Experiment No 2

Number System conversion and Compliment Arithmetic

2.1 Objectives:

After completing this experiment, student will be able to:

- Students should be able to understand decimal, binary, octal and hexadecimal number systems.
- They should get hold on the conventions and complement used for numbers.
- Convert binary or binary coded decimal (BCD) numbers to decimal.
- Construct a portion of a digital system that decodes a BCD number and displays it on a seven-segment display.

2.2 Background Theory

The number of symbols in a number system is called the base, or radix, of that system. There are different number systems. The decimal number system uses ten counting symbols, the digits 0 through 9, to represent quantities. Thus it is a base ten system. In this system, we represent quantities larger than 9 by using positional weighting of the digits. The position, or column, that a digit occupies indicates the weight of that digit in determining the value of the number. The base 10 number system is a weighted system because each column has a value associated with it.

2.2.1 Number Systems

There are four important number systems which you should become familiar with. These are **decimal**, **binary**, **octal** and **hexadecimal**. The decimal system, which is the one you are most familiar with, utilizes ten symbols to represent each digit. These are 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. This system is referred to as base 10, or radix 10 system. Similarly, the binary system is base 2, octal is base 8, and hexadecimal is base 16.

Table 2.1: Number System

Sr. No	Number System	Radix	Symbols
1	Binary	2	0 1
2	Octal	8	0 1 2 3 4 5 6 7
3	Decimal	10	0 1 2 3 4 5 6 7 8 9
4	Hexadecimal	16	0 1 2 3 4 5 6 7 8 9 A B C D E F

2.2.1.1 Decimal Number System

In the **decimal number system**, the numbers are represented with base 10. The way of denoting the decimal numbers with base 10 is also termed as decimal notation. This number system is widely used in computer applications. It is also called the base-10 number system which consists of 10 digits, such as, 0,1,2,3,4,5,6,7,8,9. Each digit in the decimal system has a position and every digit is ten times more significant than the previous digit. Suppose, 25 is a decimal number, then 2 is ten times more than 5. Some examples of decimal numbers are:

$(12)_{10}$, $(345)_{10}$, $(119)_{10}$, $(200)_{10}$, $(313.9)_{10}$

2.2.1.2 Binary Number System

The binary number system is a base 2 system with only two digits: 0 and 1. A binary number such as "11010" is expressed with a string of 1s and 0s. The decimal equivalent of binary number can be found by expanding the number into a power series with base of 2.

2.2.1.3 Octal Number System

To avoid writing down long binary words, it is often easier to use larger base systems. Two commonly-used systems are octal and hexadecimal. The octal number system is base eight, i.e. values can be represented using an 8-symbol dictionary: 0-7 to convert from binary to octal, binary numbers are grouped on 3-bitswords.

2.2.1.4 Hexadecimal Number System

The hexadecimal number system (HEX) is a base 16 notation. It is the most popular large-base system for representing binary numbers. Each symbol represents 4-bits (1 nibble), that can take one of 16 different values: the values 0-9 are represented by the digits 0-9, and the values 10-15are represented by the capital letters A-F respectively. Conversions are performed as with the other number systems.

2.2.1.5 Number System Conversion

There are two types of number system conversion:

- Decimal to Base-N
- Base-N to Decimal

2.2.1.5.1 Base-N to Decimal

Convert from source base to decimal (base 10) by multiplying each digit with the base raised to the power of the digit number (starting from right digit number 0)

decimal = $\sum$ (digit$\times$base$^{\text{digit number}}$)

For Example

i) Convert $(11010)_2$ to decimal

$= 1x2^4 + 1x2^3 + 0x2^2 + 1x2^1 + 0x2^0$

$= 16 + 8 + 0 + 2 + 0$

$= (26)_{10}$

ii) Convert (10110.01) to decimal

$= 1x2^4 + 0x2^3 + 1x2^2 + 1x2^1 + 0x2^0 + 0x2^{-1} + 1x2^{-2}$
= 16 + 0 + 4 + 2 + 0 + 0 + 0.25
$= (22.25)_{10}$

