Digital Electronics

Grade 10, 11, or 12

Prerequisite: Introduction to Engineering Design

Credit Value: 5

ABSTRACT

Digital Electronics is a core course of study in the Project Lead The Way (PLTW) program. The purpose of this introductory pre-engineering course is to develop the student’s logical thinking skills by solving problems and designing control systems. In this manner, students gain a better understanding of the digital circuits in microelectronic design, manufacturing, computer technology, and information systems. Students participate in a capstone project implementing a solution to a problem: representing the solution schematically, presenting their design to the class, and submitting a report summarizing their work.

Adopted by the Somerville Board of Education on July 25, 2017
<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
</tr>
</thead>
</table>

**Essential Question:**

What laws and principles of electronics and electricity apply to digital electronics?

Why is the binary number system used in digital electronics?

What are the building blocks of digital design?

How can expressions be simplified to create efficient real-world solutions?

How is the environment impacted if circuits are not simplified?

**Content:**

**Fundamentals**

- link schematic symbols to each logic gate
- write each gate as a Boolean expression
- use truth tables to represent the relationship between outputs and inputs
- represent binary logic levels as ones (highs) and zeros (lows)
- use schematics and symbolic algebra to represent digital gates in the creation of solutions to design problems
- identify the name, symbol, and function of basic logic gates
- create Boolean expressions, logic circuit diagrams, and/or truth tables from information provided in the solution of design problems
- describe how Boolean algebra minimizes the number of logic gates in a circuit
- identify Karnaugh mapping (K-map) as a graphical technique used to simplify logic expressions
- use a systematic approach to create a circuit, solving a problem by producing the simplest, most effective, and inexpensive circuitry
- combine gates to produce the required output using combinational logic
- simplify combinational logic circuits using K-maps and Boolean algebra
- restate and simplify a digital design problem as part of the systematic approach to solving a problem

**Number Systems**

- compare the binary number system to others, such as the decimal and hexadecimal systems
- identify the binary number system as the basis for digital electronics
- demonstrate the relationship of binary and hexadecimal to bits and bytes of information used in computers
- explain how binary numbers are used to add and subtract in electronic systems
- create and prove the truth table for both half and full adders

**Gates**

- distinguish between direct and alternating current
- determine the physical characteristics of materials classified as insulators and conductors
- measure resistors in ohms and rate the power dissipated in watts
- relate the material makeup of resistors to how they are used in circuit design
- use symbols associated with resistors

**Boolean Algebra**

- use symbols associated with resistors

**Combinational Circuit Design**

- compare the binary number system to others, such as the decimal and hexadecimal systems
- identify the binary number system as the basis for digital electronics
- demonstrate the relationship of binary and hexadecimal to bits and bytes of information used in computers
- explain how binary numbers are used to add and subtract in electronic systems
- create and prove the truth table for both half and full adders

**Skills and Topics:**

- link schematic symbols to each logic gate
- write each gate as a Boolean expression
- use truth tables to represent the relationship between outputs and inputs
- represent binary logic levels as ones (highs) and zeros (lows)
- use schematics and symbolic algebra to represent digital gates in the creation of solutions to design problems
- identify the name, symbol, and function of basic logic gates
- create Boolean expressions, logic circuit diagrams, and/or truth tables from information provided in the solution of design problems
- describe how Boolean algebra minimizes the number of logic gates in a circuit
- identify Karnaugh mapping (K-map) as a graphical technique used to simplify logic expressions
- use a systematic approach to create a circuit, solving a problem by producing the simplest, most effective, and inexpensive circuitry
- combine gates to produce the required output using combinational logic
- simplify combinational logic circuits using K-maps and Boolean algebra
- restate and simplify a digital design problem as part of the systematic approach to solving a problem
## Digital Electronics
**Grade 10, 11, or 12**

