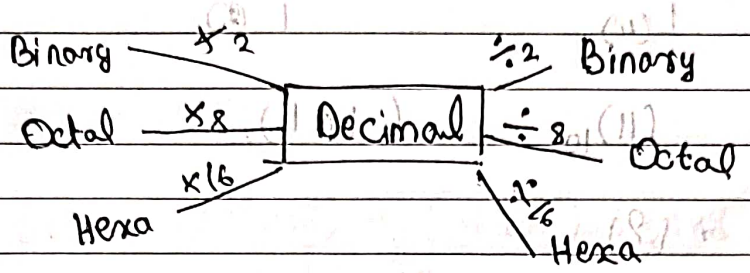
Module 4

LOGIC DESIGN

Number system

- Binary [Base 2] $(a)_2$
- Octal [Base 8] $(a)_8$
- Decimal [Base 10] $(a)_{10}$
- Hexadecimal [Base 16] $(a)_{16}$



Binary, $X = \{0, 1\}$

Octal, $Y = \{0, 1, 2, 3, 4, 5, 6, 7\}$

Decimal, $Z = \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$

Hexa, $W = \{0, 1, \ldots, 7, 8, 9, A, B, C, D, E, F\}$

Examples → Binary → Decimal

$(1011)_2$ = $(?)_{10}$

MSB LSB

$= (1\times2^3) + (0\times2^2) + (1\times2^1) + (1\times2^0)$

$= (8\times1) + (0\times4) + (1\times2) + (1\times1)$

$8+0+2+1$

$(11)_{10}$

2) (1011.10) = $(?)$

$11. (1\times2^{-1}) + (0\times1^{-2})$

$11 (1\times1/2) + 0$

$(11.5)_{10}$

SONA ROOPA Page No.
Date

* Decimal to Binary

* Octal to Decimal

1) $(278)_8 = (?)_{10}$

$(2 \times 8^2) + (7 \times 8^1) + (6 \times 8^0)$

$= (2 \times 64) + (56) + (6)$

$= 190$

2) $(276.13)_8 = (?)_{10}$

$(8^2 \times 2) + (7 \times 8^1) + (6 \times 8^0) + (1 \times 8^{-1}) + (3 \times 8^{-2})$

$= 190 + \frac{1}{8} + \frac{3}{82}$

$= \cancel{190.1718}$

$= (190.1718)_{10}$

3) $(190.1718)_{10} = (?)_8$

$8 \overline{)190} \; 23$
16
30
24
6

$8 \overline{)23} \; 2$
16
7

$8 \overline{)2} \; 0$
0
2

$(276)_8$

$0.1718 \times 8 = 1.3744 = 1$
$.374 \times 8 = 2.992 = 2$
$.99 \times 8 = 7.9 = 7$
$.9 \times 8 = 7.2 = 7$

round up
.1277
.128
.13

$= (276.13)_8$

	$2^3=8$	$2^2=4$	$2^1=2$	$2^0=1$
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 - A	1	0	1	0
11 - B	1	0	1	1
12 - C	1	1	0	0
13 - D	1	1	0	1
14 - E	1	1	1	0
15 - F	1	1	1	1

Binary - Octal / HD

(1) $(010101101.110100)_2 = (255.64)_8$

2 5 5 6 4

(2) $(10101101.11010000)_2$ 16 = 4 Variable

$(AD.D0)_{16} = (1013.130)_{16}$

$= (AD.D)_{16}$

(3) $(AD.D)_{16} = (?)_8$

$(010101101.110100)_{16} = (255.64)_8$

(4) $(255.64)_8 = (?)_{16}$

(010101101.110100)

$(AD.D)_{16}$

* Binary Addition and Subtraction :

