) be used in a product that you use?
6. Why is it important to have a counter or to start at specific values?
7. How can D flip-flops or J/K flip-flops be arranged to create a desired synchronous clock signal?
8. How can a small-scale integration (SSI) and medium-scale integration (MSI) be used in a product that you use?
9. How can a synchronous counter be designed to start and stop or repeat a count at the desired values?

**21st-Century Life & Career Skills:** All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures.

## Learning Targets

**Standards:** 8.2 Technology Education, Engineering, and Design All students will develop an understanding of the nature and impact of technology, engineering, technological design, and the designed world, as they relate to the individual, global society, and the environment.

**Content Statements:**

A. Nature of Technology: Creativity and Innovation: Technology products and systems impact every aspect of the world in which we live.
B. Design: Critical Thinking, Problem Solving, and Decision-Making: The design process is a systematic approach to solving problems.
C. Technological Citizenship, Ethics, and Society: Knowledge and understanding of human, cultural, and societal values are fundamental when designing technology systems and products in the global society

D. Communication and Collaboration: Digital tools facilitate local and global communication and collaboration in designing products and systems.
E. Resources for a Technological World: Technological products and systems are created through the application and appropriate use of technological resources.
F. The Designed World: The designed world is the product of a design process that provides the means to convert resources into products and systems.

**Goals:**

1. How can sequential and differential logic circuits be used in a product that you use?
2. How would you explain the function and use of a flip-flop to someone with limited electronics background?
3. What are some of the common applications of flip-flops?

1. How can D flip-flops or J/K flip-flops be arranged to create a desired asynchronous clock signal?
2. How can a small-scale integration (SSI) and medium-scale integration (MSI) be used in a product that you use?
3. Why is it important to have a counter or to start at specific values?

1. How can D flip-flops or J/K flip-flops be arranged to create a desired synchronous clock signal?
2. How can a small-scale integration (SSI) and medium-scale integration (MSI) be used in a product that you use?
3. How can a synchronous counter be designed to start and stop or repeat a count at the desired values?

**Students will be able exhibit the following professional skills:**

- Team collaboration
- Project management
- Problem-solving
- Communication skills
- Presentation skills
- Technical writing
- Ethical practice
- Global perspective

## Unit 3 Framework

**Transportable Knowledge and Skills**

Core workplace skills that students and workers need to acquire, that can be used across all stages of a career, and that, because of their universal utility, are transportable from job to job, from employer to employer, across the economy.

Communication (COM):

Engineering practice requires effective communication with a variety of audiences using multiple modalities.

COM-A. Communicate effectively with an audience based on audience characteristics.

COM-A.2 Follow acceptable formats for technical writing and professional presentations.

Critical and Creative Problem-Solving (CCP):

The skills necessary for students to generate ideas and solutions to problems.

CCP-A. Demonstrate independent thinking and self-direction in pursuit of accomplishing a goal.

1. CCP-A.1 Plan and use time in pursuit of accomplishing a goal without direct oversight.
2. CCP-A.2 Plan how to gain additional knowledge and learning to accomplish a goal.

CCP-A. Explain and justify an engineering design process.

CCP-A.5 Document a design process in an engineering notebook according to best practices.

**Technical Knowledge and Skills**

Every career field requires technical literacy and career-specific knowledge and skills to support professional practice.

Sequential Logic (SLO):

The foundation of digital circuits based on the use of memory.

SLO-A. Design, interpret, and/or modify common sequential logic circuits, such as counters, event detectors, and shift registers, using flip-flops based on given design requirements.

3. SLO-A.1 Draw or analyze 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.
4. SLO-A.2 Analyze and/or design introductory flip-flop applications, such as latches, event detection circuits, data synchronizers, shift registers, and frequency dividers.
5. SLO-A.3 Describe the advantages and disadvantages of counters using an asynchronous counter design or synchronous counter design.

SLO-B. Design, interpret, and/or modify asynchronous counter circuits based on specific design requirements using SSI and/or MSI to count up/down, hold/rest, and start/stop counts according to any desired range.

