ECE 274 Digital Logic – Fall 2009

MWF 12-12:50PM, ILC 150

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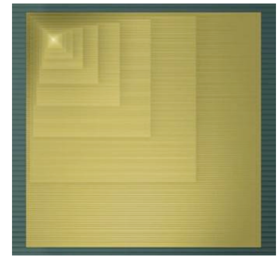
Digital Design

Chapter 1:
Introduction



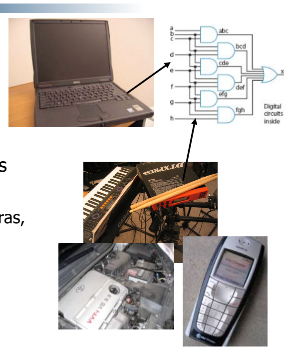
Slides to accompany the textbook *Digital Design*, First Edition,
by Frank Vahid, John Wiley and Sons Publishers, 2007.
http://www.ddvahid.com

Digital Logic – Introduction

Why Study Digital Design?

1.1

- 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



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

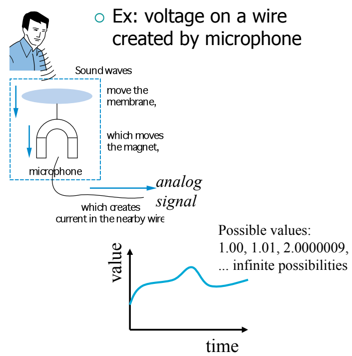
- Years shown above indicate when digital version began to *dominate*
  – (*Not* the first year that a digital version appeared)

Digital Logic – Introduction

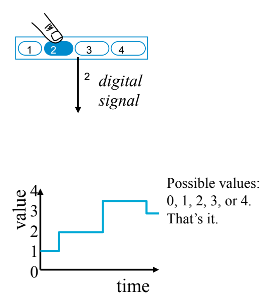
What Does "Digital" Mean?

1.2

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



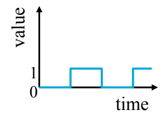
- Digital signal
  - Finite possible values
    - Ex: button pressed on a keypad



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)



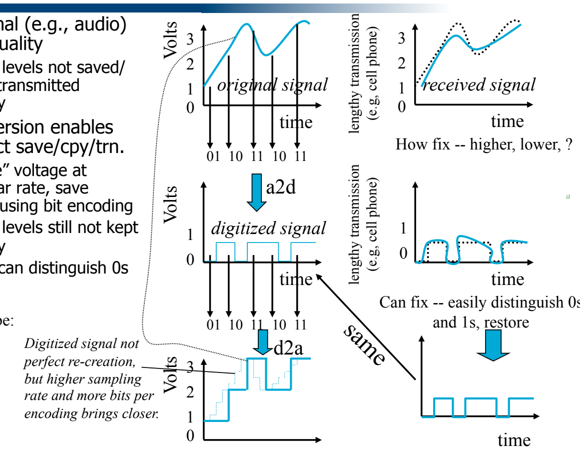
5

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

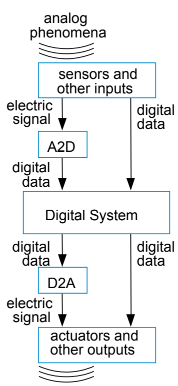
Let bit encoding be:
1 V: "01"
2 V: "10"
3 V: "11"



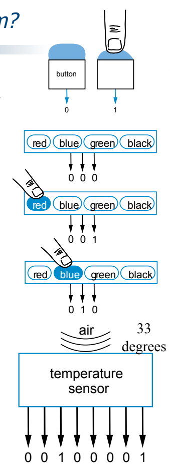
6

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

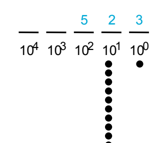


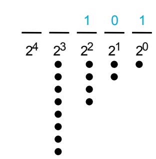
7

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





8

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)

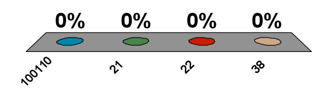
10^3	10^2	10^1	10^0
1000	100	10	1

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

9

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



10

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

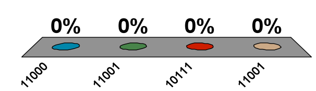
Remaining quantity: 12

32	16	8	4	2	1	
1						32 is too much
0	1					16 is too much
0	0	1				12 – 8 = 4
0	0	1	1			4-4=0 DONE
0	**0**	**1**	**1**	**0**	**0**	answer

11

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



12

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

Decimal Number — Binary Number

2 √12 = 6, divide by 2; −12; remainder 0 — insert remainder → 0/1

Continue dividing since quotient (6) is greater than 0

2 √6 = 3, divide by 2; −6; remainder 0 — insert remainder → 0/2 0/1

Continue dividing since quotient (3) is greater than 0

13

Digital Logic – Introduction
Converting from Decimal to Binary

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

Decimal Number — Binary Number

2 √3 = 1, divide by 2; −2; remainder 1 — insert remainder → 1/4 0/2 0/1

Continue dividing since quotient (1) is greater than 0

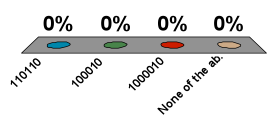
2 √1 = 0, divide by 2; −0; remainder 1 — insert remainder → 1/8 1/4 0/2 0/1

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

14

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*



15

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	hex	binary
0	0000	8	1000
1	0001	9	1001
2	0010	A	1010
3	0011	B	1011
4	0100	C	1100
5	0101	D	1101
6	0110	E	1110
7	0111	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

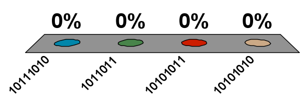
16

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

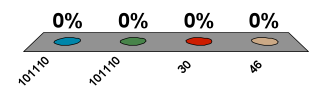


Digital Logic – Introduction
Converting from Hexadecimal to Decimal

- 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



Digital Logic – Introduction
An attempt at humor

- There are 10 types of people in the world: Those who get binary and those who don't. Which type are you?
  1. I get it.
  2. I don't get it.