2.2.1.5.2 Decimal to Base-N

Convert from decimal to destination base by divide the decimal with the base until the quotient is 0 and calculate the remainder each time. The destination base digits are the calculated remainders.

i) Convert $(29)_{10}$ to binary

29/2 = 14 remainder 1 (LSB)

14/2 = 7 remainder 0

7/2 = 3 remainder 1

3/2 = 1 remainder 1

1/2 = 0 remainder 1 (MSB)

$(29)_{10} = (11101)_2$

ii) Convert $(22.25)_{10}$ to binary (LSB)

22 / 2 = 11 remainder 0

11 / 2 = 5 remainder 1

5 / 2 = 2 remainder 1

2 / 2 = 1 remainder 0

1 / 2 = 0 remainder 1 (MSB)

For converting decimal fraction 0.25 to binary number

$0.25 \times 2 = 0 + 0.5$

$0.5 \times 2 = 1 + 0$

The answer to 0.25 decimal to binary number is 0.01

$(22.25)_{10} = (10110.01)_2$

Table 2.2: Number system Conversion

Sr. No	DECIMAL NUMBER (base 10)	BINARY NUMBER (base 2)	OCTAL NUMBER (base 8)	HEX NUMBER (base 16)
1	0	0	0	0
2	1	1	1	1
3	2	10	2	2
4	3	11	3	3
5	4	100	4	4
6	5	101	5	5
7	6	110	6	6
8	7	111	7	7
9	8	1000	10	8
10	9	1001	11	9
11	10	1010	12	A
12	11	1011	13	B
13	12	1100	14	C
14	13	1101	15	D
15	14	1110	16	E
16	15	1111	17	F

2.2.2 Binary coded decimal (BCD) Codes

The BCD system uses four binary bits to represent each decimal digit. It is a convenient code because it allows ready conversion from base ten to a code that a machine can understand; however, it is wasteful of bits. A 4-bit binary number could represent the numbers 0 to 15, but in BCD it represents only the quantities 0 through 9. The binary representations of the numbers 10 through 15 are not used in BCD and are invalid.

Table 2.3: Example of BCD

Sr. No	Decimal	BCD
1	0	0000
2	1	0001
3	2	0010
4	3	0011
5	4	0100
6	5	0101
7	6	0110
8	7	0111

9	8	1000
10	9	1001

2.2.3 Binary Subtraction Using Complement Arithmetic

Complements are used in digital computers for simplifying the subtraction operation. There are two types of complements for each base-r system.

- r's complement
- (r-1)'s complement

When the value of the base is substituted the two types receive.

- 2's and 1's complements for binary numbers
- 10's and 9's for decimal numbers

2.2.3.1 r's Complement

The r's complement is also known as Radix complement. It gives a positive number N with an integer part of n digits the r's complement of N is defined as:

$$(r^n - N)$$

For example

The 10's complement of $(52520)_{10}$ is 10^5-52520 = 47480

Where n is number of digits in the number.

The 10's complement of $(0.3267)_{10}$ is 1-0.3267 = 0.6733

No inter part so $10^n=10^0=1$

The 10's complement of $(25.639)_{10}$ is 10^2-25.639 = 74.631

The 2's complement of $(101100)_2$ is $(2^6)_{10}-(101100)_2$

= $(1000000-101100)_2$ = 010100

The 2's complement of $(0.0110)_2$ is $(1-0.0110)_2$ = 0.1010

2.2.3.2 (r-1)'s Complement

The (r-1)'s complement is also known as Diminished Radix complement. It give a positive number N with an integer part of n digits and a fraction part of m digits, the (r-1)'s complement of N is defined as:

$$(r^n - r^{-m} - N)$$

For example

The 9's complement of $(52520)_{10}$ is $(10^5$-1-52520) = 47479

No fraction part, so $10^{-m} = 10^0 = 1$

The 9's complement of $(0.3267)_{10}$ is $(1\text{-}10^{-4}\text{-}0.3267)$

= 0.9999-0.3267 = 0.6732

No inter part so $10^n = 10^0 = 1$

The 1's complement of $(101100)_2$ is $(2^6\text{-}1)\text{-}(101100)_2$

= $(111111\text{-}101100)_2$ = 010011

The 1's complement of (0.0110)2 is $(1\text{-}2^{-4})_{10}\text{-}(0.0110)_2$

= (0.1111-0.0110) = 0.1001

2.2.3.3 Subtraction with r's Complement

Subtraction of two +ve number (M-N) both of base r may be done as follows:

Add the minuend M to the r's complement of the subtrahend N

$$M + (r^n - N) = M - N + r^n$$

Inspect the result obtained in step 1 for an end carry:

- If an end carry occurs, discard it.
- If an end carry does not occur, take the r's complement of the number obtained in step 1 and place a –ive sign in front of it.

For Example:

i) Using 10's complement subtract 72532-3250

M = 72532

N = 03250

M = 72532

10's complement of N = +96750

Sum = 169282

End carry discard it

Answer = 69282

ii) Using 10's complement subtract 3250-72532
M = 03250

N = 72532

M = 03250

10's complement of N = +27468

Sum = 30718

No end carry

So Answer = -(10's complement of 30718)

= -69282

iii) Using 2's complement subtract (1010100-1000100)
M = 1010100

N = 1000100

M = 1010100

2's complement of N = +0111100

Sum = 0010000

End carry one

So Answer = 10000

iv) Using 2's complement subtract (1000100-1010100)
M = 1000100

N = 1010100

M = 1000100

2's complement of N = +0101100

Sum = 1110000

No end carry

So Answer = -(2's complement of 1110000)

= -10000

2.2.3.4 Subtraction with (r-1)'s Complement

Subtraction of two +ve number (M-N) both of base r may be done as follows:

Add the minuend M to the (r-1)'s complement of the subtrahend N

Inspect the result obtained in step 1 for an end carry:

- If an end carry occurs, add 1 to least significant digit.
- If an end carry does not occur, take the (r-1)'s complement of the number obtained in step 1 and place a –ive sign in front of it.

For Example:

i) Using 9's complement subtract 72532-3250

M = 72532

N = 03250

M = 72532

9's complement of N = +96749

Sum = 169281

End carry one

So Answer = 69281+1 = 69282

ii) Using 9's complement subtract 3250-72532

M = 03250

N = 72532

M = 03250

9's complement of N = +27467

Sum = 30717

No end carry

So Answer = -(9's complement of 30717)

= -69282

iii) Using 1's complement subtract (1010100-1000100)

M = 1010100

N = 1000100

M = 1010100

1’s complement of N = +0111011

Sum = 10001111

End carry one

So Answer = 0001111+1 = 0010000

iv) Using 1’s complement subtract (1000100-1010100)
M = 1000100

N = 1010100

M = 1000100

2’s complement of N = +0101011

Sum = 1101111

No end carry

So Answer = -(1’s complement of 1101111)

= -10000

2.2.4 Seven-Segment Display

The 7-segment display, also written as “seven segment display”, consists of seven LEDs (hence its name) arranged in a rectangular fashion as shown. Each of the seven LEDs is called a segment because when illuminated the segment forms part of a numerical digit (both Decimal and Hex) to be displayed. An additional 8th LED is sometimes used within the same package thus allowing the indication of a decimal point, (DP) when two or more 7-segment displays are

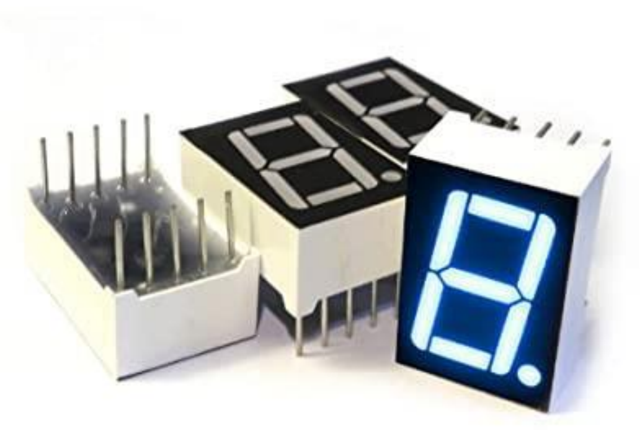

Figure 2.1: Seven segment

connected together to display numbers greater than ten.

