



MICROPROCESSOR SYSTEMS

Number Systems & Conversion

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Numbering Systems and Conversion

- Binary Numbers
- Hexadecimal Numbers
- BCD Numbers
- Conversion among Binary, Decimal, and Hexadecimal
- Binary Arithmetic
- Two's Complement Notation
- Two's Complement Arithmetic
- Bit Grouping
- Alphanumeric Codes
- Floating Point Number representation



Binary Numbers

- Binary digits or Bits are used by the Digital Computers
- Also called Base 2 Numbers
- 1 means a High voltage Level and 0 means Low voltage level (may be 0)
- Similarity with the Decimal Number System
- Decimal 1327 is 1 thousands, 3 hundreds, 2 twenties, and 7 ones
- Place value characteristics in Binary (...64, 32, 16, 8, 4, 2,1)
- ... 2^7 , 2^6 , 2^5 , 2^4 , 2^3 , 2^2 , 2^1 , 2^0
- LSB and MSB in Binary Numbers



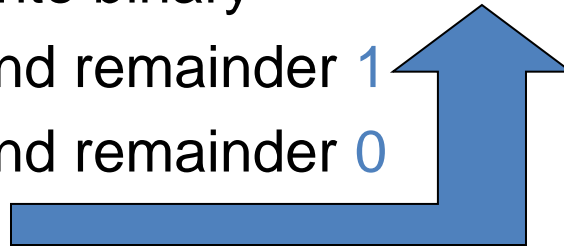
Binary – Decimal Conversion

- $(0001)_2 = ?_{10}$
- $(0101)_2 = ?_{10}$
- $(1000)_2 = ?_{10}$
- $(1011)_2 = ?_{10}$
- $(1111)_2 = ?_{10}$
- $(0111)_2 = ?_{10}$



Decimal - Binary Conversion

- Number is repeatedly divided by 2 (keeping remainder) until it result is 0 or 1 (End)
- Try to convert $(5)_{10}$ into binary
 - $5 \% 2 \rightarrow$ Ans. 2 and remainder 1
 - $2 \% 2 \rightarrow$ Ans. 1 and remainder 0
- Answer is: 101





Decimal - Binary Conversion

- $(155)_{10} = (??)_2$
- $(77)_{10} = (??)_2$
- $(38)_{10} = (??)_2$
- $(48)_{10} = (??)_2$
- $(215)_{10} = (??)_2$
- $(455)_{10} = (??)_2$



Hexadecimal Numbers

- Remembering and typing Long strings of bits is tedious and error prone
- Using Decimal Conversion is a good idea but the conversion process takes a long time
- In most of systems, hexadecimal numbers are used as shorthand representation of binary numbers
- 16 digits. First 10 digits are same as decimal then A-F
- First 16 Hexadecimal numbers and their binary equivalents
- 10011110 in Hexadecimal is 9Eh
- Letter h differentiate it from the other numbers



Binary - Hexadecimal Conversion

- Starting from LSB, make group of four bits and write their Hexadecimal equivalent
- $(111010)_2 = (??)_{16}$
- $(1111111)_2 = (??)_{16}$
- $(101000)_2 = (??)_{16}$
- $(1011110)_2 = (??)_{16}$
- $(1001100)_2 = (??)_{16}$
- $(1110011)_2 = (??)_{16}$



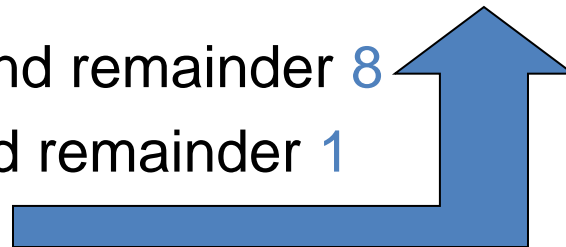
Hexadecimal – Binary Conversion

- Replace each hexadecimal digit with its four bit binary equivalent
- $(7F)_{16} = (??)_2$
- $(2C)_{16} = (??)_2$
- $(5A)_{16} = (??)_2$
- $(97)_{16} = (??)_2$
- $(100)_{16} = (??)_2$
- $(255)_{16} = (??)_2$



