DIGITAL ELECTRONICS

1. Course Outline
Definition
Number systems. - Decimal - Binary - Octal - Hexadecimal
Binary Number System.
Binary Coded Number System.
8421 BCD
2421 BCD
excess 3 BCD
GRAY CODE Number System.

2. Logic Circuits.
Definition
Logic circuit and logic gates
Classification of logic circuits.
* - Combination circuits
- Circulation circuits

Combination Circuit - Logic gates
Arithmetic Logic Gates - Binary addition
- " subtraction.
- " comparator

Code Converters.
Logic Circuit design tools
- Boolean algebra
- Karnaugh map

Arithmetic Logic Circuit ~~Additi~~
- Binary adder - Subtraction operator.
- Binary subtractor
- " comparator

Code Converter.
SEQUENTIAL CIRCUITS
Definition
Classification
- Asynchronous circuit
Synchronous circuits.

Components.

FLIP FLOP

- R-S / S-R flip flop
- Clocked S-R flip flop
- J K flip flop

Asynchronous circuits

- Binary counters

Synchronous circuits

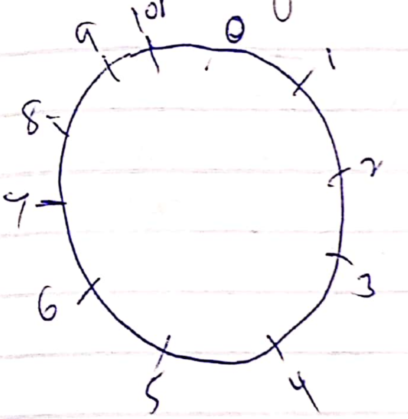
- Counters - Registers.

Digital Electronics

Base 10 numbers ~~are~~ system

Has 10 steps in the counting cycle. Each step is represented by a unique symbol.

The unique symbols (1, 2, 3, 4, 5, 6, 7, 8, 9, 10) symbols are known as digits



The ten counting steps in a decimal counting cycle with the ten unique symbols of representation after each step.

This is a weighted number system incase of combination of digits the least to the most significant the digits will be occupying the position weigh as, 0 100, 10, 10

In decimal number system. This is a natural God given number system.

Decimal Arithmetic

Addition

$0_{10} + 0_{10} = 0_{10}$

$0_{10} + 1_{10} = 1_{10}$

$1_{10} + 0_{10} = 1_{10}$

$1_{10} + 1_{10} = 2_{10}$

$9_{10} + 1_{10} = 10_{10}$

Subtraction

$0_{10} - 1_{10}$ = Impossible.

$0_{10} - 0_{10}$ = ~~Not possible~~ 0_{10}

$1_{10} - 0_{10} = 1_{10}$

$1_{10} - 1_{10} = 0_{10}$

$13_{10} - 5_{10} = 8_{10}$

Multiplication

$0_{10} \times 0_{10} = 0_{10}$

$0_{10} \times 1_{10} = 0_{10}$

$1_{10} \times 0_{10} = 0_{10}$

$1_{10} \times 3_{10} = 3_{10}$

$3_{10} \times 1_{10} = 3_{10}$

Division

$0_{10} \div 0_{10} = 0_{10}$

$0_{10} \div 1_{10}$ = Impossible (0)

$1_{10} \div 0_{10}$ = Impossible or ∞

$1_{10} \div 1_{10} = 1_{10}$

$3_{10} \div 2_{10} =$

Binary Digits

It is a weighted number system. The weighting is such that the positional value is obtained by having the base of the number for this case 2 to the power of the bit position

$0_2 + 0_2 = 0_2$

$1_2 + 0_2 = 1_2$

$0_2 + 1_2 = 1_2$

$1_2 + 1_2 = 10_2$

$11_2 + 1_2 = 100_2$

$(0 - 0)_2 = 0_2$

$(0 - 1)_2 = 0_2$ Not possible

$(1 - 0)_2 = 1_2$

$(1 - 1)_2 = 0_2$

$(10 - 1)_2 =$

Binary Multiplications.

$0 \times 0 = 0_2$

$0 \times 1 = 0_2$

$1 \times 0 = 0_2$

$1 \times 1 = 1_2$

$11 \times 10 = 110$

Division

$0 \div 0 = 0$

$0 \div 1$ = Not possible

$1 \div 0$ = ???