6. SLO-B.1 Describe the ripple effect of an asynchronous counter.
7. SLO-B.2 Analyze and/or design up, down, and modulus asynchronous counters using discrete D and J/K flip-flops.
8. SLO-B.3 Analyze and/or design up, down, and modulus asynchronous counters using medium-scale integrated (MSI) circuit counters.
9. SLO-B.4 Describe where a count starts and where a count stops/repeats on a modulus asynchronous counter.

SLO-C. Design, interpret, and/or modify synchronous counter circuits based on specific design requirements using SSI and/or MSI to count up/down, hold/rest, and start/stop counts according to any desired range.

10. SLO-C.1 Analyze and design up, down, and modulus synchronous counters using discrete D and J/K flip-flops.
11. SLO-C.2 Analyze and design up, down, and modulus synchronous counters using medium-scale integrated (MSI) circuit counters.
12. SLO-C.3 Describe where a count starts and where a count stops/repeats on a modulus synchronous counter.

Foundations in Electronics (FIE):

Electronics requires specific knowledge related to working safely, the tools, and the electrical components used within the field.

FIE-B. Identify and describe the characteristics of common components and logic gates.

FIE-B.5 Know that common logic gates are designed to fit in Integrated Circuits (ICs) for easier use in design. These ICs are most often found in two styles: Small Scale Integration (SSI) and Medium Scale Integration (MSI).

FIE-B.6 Identify, implement, and/or describe integrated circuits' properties from their part number, schematic symbol, and/or data sheet.

FIE-C. Select and apply the appropriate components, tools, and technology when creating or characterizing a design.

FIE-C.1 Troubleshoot circuits (mechanics of circuit and logic of circuit).

FIE-D. Clock signals trigger events in circuits.

FIE-D.1 Select and apply components in a design to produce a desired waveform, frequency, period, and/or duty cycle

