WELCOME TO

Modern Digital System Design

ECE 2372 / Spring 2019 / Lecture 01

Texas Tech University
Dr. Tooraj Nikoubin

Introduction,
Number Systems and Conversion

Grading Scheme

Course Requirements and Corresponding Weight		
1	Test # 1	15%
2	Test # 2	15%
3	Final exam	30%
4	Project	20%
5	Homework and Quiz	20%

Bonus ?%

Topic	Lectures
• Introduction, Number Systems and Conversion	1L
• Logic Gates and Boolean Algebra	1L
• Applications of Boolean Algebra, Minterm and Maxterm Expansions	2L
• Multi- Level Gate Circuits , NAND and NOR Gates	1L
• Karnaugh Maps and Quine-McClusky Method for simplification	1L
<< Review and Test #1 >>	1L
• Combinational Circuit Design,	1L
• Multiplexers, Decoders, ROM and Programmable logic Devices	2L
• Add and Sub, Adders, Subtractors and Comparators	1L
• Coding	1L
• Hardware description language for combinational circuits	1L
<< Review and Test #2 >>	1L
• Latch and Flip-Flops	2L
• Registers and Buffers	1L
• Counters and Counter circuit design	2L
• Analysis of clocked Sequential Circuits	2L
• Sequential Circuit Design	2L
• State machine design	2L
• Arithmetic Circuits	1L
• Hardware description language for sequential circuits	1L
<< Review and Final exam >>	1L
L=75min Total	28L

Grading and Scheme

Bonus

Class attending policy

1. Efficient study and class attention
2. Cellphone & Laptop ?
3. Class activities (Quiz, Present & absence)
4. Polite or shy ?
5. Challenge or stress ?
6. Who is Brave ?
7. Sample of Tests

Main Sources

- 1-M.M. Mano and C.R. Kime,

  "Logic and Computer Design Fundamentals" 4 th Edition,

  Pearson -Prentice Hall.

- 2-Charles H.Roth, Jr. and Larry L. Kinney,

  " **Fundamentals of Logic Design**"

Other References

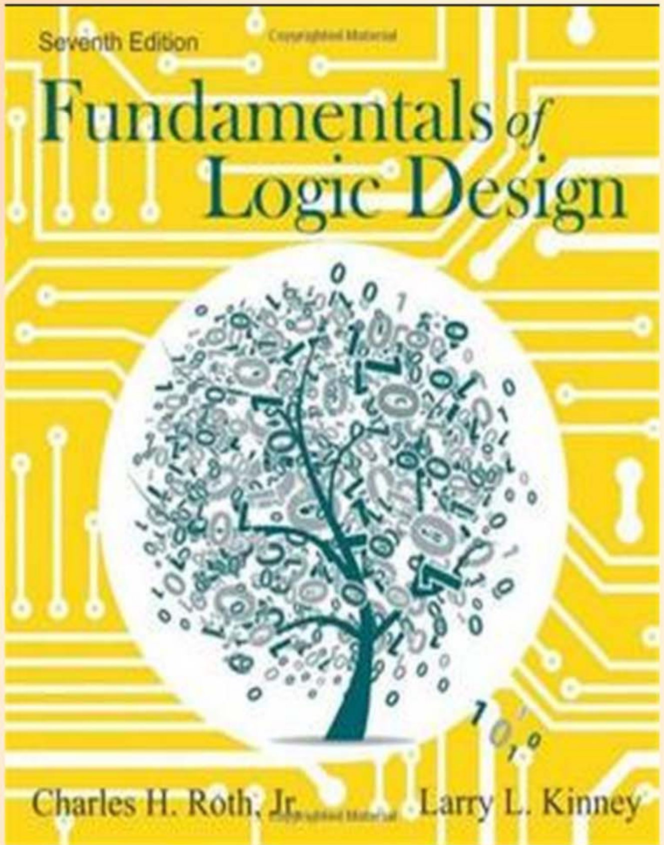
1. Victor P. Nelson, H. Troy Nagle, Bill D. Carroll, David Irwin
   "**Digital Logic Circuit Analysis and Design** "

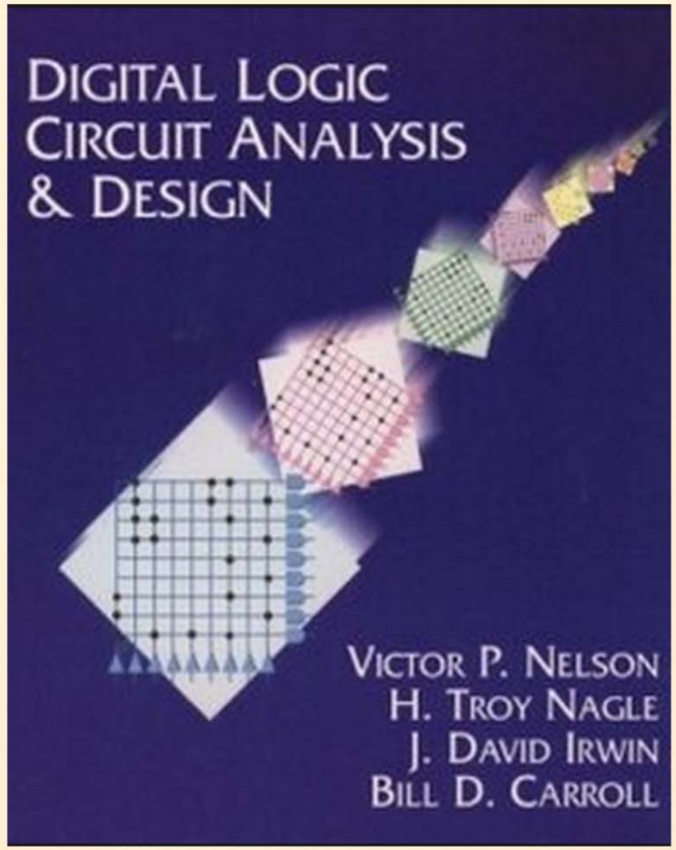
2. M. Mano, "***Digital Design***", 3rd Edition, Prentice Hall, Upper-Saddle River, New Jersey, 2002

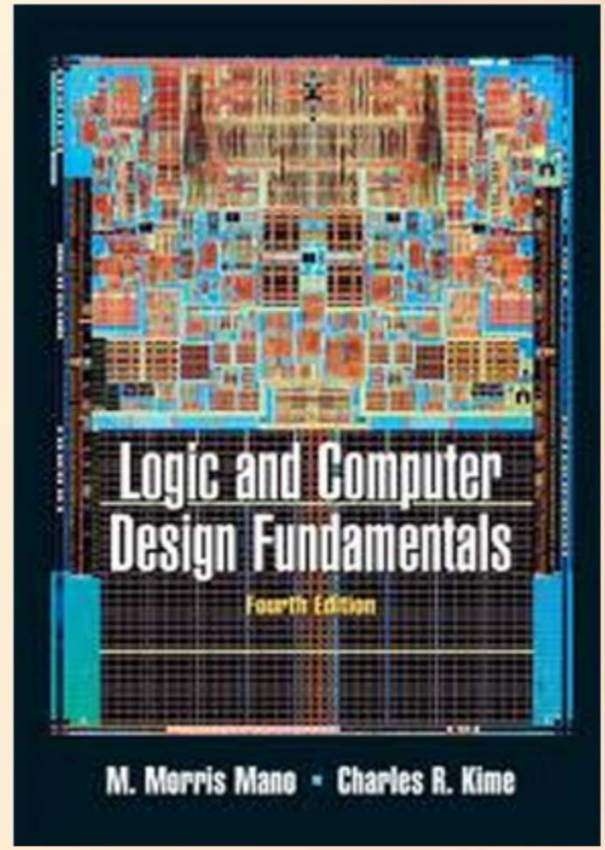
3. Nazeib M. Botros,
   "**HDL programming Fundamentals VHDL and Verilog**"

