ECE 274 Digital Logic – Spring 2009

MWF 12-12:50PM, ILC 150

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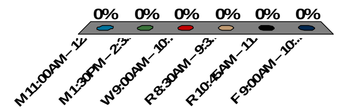
Which office hours work best for you?

1. M 11:00AM – 12:00PM
2. M 1:30PM – 2:30PM
3. W 9:00AM – 10:00AM
4. R 8:30AM – 9:30AM
5. R 10:45AM – 11:45AM
6. F 9:00AM – 10:00AM



Digital Design

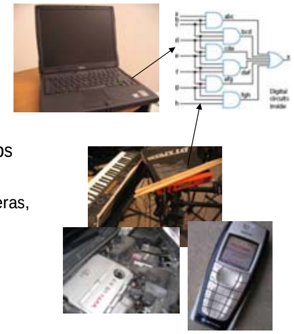
Chapter 1:
Introduction

Slides to accompany the textbook *Digital Design*, First Edition,
by Frank Vahid, John Wiley and Sons Publishers, 2007.
http://www.ddvahid.com

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



Portable music players (1995), Satellites (1997), Cell phones (1999), DVD players (2001), Cameras (2003), Video recorders (2005), TVs (2007), Musical instruments, ???

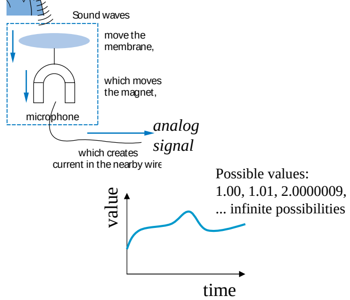
1995 1997 1999 2001 2003 2005 2007

- Years shown above indicate when digital version began to *dominate*
  - (*Not* the first year that a digital version appeared)

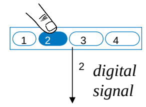
Digital Logic – Introduction

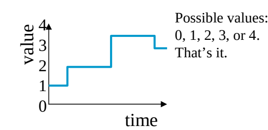
What Does "Digital" Mean?

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



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

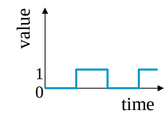




Digital Logic – Introduction

Binary - Digital Signals with Only Two Values

- ***Binary*** digital signal -- only *two* possible values
  - Typically represented as **0** and **1**
  - One *b*inary dig*it* 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)

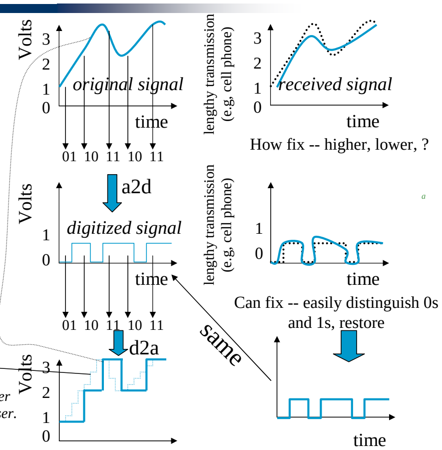


Digital Logic – Introduction

Example of Digitization

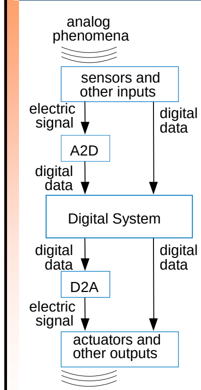
- Analog signal (e.g., audio) may lose quality
  - Voltage levels not saved/copied/transmitted perfectly
- Digitized version enables near-perfect save/cpy/trn.
  - "Sample" voltage at particular rate, save sample using bit encoding
  - Voltage levels still not kept perfectly
  - But we can distinguish 0s from 1s

Let bit encoding be:
1 V: "01"
2 V: "10"
3 V: "11"

