MPI: Microprocessors and Interfacing
Academic Year: 2022 - 23

Dr. Praveen Kumar Alapati
praveenkumar.alapati@mahindrauniversity.edu.in
Department of Computer Science and Engineering
Ecole Centrale School of Engineering

Lab-6 Due Date: November 24, 2023

1. Write an assembly language program to perform the addition of two N x N matrices.

2. Write an assembly language program to perform the multiplication of two N x N matrices.

Note: Use NASM and consider the value of N during run time.

Lab-5 Due Date: November 05, 2023

Take any five problems that we discussed in the first four lab assignments (i.e., Lab-1 to Lab4) and implement them using the MASM assembler.

Lab4- Due Date: October 20, 2023

Assume that you have a processor (P) and it supports **ADD** (Addition), **SUB** (Subtraction), **INC** (Increment), **DEC**, **CMP** (Compare), **Jcc** (Jump if a condition is met), **JMP**, **XOR**, and **MOV**operations. Assume that A and B are positive integers and $A > B$.

1. Write an assembly language program to compute the $(A^2 - B^2)$ on P.
2. Write an assembly language program to compute the quotient of $\frac{(A^3 - B^3)}{(A+B)}$ on P.
3. Compute A choose B (i.e., $\binom{A}{B}$) on P

Lab3- Due Date: September 30, 2023

You are given with n positive Integers. Write functions to compute the following using **assembly language instructions**.

1. To find the number of even numbers
2. To find the number of odd numbers
3. To find the number of prime numbers
4. To find the GCD of n numbers
5. To find the LCM of n numbers

Lab2- Due Date: September 15, 2023

Write assembly language programs to compute the following(use NASM assembler). Assume that all elements are integers.

1. Find the **maximum** of *n* numbers.
2. Find the **minimum** of *n* numbers.
3. Assume that you are given with a list of *n* elements then find the **mode**.
4. Assume that you are given with a list of *n* elements then find the **median**.
5. Assume that you are given with a list of *n* elements and **key**, search the **key** using **linear search**. If the required **key** is found, return its position. Otherwise, return **-1**.

Lab1 - Due date: August 31, 2023.

1. Give the configuration of your laptop.
2. Give the configuration of a system in IT-Lab.
3. Develop C-Programs for the following problem statements:
   3.1. Print the internal representation of data stored in primary data types: **int, float, and double**.
   3.2. Perform addition and multiplication of two 32-bit numbers (Please remember that the input is a 32-bit binary number). The numbers can either be integers or real numbers.

Submission Guide Lines

Max. team size is 6.

Mail-ID: cs3106.mpi@gmail.com

Sub:TEAM_NUM_LAB_NUM

Attach.Name and Type: (Sub.).zip

Late Submission:50%.

Write a readme file to understand your solutions.

- Representation of Integer Numbers
  - Signed Magnitude Representation
  - 1's Complement Representation
  - 2's Complement Representation
- Representation of Real Numbers
  - Fixed Point Representation
  - Floating Point Representation

Resolution is difference between two successive numbers.

Let A $= a_{n-1}a_{n-2}a_{n-3}...a_0$ is an n-bit binary number
if A is an **unsigned integer**, then value of A is : $\sum_{i=0}^{n-1}(2^i \times a_i)$.
if A is a **signed integer**:

Signed Magnitude Representation:

$$A = \sum_{i=0}^{n-2}(2^i \times a_i), \text{ if } a_{n-1} = 0$$
$$A = -\sum_{i=0}^{n-2}(2^i \times a_i), \text{ if } a_{n-1} = 1$$

1's Complement Rep.: $A = -(2^{n-1} - 1) \times a_{n-1} + \sum_{i=0}^{n-2}(2^i \times a_i)$

2's Complement Rep.: $A = -2^{n-1} \times a_{n-1} + \sum_{i=0}^{n-2}(2^i \times a_i)$

Resolution: 1

Range of Numbers

Let A $= a_{n-1}a_{n-2}a_{n-3}...a_0$ is an n bit binary number
if A is an **unsigned integer**, then range of A is : 0 to $(2^n - 1)$.
if A is a **signed integer**:

Signed Magnitude Rep., range of A is : $-(2^{n-1} - 1)$ to $(2^{n-1} - 1)$.