The displays common pin is generally used to identify which type of 7-segment display it is. As each LED has two connecting pins, one called the “Anode” and the other called the “Cathode”, there are therefore two types of LED 7-segment display called: **Common Cathode** (CC) and **Common Anode** (CA).

The difference between the two displays, as their name suggests, is that the common cathode has all the cathodes of the 7-segments connected directly together and the common anode has all the anodes of the 7-segments connected together and is illuminated as follows.

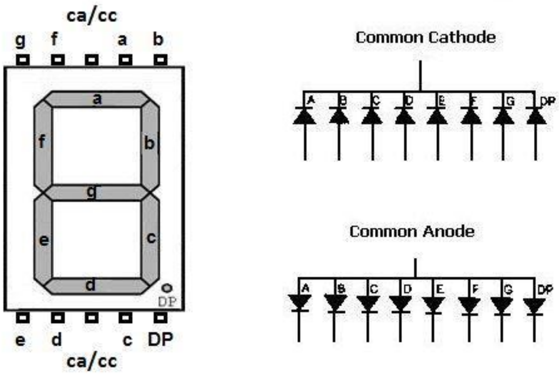

Figure 2.2: Pin Configuration and CA/CC circuitry

2.2.5 BCD to 7-Segment Decoders (7447A)

The 46A and 47A feature active-low outputs designed for driving common-anode LEDs or incandescent indicators directly. All of the circuits have full ripple-blanking input/output controls and a lamp test input. Display patterns for BCD input counts above nine are unique symbols to authenticate input conditions. All of the circuits incorporate automatic leading and/or trailing-edge, zero-blanking control (RBI and RBO). Lamp test (LT) of these devices may be performed at any time when the BI/RBO node is at a high logic level. All types contain an overriding blanking input (BI) which can be used to control the lamp intensity (by pulsing) or to inhibit the outputs.

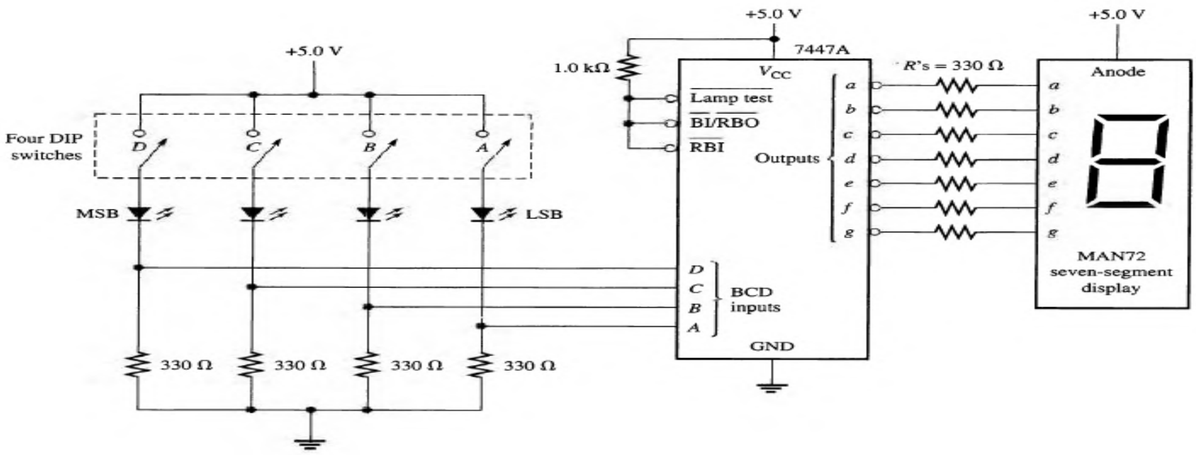

Figure 2.3: BCD to 7-Segment Decoders

1) Take a moment to review “Circuit Wiring” in the Introduction before constructing the circuit in this experiment. The pin numbers for the integrated circuits (ICs) may be

found on the data sheets or on the manufacturer's website. It is a good idea to write the pin numbers directly on the schematic before you begin wiring.