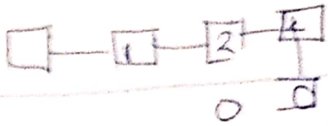
$1 \div 1 = 1$

$11 \div 10$

$10 \overline{)11} = 1\frac{1}{10}$

Decimal to Binary Conversion

$f_{10} \longrightarrow x_2$



$2\overline{)4}$ 0100

2	4	0
2	2	0
2	1	1
	0	

$\underline{\underline{100}}$

Binary to Decimal

$(111)_2$

$(2^0 + 2^1 + 2^2)$

$1 + 2 + 4 = \underline{\underline{7}}$

Decimal	Binary
0	0 0 0 0
1	0 0 0 1
2	0 0 1 0
3	0 0 1 1
4	0 1 0 0
5	0 1 0 1
6	0 1 1 0
7	0 1 1 1
8	1 0 0 0
9	1 0 0 1
10	1 0 1 0
11	1 0 1 1
12	1 1 0 0
13	1 1 0 1
14	1 1 1 0
15	1 1 1 1
16	1 0 0 0 0
17	1 0 0 0 1
18	1 0 0 1 0
19	1 0 0 1 1
20	1 0 1 0 0

Octal Number System. Its a base 8 number system. Has 8 steps in its counting cycle rep by 8 unique symbols. (0,1 2 3 4 5 6 7)$_8$. The symbols are known as digits. This is a weighted number system. The weighting is such that the weight of the number system is raised to the power of the digit position starting from the LCD to MCD ie $8^0, 8^1, 8^2 \ldots 8^n$.
It is a shorthand form for the binary no. system.

Decimal To Octal.

E.g

8 | 8
8 | 1 → 0
0 → 1

$8_{(10)} = \cancel{(10)_8}$ $10_{(8)}$

1×8
$8 - 8 = 0$

28_{10} Soln

8 | 28
8 | 3 → 4
0 → 3

$8 \times 0 = 0$
$3 - 0 = 3$

$= 34_8$

Conversion Table.

Decimal	Octal.
0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	10
9	11
10	12
11	13
12	14
13	15

Decimal	Octal
13	15
14	16
15	17
16	20
17	21

64GB 64,000,000 bytes

Octal To Decimal.

$10_8 \equiv (8)_{10}$

$8^1 \; 8^0$

$8 \quad 1$

$1 \quad 0$

$8 + 0 = 8_{10}$ //

$34_8 \equiv (?)_{10}$

$8^1 \; 8^0$

$8 \quad 1$

$3 \quad 4$

$24 + 4 = 28_{10}$ //

Octal to Binary

via Decimal, Power approach

e.g 1

$6_{(8)} \equiv (\;)_2$

$6_{(8)} \equiv (6)_{10}$

8^0

6

1

6

6 //

Dec to Bin

6_{10}

$2 | 6 \quad 0$

$2 | 3 \quad 1$

$2 | 1 \quad 1$

0

110 //

e.g 2

$15_8 \equiv x_2$

$15_8 \equiv x_{10}$

$8^1 \; 8^0$

$1 \quad 5$

$8 \quad 1$

$1 \quad 5$

$8 + 5 = 13_{10}$

13_{10}

$2 | 13 \quad 1$

$2 | 6 \quad 0$

$2 | 3 \quad 1$

$2 | 1 \quad 1$

0

1101_2

Cramers Approach.

$6_8 \equiv (?)_{10}$

$8 = 2^3$

$6_8 \equiv 110$

$6_8 = ?$

$8 = 2^3$

Example 2

$15_8 \equiv (?)_2$

$8 = 2^3$

1	5	We concatenate	$\Rightarrow 15_8 \equiv 1101_2$
001	101	001101_2	

Binary To Octal Conversion.

There are 3 methods of approach (a) Through decimal (b) Cramers approach (c)

Through Decimals.

Binary to decimal
Decimal to octal
The resultant combination of the digit is the octal equivalent of of the given binary number.

Example.

