Which office hours work best for you?

1. M 11:00AM – 12:00PM
2. M 1:30PM – 2:30PM
3. W 9:00AM – 10:00AM
4. R 9:00AM – 10:00AM
5. R 10:00AM – 11:00AM
6. F 9:00AM – 10:00AM

Digital Logic – Introduction

Why Study Digital Design?

- Look “under the hood” of computers
  - Solid understanding → confidence, insight, even better programmer when aware of hardware resource issues
- Electronic devices becoming digital
  - Enabled by shrinking and more capable chips
  - Enables:
    - Better devices: Better sound recorders, cameras, cars, cell phones, medical devices, ...
    - New devices: Video games, PDAs, ...
- Known as “embedded systems”
  - Thousands of new devices every year
  - Designers needed: Potential career direction

Digital Design

Chapter 1: Introduction


http://www.ddvahid.com

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**Digital Logic – Introduction**

## What Does “Digital” Mean?

- **Analog signal**
  - Infinite possible values
  - Ex: voltage on a wire created by microphone

- **Digital signal**
  - Finite possible values
  - Ex: button pressed on a keypad

### Analog Signal

- Sound waves from the speaker
- Voltage on the microphone wire

### Digital Signal

- Digital signal on the wire
- Variable value as a function of time

#### Possible values:

- An analog signal
  - Infinite possible values
  - Ex: voltage on a wire created by microphone

#### Digital Signal

- Digital signal
  - Finite possible values
  - Ex: button pressed on a keypad

#### Possible values:

- 0, 1, 2, 3, or 4

---

## Binary - Digital Signals with Only Two Values

- **Binary digital signal** -- only two possible values
  - Typically represented as 0 and 1
  - One binary digit is a bit

- We’ll only consider binary digital signals

- Binary is popular because
  - Transistors, the basic digital electric component, operate using two voltages
  - Storing/transmitting one of two values is easier than three or more (e.g., loud beep or quiet beep, reflection or no reflection)

---

## Example of Digitization

- Analog signal (e.g., audio) may lose quality
  - Voltage levels not saved/copied/transmitted perfectly

- Digitized version enables near-perfect save/copy/transmission
  - “Sample” voltage at particular rate, save sample using bit encoding
  - Voltage levels still not kept perfectly
  - But we can distinguish 0s from 1s

- Let bit encoding be:
  - 1 V: “01”
  - 2 V: “10”
  - 3 V: “11”

**Digitized signal not perfect re-creation**

- Higher sampling rate and more bits per encoding brings closer.

---

## How Do We Encode Data as Binary for Our Digital System?

- Some inputs inherently binary
  - Button: not pressed (0), pressed (1)

- Some inputs inherently digital
  - Just need encoding in binary
  - E.g., multi-button input: encode red=001, blue=010, ...

- Some inputs analog
  - Need analog-to-digital conversion
  - As done in earlier slide -- sample and encode with bits

---

**Digital System**

- Sensors and other inputs
  - Digital data
  - Digital System

- Digital data
  - Digital System
  - Digital data
  - Sensors and other inputs
Digital Logic – Introduction
How to Encode Numbers: Binary Numbers

- Each position represents a quantity; symbol in position means how many of that quantity
  - Base ten (decimal)
    - Ten symbols: 0, 1, 2, ..., 8, and 9
    - More than 9 -- next position
    - So each position power of 10
    - Nothing special about base 10 -- used because we have 10 fingers
  - Base two (binary)
    - Two symbols: 0 and 1
    - More than 1 -- next position
    - So each position power of 2

- Working with binary numbers
  - In base ten, helps to know powers of 10
    - one, ten, hundred, thousand, ten thousand, ...
  - In base two, helps to know powers of 2
    - one, two, four, eight, sixteen, thirty two, sixty four, one hundred twenty eight
    - (Note: unlike base ten, we don’t have common names, like “thousand,” for each position in base ten -- so we use the base ten name)

Digital Logic – Introduction
Converting from Decimal to Binary

- What is the value of the binary number 100110 in decimal?
  1. 100,110
  2. 21
  3. 22
  4. 38

- Subtraction Method (Easy for Humans)
  - Goal: Get the binary weights to add up to the decimal quantity
    - Work from left to right
      - (Right to left – may fill in 1s that shouldn’t have been there – try it).
      - Subtraction method
    - Subtract a selected binary weight from the (remaining) quantity
      - Then, we have a new remaining quantity, and we start again (from the present binary position)
    - Stop when remaining quantity is 0

- Converting from Decimal to Binary Numbers

- Remaining quantity: 12

- Subtract a selected binary weight from the (remaining) quantity

- Subtraction method

- Goal: Get the binary weights to add up to the decimal quantity

- Work from left to right

- (Right to left – may fill in 1s that shouldn’t have been there – try it).

- Subtraction method

- Subtract a selected binary weight from the (remaining) quantity

- Then, we have a new remaining quantity, and we start again (from the present binary position)

- Stop when remaining quantity is 0
Digital Logic – Introduction
Converting from Decimal to Binary

- What is the value of the decimal number 25 in binary?
  1. 11000
  2. 11001
  3. 10111
  4. 011001

- Division Method (Good for Computers)
  - Divide decimal number by 2 and insert remainder into new binary number.
  - Continue dividing quotient by 2 until the quotient is 0.

- Example: Convert decimal number 12 to binary

  \[
  \begin{array}{c|c}
    \text{Decimal Number} & \text{Binary Number} \\
    \hline
    12 & \text{1100} \\
  \end{array}
  \]

- Example: Convert decimal number 12 to binary (continued)

  \[
  \begin{array}{c|c}
    \text{Decimal Number} & \text{Binary Number} \\
    \hline
    6 & \text{110} \\
  \end{array}
  \]

- Example: Convert decimal number 12 to binary (continued)

  \[
  \begin{array}{c|c}
    \text{Decimal Number} & \text{Binary Number} \\
    \hline
    3 & \text{011} \\
  \end{array}
  \]

- Example: Convert decimal number 12 to binary (continued)

  \[
  \begin{array}{c|c}
    \text{Decimal Number} & \text{Binary Number} \\
    \hline
    1 & \text{011} \\
  \end{array}
  \]

- Since quotient is 0, we can conclude that 12 is 1100 in binary

- What is the value of the decimal number 54 in binary?
  1. 110110
  2. 100010
  3. 1000010
  4. None of the above
Digital Logic – Introduction

Hexadecimal Numbers

- Nice because each position represents four base two positions
- Used as compact means to write binary numbers
- Known as hexadecimal, or just hex

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<th>binary</th>
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<td>E</td>
<td>1110</td>
</tr>
<tr>
<td>F</td>
<td>1111</td>
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</tbody>
</table>

Convert 1110000 to hex:

- 0
- 1
- 6

Digital Logic – Introduction

Converting from Hexadecimal to Binary

- What is the value of the hexadecimal number AB in binary?
  1. 10111010
  2. 01011011
  3. 10101011
  4. 10101010

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Digital Logic – Introduction

Converting from Hexadecimal to Decimal

- What is the value of the hexadecimal number 2E in decimal?
  1. 101110
  2. 00101110
  3. 30
  4. 46

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