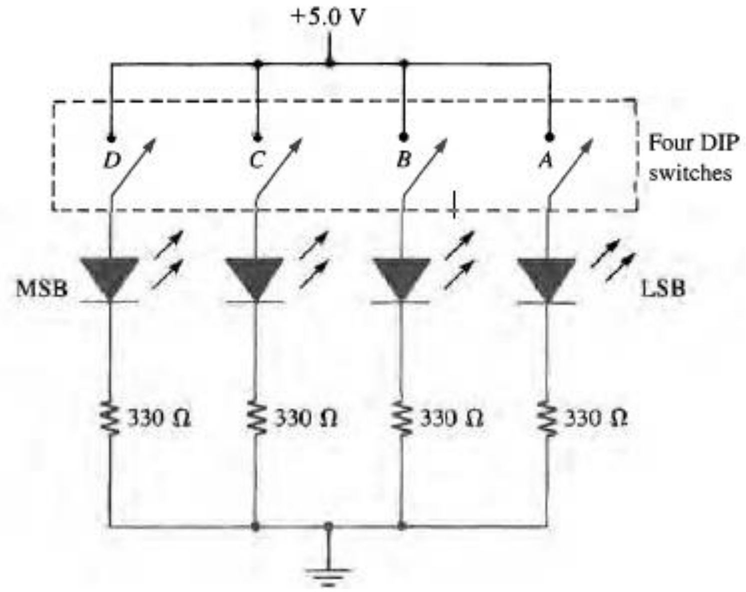

Figure 2.4: BCD Input

2) Begin by constructing the circuit shown in Figure 2.4, which will represent a BCD input. After wiring the circuit, connect power and test each switch to see that it lights an LED.
3) Remove power and add the circuit shown in Figure 2.3. Note that the 7447A has 16 pins, but the MAN72 has only 14 pins. Before applying power, check that you have connected a 330 Q current-limiting resistor between each output of the decoder and the input to the MAN72. Connect the Lamp test, BI/RBO, and RBI inputs through a 1.0 kQ resistor to +5.0 V. This is a pull-up resistor, used to assure a solid logic HIGH is present at these inputs.
4) When you have completed the wiring, apply power, and test the circuit by setting each switch combination listed in Table 2.4 of the report. The last six codes are invalid BCD codes; however, you can set the switch combinations in binary and observe the display. It will show a unique display for each of the invalid codes. Complete the table by showing the appearance of the seven-segment display in the output column.

2.3 Lab Activities

2.3.1 Task-1: Number system conversion

Convert each number into the other bases. Write your solution in the space given below:

Table 2.3

Binary	Octal	Hex	Decimal	BCD
01001100				
	304			
		E6		
			57	
				01001001
			57.35	

2.3.2 Task-2: Complement and Subtraction

Perform following subtraction using 2's complement arithmetic covert the answer from binary to decimal and cross check with decimal answer.

a) 42-29
b) 53-37

2.3.3 Task-3: BCD to Seven Segment

Construct BCD to seven segment circuit as shown in Figure 2.3. Follow the given steps while performing given task:

1) Construct the given circuit on bread board.
2) Don't turn on power supply unless until you are sure your circuit is complete in all aspects.
3) Verify your circuit and show it to your instructor before measuring/displaying the output values.
4) Turn on power supply and fill the Table 2.4 using different combinations of input switches
5) Shown the filled table to your instructor.

Table 2.4

Inputs				Output
Binary Number	**BCD Number**	**Octal Number**	**Hex Number**	**Seven-segment Display**
0000				
0001				
0010				
0011				
0100				
0101				
0110				
0111				
1000				
1001				
1010				
1011				
1100				
1101				
1110				
1111				

Lab Exercise and Summary

Summary should cover Introduction, Procedure, Data Analysis and Evaluation.