(a) $111_2 \equiv (?)_8$

(b) $1011_2 \equiv (?)_8$

$\overset{1}{2^3}\ \overset{0}{2^2}\ \overset{1}{2^1}\ \overset{1}{2^0}$

$8+0+2+1$

$= 11_{10}$

$11_{10} \equiv (?)_8$

$8 \,|\, 11$
$8 \,|\, 1 \quad 3$
$\quad 0 \quad 1$

$= 13_8$

Cramers Approach.

$10_2 \equiv (?)_8$

$2^{3} = 8$

No of bits we combine to rep a single unique octal digit.

$10_2 \equiv (?)_8$

Grouping the bits in the binary number starting from the most sgf to the least sgf into groups of three bits, Should any fail short of the number three, add zeros to make the no. three. Make the no 3 from the conversion table interprete the value of each group. The combination of the digits is the octal equivalent of the binary numbers.

(i) $\underline{010}$
$\quad 2$

$10_2 \equiv (2)_8$

(ii) Eg $111_2 \equiv (?)_8$

$2^{3} = 8$

3 bits in each digit

$\underline{111}$
$\quad 7$

$111_2 = 7_8$

(iii) $1011_2 \equiv (?)_8$

$2^3 = 8$

$\underline{001}\,\underline{011}$
$\quad 1 \quad 3$

$1011_2 = 13_8$

Hexadecimal: Base 16 no. system

Has 16 counting steps in its counting cycle.
Each of the 16 steps is rep by a unique symbol.
The 16 unique symbols are 0, 1, ... F, known as digits.

Dec	Hex
0	0
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	A
11	B
12	C
13	D
14	E
15	F

It is also known as alphanumerical number systems.
This is a weighted number system. The digit position are such as from LSD to MSD in the form $16^0 \cdot 16^1 \; 16^2 \; 16^3 \ldots 16^n$

Decimal To Hexadecimal Conversion.

Decimal is standard Hex is not.

$8_{10} \ldots \equiv (?)_{16}$

$16 \underline{|8}$
$0 \; -8$

$\underline{\underline{8_{10} \equiv 8_{10}}}$

$15_{10} = (?)_{16}$

$16 \underline{|15}$
$0 \rightarrow 15$

$15_{10} \equiv F_{16}$

$43_{(10)} \equiv (?)_{16}$

$16 \underline{|43}$

$75_{10} \equiv (?)_{16}$

$16 \,|\, 75$
$16 \,|\, 4 \quad 11\,(B)$
$\quad\;\; 0 \quad 4$

$75_{10} \equiv 4BH / 4B_{16}$

Hexadecimal to Binary

$37C_{16} \Rightarrow (?)_{10}$

$3C7 \Rightarrow (?)_{10}$

$\begin{array}{ccc} 3 & C & 7 \\ 16^2 & 16^1 & 16^0 \end{array}$

$\begin{array}{ccc} 16^2 & 16^1 & 16^0 \\ 256 & 16 & 1 \\ \times & \times & \times \\ 3 & 12 & 7 \\ \hline 768 & +192 & +7 \end{array}$

$= 967_{10}$

Hexadecimal to binary conversion.
Two approaches
① Via Decimal ② Cramers Approach.

Example; $4_{16} \equiv ?_2$

4_{16}

16^0

$4 = 4_{10}$

$4_{10} \equiv x_2$

2	4	
2	2	0
2	1	0
	0	1

$4_{16} \equiv 100_2$

$1A_{16} = x_2$

$1A_{16} = x_{10}$

$16^1 \; 16^0$
$1 \;\; A$
$16^1 \; 16^0$
$16 \;\; 1$
$1 \;\; 10$
$16 + 10$
$x_{16} = 26_{10}$

$26_{10} = x_2$

2	26	
2	13	0
2	6	1
2	3	0
2	1	1
	0	1

11010_2

$1A_{16} = 11010_2$

Cramers Approach.

$4_{16} \equiv x_2$
$16 = 2^4$

4
0 1 0 0 $= 100_{(2)}$
$4_{(16)} \equiv 100_{(2)}$

$1A_{16} = x_{(2)}$
$16 = 2^4$ - rep. the no of binary bits for hexadecimal digit.

