Digital Electronics

Level: 2
Career Cluster: Advanced Manufacturing
Program: Engineering
Pathway: Aerospace Engineering Technician, Engineering, Engineering Applications UAS

Course Catalog Description

Introduces students to the principles and applications of digital systems through hands-on circuit construction, logic design, and technical problem solving. Students build and troubleshoot digital circuits while applying concepts such as logic gates, binary numbers, Boolean algebra, combinational and sequential logic, and technical documentation.

Summary

Digital Electronics is an intermediate engineering course in which students explore the principles, components, and applications of modern digital systems through hands-on investigation, circuit design, and technical problem solving. Students develop an understanding of how digital electronics differ from analog systems and apply core concepts including logic gates, TTL and CMOS devices, binary number systems, arithmetic circuits, Boolean algebra, truth tables, and combinational and sequential logic. Through lab activities, students build, test, troubleshoot, and refine digital circuits using standard tools, safe lab practices, and technical documentation. As the course progresses, students analyze and implement more advanced systems involving flip-flops, counters, registers, encoding and decoding, display systems, and programmable devices when available. Students also strengthen collaboration, communication, and career-readiness skills by documenting their work, explaining design decisions, and completing a capstone-style project in which they design, construct, evaluate, and present a complete digital system.

Notes

This revised version is more fully developed, more clearly sequenced, and better aligned to current CTE course design expectations. The earlier document functioned primarily as a draft list of competencies and technical skills, while this updated version organizes the course into a more complete instructional framework that includes a course catalog description, a detailed summary, section-based objectives, and grouped student learning outcomes. The revised course also strengthens instructional coherence by clarifying how students move from foundational concepts such as analog versus digital systems, safety, logic gates, TTL and CMOS devices, binary numbers, and Boolean algebra into more advanced applications involving arithmetic circuits, combinational and sequential logic, flip-flops, counters, registers, encoding and decoding, display systems, programmable devices, and circuit design documentation. In addition, the new document places greater emphasis on collaboration, communication, leadership, and work-based learning so that students are not only building technical knowledge but also demonstrating employability and project-based skills that connect classroom learning to real-world engineering practice.

Student Learning Outcomes

1. Career Exploration and Postsecondary Opportunities

***Objective**: Students will explore and analyze career pathways related to engineering by examining professional roles, tools, work environments, ethical and legal responsibilities, certifications, professional organizations, and Colorado postsecondary education options in order to make informed academic and career decisions*

1) Identify employment opportunities in various fields with a focus in the area of engineering
    a. Recognize the work typically performed, tools and technology used, and nature of work environments
    b. Identify potential certifications within the careers
    c. Find membership organizations associated with the careers
    d. Understand the necessary education associated within the careers
2) Define professionalism within the context of engineering
    a. Criticism and evaluation
    b. Presentation
    c. Assessment
3) Recognize laws, regulations, and ethics significant to the fields of engineering
4) Identify postsecondary opportunities offered in the state of Colorado
    a. Technical college, community college, 4-year institutions
    b. Certificates, associates, bachelor, and advanced degree opportunities

2. Foundations of Digital Electronics

***Objective**: Students will understand and compare the fundamental concepts of digital and analog systems and analyze how digital electronics are used in modern engineered devices.*

5) Define digital electronics and explain its role in modern technology.
6) Differentiate between analog and digital variables and systems.
7) Describe advantages of analog systems and advantages of digital systems.
8) Explain how digital electronics support devices such as computers, phones, and control systems.
9) Analyze why digital signals improve storage, speed, and reliability in engineering systems.

3. Safety, Tools, and Lab Practices

***Objective**: Students will apply safe practices and demonstrate proper use of tools, components, and procedures when building and testing digital circuits.*

10) Interpret classroom and lab safety expectations related to electronics work.
11) Identify the intended use of safety equipment and ESD-related precautions when handling components.
12) Demonstrate safe operating procedures with tools, breadboards, and digital components.
13) Inspect tools and electronic equipment for safe and proper use before operation.
14) Evaluate how safe lab habits improve troubleshooting accuracy and system reliability.