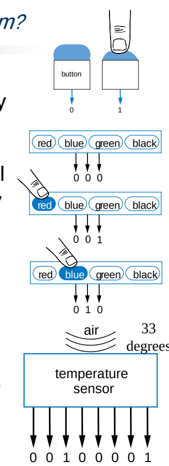


Digital Logic – Introduction

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

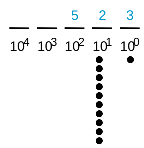


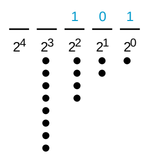
- Some inputs inherently binary
  - Button: not pressed (0), pressed (1)
- Some inputs inherently digital
  - Just need encoding in binary
  - e.g., multi-button input: encode red=001, blue=010, …
- Some inputs analog
  - Need analog-to-digital conversion
  - As done in earlier slide -- sample and encode with bits



Digital 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





Digital Logic – Introduction
How to Encode Numbers: Binary Numbers

- 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)

10^3 10^2 10^1 10^0

1000 100 10 1

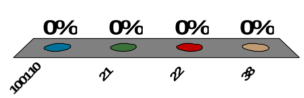
2^9 2^8 2^7 2^6 2^5 2^4 2^3 2^2 2^1 2^0

512 256 128 64 32 16 8 4 2 1

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



Digital Logic – Introduction
Converting from Decimal to Binary Numbers

- 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

Remaining quantity: 12

_ _ _ _ _ _ (32 16 8 4 2 1)

1 _ _ _ _ _ (32 16 8 4 2 1) — 32 is too much

0 1 _ _ _ _ (32 16 8 4 2 1) — 16 is too much

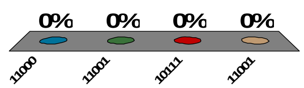
0 0 1 _ _ _ (32 16 8 4 2 1) — 12 – 8 = 4

0 0 1 1 _ _ (32 16 8 4 2 1) — 4-4=0 DONE

0 0 1 1 0 0 (32 16 8 4 2 1) — answer

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



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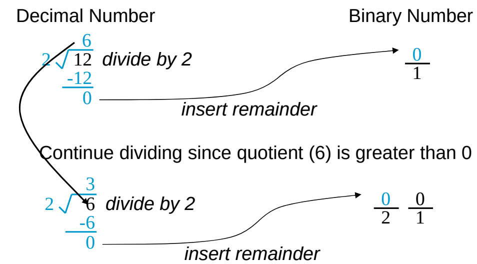
Digital Logic – Introduction
Converting from Decimal to Binary

- 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



Continue dividing since quotient (3) is greater than 0

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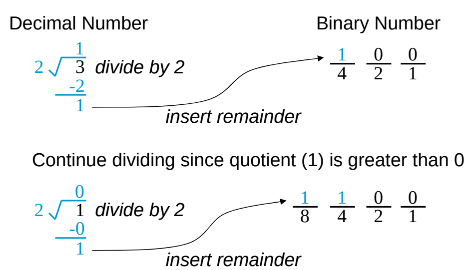
Digital Logic – Introduction
Converting from Decimal to Binary

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



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

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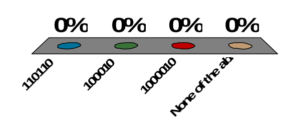
Digital Logic – Introduction
Converting from Decimal to Binary

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



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Digital Logic – Introduction

Hexadecimal Numbers

		8	A	F
16^4	16^3	16^2	16^1	16^0

8 → 1000, A → 1010, F → 1111

hex	binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111

hex	binary
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

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

Convert 11110000 to hex:

F 0

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Digital Logic – Introduction

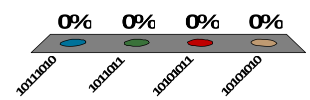
Converting from Hexadecimal to Binary

- What is the value of the hexadecimal number AB in binary?

1. 10111010
2. 01011011
3. 10101011
4. 10101010

hex	binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111

hex	binary
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111



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Digital Logic – Introduction

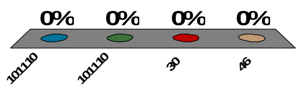
Converting from Hexadecimal to Decimal

- What is the value of the hexadecimal number 2E in decimal?

1. 101110
2. 00101110
3. 30
4. 46

hex	binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111

hex	binary
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111



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