① $(4)_{10} + (6)_{10} = (?)_{10}$

$(100)_2 + (110)_2 = (1010)_2$

$$\begin{array}{r} 100 \\ 110 \\ \hline 1010 \end{array}$$

A = 10

0 → 0
1 → 1
2 → 10
3 → 11

② $(5)_{10} + (7)_{10} = (?)_{10}$

$(101)_2 + (111)_2 = (1100)_2$

$$\begin{array}{r} 101 \\ 111 \\ \hline 1100 \end{array}$$

$(12)_{10}$

③ $(12)_{10} + (7)_{10} = (?)_{10}$

$(1100)_2 + (0111)_2 = (?)_2$

$$\begin{array}{r} 1100 \\ 0111 \\ \hline 10011 \end{array}$$

* Binary Subtraction

④ $(8A4)_{16} + (F95)_{16}$

$(8104)_{16} + (1595)_{16}$

$$\begin{array}{r} 8104 \\ 1595 \\ \hline 9699 \end{array}$$

8104 = 1000 1010 0100
1595 = 1111 1001 0101
11000 0011 1001

$(1839)_{16}$

* Binary subtraction :-

The subtraction operation can be done by using addition operator. ~~to do that~~ by using compliment method there are two types of compliment.

1] ~~One's~~ 1's compliment

Eg :- If $A = (9)_{10}$ then $\bar{A}$?

$\rightarrow (9)_{10} = (1001)_2 = A$

$\bar{A} = (0110)_2$

2] 2's compliment

if $A = (9)_{10}$ then 2's compliment ?

$A = (9)_{10} = (1001)_2$

$\bar{A} = (0110)$

2's compliment $\begin{array}{r} 0110 \\ +1 \\ \hline (0111)_2 \end{array}$

① Using 1's compliment

i] $(6)_{10} - (4)_{10} = (?)_{10}$

$A - B = C$

$A + \bar{B} = C$

$(110)_2 + (100)_2 = 100 = 011$

$\begin{array}{r} 110 \\ 100 \\ \hline \boxed{1}010 \end{array}$ $\begin{array}{r} 110 \\ 100 \\ \hline 1 \end{array}$ $\begin{array}{r} 110 \\ 011 \\ \hline \boxed{1}001 \end{array}$

$\begin{array}{r} 001 \\ +1 \\ \hline (010)_2 \end{array}$

(2) $(12)_{10} - (9)_{10} = (?)_{10}$

$A - B = C$

$A + \bar{B} = C$

$A = 1100$ $B = 1001$

$\bar{B} = 0110$

$$\begin{array}{r} 1100 \\ 0110 \\ \hline 10010 \end{array} \qquad \begin{array}{r} 0010 \\ +\ 1 \\ \hline (0011)_2 \end{array}$$

(3) $(4)_{10} - (6)_{10} = (?)_{10}$

$A - B = C$

$A + \bar{B} = C$

$A = 100$ $B = 110$ $\bar{B} = 001$

$$\begin{array}{r} 100 \\ 001 \\ \hline 101 \end{array}$$

If carry is 0 you should convert it into 1's compliment

C

$\bar{C} = 010$

(4) $(9)_{10} - (12)_{10} = (?)_{10}$

$A - B = C$

$A = 1001$ $B = 1100$ $\bar{B} = 0011$

$$\begin{array}{r} A\ 1001 \\ \bar{B}\ +0011 \\ \hline \bar{C} = 1100 \end{array}$$