1
0 0 0 1

A
1 0 1 0

0001 1010

Binary To Hexadecimal
Two Approaches ① Via decimal ② Cramers

$10_2 \equiv x_{10}$

1 0 1
$2^2 \; 2^1 \; 2^0$
0 1

$4+0+1 = 5_{10}$

$5_{10} \equiv x_{16}$

16	5	
	0	5

$101_{(2)} \equiv 5_{16}$

$1011101_2 = x_{16}$

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

1 0 1 1 1 0 1

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

64 32 16 8 4 2 1

1 0 1 1 1 0 1

64 0 16 8 4 0 1 = 93

$93_{10} \Rightarrow x_{16}$

16 | 93

16 | 5 — 13 (D)

0 — 5

$1011101_2 = 5D_{16}$

Cramers Approach.

(a) $101_2 = x_{16}$

$2^4 = 16$

0101

5

$101_2 = 5_{16}$

(b) $1011101_2 \equiv (x)_{16}$

$2 \equiv 16$

010 | 1101

5 | D

$1011101_2 = 5D_{16}$

Binary Classification.

Binary Code Decimal (BCD) A family member of the binary number system. Uses bits to represent the values. The ten unique decimal symbols are rep by their 4 bits binary equivalent.

Four bit system is fixed so that all the decimal digits that need to be are comfortably covered. The ~~lag~~ largest unique digit in binary is 1001_2. In this number system each of the decimal digit is represented by the four bits equivalent. It is a weighted no. system.

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

0 0 0 0

8 4 2 1 BCD

The weighting of this binary number system is such that the MSB is weighted 2^3, to 2^2, 2^1, 2^0 to form 8421 BCD.

Dec	Binary	BCD
0	0	0000
1	1	0001
2	10	0010
3	11	0011
4	100	0100
5	101	0101
6	110	0110
7	111	0111
8	1000	1000
9	1001	1001
10	1010	~~1001~~ XXXX

EXCESS THREE BCD

This is a BCD member. The weighting is similar to the 8421 BCD except the count of zero is elevated by a value of 3. All the others counts are elevated by the value 3.

Dec	BCD 8421	BCD
0	0000	0011
1	0001	0100
2	0010	0101
3	0011	0110
4	0100	0111
5	0101	1000
6	0110	1001
7	0111	1010
8	1000	1011
9	1001	1100
10	XXXX	XXXX
11	XXXX	XXXX
12	XXXX	XXXX
13	XXXX	XXXX
14	XXXX	XXXX
15	XXXX	XXXX
16	0000	~~XXXX~~
		0011
		0100

16

$2^4 = 16$

1101
1110
1111
0000
0001
0010
0011

Gray Code Number System.

It a no. of the binary system by virtue of using the two unique symbols 0 and 1 just as the ordinary binary. It is a weighted number system. Its a no. system that follows the sequence for every single step change there will be a single bit change. It is a self reflecting code number system ∴ It has a mirror effect.

Binary	Grey Code
0	000
1	001
10	011
11	010
100	0110
101 ~~1000~~	0111 101
101	~~0101~~ 0
111	

Binary	Grey Code
0	0000
1	0001
10	0001
11	0011
100	0110
101	0111
110	0101
111	1100
1000	~~1001~~ 0110
1001	~~1111~~ 01101
1010	01111
1011	01110
1100	01010
1101	01011
1110	01001
1111	01000
10000	11000
10001	11001

Binary to Grey Code conversion.

$10_2 = (?)_{grey}$

Get the binary number

Copy the most significant bit of the binary to be the MSB of grey code number.

Compare the most significant bit of binary with the bit

If the two bits are equal the next grey code bit is a zero

If the two bits are not equal the next grey bit is a one

Compare the second binary bit with the next binary bit

If the two bits are equal, the next bit is zero

If the two bits are not equal the next grey is one

~~Continue until all the comparison~~

Continue with the comparison untill the LSB is considered. The resulting combination of Bits is the Gray code equivalent of the binary numbers.