4. Logic Gates and Basic Circuit Construction

***Objective**: Students will identify, build, and test fundamental logic circuits using standard digital components.*

15) Identify the basic logic gates including AND, OR, NOT, NAND, and NOR.
16) Describe the input and output behavior of each basic logic gate.
17) Build simple TTL logic circuits on a breadboard.
18) Troubleshoot TTL logic circuits using appropriate techniques.
19) Analyze how combinations of basic logic gates produce more complex outcomes.

5. TTL, CMOS, and Special Purpose Gates

***Objective**: Students will compare and apply different digital logic families and evaluate special-purpose functions used in circuit design.*

20) Identify the logic gates available in CMOS devices.
21) Locate important specifications such as ESD considerations in TTL and CMOS datasheets.
22) Explain the operation of XOR and XNOR logic functions.
23) Implement logic circuits using AND-OR-Invert chips.
24) Explain the purpose of Schmitt trigger circuits.
25) Compare TTL and CMOS devices in terms of application, handling, and circuit use.

6. Binary Numbers and Digital Number Systems

***Objective**: Students will convert, represent, and compute values in binary and related number systems used in digital electronics.*
26) Explain numbers in unsigned and signed binary form.
27) Convert numbers among decimal, binary, octal, hexadecimal, and BCD formats.
28) Represent negative binary numbers in two's complement form.
29) Add, subtract, multiply, and divide signed and unsigned binary numbers.
30) Add numbers in BCD format.
31) Analyze how binary systems support digital processing and circuit design.

7. Arithmetic Circuits and Combinational Logic

***Objective**: Students will design and analyze combinational circuits that perform arithmetic and logic functions.*

32) Build a half-adder circuit using TTL gates.
33) Build a full-adder circuit using TTL gates.
34) Build a 4-bit adder using a TTL adder chip.
35) Build a 4-bit BCD adder using a TTL adder chip.
36) Explain how combinational logic supports arithmetic operations in digital systems.
37) Evaluate circuit performance by comparing expected and observed outputs.

8. Boolean Algebra and Logic Representation

***Objective**: Students will translate and simplify digital logic using Boolean algebra, truth tables, and circuit diagrams.*

38) Write Boolean expressions for basic logic gates.
39) Write Boolean expressions for combinational logic circuits.
40) Write Boolean expressions from truth tables.
41) Simplify Boolean expressions using valid methods.
42) Translate among logic circuits, truth tables, and Boolean expressions.
43) Apply DeMorgan's Theorem to simplify logic circuits.

9. Troubleshooting and Circuit Analysis

***Objective**: Students will diagnose, test, and refine digital circuits using systematic troubleshooting methods.*

44) Use a logic probe to identify open pins or traces.
45) Use a logic probe to identify shortened pins or traces.
46) Develop a troubleshooting methodology for a digital circuit that could be used by a new technician.
47) Analyze circuit behavior to determine probable sources of error.
48) Evaluate whether a circuit meets intended design criteria after repair or redesign.

10. Sequential Logic, Flip-Flops, and Counters

***Objective**: Students will explain and apply sequential logic concepts using flip-flops and counters to control digital systems.*

49) Explain the operation of an SR latch, gated SR latch, and master-slave latch.
50) Use state tables to explain D, T, and JK flip-flop behavior.
51) Implement a frequency divider circuit using JK flip-flops.
52) Explain the operation of synchronous and asynchronous counters.
53) Construct modulus synchronous counters and asynchronous up/down counters using JK flip-flops.
54) Evaluate advantages and limitations of synchronous and asynchronous counters.

11. Registers, Encoding, and Display Systems

***Objective**: Students will analyze and construct digital systems that store, encode, decode, and display information.*

55) Explain the operation of Johnson counters and ring counters.
56) Compare serial and parallel data transmission.
57) Explain the operation of an 8-3 octal encoder and a 3-8 decoder.
58) Explain Gray coding and its purpose.
59) Build a display circuit using a 7-segment decoder.
60) Map the pins of a 7-segment LED display using a logic probe.