<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skills and Topics:</strong></td>
<td>• setup lab equipment to measure resistor values to compare measured and rated values</td>
<td>• design, construct, and test adder circuits using both discrete and MSI gates</td>
<td>• determine the truth table and Boolean expression for basic logic gates through experimentation</td>
<td>• apply the rules of Boolean algebra to logic diagrams and truth tables, minimizing the circuit size necessary to solve a design problem</td>
<td>• design, construct, build, troubleshoot, and evaluate a solution to a design problem</td>
</tr>
<tr>
<td></td>
<td>• calculate the tolerance levels of various resistors to determine if the measured value is within specifications</td>
<td>• use dimensional analysis to convert values from one number system to another</td>
<td>• using gates, apply logic to design and create solutions to a problem</td>
<td>• use DeMorgan’s Theorem to simplify a negated expression and to convert a sum-of-products (SOP) to a product-of-sums (POS) to save resources in the production of circuits</td>
<td>• present the solution and evaluation of a design problem orally</td>
</tr>
<tr>
<td></td>
<td>• describe the relationship among voltage, resistance, and current in all electronic circuits</td>
<td></td>
<td>• identify the purpose of integrated circuits within multiple gates</td>
<td></td>
<td>• classify integrated circuit (IC) chips according to the number of equivalent gate circuits</td>
</tr>
<tr>
<td></td>
<td>• recognize circuits as composed of a source of electromotive force, a load, and a conductor</td>
<td></td>
<td>• draw a pinout diagram identifying pin functions</td>
<td></td>
<td>• discover the code to create numbers on a seven segment display experimentally</td>
</tr>
<tr>
<td></td>
<td>• define the role of a switch in an electrical circuit</td>
<td></td>
<td>• derive Boolean expressions and truth tables from logic circuits</td>
<td></td>
<td>• design a circuit to control a seven segment display with a decimal to binary coded decimal (BCD) encoder and a display driver</td>
</tr>
<tr>
<td></td>
<td>• use the symbols based on industry standards to draw circuits</td>
<td></td>
<td>• design logic circuits from Boolean expressions and from truth tables</td>
<td></td>
<td>• program a programmable logic device (PLD) with SOP expressions to provide specific logic functions</td>
</tr>
<tr>
<td></td>
<td>• calculate the voltage drop of closed pathways in circuits and the electromotive forces in that pathway</td>
<td></td>
<td>• write product-of-sums and/or sum-of-products expressions from a truth table</td>
<td></td>
<td>• list the benefits of PLDs in digital designs</td>
</tr>
<tr>
<td></td>
<td>• draw and label the parts of a simple circuit</td>
<td></td>
<td>• recognize the relationship between a Boolean expression, logic diagram, and truth table</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Digital Electronics

**Grade 10, 11, or 12**

<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skills and Topics:</strong></td>
<td>• using simulation software and proto-boards, prove the accuracy of Ohm’s and Kirchhoff’s laws</td>
<td>• select the sum-of-products or the product-of-sums form of a Boolean expression to be used in the solution of a problem</td>
<td>• create circuits to solve a problem using NOR or NAND gates replicating all logic functions</td>
<td>• apply understanding of the workings of NOR and NAND gates to make comparisons with standard combinational logic solutions to determine the resultant amount of resource reduction</td>
<td>• design and implement combinational logic circuits using reprogrammable logic devices</td>
</tr>
<tr>
<td></td>
<td>• utilize electrical meters to determine voltage, resistance, and current in simple circuits</td>
<td></td>
<td></td>
<td>• create circuits to solve a problem using NOR or NAND gates replicating all logic functions</td>
<td>• create PLD logic files that define combinational circuit designs using Boolean expressions</td>
</tr>
<tr>
<td></td>
<td>• describe the role of a capacitor and its uses</td>
<td></td>
<td></td>
<td>• apply understanding of the workings of NOR and NAND gates to make comparisons with standard combinational logic solutions to determine the resultant amount of resource reduction</td>
<td>• use logic compiler software to create JEDEC (Joint Electronic Device Engineering Council) files for the programming of PLDs</td>
</tr>
<tr>
<td></td>
<td>• describe the distinctive characteristics of analog and digital signals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• draw and label the components of digital waveforms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Integration of Technology:**
- Internet, Web Quests, wireless laptop computers, computer laboratory, portable language, laboratory, classroom computers, SMART Boards, multimedia presentations, simulations, video streaming, podcasting

**Writing:**
- Open-ended responses, conclusions and analysis of exploratory activities

**Formative Assessments:**
- Warm-up activities, exploratory activities, class discussions, student participation, quizzes, design briefs, sketches, Inventor research

**Summative Assessments:**
- Quizzes, tests, authentic assessments, projects, midterm examination

**Performance Assessments:**
- Exploratory activities, authentic assessments
# Digital Electronics

## Grade 10, 11, or 12

<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>World Language:</strong></td>
<td>7.1.AL.B.5</td>
<td>7.1.AL.B.5</td>
<td>7.1.AL.B.5</td>
<td>7.1.AL.B.5</td>
<td>7.1.AL.B.5</td>
</tr>
</tbody>
</table>