| Unit 3 Lessons | | |
|---|---|---|
| **Lesson Title:** | **Timeframe (Periods)** | **Knowledge & Skills** |
| Lesson 3.1 Sequential Logic Circuit Design<br>In this lesson students begin the study of sequential logic by examining the basic operation of the two most common flip-flop types, the D and J/K flip-flops. As part of this analysis, they will review the design of four typical flip-flop applications: event detector, data synchronizer, frequency divider, and shift register. In later lessons the application of flip-flops for asynchronous counters, synchronous counters, and state-machines will be studied. | 9 days | KS 1.1.1 KS 1.1.2 KS 1.2.1 KS 1.4.1 KS 1.4.2 KS 1.4.3 KS 1.4.4 KS 2.1.1 KS 2.1.2 KS 2.1.3 KS 2.1.4 KS 2.1.5 KS 2.1.6 KS 4.2.2 KS 5.1.1 KS 6.1.1 KS 6.1.2 KS 6.2.1<br>KS 6.2.2 KS 6.2.3 KS 6.2.4 KS 7.1.2 KS 7.1.3 KS 7.2.1 KS 7.2.2 KS 7.2.3 KS 7.3.1 KS 7.3.2 KS 8.1.1 KS 8.1.2 KS 8.1.3 KS 8.1.4 KS 8.1.5 KS 8.1.6 KS 8.1.7 KS 9.1.1<br>KS 9.1.2 KS 9.1.3 KS 9.1.4 KS 9.2.4 KS 10.1.1 KS 10.3.1 KS 10.3.2 KS 10.3.4 KS 10.3.5 KS 11.1.2 KS 11.1.3 KS 11.2.1 KS 12.2.2 KS 13.1.1 KS 13.1.2 KS 13.3.3 KS 13.2.5 KS 13.6.2 |
| Lesson 3.2 Asynchronous Counters<br>The ability to count in a digital design application is a fundamental need in most circuits. These counting applications range from the simple Now Serving sign at the neighborhood deli counter to the countdown display used by NASA to launch rockets. A number of techniques are used to design counters, but they all fall into two generals categories, each with their own advantages and disadvantages. These two categories are called asynchronous counters and synchronous counters.<br>The primary design characteristic of asynchronous counters that distinguish them from synchronous counters is that the flip-flop of each stage is clocked by the flip-flop output of the prior stage. Thus, rather than all the flipflops changing simultaneously, the clock ripples its way from the first flip-flop to the last. This is why asynchronous counters are sometimes referred to as ripple counters.<br>After completing a series of activities on the process for designing Small Scale Integration (SSI) and Medium Scale Integration (MSI) asynchronous counters, this lesson will conclude with a design problem that requires the students to design, simulate, and create a Now Serving display circuit. | 30 days | KS 1.1.3 KS 1.2.1 KS 1.2.2 KS 1.4.1 KS 1.4.2 KS 1.4.3 KS 1.4.4 KS 2.1.1 KS 2.1.2 KS 2.1.3 KS 2.1.4 KS 2.1.5 KS 2.1.6 KS 2.1.7 KS 3.1.1 KS 3.2.3 KS 3.2.4 KS 4.1.1<br>KS 6.1.1 KS 6.1.2 KS 6.2.1 KS 6.2.2 KS 6.2.3 KS 6.2.4 KS 7.1.3 KS 7.2.2 KS 7.2.4 KS 8.1.1 KS 8.1.2 KS 8.1.3 KS 8.1.4 KS 8.1.5 KS 8.1.6 KS 8.1.7 KS 9.1.3 KS 9.2.2<br>KS 9.2.3 KS 9.2.4 KS 10.3.2 KS 10.3.5 KS 11.1.1 KS 11.1.3 KS 11.2.1 KS 12.1.1 KS 12.2.2 KS 12.4.1 KS 12.4.2 KS 13.1.2 KS 13.2.1 KS 13.2.5 KS 13.5.1 KS 13.5.2 KS 13.5.4 |
| Lesson 3.3 Synchronous Counters<br>As discussed in the previous lesson of this unit, the two categories of digital counters are asynchronous and | 16 days | KS 1.1.2 KS 1.1.3 KS 1.2.1 KS 1.2.2<br>KS 6.1.1 KS 6.1.2 KS 6.2.2 KS 6.2.3<br>KS 10.1.3 KS 10.1.4 KS 10.3.4 KS 11.1.1 |

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|---|---|---|---|---|
| synchronous. The analysis and design of synchronous counters is the topic of study of this lesson. The primary design characteristic of synchronous counters is that all of the flip-flops are clocked simultaneously. This simultaneous clocking avoids the rippling effect that is present in asynchronous counters. After completing a series of activities on the process for designing SSI and MSI synchronous counters, this lesson will conclude with a project that requires the students to design and simulate a Sixty Second Timer circuit. | | KS 1.2.4<br>KS 1.3.1<br>KS 1.3.2<br>KS 1.4.2<br>KS 1.4.4<br>KS 2.1.4<br>KS 2.1.5<br>KS 3.2.4<br>KS 4.2.2<br>KS 5.1.1<br>KS 5.1.2<br>KS 5.1.3 | KS 7.1.1<br>KS 7.1.2<br>KS 7.1.3<br>KS 7.2.1<br>KS 7.2.2<br>KS 7.3.2<br>KS 8.1.1<br>KS 8.1.5<br>KS 8.1.6<br>KS 9.1.3<br>KS 10.1.1<br>KS 10.1.2 | KS 11.1.3<br>KS 11.2.1<br>KS 12.1.1<br>KS 12.2.1<br>KS 12.2.2<br>KS 12.5.1<br>KS 13.1.2<br>KS 13.2.1<br>KS 13.5.1<br>KS 13.5.2<br>KS 13.6.1<br>KS 13.6.2 |