$\bar{C} = (0011)_2$

Using 2's compliment

(1) $(6)_{10} \mp (4)_{10} = (?)_{10}$

$A + \bar{B} = C$

$A = 110$ $B = 100$ $\bar{B} = 011$

$+1$

$100 \rightarrow$ 2's compliment

A 110
2's 100
1010

This time carry should be ignored

(2) $(12)_{10} - (9)_{10} = (?)$

A = 1100 B = 1001 $\bar{B}$ = 0110
+1
0111

1100
0111
1 0011

(3) $(4)_{10} - (6)_{10} = (?)_{10}$

→ A = (100) B = (110) $\bar{B}$ = (001)
2's = ~~(110)~~ 001
+1
$B^{\wedge}$ 010

$A + \hat{B}$ = 110 $\bar{C}$ = 001 $\bar{C}+1$ = 010
$\hat{C}$

(4) $(9)_{10} - (12)_{10} = (?)_{10}$

A = (1001) B = (1100) $\bar{B}$ = (0011)
2's = 0011
+1
0100

1001
0100
C 1101
$\hat{C}$ = 0010 $\hat{C}+1$ = 0010
+1
$\hat{C}$ = 0011

* Logical gates :-

There are 3 basic gates

i] AND $C = A \overset{\text{symbol}}{\cdot} B$

ii] OR $C = A + B$

iii] NOT $C = \bar{A}$ / A'

There are two special gates which are the part of basic gates

i] XOR $C = A \oplus B$

ii] XNOR $C = \overline{A \oplus B}$ / $A \odot B$

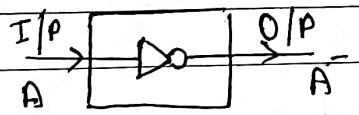
There are two universal gates

i] NAND $C = \overline{(A \cdot B)}$

ii] NOR $C = \overline{(A + B)}$

* Basic gates :-

i] NOT $C = \bar{A}$ / A'



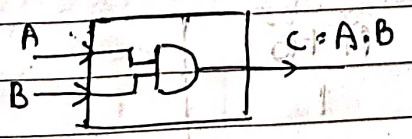
Truth table

A	$\bar{A}$
0	1
1	0

Binary data (0, 1)

$A = \{0, 1\}_2$

ii] AND $C = A \cdot B$

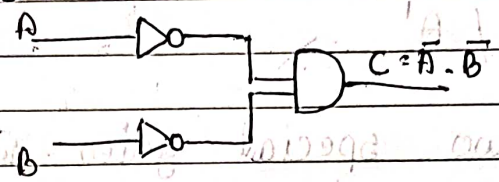


Truth table

I/P		O/P
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

1] Draw the logical gates (circuit) from the given logical function and also write the behaviours of the function.

→ $C = \bar{A} \cdot \bar{B}$

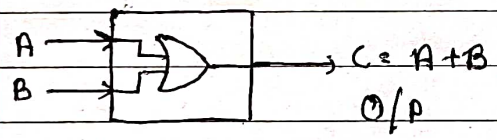


Truth Table

A.B	$\bar{A} \cdot \bar{B}$	$\bar{A} \cdot \bar{B}$
00	1	1
10	01	0
01	10	0
11	00	0

iii] OR Gate

I/P



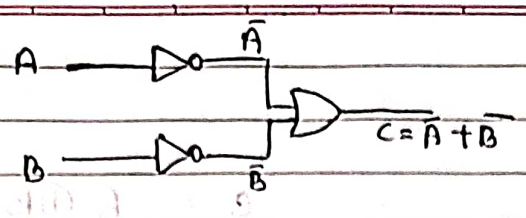
logical symbol :

Truth table

A	B	C = A + B
0	0	0
0	1	1
1	0	1
1	1	1

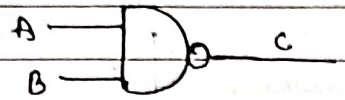
Eg $\bar{A} + \bar{B}$

A	B	$\bar{A}$	$\bar{B}$	$\bar{A} + \bar{B}$
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