1101_2

1011_{Gray}

1000_{gray}

Gray code to Binary

$11_{gray} \equiv ?_2$

Get the gray code no.
Copy the most significant bit.
Comp. The binary MSB with the gray next

$1011_{gray} = ?_2$

1 0 1 1

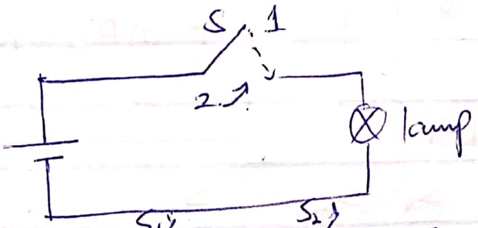
$1101_2 = 1101_2$

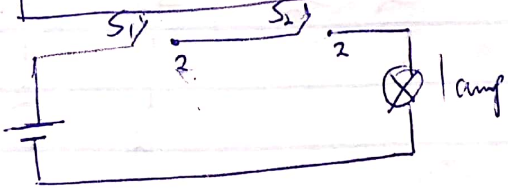
If same zero

$11 \to 10 = 10_2$

LOGIC CIRCUITS

Logic circuit is an ~~element~~ electronic circuit they may have as many inputs as the situation may demand but will have only one output. The output may assume only one of the two logical conditions at a time. The two logical conditions are on or off, 0 upto 1, True or False.





S_2	S_1	L
1	1	0
1	2	0
2	1	0
2	2	1

Functional table

The lamp will light up only if both switches are in position 2

S_2	S_1	L
OFF	OFF	OFF
OFF	ON	OFF
ON	OFF	OFF
ON	ON	ON

OFF ⇒ logic 0
ON ⇒ logic 1

S_2	S_1	L
0	0	0
0	1	0
1	0	0
1	1	1

Truth Table

S_2 & S_1 Must be at logic 1 for the output L to be logic 1.

Let us Δ: Logic 1 as the input and S logic 0 at the input as $\bar{S}$. Logic 1 at the dp as L Logic 0 at the OP as $\bar{L}$

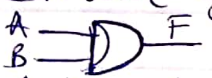
$L(S_1, S_2) = S_1 \times S_2$ AND operator.

$L(S_1 S_2) = (S_1 S_2)$ so A boolean expression.

LOGIC GATES.

This is an electronic circuit which may have many inputs as the situation may demand. but with a single output. Both the inputs variable and the output will each assume a logic state of 1 and 0 at any instant in time

Circuit Symbols.



And operator.

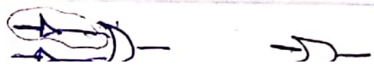
A	B	F
0	0	0
0	1	0
1	0	0
1	1	1

Truth table

$F(AB) = AB$

S_1 \ S_2

S_2	S_1	L
1	1	OFF
1	2	ON
2	1	ON
2	2	ON



S_2	S_1	L
OFF	OFF	OFF
OFF	ON	ON
ON	OFF	ON
ON	ON	ON

Functional table.
The lamp will be ON when
(1) S_1 OFF AND S_1 is ON
or (2) S_2 ON and S_1 OFF
or (3) S_2 ON and S_1 ON

The circuit is able to realise an OR function of the logic operation

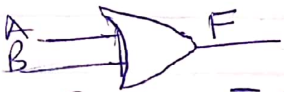
S_1	S_2	L
0	0	0
0	1	1
1	0	1
1	1	1

Truth table
OR Gate.

Let us A;' s ~~individuals~~ out logic L
output logic $\bar{L}$
Input logic H
Input logic $\bar{H}$

$L(S_2, S_1) = \bar{S_2} S_1$ OR $S_2 \bar{S_1}$ OR $S_2 S_1$
⊕ - logic plus operator.

$L(S_2, S_1) = \bar{S}_2 S_1 + S_2 \bar{S}_1 + S_2 S_1$
Grant symbol for the logic gate.



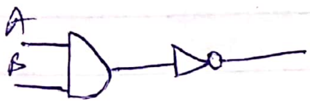
A	B	L
0	0	0
0	1	1
1	0	1
1	1	1

$F(AB) = \bar{A}B + A\bar{B} + AB$

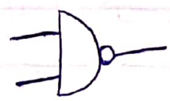
The three logic gates are namely; AND, OR and NOT are known as fundamental logic gates (conventional logic gates)

UNIVERSAL LOGIC GATES: These are logic gates from which the basic logic gates may be obtained by various modes of configuring.

NOT gate

A	B	X	F
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0


NAND Gate

A	B	F
0	0	1
0	1	1
1	0	1
1	1	0