TN Department of Education | College, Career and Technical Education

May 2024

Digital Electronics

Primary Career Clusters:	Advanced Manufacturing and STEM
Course Contact:	CTE.Standards@tn.gov
Course Code(s):	C13H07
Pre-requisite(s):	*Algebra I* (G02X02, G02H00)
Credit:	1
Grade Level:	10
Focus Elective Graduation Requirement:	This course satisfies one of three credits required for an elective focus when taken in conjunction with other Advanced Manufacturing or *STEM* courses.
Program of Study (POS) Concentrator:	This course satisfies one out of two required courses that meet the Perkins V concentrator definition, when taken in sequence in the approved program of study.
Programs of Study and Sequence:	This is the second course in the *Mechatronics* and *Technology* programs of study.
Aligned Student Organization(s):	SkillsUSA: http://www.skillsusatn.org/ Technology Student Association (TSA): http://www.tntsa.org
Coordinating Work-Based Learning:	Teachers are encouraged to use embedded WBL activities such as informational interviewing, job shadowing, and career mentoring. For information, visit https://www.tn.gov/education/educators/career-and-technical-education/work-based-learning.html.
Promoted Tennessee Student Industry Credentials:	Credentials are aligned with postsecondary and employment opportunities and with the competencies and skills that students acquire through their selected program of study. For a listing of promoted student industry credentials, visit https://www.tn.gov/education/educators/career-and-technical-education/student-industry-certification.html.
Teacher Endorsement(s):	013, 014, 015, 016, 017, 018, 047, 070, 078, 081, 125, 126, 127, 128, 129, 157, 210, 211, 212, 213, 214, 230, 231, 232, 233, (042 and 043), (042 and 044), (042 and 045), (042 and 046), (042 and 047), (042 and 077), (042 and 078), (042 and 079), (043 and 044), (043 and 045), (043 and 046), (043 and 047), (043 and 077), (043 and 078), (043 and 079), (044 and 045), (044 and 046), (044 and 047), (044 and 077), (044 and 078), (044 and 079), (045 and 046), (045 and 047), (045 and 077), (045 and 078), (045 and 079), (046 and 047), (046 and 077), (046 and 078), (046 and 079), (047 and 077), (047 and 078), (047 and 079), (077 and 078), (077 and 079), (078 and 079), 413, 414, 415, 416, 417, 418, 449, 470, 477, 501, 502, 519, 523, 531, 537, 551, 552, 553, 554, 555, 556, 557, 567, 575, 582, 584, 585, 595, 596, 598, 700, 701, 705, 707, 740, 760, 982
Required Teacher Certifications/Training:	Some endorsements require NIMS industry certification to teach this course. Please refer Occupational Endorsement License Guide for a full list.
Teacher Resources:	https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-advanced-manufacturing.html https://www.tn.gov/education/educators/career-and-technical-education/career-clusters/cte-cluster-stem.html Best for All Central: https://bestforall.tnedu.gov/

Course at a Glance

CTE courses provide students with an opportunity to develop specific academic, technical, and 21st century skills necessary to be successful in career and in life. In pursuit of ensuring every student in Tennessee achieves this level of success, we begin with rigorous course standards which feed into intentionally designed programs of study.

Students engage in industry relevant content through general education integration and experiences such as career and technical student organizations (CTSO) and work-based learning (WBL). Through these experiences, students are immersed with industry standard content and technology, solve industry-based problems, meaningfully interact with industry professionals and use/produce industry specific, informational texts.

Using a Career and Technical Student Organization (CTSO) in Your Classroom

CTSOs are a great resource to put classroom learning into real-life experiences for your students through classroom, regional, state, and national competitions, and leadership opportunities. Below are CTSO connections for this course, note this is not an exhaustive list.

- Participate in CTSO Fall Leadership Conference to engage with peers by demonstrating logical thought processes and developing industry specific skills that involve teamwork and project management.
- Participate in contests that highlight job skill demonstration. These include Career Pathways Showcase, Job Interview, Automated Manufacturing Technology, and Electronics Technology.

Using a Work-Based Learning (WBL) in Your Classroom

Sustained and coordinated activities that relate to the course content are the key to successful work-based learning. Possible activities for this course include the following. This is not an exhaustive list.