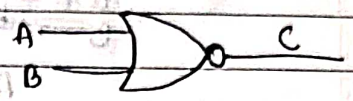


Universal Gates

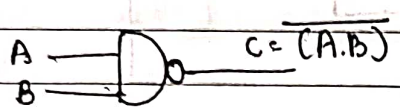
1] NAND



2] NOR



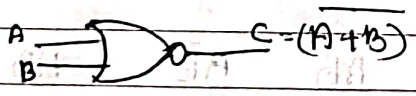
i] NAND Gate



Truth table

A	B	A.B	$\overline{(A.B)}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

ii] NOR Gate

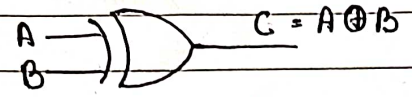


Truth table

A	B	A+B	$\overline{(A+B)}$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

* Special Gates

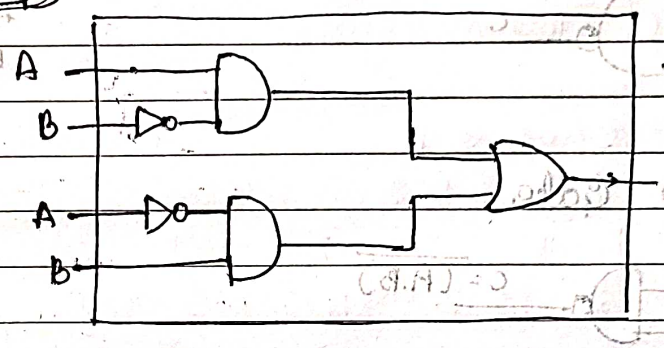
i] XOR Gate



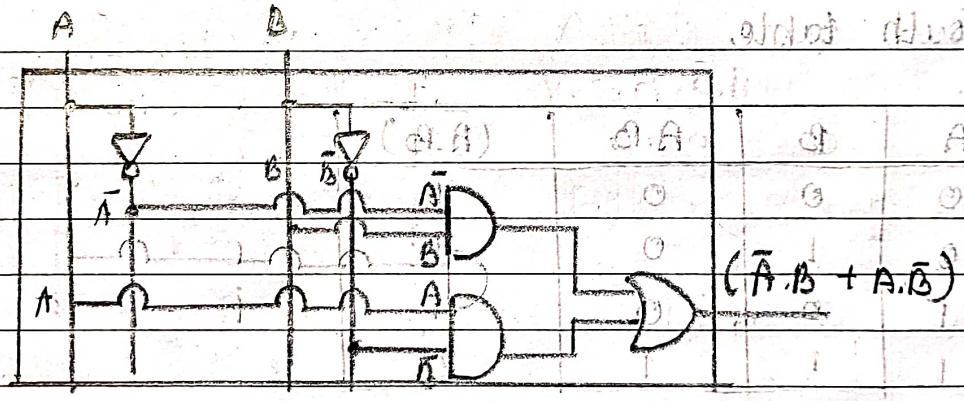
$C = A \oplus B$

$\cancel{\bar{A}B + \bar{B}A}$

$$\boxed{C = A.\bar{B} + \bar{A}.B}$$



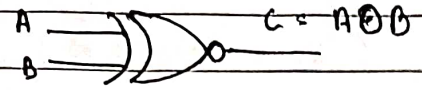
Truth table



Truth Table

A	B	$\bar{A}$	$\bar{B}$	$\bar{A}B$	$A\bar{B}$	$\bar{A}B + A\bar{B}$
0	0	1	1	0	0	0
0	1	1	0	1	0	
1	0	0	1	0	1	1
1	1	0	0	0	0	0

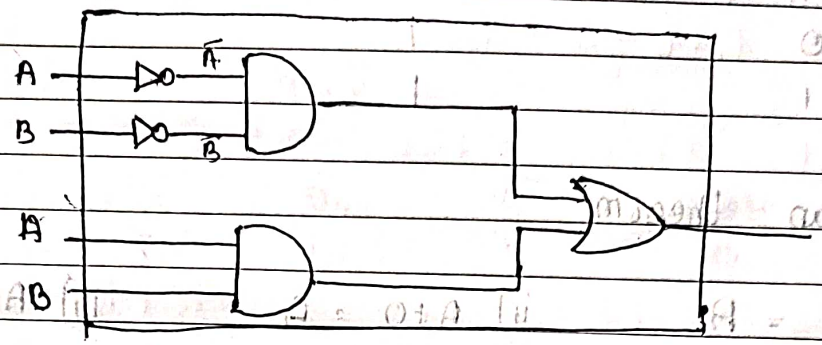
ii] XNOR gate



Basic gate : $A \odot B$

$\bar{A}\bar{B} + AB$

Circuit diagram



Truth table

A	B	$\bar{A}$	$\bar{B}$	$\bar{A}\bar{B}$	AB	$\bar{A}\bar{B} + AB$
0	0	1	1	1	0	1
0	1	1	0	0	0	0
1	0	0	1	0	0	0
1	1	0	0	0	1	1