1's Complement Rep., range of A is : $-(2^{n-1} - 1)$ to $(2^{n-1} - 1)$.

2's Complement Rep., range of A is : -2^{n-1} to $(2^{n-1} - 1)$.

Expansion of Bit Length

Add additional bit positions to the left and fill in with value of the sign bit.
Let A = **1 0 1 0** is a 4-bit binary number,
Representation of A using 8-bits (i.e. B): **1 1 1 1 1 0 1 0**.
is A=B ?

- In 2's Complement Rep.: **Yes**.
- In 1's Complement Rep.: **Yes**.
- In Signed Magnitude Rep.: **No**.

Expansion of Bit Length

Add additional bit positions to the left and fill in with value of the sign bit.
Let A = **1 0 1 0** is a 4-bit binary number,
Representation of A using 8-bits (i.e. B): **1 1 1 1 1 0 1 0**.
is A=B ?

- In 2's Complement Rep.: **Yes**.
- In 1's Complement Rep.: **Yes**.
- In Signed Magnitude Rep.: **No**.

Expansion of Bit Length

Add additional bit positions to the left and fill in with value of the sign bit.
Let A = **1 0 1 0** is a 4-bit binary number,
Representation of A using 8-bits (i.e. B): **1 1 1 1 1 0 1 0**.
is A=B ?

In 2's Complement Rep.: **Yes**.

In 1's Complement Rep.: **Yes**.

In Signed Magnitude Rep.: **No**.

Expansion of Bit Length

Add additional bit positions to the left and fill in with value of the sign bit.
Let A = **1 0 1 0** is a 4-bit binary number,
Representation of A using 8-bits (i.e. B): **1 1 1 1 1 0 1 0**.
is A=B ?

In 2's Complement Rep.: **Yes**.

In 1's Complement Rep.: **Yes**.

In Signed Magnitude Rep.: **No**.

Real Numbers

1. $(4.5)_{10} = (100.1)_2$
2. $(8.25)_{10} = (1000.01)_2$
3. $(16.125)_{10} = (10000.001)_2$
4. $(0.875)_{10} = (0.111)_2$
5. $(4.5)_{10} = (1.001)_2 \times 2^2$
6. $(8.25)_{10} = (1.00001)_2 \times 2^3$
7. $(16.125)_{10} = (1.0000001)_2 \times 2^4$
8. $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

Representations 5 to 8 are called Normalized Representations.
Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Real Numbers

1. $(4.5)_{10} = (100.1)_2$
2. $(8.25)_{10} = (1000.01)_2$
3. $(16.125)_{10} = (10000.001)_2$
4. $(0.875)_{10} = (0.111)_2$
5. $(4.5)_{10} = (1.001)_2 \times 2^2$
6. $(8.25)_{10} = (1.00001)_2 \times 2^3$
7. $(16.125)_{10} = (1.0000001)_2 \times 2^4$
8. $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

Representations 5 to 8 are called Normalized Representations.
Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Real Numbers

1. $(4.5)_{10} = (100.1)_2$
2. $(8.25)_{10} = (1000.01)_2$
3. $(16.125)_{10} = (10000.001)_2$
4. $(0.875)_{10} = (0.111)_2$
5. $(4.5)_{10} = (1.001)_2 \times 2^2$
6. $(8.25)_{10} = (1.00001)_2 \times 2^3$
7. $(16.125)_{10} = (1.0000001)_2 \times 2^4$
8. $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

Representations 5 to 8 are called Normalized Representations.

Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Real Numbers

1. $(4.5)_{10} = (100.1)_2$
2. $(8.25)_{10} = (1000.01)_2$
3. $(16.125)_{10} = (10000.001)_2$
4. $(0.875)_{10} = (0.111)_2$
5. $(4.5)_{10} = (1.001)_2 \times 2^2$
6. $(8.25)_{10} = (1.00001)_2 \times 2^3$
7. $(16.125)_{10} = (1.0000001)_2 \times 2^4$
8. $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

Representations 5 to 8 are called Normalized Representations.

Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Real Numbers

1. $(4.5)_{10} = (100.1)_2$
2. $(8.25)_{10} = (1000.01)_2$
3. $(16.125)_{10} = (10000.001)_2$
4. $(0.875)_{10} = (0.111)_2$
5. $(4.5)_{10} = (1.001)_2 \times 2^2$
6. $(8.25)_{10} = (1.00001)_2 \times 2^3$
7. $(16.125)_{10} = (1.0000001)_2 \times 2^4$
8. $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

Representations 5 to 8 are called Normalized Representations.

Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Real Numbers

1. $(4.5)_{10} = (100.1)_2$
2. $(8.25)_{10} = (1000.01)_2$
3. $(16.125)_{10} = (10000.001)_2$
4. $(0.875)_{10} = (0.111)_2$
5. $(4.5)_{10} = (1.001)_2 \times 2^2$
6. $(8.25)_{10} = (1.00001)_2 \times 2^3$
7. $(16.125)_{10} = (1.0000001)_2 \times 2^4$
8. $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

Representations 5 to 8 are called Normalized Representations.

Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a **True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Real Numbers

1. $(4.5)_{10} = (100.1)_2$
2. $(8.25)_{10} = (1000.01)_2$
3. $(16.125)_{10} = (10000.001)_2$
4. $(0.875)_{10} = (0.111)_2$
5. $(4.5)_{10} = (1.001)_2 \times 2^2$
6. $(8.25)_{10} = (1.00001)_2 \times 2^3$
7. $(16.125)_{10} = (1.0000001)_2 \times 2^4$
8. $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

Representations 5 to 8 are called Normalized Representations.

Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Real Numbers

1. $(4.5)_{10} = (100.1)_2$
2. $(8.25)_{10} = (1000.01)_2$
3. $(16.125)_{10} = (10000.001)_2$
4. $(0.875)_{10} = (0.111)_2$
5. $(4.5)_{10} = (1.001)_2 \times 2^2$
6. $(8.25)_{10} = (1.00001)_2 \times 2^3$
7. $(16.125)_{10} = (1.0000001)_2 \times 2^4$
8. $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

Representations 5 to 8 are called Normalized Representations.

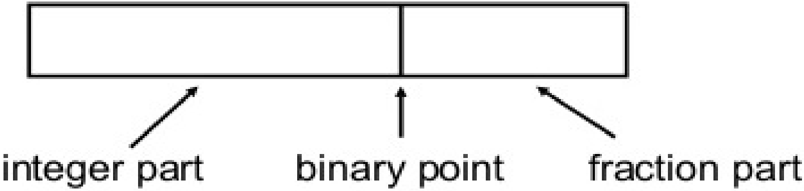
Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Real Numbers

1. $(4.5)_{10} = (100.1)_2$
2. $(8.25)_{10} = (1000.01)_2$
3. $(16.125)_{10} = (10000.001)_2$
4. $(0.875)_{10} = (0.111)_2$
5. $(4.5)_{10} = (1.001)_2 \times 2^2$
6. $(8.25)_{10} = (1.00001)_2 \times 2^3$
7. $(16.125)_{10} = (1.0000001)_2 \times 2^4$
8. $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

Representations 5 to 8 are called Normalized Representations.
Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Fixed Point (FP) Representation



Find the decimal equivalent of the following binary numbers. Assume that the binary numbers are represented using FP representation (6,2), i.e., 6 bits for integer part and 2 bits for fractional part.

$(00101011)_2 =$ **?**

$(11111011)_2 =$ **?**

Smallest $+ve$ number that can be represented using FP (6,2) rep.: **?**
Biggest $+ve$ number that can be represented using FP (6,2) rep.: **?**

Fixed Point Arithmetic

Consider a 16-bit binary representation, in which least significant 8 bits are used for precision then give the range of values that can be represented using the 16-bit representation.

- $+ve$ Values: 2^{-8} to $2^{7} - 2^{-8}$
- $-ve$ Values: -2^{7} to -2^{-8}
- Zero
- Resolution is **?**

Advantages of FP Arithmetic:

- Easy to implement and occupies less space.
- If performance is important than precision.
- Once can choose a trade off between range and precision.

Fixed Point Arithmetic

Consider a 16-bit binary representation, in which least significant 8 bits are used for precision then give the range of values that can be represented using the 16-bit representation.

- $+ve$ Values: 2^{-8} to $2^{7} - 2^{-8}$
- $-ve$ Values: -2^{7} to -2^{-8}
- Zero
- Resolution is **?**

Advantages of FP Arithmetic:

- Easy to implement and occupies less space.
- If performance is important than precision.
- Once can choose a trade off between range and precision.