- **Standards 1.1-1.2** | Include a safety briefing in a visit to an industry partner/job site.
- **Standards 2.1-2.2** | Visit an employer and talk with those employees about career options.
- **Standards 3.3-3.4, 6.2-7.1, 8.2, 10.1** | Do a project that is used by local industry or evaluated by local industry managers.
- **Standards 5.1-5.2** | Have an industry person visit the class to talk about and demonstrate the importance of logic circuits on the job.
- **Standard 9.1** | Discuss troubleshooting with an employee responsible for troubleshooting.

Course Description

Digital Electronics is intended to provide students with an introduction to the basic components of digital electronic systems and equip them with the ability to use these components to design more complex digital systems. Proficient students will be able to (1) describe basic functions of digital components (including gates, flip flops, counters, and other devices upon which larger systems are designed); (2) use these devices as building blocks to design larger, more complex circuits; (3) implement these circuits using programmable devices; and (4) effectively communicate designs and systems. Students develop additional skill in technical documentation when operating and troubleshooting circuits. Upon completion of the *Digital Electronics* course, proficient students will be able to design a complex digital system and communicate their designs through a variety of media.

Course Standards

1. Safety

1.1 Safety Rules: Accurately read, interpret, and **demonstrate adherence to safety rules** including (1) rules published by the National Science Teachers Association (NSTA), (2) rules pertaining to electrical safety, (3) Occupational Safety and Health Administration (OSHA) guidelines, and (4) state and national code requirements. Be able to distinguish between the rules and explain why certain rules apply.

1.2 Safety Equipment: Identify and explain the intended **use of safety equipment** available in the classroom. For example, demonstrate how to properly inspect, use, and maintain safe operating procedures with tools and equipment.

2. Citizenship and Career Exploration

2.1 Citizenship: Explain the **importance of electrical and/or computer engineers' contributions to society.** Select several such contributions as justification and provide compelling evidence for how electrical/computer engineers' designs are used in everyday applications. Incorporate a variety of sources to gather data, including print and electronic; cite each source, and briefly describe why the particular source is reliable.

2.2 Postsecondary: Identify the **postsecondary institutions** in Tennessee that offer electrical engineering or electrical and/or computer engineering technology. Individually or in teams, develop and publish information that identifies admissions criteria, the postsecondary programs of study, and the secondary courses that will prepare students for success after high school in electrical or computer engineering fields. Cite each source adhering to standard citation conventions used in engineering disciplines.

3. Gates in Logic Circuits

3.1 Logic Gates: Identify each type of **logic gate** with a drawing, a description of its function in a short sentence or paragraph, a specification of each truth table, and the equation for each gate (buffer, inverter, AND, NAND, OR, NOR, XOR [difference], and XNOR [equivalence]), including the valid number of input(s) and output(s) for each gate.

3.2 Flip Flops: Define **D and JK flip flops** by including a drawing, a description of the function in a short sentence or paragraph, and a specification of each truth table and equation. The description should explain how the "clock" signal is related to the flip flop.

3.3 Combinational Devices: Design three (or more) **combinational (without a clock signal) devices** to a scale that would be typically implemented in a medium-scale integrated circuit (MSI: typically 10-1000 gates). One of the devices should incorporate XOR / XNOR gates. Examples of devices include 4-bit or greater versions of the following: adder/subtractor, comparator, multiplexer, and calculator. Upon completion of the design, provide an overview of the device and its specifications, an accompanying schematic, and a list of the gates used. Present the project to classmates and refine the presentation based on their feedback.

3.4 Combinational Project: Develop and publish information detailing a rich description of one of the **combinational projects**, and including a schematic and summary of test results. If a prototyping system is available in the classroom (Xilinx, Altera, or similar), physically test the project and report results. If possible, include a video of the test. Present the project to the class, and revise based on peer feedback.

3.5 Diagram and Schematic: Design a counter with up to 32 states and write an explanatory text describing how the counter operates using technical and domain-specific vocabulary. **Provide a state diagram and draw a schematic** for the circuit using D or JK flip flips.

4. Counters in Logic Circuits

4.1 Counter: Design two (or more) **sequential devices that utilize a counter**. For example, design a traffic light system with two turn arrows. Explain the project with a description of the device, an accompanying schematic, and a list of the gates used.