4. Stephen Brown and Zvonko Vranesic,
   "***Fundamentals of Digital Logic with Verilog Design***"

, McGraw-Hill, 2003


Seventh Edition
Fundamentals of Logic Design
Charles H. Roth, Jr.
Larry L. Kinney


DIGITAL LOGIC
CIRCUIT ANALYSIS
& DESIGN
VICTOR P. NELSON
H. TROY NAGLE
J. DAVID IRWIN
BILL D. CARROLL


Logic and Computer
Design Fundamentals
Fourth Edition
M. Morris Mano
Charles R. Kime

Main Sources for the test

1-**PowerPoint slides**

2-Charles H.Roth, Jr. and Larry L. Kinney, " **Fundamentals of Logic Design**"

3-M.M. Mano and C.R. Kime, "Logic and Computer Design Fundamentals" 4 th Edition, Pearson -Prentice Hall.

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4. Homework

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5. Quiz

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6. Sample of test

ECE 2372 (Modern Digital System Design)

TA: TBA

Tutors: TBA

Email:

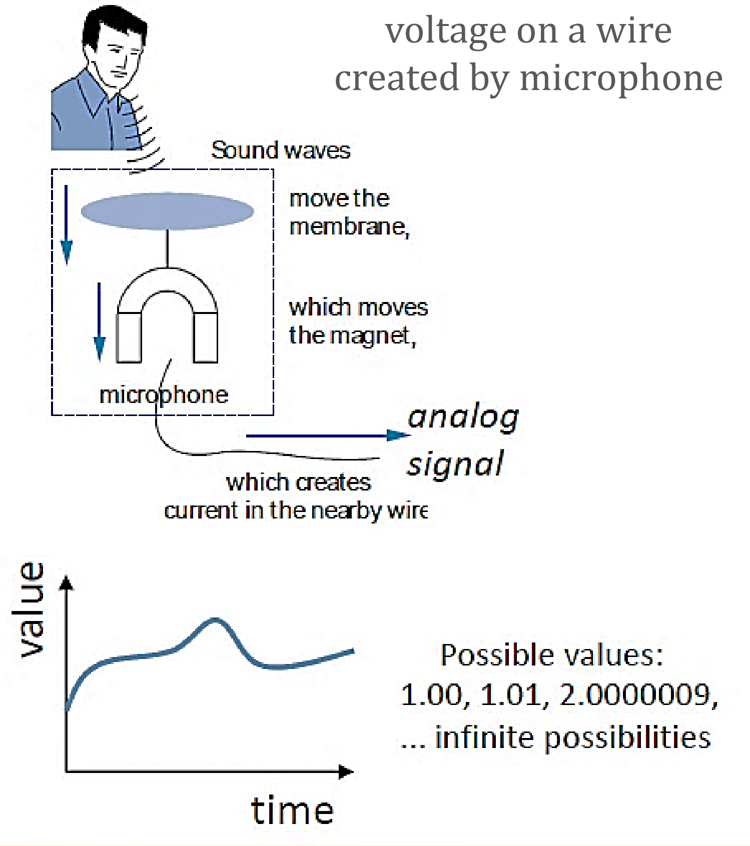
Office Hours:

	8	9	10	11	12	1	2	3	
Monday									
Tuesday									
Wednesday									
Thursday									
Friday									
Saturday									
Sunday									

