

# MPI: Microprocessors and Interfacing

## Academic Year: 2021 - 22

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# Sample C Code

```
// Example1: Addition (eg1.c)
#define A 10
#define B 20
int main(){
    int a=A;
    int b=B;
    a=a+b;
    return a;
}
```

Table 1: Addition of Two Integers

```
// Example2: Addition (eg2.c)
#include<stdio.h>
#define A 10
#define B 20
int main(){
    int a=A;
    int b=B;
    a=a+b;
    printf("Result is %d",a);
    return a;
}
```

Table 2: Addition of Two Integers

```
gcc -E eg1.c > eg1.i
gcc -S eg1.i > eg1.s
as eg1.s -o eg1.o
gcc -o eg1.exe eg1.o
./eg1.exe
```

## Lab1 - Due date: September 1, 2021.

Develop C-Programs for the following problem statements and generate assembly code using that C-code.

- 1 Print the internal representation (2's complement form) of data stored in primary data types (int, float, and double).
- 2 Perform addition and multiplication of two 32-bit numbers (Please remember that the input is 32-bit binary number). The numbers can either be integers or real numbers. Assume that the integers are represented in 2's complement form and the real numbers are represented using single-precision IEEE 754 standard.
- 3 Convert a decimal number into an equivalent BCD number, and vice versa.

# Submission Guide Lines

- ▶ **Max. team size is 3.**
- ▶ Mail-ID: cs309.mpi.2021@gmail.com
- ▶ Sub:TEAM\_NUM\_LAB1/\_ASSIGN1
- ▶ Attach.Name and Type: (Sub.).zip
- ▶ Late Submission $\leq$ 3-Days:50%.
- ▶ Write a readme file to understand your solutions.

# Number Systems

- ▶ 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.**

# Representation of Integer Numbers

Let  $A = a_{n-1}a_{n-2}a_{n-3}\dots a_0$  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:

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

▶  $A = -\sum_{i=0}^{n-2}(2^i \times a_i)$ , 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  $A = a_{n-1}a_{n-2}a_{n-3}\dots a_0$  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**.



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❶  $(4.5)_{10} = (100.1)_2$

❷  $(8.25)_{10} = (1000.01)_2$

❸  $(16.125)_{10} = (10000.001)_2$

❹  $(0.875)_{10} = (0.111)_2$

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

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❽  $(0.875)_{10} = (1.11)_2 \times 2^{-1}$

**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**.

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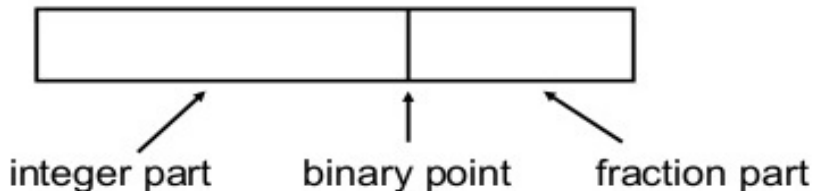
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# Fixed Point (FP) Representation



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.

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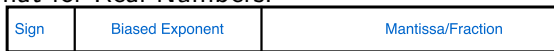
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# IEEE 754 Representation of Real Numbers

## ▶ IEEE 754 format for Real Numbers.



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**

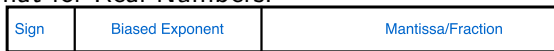
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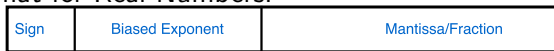
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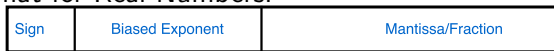
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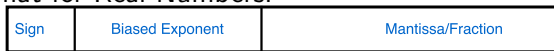
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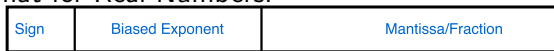
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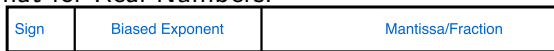
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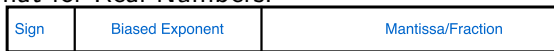
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## IEEE 754

- ▶ Biased Exponent = True Exponent + Bias Value,  
where  $1 \leq \text{Biased Exponent} \leq (2^{\text{Length of Biased Exponent}} - 2)$ .
- ▶ Single Precision (N=32),  $1 \leq \text{Biased Exponent} \leq 254$ .
- ▶ Biased Exponent = 0,
  - ▶ Mantissa =  $\pm 0$ , then Value is  $\pm 0$ .
  - ▶ 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:  $2^{-23} \times 2^{\text{True Exponent}}$



# 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 3: BCD equivalent of a decimal number.

All the best 😊