IEEE 754 Representation of Real Numbers

IEEE 754 format for Real Numbers.

	Sign	Biased Exponent	Mantissa/Fraction	
Single Precision N=32	1 bit	8 bits	23 bits	Bias Value:+127
Double Precision N=64	1 bit	11 bits	52 bits	Bias Value :+1023

Biased Exponent=True Exponent + Bias Value

Rep. of $(4.5)_{10}$ using Single Precision

$(4.5)_{10} = (100.1)_2 = (1.001)_2 \times 2^2$

Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Biased Exponent $= \mathbf{2} + \mathbf{127} = \mathbf{129} = \mathbf{1000\ 0001}$

Mantissa $= \mathbf{001} = \mathbf{0010000\ 0000\ 0000\ 0000\ 0000}$

Sign$= +$ ve $= 0$

$(4.5)_{10} = (1.001)_2 \times 2^2 = 0\ \mathbf{10000001\ 00100000000000000000000}$

IEEE 754 Representation of Real Numbers

IEEE 754 format for Real Numbers.

Sign	Biased Exponent	Mantissa/Fraction

Single Precision N=32	1 bit	8 bits	23 bits	Bias Value:+127
Double Precision N=64	1 bit	11 bits	52 bits	Bias Value :+1023

Biased Exponent=True Exponent + Bias Value

Rep. of $(4.5)_{10}$ using Single Precision

$(4.5)_{10} = (100.1)_2 = (1.001)_2 \times 2^2$

Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a **True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Biased Exponent $= \mathbf{2} + \mathbf{127} = \mathbf{129} = \mathbf{1000\ 0001}$

Mantissa $= \mathbf{001} = \mathbf{0010000\ 0000\ 0000\ 0000\ 0000}$

Sign$= +$ ve $= 0$

$(4.5)_{10} = (1.001)_2 \times 2^2 = 0$ **10000001 00100000000000000000000**

IEEE 754 Representation of Real Numbers

IEEE 754 format for Real Numbers.

	Sign	Biased Exponent	Mantissa/Fraction	
Single Precision N=32	1 bit	8 bits	23 bits	Bias Value:+127
Double Precision N=64	1 bit	11 bits	52 bits	Bias Value :+1023

Biased Exponent=True Exponent + Bias Value

Rep. of $(4.5)_{10}$ using Single Precision

$(4.5)_{10} = (100.1)_2 = (1.001)_2 \times 2^2$

Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a **True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Biased Exponent $= \mathbf{2} + \mathbf{127} = \mathbf{129} = \mathbf{1000\ 0001}$

Mantissa $= \mathbf{001} = \mathbf{0010000\ 0000\ 0000\ 0000\ 0000}$

Sign$= +$ ve $= 0$

$(4.5)_{10} = (1.001)_2 \times 2^2 = 0\ \mathbf{10000001\ 00100000000000000000000}$

IEEE 754 format for Real Numbers.

	Sign	Biased Exponent	Mantissa/Fraction	
Single Precision N=32	1 bit	8 bits	23 bits	Bias Value:+127
Double Precision N=64	1 bit	11 bits	52 bits	Bias Value :+1023

Biased Exponent=True Exponent + Bias Value

Rep. of $(4.5)_{10}$ using Single Precision

$(4.5)_{10} = (100.1)_2 = (1.001)_2 \times 2^2$

Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a **True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Biased Exponent = **2** + **127** = **129** = **1000 0001**

Mantissa = **001** = **0010000 0000 0000 0000 0000**

Sign= + ve = 0

$(4.5)_{10} = (1.001)_2 \times 2^2$= 0 **10000001 00100000000000000000000**

IEEE 754 format for Real Numbers.

Sign	Biased Exponent	Mantissa/Fraction	

	Sign	Biased Exponent	Mantissa/Fraction	
Single Precision N=32	1 bit	8 bits	23 bits	Bias Value:+127
Double Precision N=64	1 bit	11 bits	52 bits	Bias Value :+1023

Biased Exponent=True Exponent + Bias Value

Rep. of $(4.5)_{10}$ using Single Precision
$(4.5)_{10} = (100.1)_2 = (1.001)_2 \times 2^2$
Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Biased Exponent = **2** + **127** = **129** = **1000 0001**

Mantissa = **001** = **0010000 0000 0000 0000 0000**

Sign= + ve = 0

$(4.5)_{10} = (1.001)_2 \times 2^2 =$ 0 **10000001 00100000000000000000000**

IEEE 754 Representation of Real Numbers

IEEE 754 format for Real Numbers.