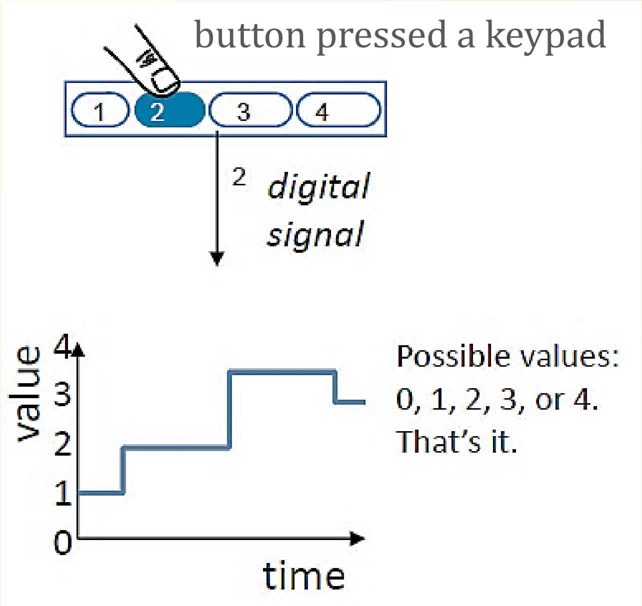
Office : ECE Computer Lab

Digital and Analog Signals

Analog signal
With Infinite possible values



Digital signal
With Finite possible values

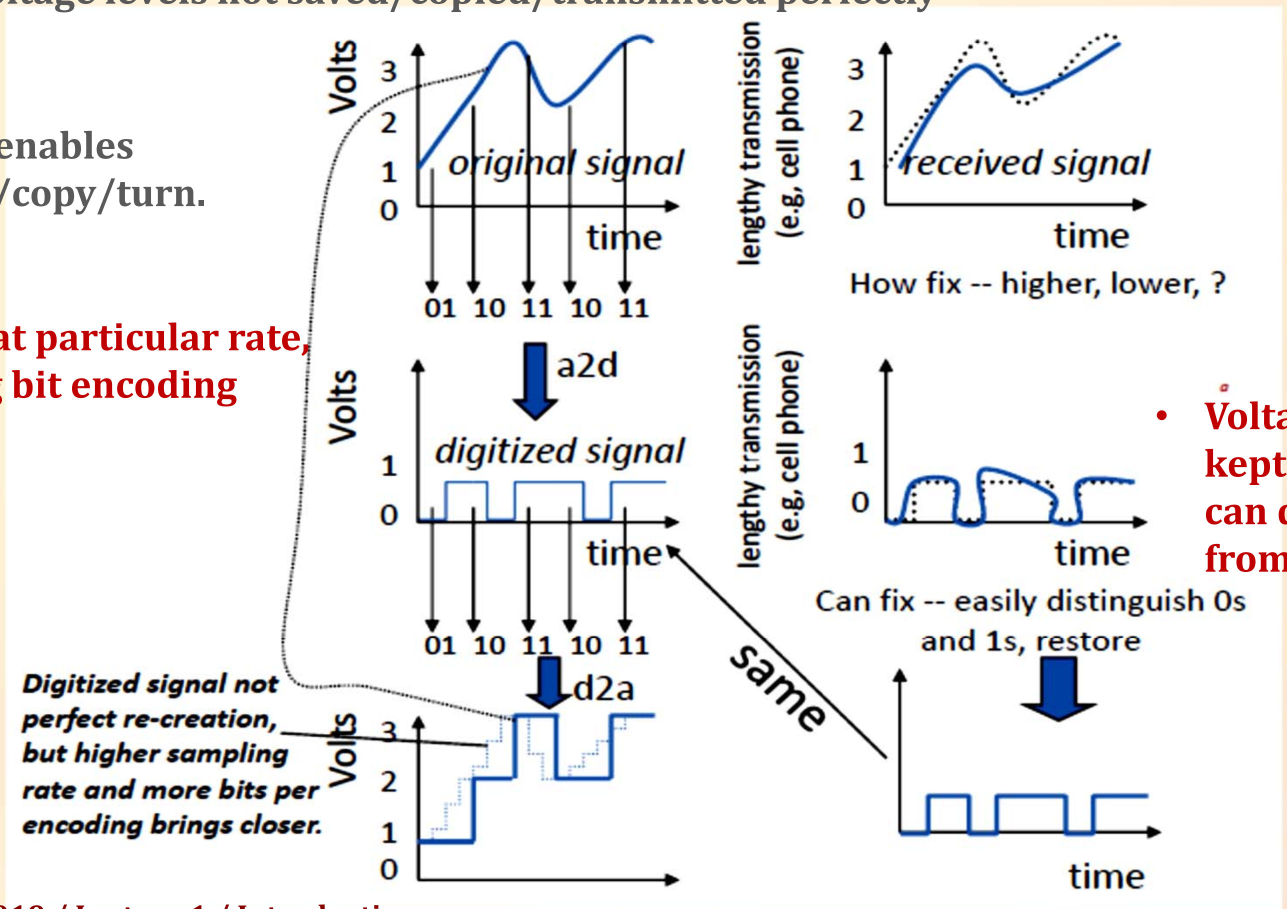


Example of Digitization Benefit

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

- Digitized version enables near-perfect save/copy/turn.

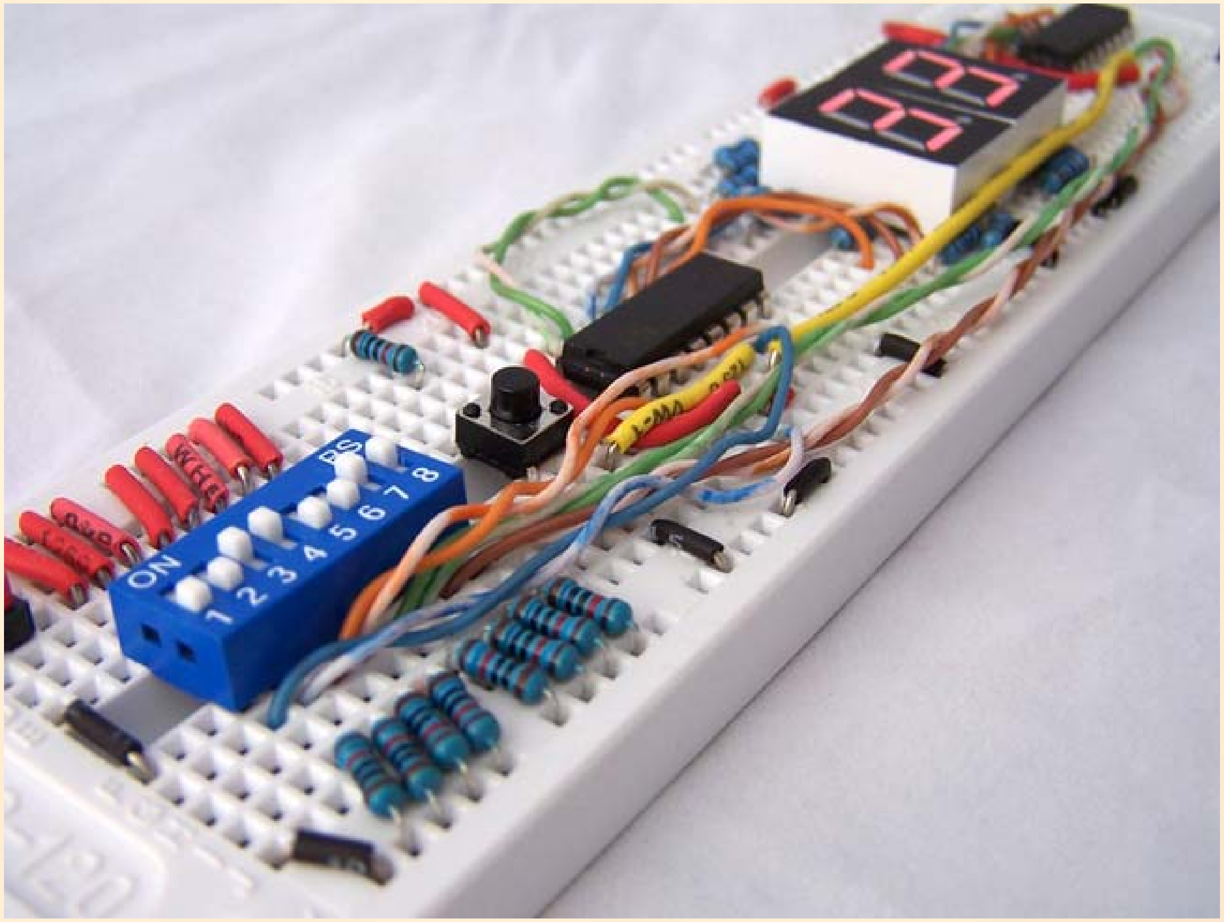
- “Sample” voltage at particular rate, save sample using bit encoding



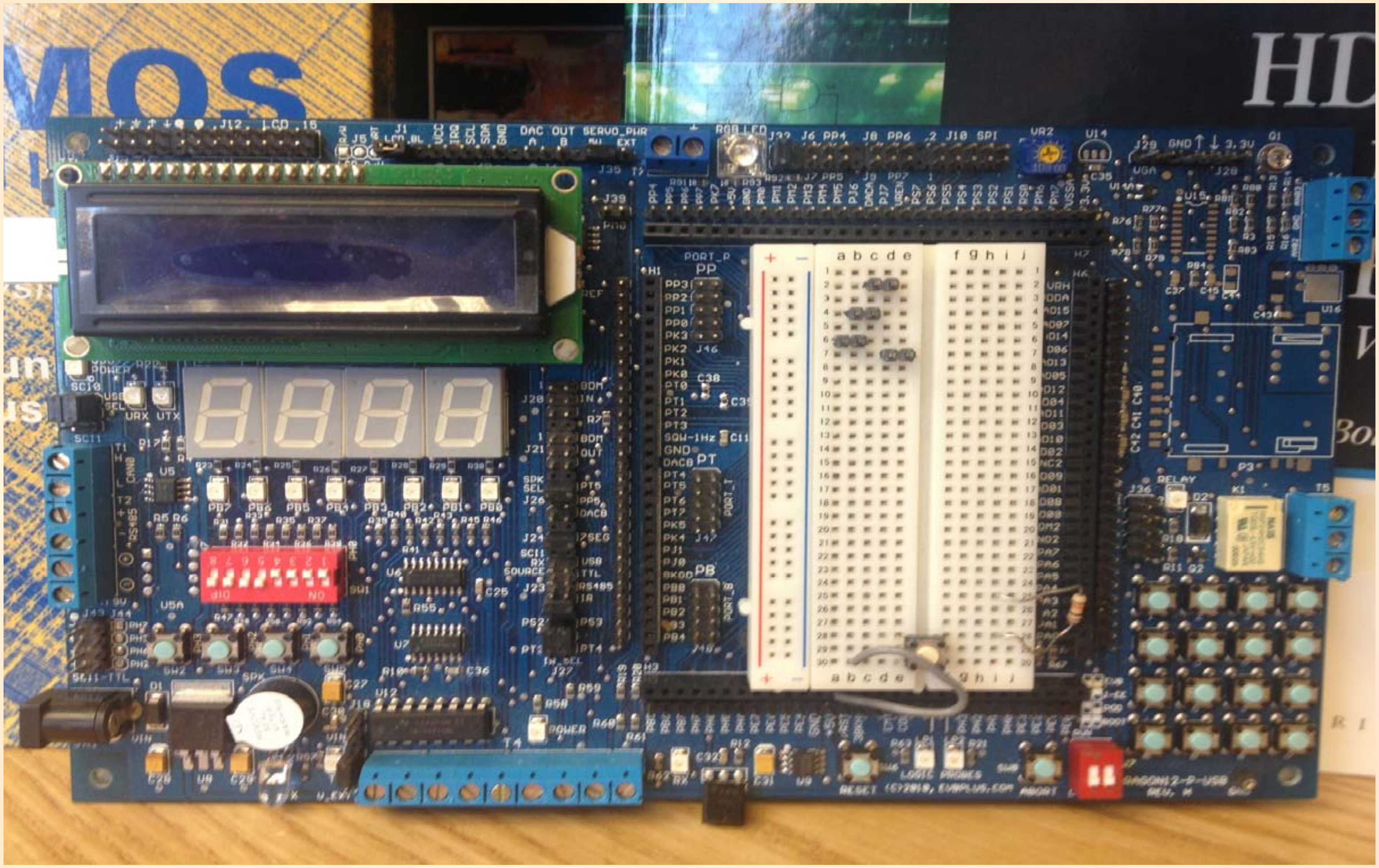
- Voltage levels still not kept perfectly But we can distinguish 0s from 1s

