Digital Logic Design

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7-2 Synchronous Counters

7-3 Random Acces Memory (RAM)

Refs :-

(1) Digital system : principle of Applications
by: ronald J. Tocci

(2) Digital Design.
by: M. Morris Mono

(3) Introduction to Digital Computer Technology
by: Louis

(4) Any Books for Digital Design

Number System

Desimal System :-

Digits : (0, 1, 2, 3, 4, 5, 6, 7, 8, 9)

Radix (r) : (10)

- Adecimal number such as 7392 represents aquantity equal to 7 thousands, plus 3 hundreds, plus 9 tens, plus 2 units. The thousands, hundreds, etc, are powers of 10.

To be more exact 7392 should be written as:-

$$7 \times 10^3 + 3 \times 10^2 + 9 \times 10^1 + 2 \times 10^0$$

In general anumber with adecimal point is represented by aseries of coefficients as follows:-

$$a_5 a_4 a_3 a_2 a_1 . a_{-1} a_{-2} a_{-3}$$

The a_j Coefficients are one of the ten Digit (0, 1, 2, 3, 4, 5, 6, 7, 8, 9) and the subscript (j) gives the place value and, hence, the power of 10 by which the Coefficient must be multipled

$$10^5 a_5 + 10^4 a_4 + 10^3 a_3 + 10^2 a_2 + 10^1 a_1 + 10^0 a_0 + 10^{-1} a_{-1} + 10^{-2} a_{-2} + 10^{-3} a_{-3}$$

Ex) $(462)_{10}$

$10^2 \quad 10^1 \quad 10^0$

$\Rightarrow 4 \times 100 + 6 \times 10 + 2 \times 1$

$= (462)_{10}$

In general:-

$$\boxed{N = a_{q-r}\, r^{q-1} + a_{q-2}\, r^{q-2} + \cdots + a_1 r^1 + a_0 r^0}$$

This eq. to find the value of each Number

- For Decimal

$$N_{10} = \sum_{i=-\infty}^{\infty} k_i\, 10^i$$

- Binary System

Digits = (0, 1)

r = 2

$$N_2 = \sum_{i=-\infty}^{\infty} k_i\, 2^i$$

In Binary number each Coefficient a_j is multiplied by 2^j for example, the decimal equivalent of the Binary Number (11010.11) is (26.75)

$1\times 2^4 + 1\times 2^3 + 0\times 2^2 + 1\times 2^1 + 0\times 2^0 + 1\times 2^{-1} + 1\times 2^{-2}$

$= (26.75)_{10}$

In general, anumber expressed in base-r system has coefficients multiplied by power of r:

$$\boxed{a_n \cdot r^n + a_{n-1} \cdot r^{n-1} + \cdots\cdots + a_2 \cdot r^2 + a_1 \cdot r^1 + a_0 \cdot r^0 + a_{-1} \cdot r^{-1} + a_{-2} \cdot r^{-2} + \cdots\cdots a_{-m} \cdot r^{-m}}$$

The Coefficient a_j range in Value from 0 to $r-1$

Decimal	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
12	1100

Ex) Convert (13–30) to the Binary System? H.W

Ex) $(101)_2$

$$2^2 \quad 2^1 \quad 2^0 \Rightarrow 1 \times 4 + 0 \times 2 + 1 \times 1 = (5)_{10}$$

$$\therefore (101)_2 \longrightarrow (5)_{10}$$

Ex) $(101010111)_2 \longrightarrow (x)_{10}$

$2^8\ 2^7\ 2^6\ 2^5\ 2^4\ 2^3\ 2^2\ 2^1\ 2^0$

$1\times2^8+0\times2^7+1\times2^6+0\times2^5+1\times2^4+0\times2^3+1\times2^2+1\times2^1+1\times2^0$

$256+0+64+0+16+0+4+2+1 = (343)_{10}$

$\therefore (101010111)_2 \longrightarrow (343)_{10}$

Ternary System :-

Digit: (0,1,2)

$r = 3$

$$N_3 = \sum_{i=-\infty}^{\infty} K_i 3^i$$

Ex) $(102) \longrightarrow (x)_{10}$

$3^2\ 3^1\ 3^0$

$1\times3^2+0\times3^1+2\times3^0$

$9+0+2 = (11)_{10}$

$\therefore (102)_3 \longrightarrow (11)_{10}$

- An example of base-5 Number is

$(4021)_5 = 4\times5^3+0\times5^2+2\times5^1+1\times5^0$

$= (511)_{10}$

<u>Note</u> that the coefficient values for base 5 can be only

Digit = (0,1,2,3,4)