12. Programmable Devices, Design Process, and Technical Documentation

***Objective**: Students will apply the engineering design process to develop and document digital systems using technical communication and programmable implementation when available.*

61) Identify a problem requiring a digital circuit solution.
62) Apply an identified design process to solve the problem using digital electronics.
63) Produce drawings and schematics for a digital circuit design.
64) Predict results from the design before implementation.
65) Implement digital circuits using programmable devices when available.
66) Document testing, revisions, and troubleshooting using clear technical notation.

13. Collaboration, Communication, and Digital Electronics Project

***Objective**: Students will synthesize digital electronics knowledge to design, build, test, troubleshoot, and communicate a complete digital system.*

67) Collaborate with peers to analyze, design, and test digital circuits.
68) Communicate design intent, circuit behavior, and troubleshooting results clearly in written and oral forms.
69) Design a complex digital system using combinational and sequential logic.
70) Construct and test the digital system using appropriate tools and methods.
71) Evaluate the final system against design requirements, constraints, and expected results.
72) Present and defend the completed system, design choices, and performance results to an audience.

14. Leadership

***Objective**: Students will demonstrate leadership skills by communicating effectively, collaborating with others, taking initiative, and applying professional responsibility in classroom, laboratory, and project-based settings.*

73) Demonstrate leadership skills through teamwork, initiative, and responsible decision-making.
74) Apply effective communication strategies when working with peers, instructors, and industry partners.
75) Model professionalism, accountability, and ethical behavior in individual and collaborative work.
76) Evaluate personal leadership strengths and identify areas for growth.

15. Work-Based Learning

***Objective**: Students will connect classroom learning to workplace expectations by exploring industry experiences, practicing employability skills, and reflecting on how digital electronics knowledge applies in real-world settings.*

77) Identify workplace skills and expectations relevant to careers in engineering and digital electronics.
78) Engage in work-based learning experiences such as guest speakers, job shadows, industry projects, or workplace tasks.
79) Demonstrate employability skills including punctuality, communication, collaboration, and adaptability.
80) Reflect on work-based learning experiences to evaluate career interests and personal readiness for postsecondary and workforce opportunities.

16. Career and Technical Student Organizations

Objective: *Using the CTSO Resource Document, chapter activities will provide some of the best opportunities CTSO members will have to learn by doing. A successful program of work creates a positive learning atmosphere in the classroom. CTSO members learn how to accept responsibility, work as a team, manage a budget, and handle success and failure. Per the CTE Admin Handbook, CTSOs are embedded into curriculum.*

Professional Development

Prepare each member for entry into the workforce and provide a foundation for success in a career. Becoming a professional does not stop with acquiring a skill, but involves an increased awareness of the meaning of good citizenship and the importance of labor and management in the world of work.

Community Service

Promote and improve goodwill and understanding among all segments of the community through services donated by CTSO chapters, and to instill in its members a lifetime commitment to community service.

Business and Industry Connections

Increase awareness of quality job practices and attitudes, and increase the opportunities for employer engagement and eventual employment.

Financial Leadership

Plan and participate in activities to allow all members to carry out the chapter's projects. Educate members on their own personal finance for current and future success.

Public Relations

Make the general public aware of the good work that students in career and technical education are doing to better themselves and their community, state, nation, and world.

Social Activities

To increase cooperation in the school and community through activities that allow CTSO members to get to know each other in something other than a business or classroom setting.

Academic Standards Alignment

Colorado CTE courses are required to integrate academic and essential skills into course content. The following academic standards have been identified as aligned to this course and should be integrated throughout instruction.

CO CTE Academic Standards Resources (Rubrics, integration strategies, etc)
CDE Colorado Academic Standards Online (Online standards lookup tool)

Note: Mathematics and Science standards will be added in the future. Visit the Colorado Academic Standards page for the most current version.

