MICROPROCESSOR SYSTEMS

Number Systems & Conversion

Zuhaib A. Shaikh,
Asst. Prof., CSE Deptt.,QUEST
Web: zuhaib-shaikh.neocities.org

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 ➔ Ans. 2 and remainder 1
  - 2 % 2 ➔ 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 ➔ Ans. 17 and remainder 8
  - 17 % 16 ➔ 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

- Binary Coded Decimal
- 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 X 11 (viii) 1101 X 1001 (ix) 1110 X 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 Standard Code for Information Interchange
- 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 ∑ (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