Radix = (r = 5)

Octal system

Digits (0, 1, 2, 3, 4, 5, 6, 7)

$r = 8$

$$N_8 = \sum_{i=-\infty}^{\infty} k_i 8^i$$

Ex) $(167)_8$

$8^2 \quad 8^1 \quad 8^0$

$1 \times 64 + 6 \times 8 + 7 = (119)_{10}$

Hexa Decimal system

Digits: (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F)

$r = 16$

Ex) $(29)_{16} \longrightarrow (x)_{10}$

$16^1 \quad 16^0$

$2 \times 16 + 9 \times 1 = (11)_{10}$

Ex) $(4C5F)_{16} \longrightarrow (x)_{10}$

$16^3 \quad 16^2 \quad 16^1 \quad 16^0$

$4 \times 16^3 + 12 \times 16^2 + 5 \times 16^1 + 15 \times 1 =$

$16384 + 3072 + 80 + 15 = (19551)_{10}$

Counting in Number system:-

Ex) write the first 23 decimal digits in base-5.

Digit = (0, 1, 2, 3, 4)

= (0, 1, 2, 3, 4, 10, 11, 12, 13, 14, 20, 21, 22, 23, 24, 30, 31, 32, 33, 34, 40, 41, 42).

Ex) write the first 28 decimal digits in base-9.

Digit = (0, 1, 2, 3, 4, 5, 6, 7, 8)

= (0, 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30).

Ex) write from 7 to 44 decimal digits in base-16.

Digits = (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F)

= (7, 8, 9, A, B, C, D, E, F, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 1A, 1B, 1C, 1D, 1E, 1F, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 2A, 2B, 2C).

Ex) write first 15 number in base-12.

Digits = (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B).

= (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, 10, 11, 12).

Numbers with different bases:-

Decimal (base 10)	Binary (base 2)	Octal (base 8)	Hexadecimal (base 16)
0	0000	00	0
1	0001	01	1
2	0010	02	2
3	0011	03	3
4	0100	04	4
5	0101	05	5
6	0110	06	6
7	0111	07	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

Number Base Conversions

Conversions from any Number system to decimal system.

To Do that by – Conversion the Integer Number.

– " " Fraction " .

Ex) Convert the following Number $(2121)_3$ to decimal?

$(2121)_3 \longrightarrow (X)_{10}$

– Integer part

$(X)_{10} = 1 \times 3^0 + 2 \times 3^1 + 1 \times 3^2 + 2 \times 3^3$

$= 1 + 6 + 9 + 54 = (70)_{10}$

Ex) Convert the Number $(0.342)_5$ to decimal system?

$(0.342)_5 \longrightarrow (X)_{10}$ (Fraction No.)

$(X)_{10} = 3 \times 5^{-1} + 4 \times 5^{-2} + 2 \times 5^{-3}$

$= 0.6 + 0.16 + 0.016 = (0.776)_{10}$

Ex) Convert the Number $(0.10101)_2 \longrightarrow (X)_{10}$

$(X)_{10} \rightarrow 1 \times 2^{-1} + 0 \times 2^{-2} + 1 \times 2^{-3} + 0 \times 2^{-4} + 1 \times 2^{-5}$

$= 0.5 + 0 + 0.125 + 0 + 0.03125$

$= (0.656)_{10}$

Ex) Convert the Number $(0.ABC2)_{14} \longrightarrow (X)_{10}$

$(X)_{10} = A \times 14^{-1} + B \times 14^{-2} + C \times 14^{-3} + 2 \times 14^{-4}$

$= 0.714 + 0.056 + 0.00437 + 0.000052$

$= (0.774)_{10}$

Ex) Convert the following Number from $(4576)_8$ to decimal system?

$$(X)_{10} = 4 \times 8^3 + 5 \times 8^2 + 7 \times 8^1 + 6 \times 8^0$$

$$= 2048 + 320 + 56 + 6$$

$$= (2430)_{10}$$

Ex) Convert the following Number from $(2ABCF)_{16}$ to decimal system?

$$(2ABCF) \longrightarrow (X)_{10}$$

$$(X)_{10} = 2 \times 16^4 + \overset{15}{A} \times 16^3 + B \times 16^2 + C \times 16^1 + F \times 16^0$$

$$= 131072 + 40960 + 2816 + 192 + 15$$

$$= (175055)_{10}$$

To convert any Number from the decimal system to any system we divided the Number into two Parts:-

① The Integer Part.