Sign	Biased Exponent	Mantissa/Fraction

Single Precision N=32	1 bit	8 bits	23 bits	Bias Value:+127
Double Precision N=64	1 bit	11 bits	52 bits	Bias Value :+1023

Biased Exponent=True Exponent + Bias Value

Rep. of $(4.5)_{10}$ using Single Precision
$(4.5)_{10} = (100.1)_2 = (1.001)_2 \times 2^2$
Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a **True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Biased Exponent $= \mathbf{2} + \mathbf{127} = \mathbf{129} = \mathbf{1000\ 0001}$

Mantissa $= \mathbf{001} = \mathbf{0010000\ 0000\ 0000\ 0000\ 0000}$

Sign$= +$ ve $= 0$

$(4.5)_{10} = (1.001)_2 \times 2^2 = 0$ **10000001 00100000000000000000000**

IEEE 754 Representation of Real Numbers

IEEE 754 format for Real Numbers.

Sign	Biased Exponent	Mantissa/Fraction	

Single Precision N=32	1 bit	8 bits	23 bits	Bias Value:+127
Double Precision N=64	1 bit	11 bits	52 bits	Bias Value :+1023

Biased Exponent=True Exponent + Bias Value

Rep. of $(4.5)_{10}$ using Single Precision
$(4.5)_{10} = (100.1)_2 = (1.001)_2 \times 2^2$
Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a**True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Biased Exponent $= \mathbf{2} + \mathbf{127} = \mathbf{129} = \mathbf{1000\ 0001}$

Mantissa $= \mathbf{001} = \mathbf{0010000\ 0000\ 0000\ 0000\ 0000}$

Sign$= +$ ve $= 0$

$(4.5)_{10} = (1.001)_2 \times 2^2 = 0$ **10000001 00100000000000000000000**

IEEE 754 Representation of Real Numbers

IEEE 754 format for Real Numbers.

Sign	Biased Exponent	Mantissa/Fraction

	Sign	Biased Exponent	Mantissa/Fraction	
Single Precision N=32	1 bit	8 bits	23 bits	Bias Value:+127
Double Precision N=64	1 bit	11 bits	52 bits	Bias Value :+1023

Biased Exponent=True Exponent + Bias Value

Rep. of $(4.5)_{10}$ using Single Precision
$(4.5)_{10} = (100.1)_2 = (1.001)_2 \times 2^2$
Normalized Rep.: $(\pm 1.xxxxxx)_2 \times 2^E$, Where 'E' is a **True Exponent**, 'xxxxxx' is a **Fraction/Mantissa**.

Biased Exponent = **2** + **127** = **129** = **1000 0001**

Mantissa = **001** = **0010000 0000 0000 0000 0000**

Sign= + ve = 0

$(4.5)_{10} = (1.001)_2 \times 2^2$= 0 **10000001 00100000000000000000000**

IEEE 754

Biased Exponent=True Exponent + Bias Value,
where $1 \leq$ Biased Exponent $\leq (2^{Length\ of\ Biased\ Exponent} - 2)$.

Single Precision (N=32), $1 \leq$ Biased Exponent ≤ 254.

Biased Exponent = 0,

Mantissa $= \pm 0$, then Value is ± 0.

Mantissa $\neq 0$, then Value is **not a normalized number**.

Biased Exponent = 255,

Mantissa $= \pm 0$, then Value is $\pm\infty$.

Mantissa $\neq 0$, then Value is **NAN**.

Range of positive values: $[1.0 \times 2^{-126}, (2 - 2^{-23}) \times 2^{127}]$

Range of negative values: $[-(2 - 2^{-23}) \times 2^{127}, -1.0 \times 2^{-126}]$

Single Precision Number Resolution: $2^{-23} \times 2^{TrueExponent}$

BCD Representation

BCD: Binary Coded Decimal

It uses a 4-bit binary number to represent each decimal digit.

Decimal Number	**BCD Rep.**
0	0000
1	0001
2	0010
3	0011
9	1001
10	0001 0000
25	0010 0101
99	1001 1001

Table 1: BCD equivalent of a decimal number.

All the best ☺