Reading, Writing and Communicating Crosswalk

Course: Digital Electronics
Colorado Academic Standards – Reading, Writing and Communicating

Standard	Prepared Graduate Competency	Description	Course Evidence / Alignment
Standard 1: Oral Expression and Listening	Prepared Graduate 1 – Collaboration	Collaborate effectively as group members or leaders.	Students work in teams to design and troubleshoot digital circuits, share responsibility for system development, and discuss logic, errors, and design decisions.
Standard 1: Oral Expression and Listening	Prepared Graduate 2 – Oral Presentations	Deliver effective oral presentations for varied audiences.	Students explain digital system designs, communicate how circuits function, and present and justify design solutions.
Standard 2: Reading for All Purposes	Prepared Graduate 4 – Informational Texts	Read a wide range of informational texts.	Students read and interpret technical documentation, datasheets, circuit specifications, diagrams, safety procedures, and standards.
Standard 2: Reading for All Purposes	Prepared Graduate 5 – Language in Context	Understand how language functions in different contexts.	Students use discipline-specific technical language

			and symbolic or logical representations such as truth tables and logic notation.
Standard 3: Writing and Composition	Prepared Graduate 7 – Informational Writing	Craft informational and explanatory texts.	Students produce technical explanations of circuits, design documentation, and system descriptions.
Standard 3: Writing and Composition	Prepared Graduate 9 – Writing Process	Demonstrate mastery of their own writing process.	The course requires iterative documentation, revision, and maintenance of clear, accurate, and polished technical records.
Standard 4: Research Inquiry and Design	Prepared Graduate 10 – Research and Ethics	Gather information from a variety of sources.	Students research electronic components and system behavior, evaluate datasheets and reference materials, and apply researched information to digital system design.

Free Resource Links

1. Career Exploration and Postsecondary Opportunities

- CareerOneStop (career exploration certifications salary education pathways)
  www.careeronestop.org
- O*NET Online (career profiles tools workplace skills job expectations)
  www.onetonline.org
- Bureau of Labor Statistics Occupational Outlook Handbook (job outlook education pathways salary data)
  www.bls.gov/ooh
- Colorado Community College System (Colorado programs degrees certificates pathways)
  www.cccs.edu

2. Foundations of Digital Electronics

- Electronics Tutorials (digital vs analog systems fundamentals concepts)
  www.electronics-tutorials.ws
- All About Circuits (digital electronics basics logic systems concepts)
  www.allaboutcircuits.com
- Khan Academy (digital systems binary logic fundamentals)
  www.khanacademy.org
- MIT Open Learning (engineering systems computing fundamentals)
  openlearning.mit.edu

3. Safety, Tools, and Lab Practices

- OSHA (electronics safety workplace practices handling equipment)
  www.osha.gov
- SafetyCulture (lab safety procedures inspection checklists)
  www.safetyculture.com
- Fluke Education (electrical measurement safety testing tools)
  www.fluke.com/en-us/learn/blog/education
- IEEE Safety Resources (electronics safety standards and practices)
  www.ieee.org

4. Logic Gates and Basic Circuit Construction

- Logic Gate Simulator (interactive logic circuits gate operations)
  logic.ly/demo
- All About Circuits Digital Logic (logic gates circuit building tutorials)
  www.allaboutcircuits.com/textbook/digital
- Electronics Hub (logic gate examples circuit construction)
  www.electronicshub.org
- CircuitVerse (digital circuit simulator logic gate design)
  circuitverse.org

5. TTL, CMOS, and Special Purpose Gates

- Electronics Tutorials Logic Families (TTL CMOS gate comparisons characteristics) www.electronics-tutorials.ws/logic/logic_1.html
- Texas Instruments Education (datasheets TTL CMOS design resources) www.ti.com/education
- SparkFun Tutorials (CMOS TTL basics practical circuits) learn.sparkfun.com
- DigiKey Education (logic gates technical specs datasheets) www.digikey.com