Divide the Number by the base of system and taken the Reminder, and Read the Number from bottom to top.

② The Fraction Part.

Doing that by Multiply by the base of system and taken the Integer part after each Multiplication and Multiply the reminder of fraction by the base until three digits.

Convert the Number $(3486.248)_{10}$ to Binary system?

Integer + Fraction

3486   0.248

		Reminder
2	3486	0
2	1743	1
2	871	1
2	435	1
2	217	1
2	108	0
2	54	0
2	27	1
2	13	1
2	6	0
2	3	1
2	1	1
	0	

Read form her

$(3486)_{10} \rightarrow (110110011110)_2$

To insure:-

$(110110011110)_2 \rightarrow (x)_{10}$

$(x)_{10} = 0\times2^0 + 1\times2^1 + 1\times2^2 + 1\times2^3 + 1\times2^4 + 0\times2^5 + 0\times2^6 + 1\times2^7 + 1\times2^8 + 0\times2^9 + 1\times2^{10} + 1\times2^{11} = (3486)_{10}$

- Fraction Part

$0.248 \times 2 = 0.496$	0	↓
$0.496 \times 2 = 0.992$	0	
$0.992 \times 2 = 1.984$	1	

$\therefore (0.248)_{10} \rightarrow (0.001)_2$

$\therefore (3486.248)_{10} \longrightarrow (110110011111.001)_2$

Number base Conversions :-

- Conversion from N system to decimal.
- Conversion from decimal system to N system.

Ex) Convert the same number $(3486.248)_{10}$ to base 5 and base 8 ?

Sol^n)

$(3486.248)_{10}$

$(3486)_{10} \rightarrow (x)_5$ $\qquad$ $(0.248)_{10} \longrightarrow (x)_5$

		R
5	3486	0
5	697	1
5	139	2
5	27	4
5	5	2
5	1	0
5	0	1

$(3486)_{10} \rightarrow (102421)_5$

$0.248 \times 5 = 1.24$ 1
$0.248 \times 5 = 1.2$ 1
$0.2 \times 5 = 1.0$ 1
$0.0 \times 5 = 0$ 0

$(0.248)_{10} \rightarrow (0.111)_5$

$\therefore (3486.248)_{10} \longrightarrow (X)_5$
$\longrightarrow (102421.111)_5$

$(3486.248)_{10} \longrightarrow (X)_8$ H.W

Ex) Convert the following Number $(5213.879)_{10}$ to Hexadecimal System. ? H.W

Octal and Hexadecimal Numbers

* Conversion from Binary to Octal system

To convert Binary Number to Octal, the Binary No. will be divide to groups each group from three digit as in table :-

No. in Octal	Group in Binary
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

* Conversion from Octal to Binary System.

Ex) Convert these Numbers:-

ⓐ $(011\,101\,011\,110)_2 \rightarrow (X)_8$

ⓑ $(2456)_8 \rightarrow (X)_2$

ⓐ $(\underset{3}{\underline{011}}\ \ \underset{5}{\underline{101}}\ \ \underset{3}{\underline{011}}\ \ \underset{6}{\underline{110}})_2$

$\therefore (011\,101\,011\,110)_2 \rightarrow (3536)_8$

ⓑ $(2456)_8 \rightarrow (X)_2$

$(2456)_8$

$010 \quad 100 \quad 101 \quad 110 \rightarrow (010\,100\,101\,110)_2$

ⓒ $(000\,111\,011\,100)_2 \rightarrow (X)_8$ H.W

ⓓ $(24573)_8 \rightarrow (X)_2$ H.W

* Conversion from Binary to Hexadecimal System.

when we convert Numbers in Binary to Hexadecimal, we divided the Number in Binary System into groups, each group consist from four digit (Binary digit) as shown in next table:-

No. in Hexadecimal	Group in Binary
0	0000
1	0001
2	0010
⋮	⋮
7	0111
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

Ex) Convert these Numbers or Do these Operations?

