

Digital Logic

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Presentation: One to three 50-minute sessions. Suitable for sixth through twelfth grades. Each module comes to a suitable concluding point, so that the introductory module can be offered alone, or the modules can be presented as a two- or three-part series.

Each module includes exercises in building digital logic circuits. The modules are designed to use the freeware Digital Works PC-based simulator, but the Logicly simulator or a hardware-based logic trainer kit such as the IDL-800 or PB-501 logic trainers can also be used. The instructor will provide copies of Digital Works. If the host school prefers Logicly or a hardware based kit, the school must provide software or equipment for each student and give significant advance notice to adapt the course material.

Module 1: Introduction to Digital Logic

This module provides an introduction to the concept of Boolean functions and to the use of electronic circuits to compute such functions.

Prerequisite: Familiarity with the binary number system and place values.

- Lecture with slides and handout covering the following (15 minutes)
 - Logic functions and truth tables
 - Digital logic gates as electronic devices (AND, OR, XOR, NOT)
 - Binary addition represented as a truth table
- A short video introducing the tool (Digital Works, Logicly, etc.) to be used. (About five minutes, depending on the selected tool.)
- Questions and exercises (30 minutes)
 - Verify that AND and XOR gates compute the truth tables they represent.
 - Implement a half-adder using the simulator or logic trainer.
 - Verify that the half-adder circuit computes the truth table for binary addition.
 - Extend the half-adder to a full adder.

Students who complete this session successfully will be able to:

- Describe the concept of Boolean functions.
- Explain the relationship of a Boolean function to its electronic implementation
- Describe the purpose and limitations of the half-adder circuit.

Module 2: From Half-Adder to Ripple-Carry Adder, Sequential Circuits

This module allows students to realize a functional circuit with advantages and limitations, and exposes the time/complexity trade-off in computer architecture.

Prerequisite: Completion of Module 1 or similar knowledge, and experience with the chosen tool.



- Lecture with slides and handout covering implementation of a full adder as a “chip” or digital Works macro. (10 minutes)
- Exercise: Implement a five bit ripple-carry adder using the trainer software/hardware and validate that it computes sums of binary digits. (15 minutes)
- Lecture: Combinational and sequential circuits. (10 minutes)
- Exercise: Implement an S-R latch and, time permitting, extend it to a D-latch. (15 minutes)

Students who complete this session successfully will be able to:

- Compare half and full adders with respect to function.
- Explain the operation of a ripple-carry adder.
- Describe the fundamental limitation of a ripple-carry adder for the addition of large (*e.g.* 32-bit) numbers.
- Explain what a nanosecond is.

Module 3: Kat’s Cat checker (Relationship of Boolean expressions to circuits)

Module 3 shows students how to derive a Boolean expression from a “word problem” and how to implement the expression in digital logic.

Prerequisite: Completion of Module 1 or similar knowledge, and experience with the chosen tool.

- Lecture: Introduction of Kat’s Cat Checker, the problem. (10 minutes)
- Exercise: Express Kat’s cat requirements as a Boolean expression.
- Exercise: Implement the Boolean expression in digital logic.
- Lecture: Identities of Boolean algebra with emphasis on the distributive law and DeMorgan’s law.

Students who complete this session successfully will be able to:

- Explain how to express a “word problem” as a Boolean expression
- Express an arbitrary Boolean expression as a digital logic circuit.
- Name two uses for Boolean algebra.

Extending the Series

The modules are structured so that Module 1 can stand alone as a brief introduction, be combined with Module 2 for more detail, and further expanded by including Module 3. Additional modules could extend the mathematics of Boolean functions, including the identities and de Morgan’s Law, further explore the combinational building blocks of digital logic, or delve further into sequential circuits and memory. The series could be extended to provide a full semester course in computer architecture and organization. One potential Module 4 would be to extend the ripple-carry adder to an adder/subtractor.