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

A Sample of Digital Board



A Sample of Digital Board



- **What is digital ?**

– Digital camera, Digital TV, Digital Watch, Digital Radio, Digital City (e-city), Digital Photo Frame ...etc

– Which gives the things in countable form

– Scene (analog) to Image (digital)

- **Why digital ?**

– Countable form, makes easy to manage

– Easy management makes more useful and versatile

- **What digit ?**

– How to count: Decimal digit: 0 to 9

What Digit? => Number System

- Famous Number System: Dec, Rom, Bin

- Decimal System: 0 -9
  – May evolves: because human have 10 finger

- Roman System
  – May evolves to make easy to look and feel
  – Pre/Post Concept: (IV, V & VI) is (5-1, 5 & 5+1)

- Binary System, Others (Oct, Hex)
  – One can cut an apple in to two

Design & Logic Design

- **What is design?**

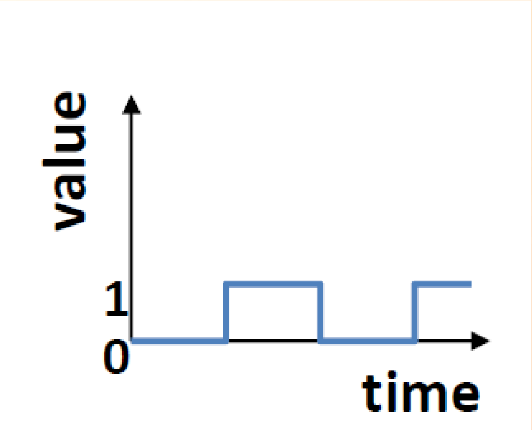
– Given problem spec, solve it with available components
– While meeting quantitative (size, cost, power) and qualitative (beauty, elegance)

- **What is logic design?**

– Choose digital logic components to perform specified control, data manipulation, or communication function and their interconnection
– Which logic components to choose?
Many implementation technologies (fixed-function components, *programmable devices*, individual transistors on a chip, etc.)
– Design optimized/transformed to meet design constraints

Digital Signals with Only Two Values: Binary

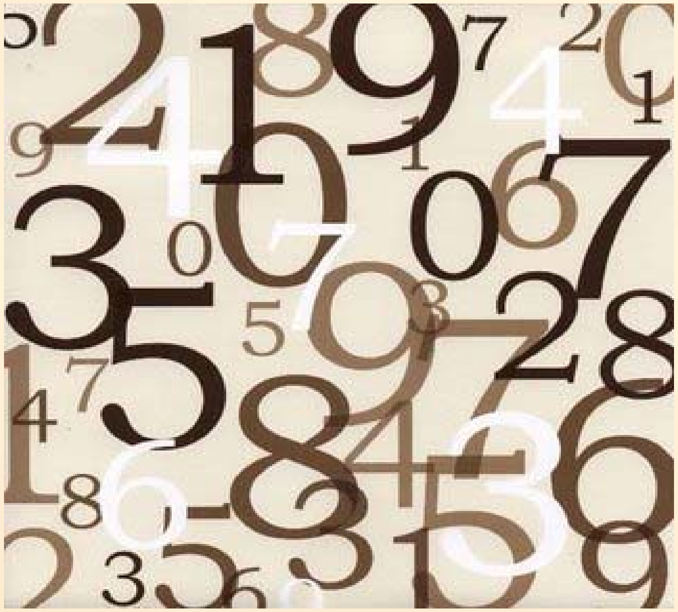
• *Binary* digital signal -- only *two* possible values
– Typically represented as 0 and 1
One Binary digit is BIT value
– We'll only consider *binary* digital signals
– Binary is popular because

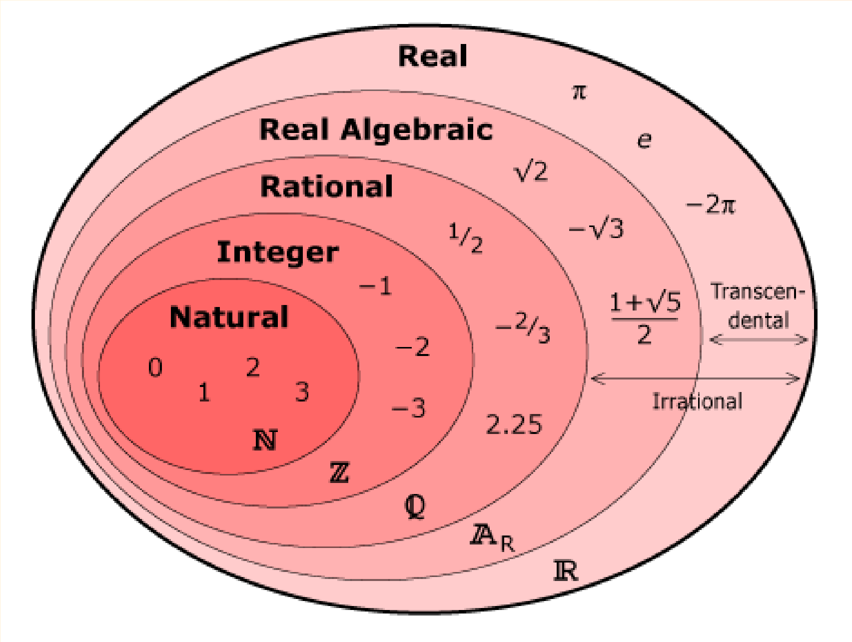


• Transistors, the basic digital electric component, operate at *two* states (switch on and switch off)

