

# Syllabus for Computer Logic and Circuit Design: PHYS306/COSC330

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## Abstract

The core concepts of digital logic and digital circuit design are presented in this course, augmented with laboratory exercises. The course begins with binary mathematics and floating point representation. The concepts of Boolean logic and logic gates, truth tables, combinatorial logic and Karnaugh maps follow. These core concepts prove useful in engineering, business, and science. Hands-on experience with programmable logic (firmware) and electronics lab equipment are emphasized in lab activities. Following the core modules, more complex digital functions are introduced. Examples include adders, comparators, multiplexers and demultiplexers, latches and flip-flops (memory elements), registers and shift registers, counters, and finite-state-machines (FSMs). We conclude with analog-to-digital conversion (ADCs), and digital-to-analog conversion (DACs). The ADC/DAC module builds to digital signal processing (DSP), as time permits. Students will create and present final projects that integrate course concepts using programmable logic and Python code.

**Pre-requisites:** PHYS180, COSC120. Pre-requisites may be waived at instructor discretion.

**Course credits, Liberal Arts Categorization:** 3 Credits, None

**Regular course hours:** Tuesdays and Thursdays from 15:00 - 16:20 in SLC 104 (lecture) and 104 (electronics lab).

**Instructor contact information:**

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**Office hours:** Booking service to schedule meeting: 10to8.com as above, and indicate in-person or online.

**Attendance/Absence:** Students needing to reschedule midterms must notify the professor a few days in advance.

**Late work policy:** Late work is generally not accepted, but is left to the discretion of the instructor.

**Text:** Digital Fundamentals, Eleventh Edition., by Thomas L. Floyd (Pearson). This is a widely adopted text with a variety of online features, bonus chapters, code examples, and excellent homework sets. As a general rule, Prof. Hanson does not require students to purchase expensive texts. Please make arrangements with Prof. Hanson if you need assistance acquiring the book.

**Grading:** The course grade will be a weighted average of assignment scores, and the weights are listed in Tab. 1.

Assignment	Weight	Date
Homework sets	20%	Weekly on Fridays
Midterm 1	20%	February 22nd (take-home)
Midterm 2	20%	March 28th (take-home)
Final Exam	20%	May 1st (take-home)
Final Project	20%	April 23rd and 25th (in-class)

Table 1: A list of major assignments and grade weights.

**Grade Settings:**  $< 60\% = F$ ,  $> 60\%, \leq 70\% = D$ ,  $> 70\%, \leq 80\% = C$ ,  $> 80\%, \leq 90\% = B$ ,  $< 90\%, \leq 100\% = A$ .  
Pluses and minuses: 0-3% minus, 3%-6% straight, 6%-10% plus (e.g. 79% = C+, 91% = A-)

**Homework Sets:** Due weekly on Thursdays, including textbook problems, submitted code, and digital designs.

**ADA Statement on Disability Services:** Whittier College is committed to make learning experiences as accessible as possible. If you experience physical or academic barriers due to a disability, you are encouraged to contact Student Disability Services (SDS) to discuss options. To learn more about academic accommodations, email [disabilityservices@whittier.edu](mailto:disabilityservices@whittier.edu), call (562) 907-4825, or go to SDS which is located on the ground floor of Wardman Library.

**Academic Honesty Policy:** <http://www.whittier.edu/academics/academichonesty>

### ***Course Objectives:***

- Fluency with binary and hexadecimal number systems, and various binary codes and checksums
- Fluency with logic gates, Boolean algebra, logic simplification, and complex logic functions
- Application of digital logic in science, engineering, and business administration
- Practice the art of translating a diagram with inputs to the expected outputs of a prototype
- Practice the art of troubleshooting digital circuits and prototypes
- Create and control digital logic within firmware using Python
- Create and verify final project designs that accomplish design tasks
- Present final project results to peers

### ***Course Outline:***

#### **1. Week 0 - Reading: Chapter 1 of Digital Fundamentals.**

- (a) First meeting - Tuesday, January 16th, 2024.
  - i. Course introduction, syllabus distribution
  - ii. *Laboratory tour and introductory laboratory exercises*
    - A. Breadboards, digital voltmeters, DC power supplies
    - B. Oscilloscopes and signal generation
- (b) Second meeting - Thursday, January 18th, 2024.
  - i. Digital concepts lecture content, block diagram of designs
  - ii. Digital concepts and introduction of integrate circuit
    - A. The PYNQ-Z1 System on a Chip (SoC) and Jupyter Notebooks
    - B. Signal properties

#### **2. Week 1 - Reading: Chapters 1-2 of Digital Fundamentals.**

- (a) First meeting - Tuesday, January 23rd, 2024. *Reading: Chapter 1.*
  - i. Logic functions: basic, combinatorial, and serial and parallel
  - ii. Programmable logic and fixed IC logic
  - iii. Test and measurement instruments
  - iv. *Laboratory exercise, part I*
    - A. Logic signal creation and measurement with oscilloscope
    - B. Capturing digital signals from PYNQ-Z1: the PL layer and logictools library
- (b) Second meeting - Thursday, January 25th, 2024. *Reading: Chapters 2-1 through 2-7*
  - i. Decimal and binary numbers, conversions and arithmetic, signed numbers
  - ii. *Laboratory exercise, part II*
    - A. Representing a binary number with LEDs
    - B. PYNQ-Z1 and logictools: boolean generator, simple version.