ⓐ $(0111\,0111\,1011\,1101)_2 \longrightarrow (X)_{16}$

ⓑ $(1010\,1010\,0001\,1101)_2 \longrightarrow (X)_{16}$ H.W

ⓒ $(ABC8976)_{16} \longrightarrow (X)_2$

ⓓ $(345AFFE8)_{16} \longrightarrow (X)_2$ H.W

Sol^n: ⓐ $(\underbrace{0111}_{7}\ \underbrace{0111}_{7}\ \underbrace{1011}_{B}\ \underbrace{1101}_{D}) \longrightarrow (77BD)_{16}$

ⓒ $(A\ B\ C\ 8\ 9\ 7\ 6)_{16} \longrightarrow (1010101111001000100101110110)_2$

$(1010\ 1011\ 1100\ 1000\ 1001\ 0111\ 0110)_2$

Note:-

Conversion from special system to special system (Not 2, 8, 16) as Below :-

Ex) ⓐ $(1243)_5 \longrightarrow (x)_9$

$(1243)_5 \longrightarrow (x)_{10} \longrightarrow (x)_9$

$(x)_{10} = 3 \times 5^0 + 4 \times 5^1 + 2 \times 5^2 + 1 \times 5^3$

$= 3 + 20 + 50 + 125 = 198$

$\therefore (198)_{10} \longrightarrow (x)_9$

		R
9	198	0
9	22	4
9	2	2
	0	

$(198)_{10} \longrightarrow (240)_9$

$\therefore (1243)_5 \longrightarrow (198)_{10} \longrightarrow (240)_9$

Ex) $(4567)_9 \longrightarrow (x)_{16}$ H.W

Ex) $(BCC2.BBA)_{13} \longrightarrow (x)_7$ H.W

Ex) $(ABCEE.FFF)_{16} \longrightarrow (x)_4$ H.W

Complements :-

Complements are used in digital computers for Simplifying the Subtraction operation and for Logical manipulations.

There are two types of Complements for each base-r system.

1. The r's complement.
2. The (r-1)'s Complement.

1 The r's Complement

Given apostive number N in base r with an integer part of n digits, the r's complement of N is defined as $r^n - N$ for $N \neq 0$ & 0 for $N = 0$

- The 10's complement of $(52520)_{10}$ is

$10^5 - 52520 = 4780$

The number of digit in the number is $n = 5$

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

$1 - 0.3267 = 0.6733$

No integer part, So $10^n = 10^0 = 1$

- The 10's compliment of $(25.639)_{10}$ is

$10^2 - 25.639 = 74.361$

- The 2's complement of $(101100)_2$ is

$(2^6)_{10} - (101100)_2 = (1000000 - 101100)$

$= 010100$

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

$(1 - 0.0110)_2 = 0.1010$

The (r−1)'s Complement.

Given a positive number N in base r with an integer part of n digits and a fraction part of m digits, the (r−1)'s Complements of N is defined as

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

- The 9's complement of $(52520)_{10}$ is

$(10^{5} - 1 - 52520) = 99999 - 52520 = 47479$

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

- The 9's complement of $(0.3267)_{10}$ is

$(1 - 10^{-4} - 0.3267) = 0.9999 - 0.3267 = 0.6732$

No integer part, So $10^{n} = 10^{0} = 1$

- The 9's complement of $(25.639)_{10}$ is

$(10^{2} - 10^{-3} - 25.639) = 99.999 - 25.639 = 74.360$

- The 1's complement of $(101100)_2$ is

$(2^{6} - 1)_{10} - (101100) = (111111 - 101100)_2 = 010011$

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

$(1 - 2^{-4})_{10} - (0.0110)_2 = 0.1111 - 0.0110)_2 = 0.1001$

<u>Note:-</u>

9's Complement
10's Complement } Used for decimal

1's Complement
2's Complement } Used for Binary

Notes:-

- R- System complement

Her we consider the base of Number system to find the complement as fellow:-

① We deal with <u>Just</u> the numbers that have negative sign, the numbers that have positive sign leave it without any operations.

② Subtract the negative number from the higher number that this system is contain $(r-1)$, then add (1) to the result from the right side.

③ After addition with the Second number, if the result of this operation has <u>carry</u>, this carry will <u>neglegable</u>.