| Activity Timeframes | |
|---|---|
| **Activity Title:** | **Timeframe (days)** |
| Activity 3.1.1 Sequential Logic: D Flip-Flops and J/K Flip-Flops | 1 day |
| Problem 3.2.4 Asynchronous Counters: Now Serving Display Using PLTW S7 | 2 days |
| Activity 3.1.2 Flip-Flop Applications: Event Detector | 4 days |
| Activity 3.1.3 Flip-Flop Applications: Shift Register Using PLTW S7 | 3 days |
| Activity 3.2.1 Flip-Flop Applications: Asynchronous Counters PLTW S7 | 3 days |
| Activity 3.1.2 Flip-Flop Applications: Event Detector | 5 days |
| Activity 3.1.3 Flip-Flop Applications: Shift Register Using PLTW S7 | 4 days |
| Activity 3.2.1 Flip-Flop Applications: Asynchronous Counters PLTW S7 | 3days |
| Activity 3.2.2 Asynchronous Counters: Small-Scale Integration (SSI) Modulus Counters (PLTW S7) | 5days |
| Activity 3.2.3 Asynchronous Counters: Medium-Scale Integration (MSI) Suspend/Reset Counts | 5days |
| Activity 3.3.2 Asynchronous Counters: Small-Scale Integration (SSI) Modulus Counters | 5days |
| Activity 3.3.3 Asynchronous Counters: Medium-Scale Integration (MSI) Suspend/Reset Counts | 5days |

| CPI # | Cumulative Progress Indicator (CPI) |
|---|---|
| 8.2.12. A.1 | Design and create a technology product or system that improves the quality of life and identify trade-offs, risks, and benefits. |
| 8.2.12. B.1 | Design and create a product that maximizes conservation and sustainability of a scarce resource, using the design process and entrepreneurial skills throughout the design process. |
| 8.2.12. B.2 | Design and create a prototype for solving a global problem, documenting how the proposed design features affect the feasibility of the prototype through the use of engineering, drawing, and other technical methods of illustration. |
| 8.2.12. B.3 | Analyze the full costs, benefits, trade-offs, and risks related to the use of technologies in a potential career path. |
| 8.2.12. C.1 | Analyze the ethical impact of a product, system, or environment, worldwide, and report findings in a web-based publication that elicits further comment and analysis. |
| 8.2.12. C.2 | Evaluate ethical considerations regarding the sustainability of resources that are used for the design, creation, and maintenance of a chosen product. |
| 8.2.12. C.3 | Evaluate the positive and negative impacts in a design by providing a digital overview of a chosen product and suggest potential modifications to address the negative impacts. |
| 8.2.12. E.1 | Use the design process to devise a technological product or system that addresses a global issue, and provide documentation through drawings, data, and materials, taking the relevant cultural perspectives into account throughout the design and development process. |
| 8.2.12. F.1 | Determine and use the appropriate application of resources in the design, development, and creation of a technological product or system. |
| 8.2.12. F.2 | Explain how material science impacts the quality of products. |
| 8.2.12. F.3 | Select and utilize resources that have been modified by digital tools (e.g., CNC equipment, CAD software) in the creation of a technological product or system. |
| 8.2.12. G.1 | Analyze the interactions among various technologies and collaborate to create a product or system demonstrating their interactivity. |

## Evidence of Learning

**Formative Assessments:**

1. Daily question and response as we go along in the topic, CSE notebook
2. Students will be asked to provide examples of certain ideas, or to apply ideas to samples of their own choosing.
3. Student work will be assessed according to the PLTW rubrics
4. Students skills
5. Peer review ability
6. Ability to work together with other students

## Additional Materials

**Digital Tools & Resources:**

Microsoft Office (Excel, Word, PowerPoint)
• Multisim 14.1
• Tinker CAD

## Unit 4 Overview

**Content Area: Digital Electronics - Project Lead the Way**

**Unit Title: Unit 4: Controlling Real-World Systems– 35 Days**

**Target Course/Grade Levels: Digital Electronics - Project Lead the Way / 9-12**

In Unit 4 students make a final transition to the use of single-board computers used widely today. State machines and computers allow students to integrate sensors and motors. This allows us to create circuits that exist in the world around us.

