Welcome to ENEE244-010x
Digital Logic Design

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Administrative Stuff

- How to reach me:
  - Email: danadach@ece.umd.edu
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- Grading:
  - Homework: 10%, Small quizzes: 5%,

    2 midterms: 50%, Final exam (cumulative): 35%.
- For detailed information see syllabus. Feel free to contact me with any questions.
- **Fill out survey on Canvas

What is this course about?

- Given a Boolean function $f: \{0,1\}^n \rightarrow \{0,1\}$, design a circuit computing f.
  - Given only a truth table for f

x_1	x_2	x_3	$f(x_1, x_2, x_3)$
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

$(x_1\ AND\ x_2)\ OR\ x_3$

There are many ways of expressing this function.

What is this course about?

- Given a Boolean function $f\colon \{0,1\}^n \to \{0,1\}$, design a circuit computing f.
  - Given only a truth table for f
  - Study techniques for finding the minimal circuit computing f
- Understand the design of basic circuit components
  - Adders, comparators, decoders, encoders, multiplexers

What is this course about?

- Previous topics were all examples of combinational networks.
  - Output depends only on the inputs at that instant.
- Sequential networks
  - Output depends on the state of memory
  - Flip-flops—basic logic element of sequential networks
  - Synchronous sequential networks—behavior determined by a clock signal

List of Topics

- Number systems
- Boolean algebra
- Combinational networks
  - Design
  - Analysis
- Synchronous sequential networks
  - Design
  - Analysis

Introduction

Digital vs. Analog

- Two general ways to represent information
  - Digital: information is denoted by a finite sequence of digits. This form is discrete.
  - Analog: a continuum is used to denote the information.
- Examples:
  - Digital vs. analog watch (range of angular displacement)
  - MP3 vs. casette tape (quantities of magnetism stored on surface of tape)

Digital vs. Analog

Digital	Analog
Any degree of precision is possible by using more digits.	Measure to read information, precision is the number of digits obtained. Limitation on precision.
Can copy without degradation. e.g. digital recording.	Copying causes degradation. e.g. analog tape.
Groups of numbers can be compressed by finding patterns. Easy to manipulate.	Harder to compress and manipulate.

Digital Computers

- The electrical values (i.e. voltages) of signals in a circuit are treated as integers (0 and 1)
- Alternative is analog, where electrical values are treated as real numbers.
- Usually assume only use two voltages: high and low (square wave).
  - Signal at high voltage: "1", "true", "set", "asserted"
  - Signal at low voltage: "0", "false", "unset", "deasserted"
- This will be our level of abstraction for most of the topics covered in this class.

Representing Data Digitally

Positional Number Systems

- The decimal number system:
  - $932.86 = 9 \times 10^2 + 3 \times 10^1 + 2 \times 10^0 + 8 \times 10^{-1} + 6 \times 10^{-2}$
- In general, can consider base r representation
  - $N = d_{n-1}d_{n-2} \cdots d_1 d_0 . d_{-1} \cdots d_{-m}$
    $= d_{n-1} \times r^{n-1} + d_{n-1} \times r^{n-2} + \cdots + d_0 \times r^0 + d_{-1} \times r^{-1} + \cdots + d_{-m} \times r^{-m}$
- We will be mainly concerned with the binary number system.
  - Two digit symbols: 0,1
  - A digit is referred to as a bit

Positional Number Systems

- Binary, Decimal, Hexadecimal
- Hexadecimal:
  - Base 16 ($r = 16$)
  - Digit symbols: 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F

Basic Arithmetic Operations—Examples

- Addition:

  101100011 + 100110010

- Subtraction:

  101100011 – 100110010

- Multiplication:

  1011 X 1001

- Division:

  100100/1100

Switching Bases

Algorithmic techniques

- There are many ways to convert bases, e.g., can eyeball it.
- Outline two algorithmic approaches to converting bases.
- Can both be straightfowardly implemented on a computer.

Polynomial method of number conversion

- Convert from base r_1 to base r_2
- Express number as polynomial in base r_1
  - $N = d_2 \times {r_1}^2 + d_1 \times {r_1}^1 + d_0 \times {r_1}^0$
- Switch each digit symbol d_i to its base $r_2$representation and each base symbol $r_1$to its base r_2 representation.
- Evaluate the polynomial in base r_2.

Polynomial Method of Number Conversion

- Example: convert from hexadecimal to decimal
- Hexadecimal number: A78E
  - $A78E = A \times \left(10_{(16)}\right)^3 + 7 \times \left(10_{(16)}\right)^2 + 8 \times \left(10_{(16)}\right)^1 + E \times \left(10_{(16)}\right)^0$
  - $A78E = (10) \times (16)^3 + (7) \times (16)^2 + (8) \times (16)^1 + (14) \times (16)^0$
  - $A78E = 42894$