• Storing/transmitting one of *two* values is easier than three or more (e.g., loud beep or quiet beep, reflection or no reflection)

Number Systems and Conversion





Decimal	Binary	Octal	Hexadecimal
0	00000	0	0
1	00001	1	1
2	00010	2	2
3	00011	3	3
4	00100	4	4
5	00101	5	5
6	00110	6	6
7	00111	7	7
8	01000	10	8
9	01001	11	9
10	01010	12	A
11	01011	13	B
12	01100	14	C
13	01101	15	D
14	01110	16	E
15	01111	17	F
16	10000	20	10

Outline

- Number System

Decimal, Binary, Octal, Hex

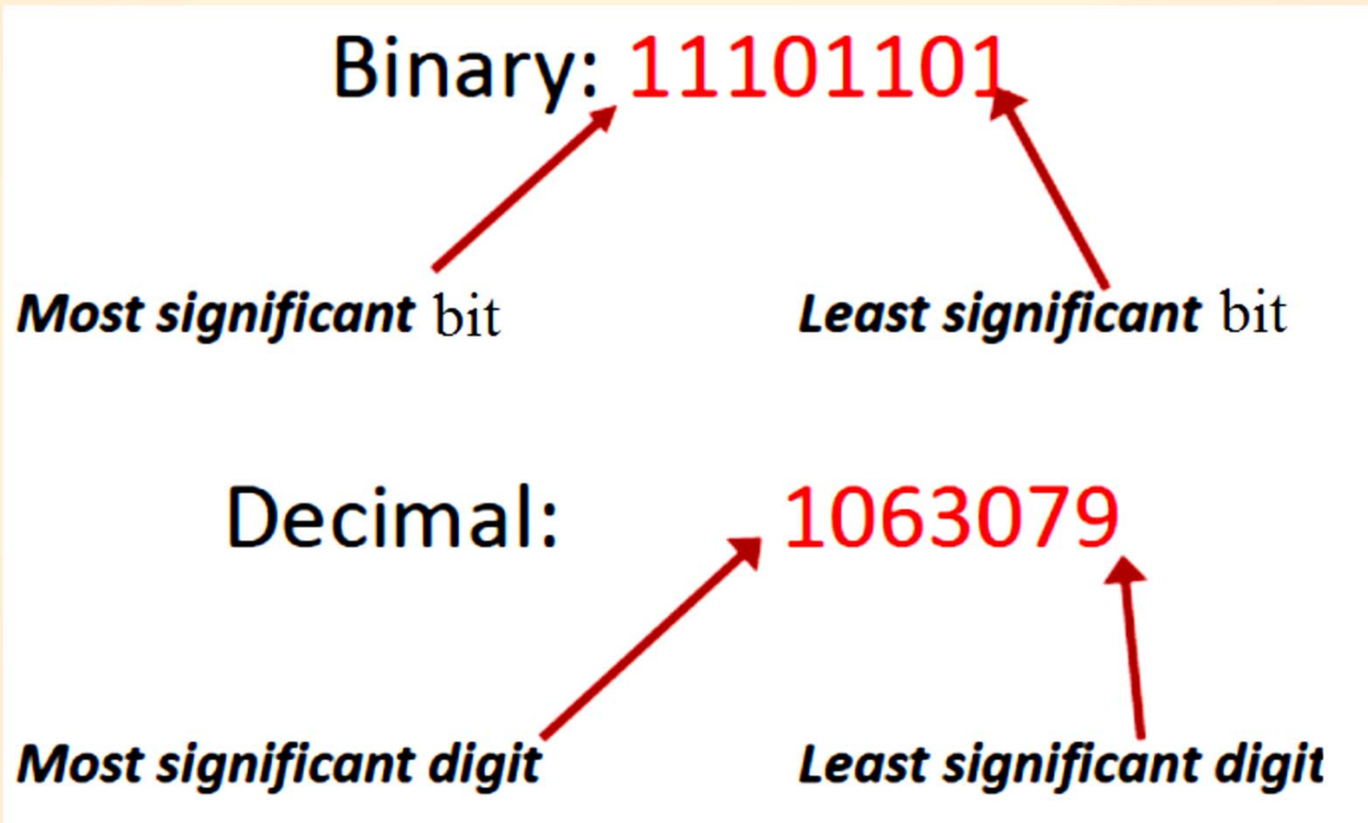
- Conversion (one to another)

Decimal to Binary, Octal, Hex & Vice Versa
Binary to HEX & vice versa

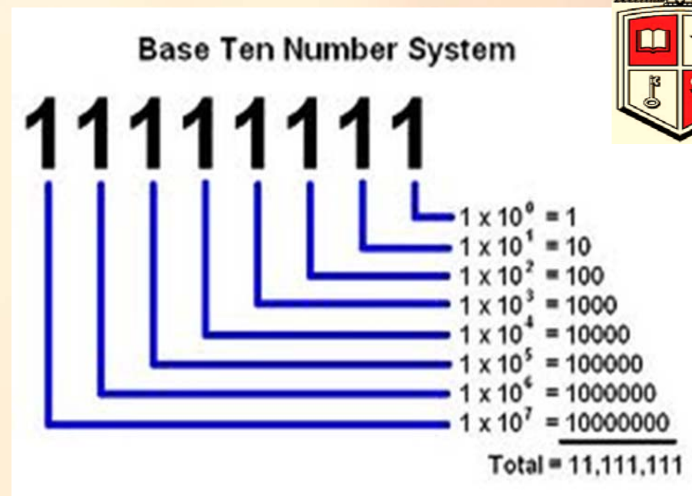
- Other representation

Signed, Unsigned, Complement

Significant Digits



Decimal (base 10)



- Uses positional representation

- Each digit corresponds to a power of 10 based on its position in the number

- The powers of 10 increment from 0, 1, 2, etc. as you move right to left

$$1{,}586 = 1 * 10^3 + 5 * 10^2 + 8 * 10^1 + 6 * 10^0$$

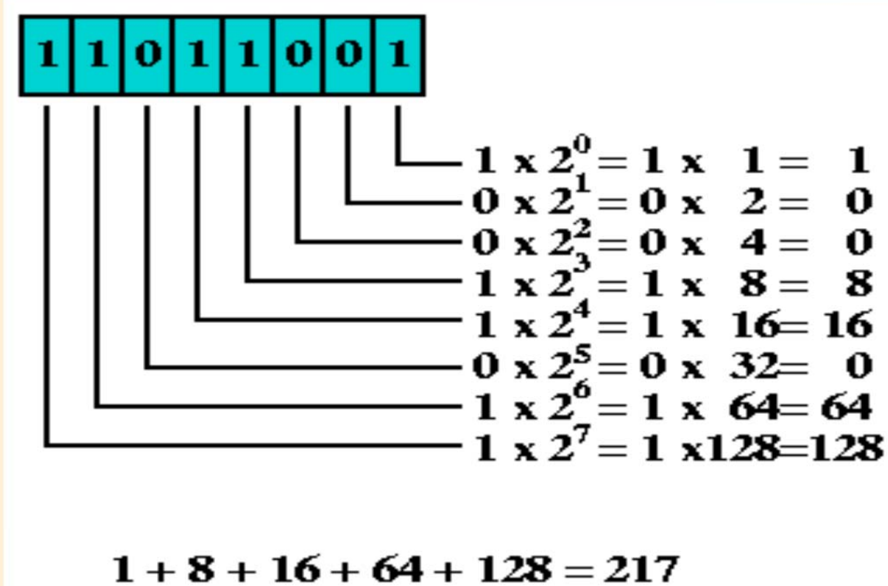
Binary (Base 2)