* Bulean Algebra and Simplification.

There are 3 laws

i] Commutative ⇒ $A+B = B+A$

ii] Associative → $A+(B+C) = (A+B)+C$

iii] Distributive → $A.(B+C) = (A.B)+(A.C)$

A	B	C	B+C	A.(B+C)	A.B
0	0	0	0	0	0
0	0	1	1	0	0
0	1	0	1	0	0
0	1	1	1	0	0
1	0	0	0	0	0
1	0	1	1	1	0
1	1	0	1	1	1
1	1	1	1	1	1

(A.C)	(A.B) + (A.C)
0	0
0	0
0	0
0	0
0	0
1	1
0	1
1	1

* Boolean theorm

i] $A+A = A$ ii] $A+0 = A$ iii] $A+1 = 1$

iv] $A+\bar{A} = 1$ v] $\bar{\bar{A}} = A$ vi] $A.A = A$

vii] $A.0 = 0$ viii] $A.1 = A$ ix] $A.\bar{A} = 0$

x] $A+AB = A$ xi] $A+\bar{A}B = A+B$ xii] $(A+B).(A+C) = A+BC$

A	B	C	A+B	A+C	(A+B)(A+C)
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	1	0	0
0	1	1	1	1	1
1	0	0	1	1	1
1	0	1	1	1	1
1	1	0	1	1	1
1	1	0	1	1	1

$A+(\bar{A}.B)$

$(A+\bar{A})\ (A+B)$

$1.x$

$= x$

$= A+B$

$(A+B).(A+C)$

$A.A + B.C + A.C + A.B$

$\cancel{A+(B.x)}\ (A+A.C) + A.B + B.C$

$A.x = A + A.B + B.C$

$A + BC$

* Demorgan's theorm :-

(i) $\overline{(A+B+C+\ldots)} = \bar{A}.\bar{B}.\bar{C}\ldots$

(ii) $\overline{(A.B.C.\ldots)} = \bar{A}+\bar{B}+\bar{C}\ldots$

Verify Demorgan's

(i) $\overline{(x+y)} = \bar{x}.\bar{y}$

x	y	$\bar{x}$	$\bar{y}$	$x+y$	$\overline{(x+y)}$
0	0	1	1	0	1
0	1	1	0	1	0
1	0	0	1	1	0
1	1	0	0	1	0

$\bar{x}.\bar{y}$

1

0

0

0

(ii) $\overline{(x.y)} = \bar{x}+\bar{y}$

x	y	$\bar{x}$	$\bar{y}$	xy	$\overline{x.y}$	$\bar{x}+\bar{y}$
0	0	1	1	0	1	1
0	1	1	0	0	1	1
1	0	0	1	0	1	1
1	1	0	0	1	0	0