### 21st Century Themes:
- Global Awareness
- Civic Literacy
- Financial, Economic, Business, and Entrepreneurial Literacy
- Health Literacy

### 21st Century Skills:
- Creativity and Innovation
- Media Literacy
- Critical Thinking and Problem Solving
- Life and Career Skills
- Information and Communication Technologies Literacy
- Communication and Collaboration
- Information Literacy
Digital Electronics
Grade 10, 11, or 12

<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
</tr>
</thead>
<tbody>
<tr>
<td>Careers:</td>
<td>Applicable career options are discussed as they arise throughout the pre-engineering program. Career options include, but are not limited to, the following career clusters: Architecture and Construction Career Cluster; Arts, A/V Technology, and Communications Career Cluster; Business, Management, and Administration Career Cluster; Education and Training Career Cluster; Government and Public Administration Career Cluster; Information Technology Career Cluster; Law, Public Safety, Correction, and Security Career Cluster; Manufacturing Career Cluster; Marketing Career Cluster; Science, Technology, Engineering and Mathematics Career Cluster; Transportation, Distribution, and Logistics Career Cluster.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*2016 NJSLS
RST: Reading in Science and Technical Subjects
WHST: Writing in History, Science, and Technical Subjects
SL: Speaking and Listening
L: Language

N: Real Number System
A: Algebra
F: Functions
G: Geometry
S: Statistics and Probability
MD: Measurement and Data
N-Q: Quantities
N-VM: Vector and Matrix Quantities
A- SSE: Seeing Structure in Expressions
A-REI: Reasoning with Equations and Inequalities
F-BF: Building Functions
F-IF: Interpreting Functions
F-LE: Linear, Quadratic, and Exponential Models
F-TF: Trigonometric Functions
G-CO: Congruence
G-SRT: Similarity, Right Triangles, and Trigonometry
G-C: Circles
G-GPE: Expressing Geometric Properties with Equations
S-ID: Interpreting Categorical and Quantitative Data
S-IC: Making Inferences and Justifying Conclusions
S-MD: Using Probability to Make Decisions
# Digital Electronics

**Grade 10, 11, or 12**

<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
</table>

**Essential Question:**
- What conditions determine the output of a latch or a flip-flop?
- How can flip-flops be made into counters to automate sequential designs?
- How can the Cartesian coordinate system be used to write code to manufacture real-world objects?
- How can a device be designed within specific constraints?
- How has the pre-engineering program prepared us to pursue lifelong learning goals?

**Content:**
- **Flip-flops**
  - Asynchronous Counters
  - Computer Integrated Manufacturing
  - Marble Sorter Project Design
  - Post-secondary Planning

**Skills and Topics:**
- distinguish between a latch and a flip-flop in storage of data
- describe the operations performed by combinational circuits
- explain why a flip-flop has two outputs, always in opposite states, whose output is connected back into the input
- construct and test simple latches and flip-flops from discrete gates
- interpret, design, draw, and evaluate circuits using the logic symbols for latches and flip-flops
- describe the function of registers
- create shift registers from a group of flip-flops, which operate as a coherent unit
- explain why manufacturers use shift registers in integrated circuit (IC) form for applications (e.g., printers, modems)
- conduct experiments to determine the basic principles of how shift registers work
- evaluate the use of shift registers in product design
- distinguish between reference and position points
- relate the axis system as the worldwide standard for machine movement
- identify the axes to delineate the commands determining the movement of the robotic arm
- plot points using absolute, relative (incremental), and polar coordinates
- identify significant points on geometric figures
- demonstrate the ability to safely setup, maintain, and operate a computer numeric control (CNC) machine center using appropriate documentation and procedures
- analyze part geometry to select appropriate cutting tools and fixturing devices needed to create the part using a CNC machine
- setup and edit the tool library of a CNC program providing offset values and tool geometry
- assess and modify personalized student learning plans to support declared career goals
- characterize education and skills needed to achieve career goals
- discuss steps needed to prepare for post-secondary options
- use online resources to examine licensing, certification, and credentialing requirements to maintain compliance with industry requirements
# Digital Electronics