6. Binary Numbers and Digital Number Systems

- Khan Academy Binary (binary numbers conversions number systems) www.khanacademy.org/computing/computer-science
- RapidTables (binary hex decimal conversion tools) www.rapidtables.com
- Math is Fun Binary (binary number explanations concepts) www.mathsisfun.com/binary-number-system.html
- Nand2Tetris (binary arithmetic digital logic computing) www.nand2tetris.org

7. Arithmetic Circuits and Combinational Logic

- All About Circuits Arithmetic (adders combinational logic circuits) www.allaboutcircuits.com/textbook/digital/chpt-8
- Electronics Hub Adders (half adder full adder circuit design) www.electronicshub.org
- CircuitVerse Arithmetic Circuits (adders combinational design simulation) circuitverse.org
- GeeksforGeeks Digital Logic (combinational circuits and logic design) www.geeksforgeeks.org

8. Boolean Algebra and Logic Representation

- Boolean Algebra Tutorials (logic expressions simplification rules) www.electronics-tutorials.ws/boolean
- Karnaugh Map Solver (logic simplification truth tables K map tools) www.dcode.fr/karnaugh-map
- All About Circuits Boolean (truth tables logic simplification) www.allaboutcircuits.com/textbook/digital/chpt-7
- MathWorld Boolean Algebra (concepts logic operations theory) mathworld.wolfram.com

9. Troubleshooting and Circuit Analysis

- Fluke Troubleshooting Guides (circuit testing diagnostics electronics repair) www.fluke.com/en-us/learn/blog
- Electronics Notes Troubleshooting (circuit fault finding techniques) www.electronics-notes.com

- SparkFun Troubleshooting (breadboard debugging circuit testing) learn.sparkfun.com
- DigiKey Troubleshooting (electronic diagnostics repair methods) www.digikey.com

10. Sequential Logic, Flip-Flops, and Counters

- All About Circuits Sequential Logic (flip flops counters circuits) www.allaboutcircuits.com/textbook/digital
- Electronics Tutorials Flip Flops (SR JK D T flip flop explanation) www.electronics-tutorials.ws
- GeeksforGeeks Sequential Circuits (flip flops counters design concepts) www.geeksforgeeks.org
- CircuitVerse Sequential Logic (flip flop counter simulations) circuitverse.org

11. Registers, Encoding, and Display Systems

- Electronics Tutorials Shift Registers (registers encoders decoders explanation) www.electronics-tutorials.ws
- SparkFun LED Displays (7 segment display circuits design) learn.sparkfun.com
- CircuitVerse Display Circuits (encoder decoder display simulation) circuitverse.org
- DigiKey Display Circuits (LED display and decoder design resources) www.digikey.com

12. Programmable Devices, Design Process, and Technical Documentation

- Arduino Education (programmable devices microcontrollers circuit design) www.arduino.cc/education
- MIT Scratch (logic programming design thinking fundamentals) scratch.mit.edu
- Autodesk Tinkercad Circuits (circuit simulation design testing) www.tinkercad.com
- Purdue OWL Technical Writing (engineering documentation writing communication) owl.purdue.edu

13. Collaboration, Communication, and Digital Electronics Project

- Google Workspace (collaboration communication project documentation tools) docs.google.com
- Canva (visual presentations design communication tools) www.canva.com
- MIT Engineering Communication (technical presentations design communication) ocw.mit.edu
- SkillsUSA (professional skills teamwork leadership engineering pathways) www.skillsusa.org

14. Leadership

- Lead4Change (leadership teamwork communication goal setting service learning)
  lead4change.org
- Center for Leadership at CU Boulder (leadership development self-awareness communication collaboration)
  www.colorado.edu/lead
- Learner-Centered Collaborative Goal-Setting Tools (reflection goal setting growth mindset leadership development)
  learnercentered.org
- Michigan Online Leading People and Teams (team leadership communication collaboration motivation)
  online.umich.edu