Ex) Do the operation by using R complement.

$$+ (43567)_8$$
$$- (23456)_8$$

$$\begin{array}{r} 77777 \\ -\ 23456 \\ \hline 54321 \\ 1\ + \\ \hline 54322 \end{array}$$

$$\begin{array}{r} 43567 \\ 54322 \\ \hline 20111 \end{array}$$

Carry $\boxed{1}$ → Cancel

Ex) Do the operation by using 2's complement

$$\begin{array}{r} 1111101 \\ -\ 1100110 \\ \hline \end{array}$$

$$\begin{array}{r} 1100110 \\ 0011001 \\ 1\ + \\ \hline 0011010 \end{array}$$ 1's comp.

$$\begin{array}{r} 1111101 \\ +\ 0011010 \\ \hline 00110111 \end{array}$$

Carry $\boxed{1}$ → Cancel

- Complement of Binary system

(a) Convert all 0's → 1's and add the sum with $\boxed{1}$
or 1's → 0's

(b)
$$\begin{array}{c} 1100110 \\ \downarrow\downarrow\downarrow\downarrow\downarrow\downarrow\downarrow \\ 0011010 \end{array}$$ 2's comp.

R-1 System:-

Here we consider the (r-1) to find the compliment as

1. we deal with <u>Just</u> the numbers that have the negative sign, the numbers that have positive sign it is leave without any operations.

2. Subtract the negative number from the higer number that this system is contain (r-1).

3. After addition with the Second number, if the result of this operation has <u>Carry</u>, the <u>Carry</u> will add to the result number from the Right side of this No.

Ex) Do the operation below by using R-1 Comp.

$$\begin{array}{r} (ABCEF)_{16} \\ -\ (48F9D)_{16} \end{array}$$

$$\begin{array}{r} FFFFF \\ -\ 48F9D \\ \hline B7062 \end{array}$$

$$\begin{array}{rr} & ABCEF \\ \text{Carry} & B7062 \\ \hline \boxed{1} & 62D51 \\ & 1 \\ \hline & 62D52 \end{array}$$

Ex) Do the operation by using 1's complement.

$$\begin{array}{r} 1110110 \\ -\ 1001100 \\ \hline \end{array}$$

$$1001100 \xrightarrow{\text{comp.}} 0110011$$

$$\begin{array}{rr} & 1110110 \\ + & 0110011 \\ \hline \text{Carry } \boxed{1} & 0101001 \\ & 1 \\ \hline & 0101010 \end{array}$$

Codes :-

Codes have been used for security reasons, so that others will not be able to read the massage.
There are several types of codes, such as:-

BCD (Binary Codes Decimal) (8421)

it used the binary number system to specified the decimal No. (0 — 9), 4-binary bits are require

Decimal	BCD (4-bit)
0	0000
1	0001
2	0001
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

- The (8421) is a type of binary codes decimal (BCD) and is composed of four bit representing the decimal number (0 — 9).

The wieght of the four bits is $[2^3\ 2^2\ 2^1\ 2^0]$

MSB LSB

The mean advantage of this codes is the easy of conversion to and from decimal.

Ex) Find the decimal No. represented the following BCD

BCD Coded	Decimal No.
0011 0110	36
0111 1000	78

Complementry Codes :-

There are several complemmtary codes such as (2421) is a comman complemntary codes, it is similar to (8421) code, in the since that the position of the digits carry a non-weight except that the (MSB) carries a weight of (2) instead of (8). The advantage is that it is complementing which is used in Arthmatical operations.

MSB LSB

The (7421) code is another code in which the weight of the (MSB) is (7) which has usefull propority that it has aminimum No. of (1's) which could be usefull for economy in power consumption.

Ex) represent the following No. in 2421

379_{10}

$(0011 \quad 1101 \quad 1111)_{2421}$

EX-3 Code (Excess-3 Code)

The EX-3 code is adigital code that is derived by adding (3) to each decimal digit and then converting the result to (4) bit binary.

Ex-3 is an anweighting code. The table below show that:-

Decimal No.	Ex-3 Code
0	0 0 1 1
1	0 1 0 0
2	0 1 0 1
3	0 1 1 0
4	0 1 1 1
5	1 0 0 0
6	1 0 0 1
7	1 0 1 0
8	1 0 1 1
9	1 1 0 0

Ex) Represent the following No. in Ex-3 code?

Decimal No.	Ex-3 code
5	1000
27	0101 1010
310	0110 0100 0011

Gray Code :—

(un weighted code)

Gray Code an unweighted Code, which means that there is No Specific weights, assigned to bit position. The Gray Code have only a single bit change from one code No. to the next. This property is important in many application such as, shift postion, an coder and optical, the Gray code is not an arithmetic code.

- Binary to Gray Convertion

	MSB				LSB
Binary	1 $\xrightarrow{+}$	0 $\xrightarrow{+}$	1 $\xrightarrow{+}$	1 $\xrightarrow{+}$	0
	↓	↓	↓	↓	↓
Gray	1	1	1	0	1

- start from the MSB
- Add first No. with 2nd No. and cancel the carry for each addition operation.