- Two digits: 0, 1

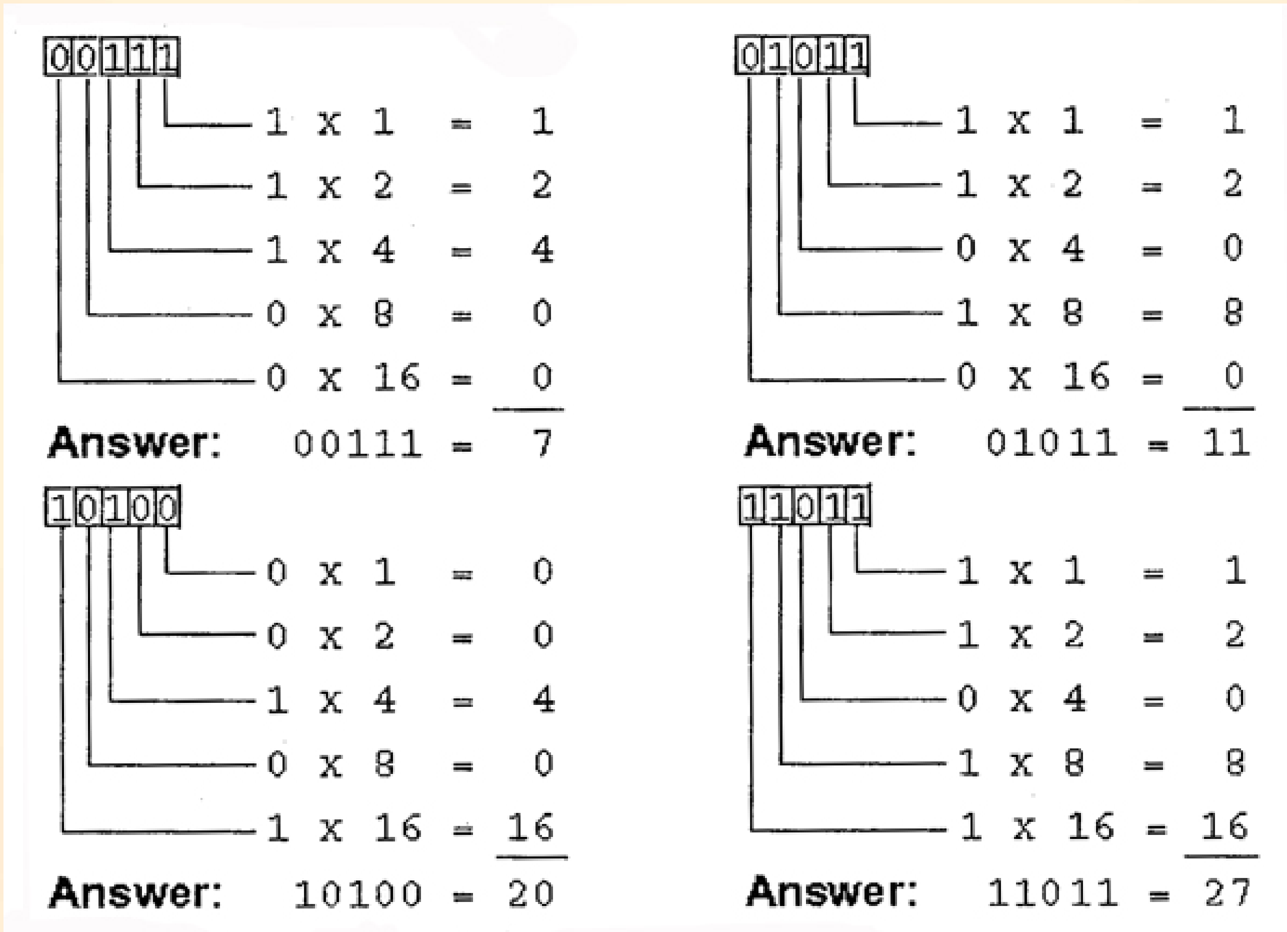
- To make the binary numbers more readable, the digits are often put in groups of 4

$$1010 = 1 * 2^3 + 0 * 2^2 + 1 * 2^1 + 0 * 2^0$$
$$= 8 + 2$$
$$= 10$$

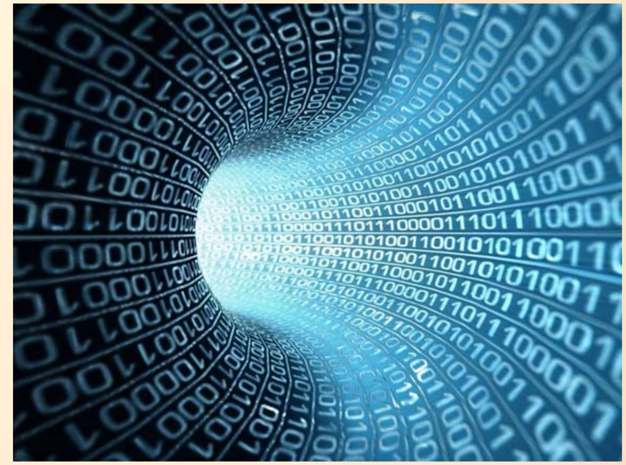
$$1100\ 1001 = 1 * 2^7 + 1 * 2^6 + 1 * 2^3 + 1 * 2^0$$
$$= 128 + 64 + 8 + 1$$
$$= 201$$



Binary to Decimal



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

- Count up by powers of two

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

Octal (base 8)

- Shorter & easier to read than binary
- 8 digits: 0, 1, 2, 3, 4, 5, 6, 7,
- Octal numbers

$$
\begin{aligned}
136_8 &= 1 * 8^2 + 3 * 8^1 + 6 * 8^0 \\
&= 1 * 64 + 3 * 8 + 6 * 1 \\
&= 94_{10}
\end{aligned}
$$

Hexadecimal (base 16)

- Shorter & easier to read than binary
- 16 digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
- "0x" often precedes hexadecimal numbers

$$
\begin{aligned}
0x123 &= 1 * 16^2 + 2 * 16^1 + 3 * 16^0 \\
&= 1 * 256 + 2 * 16 + 3 * 1 \\
&= 256 + 32 + 3 \\
&= 291
\end{aligned}
$$