15. Work-Based Learning

- NAF Work-Based Learning Resources (job shadows internships guest speakers employability skills)
  ash.naf.org
- Engineering Career Hub at CU Boulder (engineering careers internships networking professional experience)
  www.colorado.edu/engineering/engineering-career-hub
- FHI 360 Work-Based Learning Manual (job shadowing workplace observation reflection implementation)
  wbl.fhi360.org
- Chicago Public Schools Work-Based Learning Toolkit (guest speakers career exploration workplace connections)
  www.cps.edu/academics/work-based-learning/toolkit

Technology Student Association – National Competitive Events

System Control Technology

Objective: *Students will design, build, troubleshoot, document, and demonstrate an operable system-control device or model that responds to a TSA-provided problem.*

- Interpret the TSA-provided system-control problem and document the team's understanding in an inventor's log.
- Design a device or model that uses electronic, mechanical, and/or programmable control elements to solve the assigned problem.
- Construct an operable system within the competition time limit using approved materials, tools, and equipment.
- Test the device or model to verify that it functions correctly and can be reset before evaluation.
- Troubleshoot system issues related to wiring, logic, programming, mechanical operation, or reliability.
- Explain the design process, control strategy, and system operation to judges during evaluation.
- Evaluate the final system using TSA criteria for problem interpretation, functionality, design quality, documentation, and communication.

Resources

- Technology Student Association – System Control Technology competition guidelines https://tsaweb.org/competitions-programs/tsa/themes-problems
- Arduino Education – Electronics and control systems https://www.arduino.cc/education
- Tinkercad Circuits – Circuit simulation and prototyping https://www.tinkercad.com/circuits
- PhET Interactive Simulations – Circuit Construction Kit https://phet.colorado.edu/

Technology Student Association – National Competitive Events

Robotics

Objective: *Students will design, build, document, test, and operate a robot that meets the annual TSA Robotics challenge specifications.*

- Analyze the annual TSA Robotics design challenge and identify the robot's required tasks, constraints, and performance criteria.
- Design and build a robot that follows the yearly theme, stated specifications, and required safety expectations.
- Integrate mechanical, electrical, and control components into a functional robotic system.
- Test the robot during setup and testing time, making adjustments before the timed challenge.
- Operate the robot during the challenge within the required running-clock time limit.
- Prepare documentation that explains the robot's design, construction, testing, and problem-solving process.
- Participate in a semifinalist interview explaining robot systems, design decisions, troubleshooting, and team roles.

Resources

- Technology Student Association – Robotics competition guidelines
  https://tsaweb.org/competitions-programs/tsa/themes-problems
- VEX Robotics STEM Labs
  https://education.vex.com/
- Arduino Education – Robotics and electronics resources
  https://www.arduino.cc/education
- FIRST Robotics Resource Library
  https://www.firstinspires.org/resource-library

Technology Student Association – National Competitive Events

Animatronics

Objective: *Students will design, construct, control, document, and present an animatronic device that meets TSA requirements for movement, control technology, lights, sound, sensors, and mechanical systems.*

- Design an animatronic device that responds to the annual TSA theme and fits within the required starting dimensions.
- Construct an exterior shell or skin that can be removed to show internal components to judges.
- Incorporate at least three separate movements using required systems such as fluid power, gearing, linkages, cabling, or related mechanisms.
- Integrate sound, lights, sensors, and control technology into the animatronic model.
- Test the device for reliable operation, safe power use, appropriate movement, and presentation readiness.
- Prepare and deliver a presentation/interview explaining the design process, control system, internal components, and final performance.
- Evaluate the device using TSA criteria for technical function, creativity, movement, control, construction quality, and communication.

Resources

- Technology Student Association – Animatronics competition guidelines https://tsaweb.org/competitions-programs/tsa/themes-problems
- Arduino Education – Sensors, lights, and control systems https://www.arduino.cc/education
- Adafruit Learning System – Electronics, LEDs, sensors, and microcontrollers https://learn.adafruit.com/
- Instructables Circuits – Electronics and animatronics project examples https://www.instructables.com/circuits/