5. Oscillators in Logic Circuits

5.1 Astable Monovibrator: In teams, design a clock signal using a 555-timer in an **astable monovibrator** configuration. Simulate the design and/or build a prototype and measure the output frequency. If instrumentation to measure the frequency is not available (an oscilloscope for example), a clock frequency timed using a stopwatch can be used as an alternative. Compare and contrast the prediction of the outcome with actual results. Explain the circuit design, the prediction, and the results from the simulation or prototype. *Note: The instructor may wish to constrain the output frequency by supplying a resistor value and/or a capacitor value.*

5.2 Counter: In teams, **design a counter** with between 16 and 32 states. Clock the counter using an oscillator of known frequency, and predict the frequency from each output (each bit in the counter). Simulate the counter to verify the prediction. If possible, the counter should be physically prototyped to verify the prediction and simulation. Calculate the error between the prediction and simulation or prototype. Produce a technical report to summarize findings.

6. Multiplexers in Signal Distribution

6.1 Multiplexer: Design a circuit with 4-8 signals and **use a multiplexer** to select one of the signals as the output, then simulate the circuit. Explain the circuit describing the inputs, explaining the circuitry used to select the channel to output, and featuring a timing diagram illustrating the successful operation of the circuit.

6.2 Multiplexer with Gates: In teams, design a **4-channel multiplexer using gates**. Simulate or build a prototype of the circuit, and demonstrate it to the class. Participate in a class discussion that compares and contrasts the various designs exhibited. As a class, determine the best design and provide supporting evidence from observations and functionality to justify the decision.

7. Functions of Analog and Digital Convertors

7.1 Analog and Digital Counters: Design a **circuit using an A/D converter** to measure the temperature in the room. Specify the assumptions made for minimum and maximum temperatures, and calculate the resolution (step) of the system. Upon completion of the circuit, write a technical specification of the design; then present the design and technical specifications to the class, including a graph showing the input and output values. Using the feedback from classmates, write a summary describing how the design could be revised and improved in future projects. *Note: Instructors may substitute a similar project in which a continuous and limited quantity is measured.*

7.2 Uses for Converters: Explain the **uses for A/D and D/A converters** in a current technical device. For example, describe how data acquisition systems in race cars use A/D and D/A converters. Draw on the research findings to develop talking points and participate in a mock public forum on the uses for A/D and D/A converters.

8. Physical Computing and Program Microcontrollers

8.1 Computer System: Sketch and describe a **block diagram of a computer system**, detailing at least the following components:

a. microcontroller/microprocessor,
b. cache,
c. RAM (random access memory),
d. large-scale memory,
e. input devices, and
f. output devices (monitor[s]).

Show the proper connections between each component, such as data bus and address bus connections. Using visual aids, present and explain the block diagram to the class.

8.2 Microcontroller: **Program a microcontroller-based system** to perform a series of tasks. The microcontroller should be part of a larger system. Upon completion of the programming, explain the functions and intended uses of the end product. Include the specifications of the series of tasks performed by the microcontroller and the programming code with comments for each function.

8.3 Physical Computing: Create a system to **demonstrate how hardware is connected to code**. For example: write code, assemble the hardware components, run the code, and assess if the hardware does the intended action.

9. Technical Documentation and Troubleshooting

9.1 Troubleshooting: Consult technical documents (such as data sheets, timing diagrams, operating manuals, and schematics) of digital components (TTL, CMOS, etc.) to **develop a troubleshooting methodology for a digital circuit** that could be used by a new technician. Explain the troubleshooting procedure.

10. Projects

10.1 Project: Identify a problem requiring a digital circuit (including A/D, D/A conversion, and/or a microprocessor). Follow the design process to **solve the problem using digital electronics**. Explain the solution, including a background section describing the problem which cites written or electronic sources and documentation of each stage in the design process. Build a prototype proof-of-concept if feasible. Present the problem, the design process used, and the developed solution to the class and other technical or non-technical audience members (e.g., parents, teachers, school administrators, STEM professionals, etc.). The final report draft should be critiqued by a different student team or outside expert. Thereafter, incorporate feedback to refine the report and submit a final version.

Standards Alignment Notes

*References to other standards include:

- P21: Partnership for 21st Century Skills Framework for 21st Century Learning
    - Note: While not all standards are specifically aligned, teachers will find the framework helpful for setting expectations for student behavior in their classroom and practicing specific career readiness skills.