Decimal-Hexadecimal Conversion

- Similar to Decimal – Binary (Now divide by 16)
- Try to convert $(280)_{10}$ into Hexadecimal
 - $280 \% 16 \rightarrow$ Ans. 17 and remainder 8
 - $17 \% 16 \rightarrow$ Ans. 1 and remainder 1
- Answer is: 118





Hexadecimal-Decimal Conversion

- Same as Binary to Decimal. (Now powers of 16)
- $(7F)_{16} = (??)_{10}$
- $(2C)_{16} = (??)_{10}$
- $(5A)_{16} = (??)_{10}$
- $(97)_{16} = (??)_{10}$
- $(100)_{16} = (??)_{10}$
- $(255)_{16} = (??)_{10}$



BCD Numbers

- **B**inary **C**oded **D**ecimal
- A Special code to represent decimal numbers in Binary
- Straight forward conversion from decimal to binary (digit by digit)
- 8421 BCD is more commonly used. However 5421 and excess-3 too
- BCD code table
- Convert the decimal number 3691 into BCD equivalent
- Convert the BCD number 1000000001110010 into Decimal equivalent
- In microprocessors, pure binary numbers are manipulated, However some MPUs do have instructions to manipulate BCD too



Binary Arithmetic

- Addition
- Subtraction
- Multiplication
- Division

- Solve the following:
 - (i) $1010 + 0101$ (ii) $1101 + 0101$ (iii) $01011011 + 00001111$
 - (iv) $1110 - 1000$ (v) $1010 + 0101$ (vi) $01100110 - 00011010$
 - (vii) 1001×11 (viii) 1101×1001 (ix) 1110×1110



Twos Complement Notation

- To simplify the computer circuitry, twos complement codes are used
- Negative numbers are represented using Twos complement
- If sign of numbers is being taken care of then the representation is called Signed
- In signed representation negative numbers are represented using twos complement
- Inside the microprocessor, a storage location capable of storing group of bits is called a *register*
- If signed representation is being used, then the MSB of the register tells the sign of the number
- Table of 8-bit Signed numbers



Twos Complement Notation

- If MSB of the number is 0, the number is positive and is in normal form
- If MSB is 1 then number is negative and is in **Twos Complement form**
- Remaining 7 bits tell the magnitude if the number
- If register = 0100 0001 then it has value decimal +65
- If register = 0111 1111 then it has value decimal +127
- If register = 1111 1111 then it has value decimal -1
- What will be twos complement for -9?
- What will be twos complement for -16?
- What will be twos complement for -100?
- What will be twos complement for -95?



Twos Complement Arithmetic

- Using Twos complement, subtraction can be performed by means of addition
- This saves Subtraction circuitry
- Following are to be noted for Signed Arithmetic
 - If $(+A)+(+B)$ Then its like normal binary addition
 - If $(-A)+(+B)$ Then first take 2's complement of A then add with B
 - If $(+A)+(-B)$ Then first take 2's complement of B then add with A
 - If $(-A)+(-B)$ Then first take 2's complement of A and B and then add both
 - Result is also in 2's complement. (Check its MSB)



Twos Complement Arithmetic

- Perform the following signed arithmetic
 - (i) $(+7) + (+1)$
 - (ii) $(+31) + (26)$
 - (iii) $(+8) + (-5)$
 - (iv) $(+89) + (-46)$
 - (v) $(-3) + (-4)$



Bit Grouping

- A binary digit is called a Bit
- Group of four bits is called a *nibble*
- Group of eight bits is called a *byte*
- A very important component of a microprocessor is a register called *accumulator*
- The size of accumulator is an important characteristics because it is the center of computations
- If a microprocessor has accumulator size of 8-bits then it is called as an 8-bit microprocessor
- An 8-bit microprocessor transfer 8-bits of data at once
- Word sizes may be 8, 16, 32 or even 64 bit (for modern microprocessors)



Bit Grouping (Contd.)