Student's Signature: ________________ **Date: ________________**

LABORATORY SKILLS ASSESMENT (Psychomotor)

Total Marks: 100

Criteria (Max Marks)	Level 1 0% ≤ S < 50%	Level 2 50% ≤ S< 70%	Level 3 70% ≤ S< 90%	Level 4 90%≤ S ≤100%	Score (S)
Procedural Awareness (20)	Selects inappropriate skills and/or strategies required by the task	Selects and applies appropriate skills and/or strategies required by the task with some errors	Selects and applies the appropriate strategies and/or skills specific to the task without significant errors	Selects and applies appropriate strategies and/or skills specific to the task without any error	
Practical Implementation (30)	Makes several critical errors in applying procedural knowledge of number system conversion and 7 segment display	Makes few critical errors in applying procedural knowledge of number system conversion and 7 segment display	Makes some non-critical errors in applying procedural knowledge of number system conversion and 7 segment display	Applies the procedural knowledge of number system conversion and 7 segment display in perfect ways	
Safety (10)	Requires constant reminders to follow safety procedures	Requires some reminders to follow safety procedures	Follows safety procedures with only minimal reminders	Routinely follows safety procedures	
Use of Tool/Equipment (20)	Uses tools, equipment and materials with limited competence	Uses tools, equipment and materials with some competence	Uses tools, equipment and materials with considerable competence	Uses tools, equipment and materials with a high degree of competence	
Participation to Achieve Group Goals (10)	Shows little commitment to group goals and fails to perform assigned roles	Demonstrates commitment to group goals, but has difficulty performing assigned roles	Demonstrates commitment to group goals and carries out assigned roles effectively	Actively helps to identify group goals and works effectively to meet them in all roles assumed	
Interpersonal Skills in Group Work (10)	Rarely interacts positively within a group, even with prompting	Interacts with other group members if prompted	Interacts with all group members spontaneously	Interacts positively with all group members and encourages such interaction in others	
				Marks Obtained	

Instructor's Signature: ________________ **Date: ________________**

LABORATORY SKILLS ASSESMENT (Affective)

Total Marks: 40

Criteria (Max. Marks)	Level 1 $0\% \leq S < 50\%$	Level 2 $50\% \leq S < 70\%$	Level 3 $70\% \leq S < 90\%$	Level 4 $90\% \leq S \leq 100\%$	Score (S)
Introduction (5)	Very little background information provided or information is incorrect	Introduction is brief with some minor mistakes	Introduction is nearly complete, missing some minor points	Introduction complete and well-written; provides all necessary background principles for the experiment	
Procedure (5)	Many stages of the procedure are not entered on the lab report.	Many stages of the procedure are entered on the lab report.	The procedure could be more efficiently designed but most stages of the procedure are entered on the lab report.	The procedure is well designed and all stages of the procedure are entered on the lab report.	
Data Record (10)	Data is brief and missing significant pieces of information.	Data provides some significant information and has few critical mistakes.	Data is almost complete but has some minor mistakes.	Data is complete and relevant. Tables with units are provided. Graphs are labeled. All questions are answered correctly.	
Data Analysis (10)	Data is presented in very unclear manner. Error analysis is not included.	Data is presented in ways (charts, tables, graphs) that are not clear enough. Error analysis is included.	Data is presented in ways (charts, tables, graphs) that can be understood and interpreted. Error analysis is included.	Data are presented in ways (charts, tables, graphs) that best facilitate understanding and interpretation. Error analysis is included.	
Report Quality (10)	Report contains many errors.	Report is somewhat organized with some spelling or grammatical errors.	Report is well organized and cohesive but contains some grammatical errors.	Report is well organized and cohesive and contains no grammatical errors. Presentation seems polished.	
				Marks Obtained	

LABORATORY SKILLS ASSESSMENT (Cognitive)

Total Marks: 10

(If any) **Marks Obtained**	

Instructor's Signature: ________________ **Date: ________________**