**Essential Questions**

1. How is a state machine design used in electronics?
2. How can a state machine be used in a product that you use?
3. Why are microcontrollers such a valuable tool today in electronics?
4. What are the components and processes associated with programming microcontrollers to control real-world systems?

**21st-Century Life & Career Skills:** All students will demonstrate the creative, critical thinking, collaboration, and problem-solving skills needed to function successfully as both global citizens and workers in diverse ethnic and organizational cultures.

**Learning Targets**

**Standards:** 8.2 Technology Education, Engineering, and Design All students will develop an understanding of the nature and impact of technology, engineering, technological design, and the designed world, as they relate to the individual, global society, and the environment.

**Content Statements:**

A. Nature of Technology: Creativity and Innovation: Technology products and systems impact every aspect of the world in which we live.
B. Design: Critical Thinking, Problem Solving, and Decision-Making: The design process is a systematic approach to solving problems.
C. Technological Citizenship, Ethics, and Society: Knowledge and understanding of human, cultural, and societal values are fundamental when designing technology systems and products in the global society
D. Communication and Collaboration: Digital tools facilitate local and global communication and collaboration in designing products and systems.
E. Resources for a Technological World: Technological products and systems are created through the application and appropriate use of technological resources.
F. The Designed World: The designed world is the product of a design process that provides the means to convert resources into products and systems.

**Goals:**

- Use state machine diagrams to design algorithms.
- Use the design process and create a design plan.
- Create circuits using your design plans.
- Create more complex pi-top circuits.
- Use a servo motor in a circuit.
- Develop an action plan designed to help your students prepare for future career and post-secondary opportunities.
- Remote control a circuit.
- Create a prototype of a ball release machine.
- Design and program a custom machine that depends on another.
- Develop strategies for creating a classroom culture that actively engages students in learning.
- Make and execute a plan to gain additional knowledge and learning to accomplish a goal.
- Participate in structured reflection that promotes deep learning and professional behavior.

**Students will be able exhibit the following professional skills:**

- Team collaboration
- Project management
- Problem-solving
- Communication skills
- Presentation skills
- Technical writing

• Ethical practice
• Global perspective

## Unit 4 Framework

| **Lesson Title:** | | | | |
|---|---|---|---|---|
| Lesson 4.1 Introduction to State Machines<br>State machines, sometimes called Finite State Machines (FSM), are a form of sequential logic that can be used to electronically control common everyday devices such as traffic lights, electronic keypads, and automatic door openers.<br>In this lesson students will learn and apply the state machine design process. This design process will be used to implement state machines utilizing the pi-top platform, which is based on the Raspberry Pi.<br>After completing a foundational activity on state machine design, the lesson introduces students to algorithmic thinking and the use of digital and analog devices to solve a problem. The lesson concludes with a project where students design and build a preemptive traffic light using the pi-top and the Python programming language. | 25 days | KS 1.1.2<br>KS 1.2.1<br>KS 1.2.2<br>KS 1.4.2<br>KS 2.1.3<br>KS 2.1.4<br>KS 2.1.5<br>KS 2.1.6<br>KS 2.1.7<br>KS 3.1.1<br>KS 3.1.2<br>KS 3.2.1<br>KS 3.2.4<br>KS 7.1.3<br>KS 7.2.2<br>KS 7.2.3<br>KS 7.3.2 | KS 8.1.2<br>KS 8.1.3<br>KS 8.1.5<br>KS 8.1.6<br>KS 9.1.2<br>KS 9.1.3<br>KS 9.1.4<br>KS 10.1.1<br>KS 10.1.4<br>KS 10.3.5<br>KS 10.4.1<br>KS 10.4.2<br>KS 10.4.3<br>KS 10.4.4<br>KS 11.1.1<br>KS 11.1.2<br>KS 12.1.1 | |
| Lesson 4.2 Application of State Machines<br>This lesson introduces students to more algorithms and programming concepts as they learn to use servo motors and remote communication across pi-top devices. The lesson concludes with a problem in which students use all the knowledge and skills they have learned in the unit to design and implement an escape room using multiple pi tops.<br>State machines, the design process, planning, and documentation are threaded throughout the unit as students work in teams and practice transportable skills including communication and collaboration. | 10 days | KS 1.1.2<br>KS 1.2.1<br>KS 1.2.2<br>KS 1.4.2<br>KS 2.1.3<br>KS 2.1.4<br>KS 2.1.5<br>KS 2.1.6<br>KS 2.1.7<br>KS 3.1.1<br>KS 3.1.2<br>KS 3.2.1<br>KS 3.2.4<br>KS 7.1.3 | KS 8.1.2<br>KS 8.1.3<br>KS 8.1.5<br>KS 8.1.6<br>KS 9.1.2<br>KS 9.1.3<br>KS 9.1.4<br>KS 10.1.1<br>KS 10.1.4<br>KS 10.3.5<br>KS 10.4.1<br>KS 10.4.2<br>KS 10.4.3<br>KS 10.4.4 | KS<br>KS<br>KS<br>KS<br>KS<br>KS<br>KS<br>KS<br>KS<br>KS<br>KS<br>KS<br>KS<br>KS |