- **Block Diagram of memory showing binary addresses and contents**
- Each address holds an 8-bit data
- There can be any of the following meaning of this data
 - A binary number
 - A signed binary number
 - A BCD number
 - A character
 - An instruction
 - A memory address
 - A port address
- **It is revealed upon decoding!**



Block Diagram of memory

	Address	Contents							
100	0110 0100	1	1	0	0	0	0	1	1
101	0110 0101	0	0	0	0	0	0	0	1
102	0110 0110	0	1	0	0	0	0	0	0
103	0110 0111	1	0	0	0	1	1	1	0
104	0110 1000	1	0	0	0	0	0	0	1
105	0110 1000	1	1	0	0	0	0	0	0
	...								
200	1100 1000	0	1	0	0	0	0	1	0



Alphanumeric Codes

- Both characters and numbers are coded
- Used when display data on CRT, LCD or other displays
- The most common code is ASCII
- American **S**tandard **C**ode for **I**nformation **I**nterchange
- Basic ASCII codes are 7-bit wide
- Extended ASCII are 8-bit wide
- Partial ASCII chart



Floating Point Representation

- IEEE 754 Standard (32bit or 64 bit)
- 32bit standard
 - 1 bit for sign
 - 8 bits for exponent
 - 23 bits for mantissa
- Converting Decimal to Binary
 - Sign bit (0 for +ve and 1 for -ve)
 - Normalize number to set to 1 before number (i.e by dividing it with 2)
 - Adjust the power of 2 with 8 bit exponent bias (127)
 - Calculate the bits for mantissa from fractional part by multiplying it with 2 until fraction of result becomes 0 or is upto 23 times



Floating Point Representation

- Converting Binary to Decimal
 - Sign bit (0 for +ve and 1 for -ve)
 - Calculate power from exponent part by adjusting it with bias (i.e. 127)
 - Take Mantissa bits and multiply it with power of 2 (starting from -ve number i.e. 1 to n)



Logic Gates

- Digital Devices use circuits to produce digital logic signals called *Logic Gates*
- Basic 3 logic gates and their truth table
- Boolean expression shorthand's
- Combinational Logic circuits can be described by:
 - Truth Table
 - Boolean expressions
 - Logic circuits
- Draw the logic circuit for $AB'C'D + ABCD$
- Draw the truth table, Boolean expression and the logic diagram for $\sum (1,3,5)$



Flip flops and Latches

- Two categories of logic circuits
 - Combinational
 - Output is determined by combination of inputs
 - Sequential
 - Output is determined by inputs + previous state of the system
- Flip flops are basic building block of sequential circuits
- Flip flops are memory capable (i.e. Those remember the output even inputs are removed unlike logic gates)
- Mostly have two outputs (Q and Q' also called Set and Reset)
- The simplest is D-type flip flop (Data Latch)
- Other flip flops are RS, JK, T



Encoders, Decoders and Displays

- Digital Devices
- Encoders translate one representation of data into other
 - Examples are Decimal to BCD, Hexadecimal to BCD
- Decoders do the reverse process
 - BCD to Decimal, BCD to 7-segment
- Displays used to convey information to the user
 - Examples: 7-Segment, LCD, CRT



Memory

- Semiconductor memories are divided into two categories
 - Read / Write
 - Read Only
- Reading data from the memory does not destroy the contents
- Writing is only possible with Read / Write memory (often called RAM)
 - It is volatile



Memory (Contd.)

- Read only memories come under four categories
 - Standard ROM (programmed by manufacturer)
 - PROM (Programmed only once)
 - EPROM (erasable PROM)
 - EAROM (electrically alterable ROM) or EEPROM
 - Flash Memory
- They are non-volatile



Memory (Contd.)

- Read write memories come two categories
 - Static RAM
 - Composed of flip flops and needs no refreshing (expensive)
 - Dynamic RAM
 - Composed of capacitive elements and needs refreshing (cheap)
- NVRAMs combines capability of SRAM and EEPROM
- In microcomputers, RAM are used for user programs and data
- ROM are used to store monitor program and initialization routines



Questions