**Grade 10, 11, or 12**

<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skills and Topics:</strong></td>
<td>• interpret waveform diagrams from constructed circuits and compare with combinational waveforms</td>
<td>• explain how asynchronous counters are controlled by clock pulse fed counters in a series of flip-flops</td>
<td>• identify the optimum location for the program reference zero (PRZ) point</td>
<td>• calculate and verify appropriate spindle speeds and feed rates specific to each cutting tool utilized in an NC part program</td>
<td>• develop career readiness skills by participating in structured learning experiences</td>
</tr>
<tr>
<td></td>
<td>• compare and contrast the operation of synchronous and asynchronous flip-flop circuits</td>
<td>• describe why asynchronous counters (ripple counters) are slower than synchronous counters</td>
<td>• illustrate the three categories of machine movement</td>
<td>• verify NC part programs using simulation software before machining the part on a CNC device</td>
<td>• identify transferable skills in career choices and design alternative career plans based on those skills</td>
</tr>
<tr>
<td></td>
<td>• create and interpret timing diagrams and truth tables for J-K flip-flops</td>
<td>• describe how asynchronous counters are made using discrete gates or integrated chips</td>
<td>• complete a preliminary plan identifying necessary work holding devices, cutting tools, reference points, machining sequences, and safe operation</td>
<td>• demonstrate all possible methods of disabling a CNC machine in the event of an emergency</td>
<td>• interpret how changing economic and societal needs influence employment trends and future education</td>
</tr>
<tr>
<td></td>
<td>• compare and contrast the basic methods of preventing a flip-flop from changing state multiple times during a clock cycle (master/slave or edge triggered)</td>
<td>• create a circuit using discrete flip-flops to discover the operation and characteristics of asynchronous counters</td>
<td>• explain the terms alphanumeric coding, G codes, and M codes</td>
<td>• follow a safety checklist prior to running an NC part program on a CNC machine</td>
<td>• identify the sections of a program</td>
</tr>
<tr>
<td></td>
<td>• select the appropriate type of triggers used by latches and flip-flops when designing circuits</td>
<td>• design, simulate, build, and test modulus counters using discrete gates and integrated counter chips in the solution to a design problem</td>
<td>• identify the sections of a program</td>
<td>• operate the CNC machine to cut a part to specifications</td>
<td>• explore the advantages and disadvantages of shop floor programming, as well as off-line programming</td>
</tr>
<tr>
<td></td>
<td>• analyze timing diagrams that reflect triggering to identify distinguishing characteristics</td>
<td></td>
<td>• write a basic numeric control (NC) part program using necessary G and M codes, including remarks that describe the function of each code</td>
<td>• design, program, and construct a marble sorter</td>
<td>• present the marble sorter to the class for peer review</td>
</tr>
</tbody>
</table>
Digital Electronics  
Grade 10, 11, or 12

<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
</table>
| Skills and Topics:   | • discuss circuits using propagation delay and pulse width factors  
                      • explore with clock pulse width to determine the effect on the accuracy of data transmission  
                      • assemble circuits and compile information about the various applications of flip-flops | | • create a simple numeric control (NC) part program  
                      • employ software to create a part  
                      • analyze, identify, and correct errors found in NC part program files  
                      • use software to graphically verify NC program operation  
                      • generate a chart plotting the necessary points using absolute, relative (incremental), and polar coordinates  
                      • complete a pre-programming checklist identifying the following:  
                        ○ optimal PRZ  
                        ○ tools and cutting methods  
                        ○ fixturing devices  
                      • write and debug a simple NC part program file to produce a design  
                      • verify NC part program file | | | |

Integration of Technology: Internet, Web Quests, wireless laptop computers, computer laboratory, portable language, laboratory, classroom computers, SMART Boards, multimedia presentations, simulation, video streaming, podcasting

Writing: Open-ended responses, conclusions and analysis of exploratory activities
# Digital Electronics
**Grade 10, 11, or 12**

<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formative Assessments:</strong></td>
<td>Warm-up activities, exploratory activities, class discussions, student participation, quizzes, design briefs, sketches, Inventor research</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Summative Assessments:</strong></td>
<td>Quizzes, tests, authentic assessments, projects, final examination</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Performance Assessments:</strong></td>
<td>Exploratory activities, authentic assessments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Digital Electronics
Grade 10, 11, or 12

<table>
<thead>
<tr>
<th>Month/Marking Period</th>
<th>February</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
</table>

21st Century Themes:
- ☑Global Awareness
- ☑Civic Literacy
- ☑Financial, Economic, Business, and Entrepreneurial Literacy
- ☑Health Literacy