| **Activity Title:** | **Timeframe (days)** |
|---|---|
| DL: Activity 4.1.1 State Machine | 6 Days |
| DL: Activity 4.1.2 Digital Data | 6 days |
| DL: Activity 4.1.3 Detecting Distance | 6day |
| DL: Activity 4.1.4 Analog Data | 5 days |
| DL: Activity 4.2.5 Intruder Alert System | 6days |

| DL: Project 4.2.6 State Machine: Traffic Light | 6 days |
|---|---|

| CPI # | Cumulative Progress Indicator (CPI) |
|---|---|
| 8.2.12.A.1 | Design and create a technology product or system that improves the quality of life and identify trade-offs, risks, and benefits. |
| 8.2.12.B.1 | Design and create a product that maximizes conservation and sustainability of a scarce resource, using the design process and entrepreneurial skills throughout the design process. |
| 8.2.12.B.2 | Design and create a prototype for solving a global problem, documenting how the proposed design features affect the feasibility of the prototype through the use of engineering, drawing, and other technical methods of illustration. |
| 8.2.12.B.3 | Analyze the full costs, benefits, trade-offs, and risks related to the use of technologies in a potential career path. |
| 8.2.12.C.1 | Analyze the ethical impact of a product, system, or environment, worldwide, and report findings in a web-based publication that elicits further comment and analysis. |
| 8.2.12.C.2 | Evaluate ethical considerations regarding the sustainability of resources that are used for the design, creation, and maintenance of a chosen product. |
| 8.2.12.C.3 | Evaluate the positive and negative impacts in a design by providing a digital overview of a chosen product and suggest potential modifications to address the negative impacts. |
| 8.2.12.E.1 | Use the design process to devise a technological product or system that addresses a global issue, and provide documentation through drawings, data, and materials, taking the relevant cultural perspectives into account throughout the design and development process. |
| 8.2.12.F.1 | Determine and use the appropriate application of resources in the design, development, and creation of a technological product or system. |
| 8.2.12.F.2 | Explain how material science impacts the quality of products. |
| 8.2.12.F.3 | Select and utilize resources that have been modified by digital tools (e.g., CNC equipment, CAD software) in the creation of a technological product or system. |
| 8.2.12.G.1 | Analyze the interactions among various technologies and collaborate to create a product or system demonstrating their interactivity. |

## Evidence of Learning

**Formative Assessments:**

1. Daily question and response as we go along in the topic, CSE notebook
2. Students will be asked to provide examples of certain ideas, or to apply ideas to samples of their own choosing.
3. Student work will be assessed according to the PLTW rubrics
4. Students programming skills
5. Peer review ability
6. Ability to work together with other students

## Additional Materials

**Digital Tools & Resources :**

- Microsoft Office (Excel, Word, PowerPoint)
- Multisim 14.1
- Tinker CAD

**Primary & Secondary Resources**

- PLTW student website
- PLTW resource package