#### **3. Week 2 - Reading: Chapter 2 of Digital Fundamentals.**

- (a) First meeting - Tuesday, January 30th, 2024. *Reading: Chapter 2-1 through 2-7.*
  - i. Binary arithmetic, signed numbers
  - ii. *Laboratory exercise, part I*
    - A. Representing a binary number with LEDs, part II
    - B. PYNQ-Z1 and logictools: boolean generator, with multiple logic functions (python dictionaries)
- (b) Second meeting - Thursday, February 1st, 2024. *Reading: Chapters 2-8, 2-10 through 2-12*
  - i. Hexadecimal numbers
  - ii. BCD, gray codes, and the parity and CRC error codes
  - iii. *Laboratory exercise, part II*
    - A. Breadboard prototyping
    - B. Digital voltmeters, DC power supplies

#### **4. Week 3 - Reading: Chapters 3 of Digital Fundamentals.**

- (a) First meeting - Tuesday, February 6th, 2024. *Reading: Chapters 3-1 through 3-3*
    - i. Hexadecimal numbers
    - ii. BCD, gray codes, and the parity and CRC error codes
    - iii. *Laboratory exercise, part I*
      - A. Decimal, binary, and hexadecimal conversion
      - B. Python programming, random number generation, and matplotlib
  - (b) Second meeting - Thursday, February 8th, 2024. *Reading: Chapters 3-4 through 3-6*
    - i. Logic gates: NOT, AND, OR, NAND, NOR, XOR, XNOR
    - ii. *Laboratory exercise, part II*
      - A. PYNQ-Z1 and logictools: finite state machine (FSM) generator, gray code counter
5. Week 4 - **Reading: Chapters 3-4 of Digital Fundamentals.**
- (a) First meeting - Tuesday, February 13th, 2024. *Reading: Chapters 3-8 and 3-9, 4-1 and 4-2*
    - i. Programmable logic with gates
    - ii. Boolean algebra, with applications and examples in business and engineering
    - iii. *Laboratory exercise, part 1*
      - A. Complex boolean functions, simulation, programmable logic, verification, part I
  - (b) Second meeting - Thursday, February 15th, 2024. *Reading: Chapters 4-3 through 4-10*
    - i. DeMorgan's Theorems; further abstract examples in business and engineering
    - ii. Boolean analysis of logic circuits, simplification
    - iii. Truth tables, Karnaugh maps and SOP/POS minimization
    - iv. *Laboratory exercise, part II*
      - A. Complex boolean functions, simulation, programmable logic, verification, part II
6. Week 5 - **Reading: Chapter 5 of Digital Fundamentals**
- (a) First meeting - Tuesday, February 20th, 2024. *Reading: Chapters 5-1 through 5-3*
    - i. Combinatorial systems of logic gates
    - ii. Universal NAND and NOR gates
    - iii. *Laboratory exercise, part I*
      - A. PYNQ-Z1 logictools: trace analyzer and pattern generator
      - B. Use PYNQ-Z1 and pattern generator to multi-pin digital patterns, view with trace analyzer
      - C. Plot the trace of combinatorial logic, part I
  - (b) Second meeting - Thursday, February 22nd, 2024. *Reading: Chapters 5-4 through 5-7*
    - i. *Laboratory exercise, part II*
      - A. Introduction to pynq logictools control module, stepping through code
      - B. Plot the trace of combinatorial logic, part II
      - C. System simplification and plot trace to show equivalency
7. Week 6 - **Reading: Review chapters 1-5 of Digital Fundamentals**
- (a) First meeting - Tuesday, February 27th, 2024.
    - i. Review material, collection of example problems
    - ii. Catch-up on laboratory exercises and troubleshooting
  - (b) Second meeting - Thursday, February 29th, 2024.
    - i. **First midterm exam**
      - A. Covers material from chapters 1-5
      - B. Emphasis on binary operations, boolean algebra, and simple collections of gates
8. Week 8 - **Reading: Chapter 6 of Digital Fundamentals**
- (a) First meeting - Tuesday, March 5th, 2024. *Reading: Chapters 6-1 through 6-6*
    - i. Adders, comparators, and encoders
    - ii. *Laboratory exercise, part I*
      - A. Testing fixed IC adders with scope, LEDs
      - B. Testing fixed IC comparators with scope, LEDs
  - (b) Second meeting - Thursday, March 7th, 2024. *Reading: Chapters 6-7 through 6-11*

- i. Multiplexers and Demultiplexers
- ii. *Laboratory exercise, part II*
  - A. Adders in programmable logic with gates
  - B. Comparators in programmable logic with gates

9. **Spring Break:** March 11th - 15th, 2024.