Fractional Number

Point: Decimal Point, Binary Point, Hexadecimal point

Decimal

$247.75 = 2x10^{2}+4x10^{1}+7x10^{0}+7x10^{-1}+5x10^{-2}$

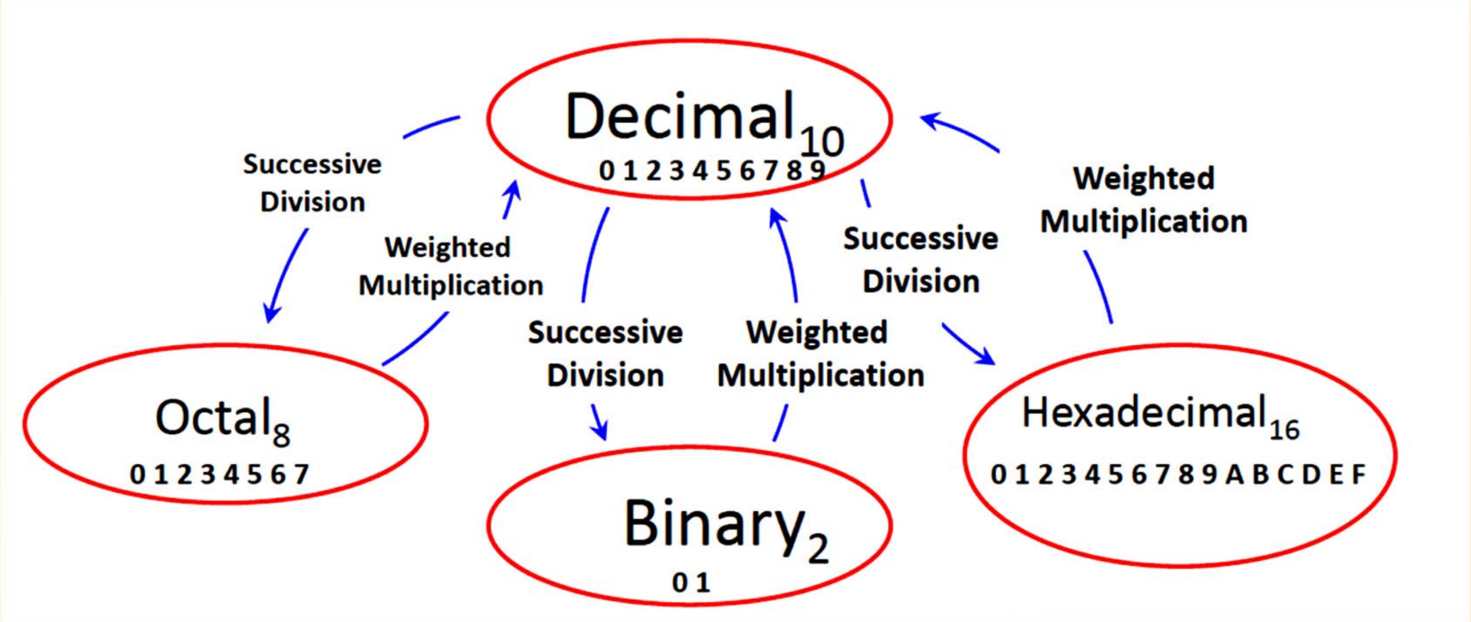
Binary

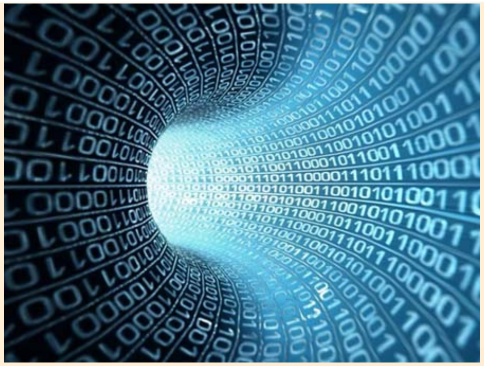
$10.101= 1x2^{1}+0x2^{0}+1x2^{-1}+0x2^{-2}+1x2^{-3}$

Hexadecimal

$6A.7D=6x16^{1}+10x16^{0}+7x16^{-1}+Dx16^{-2}$

Converting To and From Decimal





Decimal ↔ Binary

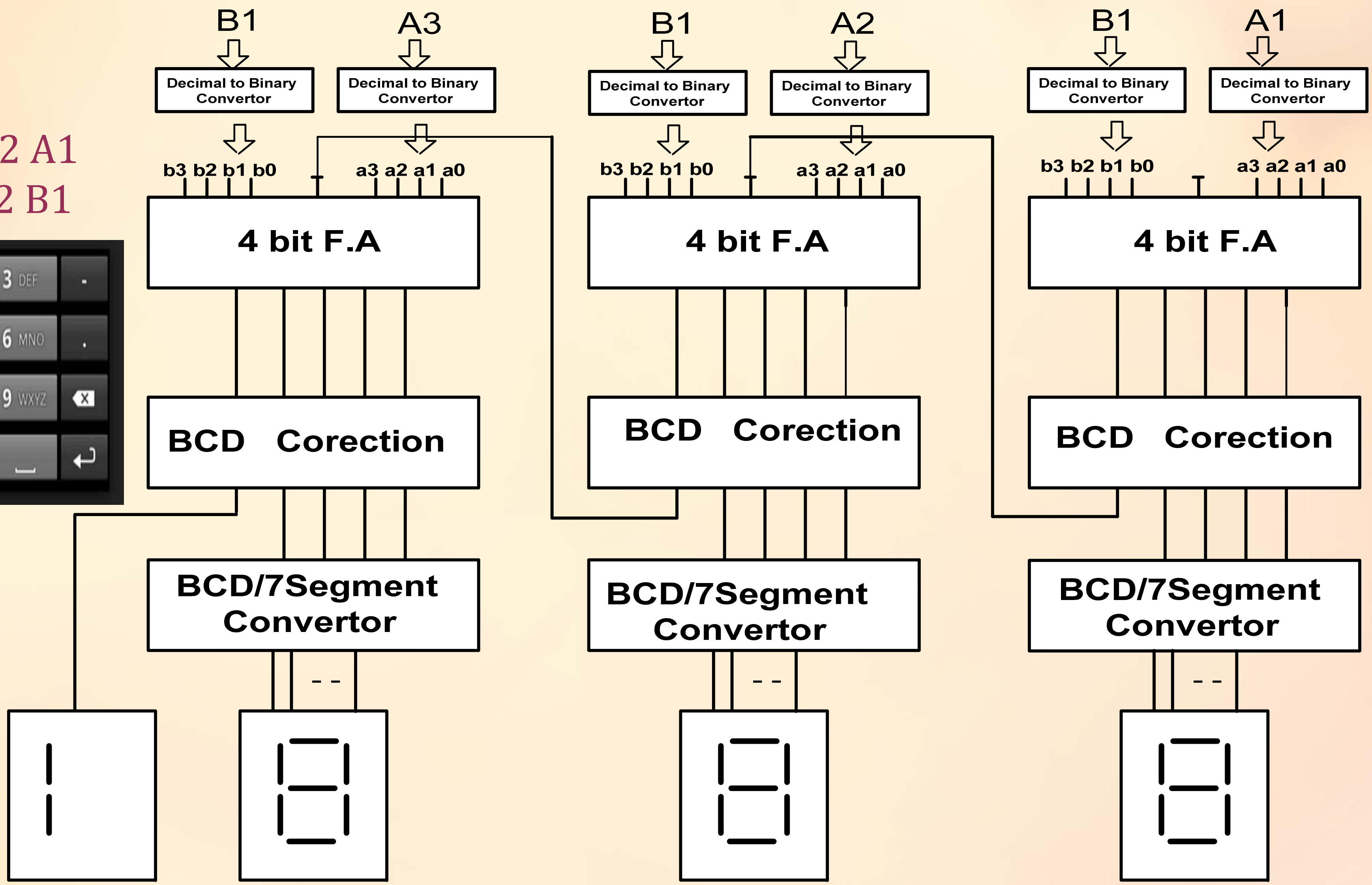
Decimal (Base 10) → **Successive Division** → **Binary (Base 2)**

a) Divide the decimal number by **2**; the remainder is the LSB of the **binary** number.
b) If the quotation is zero, the conversion is complete. Otherwise repeat step (a) using the quotation as the decimal number. The new remainder is the next most significant bit of the **binary** number.