21st Century Skills:
- ☑Creativity and Innovation
- ☑Media Literacy
- ☑Critical Thinking and Problem Solving
- ☑Life and Career Skills
- ☑Information and Communication Technologies Literacy
- ☑Communication and Collaboration
- ☑Information Literacy

Resources:

Careers:
Applicable career options are discussed as they arise throughout the pre-engineering program. Career options include, but are not limited to, the following career clusters: Architecture and Construction Career Cluster; Arts, A/V Technology, and Communications Career Cluster; Business, Management, and Administration Career Cluster; Education and Training Career Cluster; Government and Public Administration Career Cluster; Information Technology Career Cluster; Law, Public Safety, Correction, and Security Career Cluster; Manufacturing Career Cluster; Marketing Career Cluster; Science, Technology, Engineering and Mathematics Career Cluster; Transportation, Distribution, and Logistics Career Cluster.
**2016 NJSLS:**

- **RST:** Reading in Science and Technical Subjects
- **WHST:** Writing in History, Science, and Technical Subjects
- **SL:** Speaking and Listening
- **L:** Language

<table>
<thead>
<tr>
<th>N: Real Number System</th>
<th>N-VM: Vector and Matrix Quantities</th>
<th>N-Q: Quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>F: Functions</td>
<td>F-IF: Interpreting Functions</td>
<td>F-LE: Linear, Quadratic, and Exponential Models</td>
</tr>
<tr>
<td>G: Geometry</td>
<td>F-BF: Building Functions</td>
<td>F-TF: Trigonometric Functions</td>
</tr>
<tr>
<td>S: Statistics and Probability</td>
<td>F-LF: Linear, Quadratic, and Exponential Models</td>
<td>S-IC: Making Inferences and Justifying Conclusions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G-C: Circles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G-SRT: Similarity, Right Triangles, and Trigonometry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>G-GPE: Expressing Geometric Properties with Equations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S-ID: Interpreting Categorical and Quantitative Data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S-IC: Making Inferences and Justifying Conclusions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>S-MD: Using Probability to Make Decisions</td>
</tr>
</tbody>
</table>
Course Description

Digital Electronics is a core course of study in the Project Lead The Way (PLTW) program. The purpose of this introductory pre-engineering course is to develop the student’s logical thinking skills by solving problems and designing control systems. In this manner, students gain a better understanding of the digital circuits in microelectronic design, manufacturing, computer technology, and information systems. Students participate in a capstone project implementing a solution to a problem, breadboarding the solution using appropriate parts, presenting their design to the class, and submitting a report summarizing their work.

Course Content

This course will consist of the following units of study:

- Fundamentals
- Number Systems
- Gates
- Boolean Algebra
- Combinational Circuit Design
- Flip-flops
- Asynchronous Counters
- Computer Integrated Manufacturing
- Marble Sorter Project Design
- Post-secondary Planning

Course Objectives

The student will demonstrate the ability to answer in detail the following essential questions:

- What laws and principles of electronics and electricity apply to digital electronics?
- Why is the binary number system used in digital electronics?
- What are the building blocks of digital design?
- How can expressions be simplified to create efficient real-world solutions?
- How is the environment impacted if circuits are not simplified?
- What conditions determine the output of a latch or flip-flop?
Course Objectives (continued)

- How can flip-flops be made into counters to automate sequential designs?
- How can the Cartesian coordinate system be used to write code to manufacture real-world objects?
- How can a device be designed within specific constraints?
- How has the pre-engineering program prepared us to pursue lifelong learning goals?
- What are the post-graduation and/or career options that apply to the course content?

Evaluation Process

A final average of 65% or better is required to be awarded course credit. Throughout the length of this course, students may be evaluated on the basis of, but not limited to:

- Formative Assessments, such as writing prompts, journals, and portfolios
- Summative Assessments, such as quizzes, tests, and midterm and final examinations
- Performance Assessments, such as projects and presentations
- Technology-based Applications, such as electronic portfolios, Web Quests, ThinkQuest, and podcasting
- Class Participation
- Homework

Specific weights will be determined by course and level.
Digital Electronics
Student Agreement

STUDENT NAME: ___________________________________________

Last Name First Name

GRADE: ____________

My signature below indicates that I have received a copy of the Somerville Public Schools Course Requirements for Digital Electronics.

I acknowledge my responsibility to read and understand all of the information contained in the Digital Electronics Course Requirements information and syllabus packet.

__________________________________________________________
Student Signature                                      Date

Note: Please share the course requirements for Digital Electronics with your parents.