- Gray to Binary Conversion

Gray	1	1	1	0	1
Binary	1	0	1	1	0

Alpha Numaric codes :-

In order to communicate, we need not only numbers but also letter and other symboles. Such codes called "Alpha Numaric codes". most of these codes necessary or carring information at a minimum, an alpha numaric codes must represent 10 decimal digits and 26 letters of the alpha bit, for a total (36) items. which required six bits, in each code conpination since 5 bits are an sufficient ($2^5 = 32$), so that total is (64 (2^6)). for 6 bits, which means that there are 28 un used code. But there are several symbols and letters necessary for communication such as space to seperate work.

ASCII Code

one of the standard alpha numaric code is the American Standard Code for Information Interchange (ASCII).

it is a seven bit codes in which the decimal digit are precented by (8421) BCD preseded by (011).

Ex) Conversion from Binary to Gray & Gray to binary

	MSB			LSB	
	1	0	1	1	Binary
	↓	↓	↓	↓	
	1	1	1	0	Gray

in Gray
1 + 1 = 0
0 + 0 = 0
1 + 0 = 1
0 + 1 = 1

In Ex-3 Code each code chls in Ex-3 is three larger than BCD

Decimal		Ex-3
0		0011
1		0100
⋮		⋮
9		1100
22	0101	0101
86	1011	1001

Sign Magnitude Numbers:-

which is (bit) for sign to the number, if the No. is (negative) the sign is (1), if the No. is (positive) the sign is (0), to find the complements (r's) or (r-1)'s for each number.

Ex) obtain the sign magnitude, signed 1's comp & 2's compl. representation of the number -38?

sign magnitude $\boxed{1}$ 100110

$\boxed{1}$ 011001 1's comp.

$\boxed{1}$ 011001 2's comp.

$+1$

$\boxed{1}$ 011010

Ex)

	S		Sol	
(a)	1	0110	(a)	-6
(b)	0	111.11	(b)	+7.75

Ex) Use 2's comp. to perform 75 - 35

		S.b	64	32	16	8	4	2	1
		1	0	1	0	0	0	1	1
		0	1	0	0	1	0	1	1
1's comp		1	1	0	1	1	1	0	0
		0	1	0	0	1	0	1	1
		1	1	0	1	1	1	0	0
									1
2's comp.	$\boxed{1}$	1	1	0	1	1	1	0	1
		0	1	0	0	1	0	1	1
Carry $\boxed{1}$ Cancell		0	0	1	0	1	0	0	0

∴ Sol^n is (40) and (S.B) is (+).

Ex) -6 - 7

	S.b	addition bit	4	2	1
	1	0	1	1	0
	1	0	1	1	1
	1	1	0	0	1
	1	1	0	0	0 +
$\boxed{1}$	1	0	0	0	1
					1 +
			0	0 1	0

$\boxed{1}$ 1101 ⇐ negative ← $\boxed{1}$ 0010

-13

Arithmetic Oprations:-

* Binary Operations:-

(a) Addition

+	0	1
0	0	1
1	1	0+c

Ex) $(37)_{10} + (13)_{10}$

```
  1 0 0 1 0 1
  1 0 1 1 0 1  +
 ------------
  1 1 0 0 1 0
```

(b) Subtraction

−	0	1
0	0	1
1	1+b	0

Ex) $(22)_{10} - (12)_{10}$

```
  1 0 1 1 0
  0 1 1 0 0  −
 ----------
  0 1 0 1 0
```

(c) Mutiplication

```
     1 0 1 1 0 1 1
             1 0 1
   ---------------
     1 0 1 1 0 1 1
   0 0 0 0 0 0 0
 1 0 1 1 0 1 1
 -----------------
 1 1 1 0 0 0 1 1 1
```

D Division

```
            001001
       ___________
  101 | 101101
        101
        ------
        000101
           101
        ------
           000
```

Addition and Subtraction of BCD Codes:-

Ex) Represent 9's Complement of 2421 code $(271)_{10}$

$(271)_{10} = (728)_{9\text{'s comp.}} = 1101\ 0010\ 1110$

1 BCD Addition:-

Ex) 36 + 41

```
0011   0110
0100   0001
-----------
0111   0111
  7      7     = (77)
```

Ex) 36 + 25

```
0010   0101
0011   0110
-----------
0101   1011
       0110  >9
-----------
0110   0001     = (61)
```