Binary (Base 2) → **Weighted Multiplication** → **Decimal (Base 10)**

a) Multiply each bit of the **binary** number by its corresponding bit- **Multiplication** weighting factor (i.e., Bit-0→2^0=1; Bit-1→$\mathbf{2^1}$=2; Bit-2→$\mathbf{2^2}$=4; etc).
b) Sum up all of the products in step (a) to get the decimal number.

A3 A2 A1
+ B3 B2 B1



Decimal to Binary : Subtraction Method

- Goal
  - Good for human
  - 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).

Desired decimal number: **12**

32	16	8	4	2	1	
_	_	_	_	_	_	

32	16	8	4	2	1	
1	_	_	_	_	_	=32 too much

32	16	8	4	2	1	
0	1	_	_	_	_	=16 too much

32	16	8	4	2	1	
0	0	1	_	_	_	=8 ok, keep going

32	16	8	4	2	1	
0	0	1	1	_	_	=8+4=12 DONE

32	16	8	4	2	1	
0	**0**	**1**	**1**	**0**	**0**	answer

Decimal to Binary : Subtraction Method

Examples: 39, 27, 18, 7

___	___	___	___	___	___
32	16	8	4	2	1

___	___	___	___	___	___
32	16	8	4	2	1

___	___	___	___	___	___
32	16	8	4	2	1

___	___	___	___	___	___
32	16	8	4	2	1

___	___	___	___	___	___
32	16	8	4	2	1

___	___	___	___	___	___
32	16	8	4	2	1

Decimal to Binary : Division Method

- Good for computer: 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

12 div 2 = (Quo=6 , Rem=0) LSB
6 div 2 = (Quo=3, Rem=0)
3 div 2 = (Quo=1,Rem=1)
1 div 2 = (Quo=0, Rem=1) MSB
$12_{10} = 1100_2$

Conversions Process Decimal ↔ Base (n)

Decimal (Base 10) $\xrightarrow{\text{Successive Division}}$ **Any Base (Base n)**

a) Divide the decimal number by **n**; the remainder is the LSB of the **any base** number.
b) If the quotation is zero, the conversion is complete. Otherwise repeat step (a) using the quotation as the decimal number. The new remainder is the next most significant bit of the **any base** number.

Any Base (Base n) $\xrightarrow{\text{Weighted Multiplication}}$ **Decimal (Base 10)**

a) Multiply each bit of the **any base** number by its corresponding bit- **Multiplication** weighting factor (i.e., Bit-0→n^0=1; Bit-1→n^1=n; Bit-2→n^2=4; etc).
b) Sum up all of the products in step (a) to get the decimal number.

Decimal ↔ Octal Conversion

The Process: Successive Division

- Divide number by **8**; R is the LSB of the **octal** number
- While Q is 0
- Using the Q as the decimal number.
- New remainder is MSB of the **octal** number.

$$\begin{array}{r} 11 \\ 8\overline{)\,94} \end{array} \quad r = 6 \leftarrow \text{LSB}$$

$$\begin{array}{r} 1 \\ 8\overline{)\,11} \end{array} \quad r = 3$$

$$\begin{array}{r} 0 \\ 8\overline{)\,1} \end{array} \quad r = 1 \leftarrow \text{MSB}$$

$$\boxed{94_{10} = 136_8}$$

Decimal ↔ Hexadecimal Conversion

The Process: Successive Division

- Divide number by **16**; R is the LSB of the **hex** number
- While Q is 0
- Using the Q as the decimal number.
- New remainder is MSB of the **hex** number.

$$16 \overline{)\,94} = 5 \qquad r = E \quad \leftarrow \text{LSB}$$

$$16 \overline{)\,5} = 0 \qquad r = 5 \quad \leftarrow \text{MSB}$$

$$\boxed{94_{10} = 5E_{16}}$$

$1A2B3C_{16}$

$1 \times 16^5 = 1048576$

$10 \times 16^4 = 655360$

$2 \times 16^3 = 8192$

$11 \times 16^2 = 2816$

$3 \times 16^1 = 48$

$12 \times 16^0 = 12$

$\rightarrow 1048576 + 655360 + 8192 + 2816 + 48 + 12$

Example: Hex → Octal

Example:

Convert the hexadecimal number 5AH into its octal equivalent.

Solution:

First convert the hexadecimal number into its decimal equivalent then convert the decimal number into its octal equivalent.

5	A
16^1	16^0
16	1

$$80 + 10 = 90_{10}$$

$$8\,\overline{)\,90}^{\;11} \qquad r = 2 \quad \leftarrow \text{LSB}$$

$$8\,\overline{)\,11}^{\;1} \qquad r = 3$$

$$8\,\overline{)\,1}^{\;0} \qquad r = 1 \quad \leftarrow \text{MSB}$$

$$\boxed{\therefore\ 5A_H = 132_8}$$

Example: Octal → Binary

Example:

Convert the octal number 132_8 into its binary equivalent.

Solution:

First convert the octal number into its decimal equivalent, then convert the decimal number into its binary equivalent.

1	3	2
8^2	8^1	8^0
64	8	1

$$64 + 24 + 2 = 90_{10}$$

Division	Quotient	Remainder	
$90 \div 2$	45	$r = 0$	← LSB
$45 \div 2$	22	$r = 1$	
$22 \div 2$	11	$r = 0$	
$11 \div 2$	5	$r = 1$	
$5 \div 2$	2	$r = 1$	
$2 \div 2$	1	$r = 0$	
$1 \div 2$	0	$r = 1$	← MSB

$$\boxed{132_8 = 1011010_2}$$

Binary ↔ Octal ↔ Hex Shortcut

- Relation
- Binary, octal, and hex number systems
- All powers of two
- Exploit (This Relation)
- Make conversion easier.

Substitution Code

Convert $010101101010111001101010_2$ to hex using the 4-bit substitution code :

5	6	A	E	6	A
0101	0110	1010	1110	0110	1010

$\boxed{56AE6A_{16}}$

Substitution Code

Substitution code can also be used to convert binary to octal by using 3-bit groupings:

2	5	5	2	7	1	5	2
010	101	101	010	111	001	101	010

$$\boxed{25527152_8}$$

Other Representation

Signed & Unsigned Number

- **Signed number last bit (one MSB) is signed bit**

Assume: 8 bit number

Unsigned 12 : 0000 1100

Signed +12 : **0**000 1100

Signed -12 : **1**000 1100

- **Complement number**

Unsigned binary 12 = 0000**11**00

1's Complement of 12 = 1111 **00**11

Example # 1: Convert 147.8_8 to decimal.

$$147.3_8 = 1 \times 8^2 + 4 \times 8^1 + 7 \times 8^0 + 3 \times 8^{-1} = 64 + 32 + 7 +$$
$$= 103.375_{10}$$

Example # 2:

Convert 53_{10} to binary.

$$
\begin{array}{rll}
2\ /\underline{53} & & \\
2\ /\underline{26} & \text{rem.} = 1 = a_0 & \\
2\ /\underline{13} & \text{rem.} = 0 = a_1 & \\
2\ /\underline{6} & \text{rem.} = 1 = a_2 & 53_{10} = 110101_2 \\
2\ /\underline{3} & \text{rem.} = 0 = a_3 & \\
2\ /\underline{1} & \text{rem.} = 1 = a_4 & \\
0 & \text{rem.} = 1 = a_5 &
\end{array}
$$

Thank You