10. Week 9 - **Reading: Chapters 7 and 8**

- (a) First meeting - Tuesday, March 19th, 2024. *Reading: Chapters 7-1 through 7-4, 7-5*
  - i. S-R latches, flip-flops, and applications
  - ii. Timers and pulse generation
  - iii. *Laboratory exercise, part I*
    - A. Demonstration of fast pulse generation
    - B. Measurements of RF pulses, digital signal processing with NumPy/Octave
- (b) Second meeting - Thursday, March 21st, 2024. *Reading: Chapters 7-5, and 8-1 through 8-4*
  - i. One-shots (timers)
  - ii. Shift registers
  - iii. *Laboratory exercise, part II*
    - A. Formation of final project teams. *Project proposals due one week later.*

11. Week 10 - **Reading: Chapters 8 and 9**

- (a) First meeting - Tuesday, March 26th, 2024. *Reading: Chapters 8-5, 9-1 through 9-5*
  - i. Shift register applications
  - ii. Finite state machines (FSMs)
  - iii. Asynchronous and synchronous counters
  - iv. *Laboratory exercise, part I*
    - A. Testing fixed IC counters with scope
    - B. Simple FSM and counter example with PYNQ-Z1
- (b) Second meeting - Thursday, March 28th, 2024. *Reading: 9-6 through 9-8*
  - i. Cascaded counters and applications of counters
  - ii. *Laboratory exercise, part II*
    - A. Pattern generator counting and combination with boolean generator via pynq logictools control
    - B. FSM counter generation and combination with boolean generator via pynq logictools control

12. Week 11 - **Reading: Review chapters 6-9**

- (a) First meeting - Tuesday, April 2nd, 2024.
  - i. Review material, collection of example problems
  - ii. Catch-up on laboratory exercises and troubleshooting
- (b) Second meeting - Thursday, April 4th, 2024.
  - i. **Second midterm exam**
    - A. Covers material from chapters 6-9
    - B. Emphasis on adders, timers and pulse generation, shift register applications, FSMs and counters

13. Week 12 - **Reading: Chapter 12**

- (a) First meeting - Tuesday, April 9th, 2024. **Reading: Chapters 12-1 through 12-3**
  - i. Analog-to-Digital Conversion (ADC)
  - ii. Digital-to-Analog Conversion (DAC)
  - iii. *Laboratory exercise, part I*
    - A. PYNQ-Z1 PMOD (peripheral modules) ports
    - B. ADC PMOD - read in a voltage and plot it
- (b) Second meeting - Thursday, April 11th, 2024. **Reading: Chapters 12-4 through 12-5**
  - i. Digital Signal Processing (DSP) - an introduction to sampling and digitization
  - ii. *Laboratory exercise, part II*
    - A. PYNQ-Z1 PMOD (peripheral modules) ports
    - B. DAC PMOD - produce a voltage and plot it on oscilloscope

14. Week 13 - **Reading: Chapters 2 and 3 of The Scientist and Engineer's Guide to DSP**

- (a) First meeting - Tuesday, April 16th, 2024. *Reading: Chapters 2 of DSP Guide*
  - i. Selected topics in statistics and probability
  - ii. Mathematics of sampling and digitization
  - iii. *Laboratory exercise, part I*
    - A. Audio signal acquisition with PYNQ-Z1
    - B. Processing of audio data in GNU Octave
- (b) Second meeting - Thursday, April 18th, 2024. *Reading: Chapters 3 of DSP Guide*
  - i. The sampling theorem
  - ii. Aliasing and anti-aliasing
  - iii. *Laboratory exercise, part II*
    - A. More with GNU Octave
    - B. Aliasing in time-series (audio) data

15. *Optional extra topics-* **Reading: Chapters 30 and 31 of The Scientist and Engineer's Guide to DSP**

- (a) First meeting - Tuesday, April 23rd, 2024. *Reading: Chapter 30 of DSP Guide*
  - i. Complex numbers and the usage of complex numbers in DSP
  - ii. *Laboratory exercise, part I*
    - A. Exploring the Fourier transform, part I
    - B. Power spectra and spectrograms
- (b) Second meeting - Thursday, April 25th, 2024. *Reading: Chapter 31 of DSP Guide*
  - i. Complex numbers and the FFT, filters
  - ii. *Laboratory exercise, part II*
    - A. Exploring the Fourier transform, part II
    - B. Filters and filtering data

16. Week 14 - **Group presentations and Final Exam**

- (a) Meetings - Tuesday, April 23rd, 2024, and Thursday, April 25th, 2024.
  - i. *Group presentations: 15 minutes each, 1-2 students per group*
  - ii. *Final presentations can be via **option A**, live in person, or **option B** through WeVideo. A WeVideo tutorial will be given as part of the course.*
- (b) The final exam will be issued on May 1st, 2024 in take-home style. It will be due 48 hours after issued, and submitted in PDF form to Moodle.