* Simplify the following expression using boolean rules

i] $\bar{A}+A.\bar{B}$ Design using basic gates

→ $\bar{A}+A.\cancel{AB}\ \bar{A}+\bar{B}$

$\bar{A}+\bar{B}.1$

$x.1$

x

0 1 1 $b\bar{c}$

1 0 1

6] $(\bar{a}+ab)(\bar{b}+c)\bar{c}$

7] $(\overline{x+y}) \cdot (\overline{x+x}) + x$

ii] $\overline{A+1+B+C}$

$\bar{A} \cdot \bar{1} \cdot \bar{B} \cdot \bar{C}$

$= \bar{A} \cdot 0 \cdot \bar{B} \cdot \bar{C}$

$= 0$

iii] $A + \bar{A}B + ABC + \bar{A}C$

$A + B + ABC + \bar{A}C$

$A + B + C + ABC$

$A + \bar{A}B + ABC + \bar{A}C$

$\cancel{A+B}\ B + A(1+\bar{C}) + A$

$B + A + ABC + \bar{A}$

$= \cancel{1 + ABC}$

$= B$

~~4]~~ $\bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}D + A\bar{B}\bar{C}D + A\bar{B}\bar{C}\bar{D}$

$\bar{A} + \bar{B} + \bar{C} + \bar{D} + \bar{A} + \rightarrow \bar{B} + \bar{C}$

(3) $\xi \cdot xyz + yz + \bar{z}$

$\cancel{xyz + \bar{y} + \bar{z}}$

$yz(x+1) + \bar{z}$

$yz + \bar{z}$

$y\ \bar{y} + \bar{z}$

$A + \bar{A}B + ABC + A\bar{C}$

$A + B + A\bar{C} + ABC$

$B + A(1+\bar{C}) + ABC$

$B + A(1 + BC)$

$= A + B$

(4) $\bar{A}\bar{B}\bar{C}D + \bar{A}\bar{B}\bar{C}D + A\bar{B}\bar{C}D + A\bar{B}\bar{C}\bar{D}$

$\bar{A}\bar{B}\bar{C}\bar{D}(\bar{A}+A) + \bar{A}\bar{B}\bar{C}D + A\bar{B}\bar{C}D$

$\bar{B}\bar{C}\bar{D} + A\bar{B}\bar{C}(\bar{D}+D)$

$\bar{B}\bar{C}\bar{D} + \bar{B}\bar{C}D$

$\bar{B}\bar{C}(\bar{D}+D)$

$\bar{B}\bar{C} \cdot 1$

$x \cdot 1$

$x = \bar{B} \cdot \bar{C}$

(5) $xyz + yz + \bar{z}$

$yz(x+1) + \bar{z}$

$yz + \bar{z}$

$y + \bar{z} \cdot z + \bar{z}$

$y + \bar{z} \cdot 1$

$y + \bar{z}$

SONA ROOPA Page No.
Date / /

6 $(\bar{a}+ab)\ (b+c)\bar{c}$

$(\bar{a}+a).(\bar{a}+b)\ (b+c)\bar{c}$

$1.(\bar{a}+b).(b+c)\bar{c}$

$\bar{a}b+\bar{a}c+b.b+b.c \times \bar{c}$

$\bar{c}\bar{a}b+\bar{c}\bar{a}c+\bar{c}b+\bar{c}bc$

$=\bar{c}\bar{a}b+\bar{c}\bar{a}c+\bar{c}b\ (1+c)$

$\bar{c}\bar{a}b+\bar{c}\bar{a}c+\bar{c}b.1$

$\cancel{\bar{c}b(\bar{a}+1)+\bar{c}\bar{a}c}$

$\cancel{\bar{c}b.1+\bar{c}\bar{a}\bar{c}}$

$\cancel{\bar{c}.\bar{c}\bar{c}b}$

$b\bar{c}(\bar{a}+1)+\bar{c}\bar{a}c+\bar{c}bc$

$b\bar{c}+\bar{c}c(\bar{a}+b)$

$b\bar{c}+0$

$=b.\bar{c}$

7 $(x+y)\ (\bar{z}+x)+x$

$x\bar{z}+x.x+y\bar{z}+y.x+x$

$x\bar{z}+x+y\bar{z}+y.x+x$

$x\bar{z}+x+y\bar{z}+x(y+1)$

$x\bar{z}+x+y\bar{z}+\cancel{x}$

$x(\bar{z}+1)+y\bar{z}+\cancel{x}$

$x+y\bar{z}+\cancel{x}$

$\cancel{x+x+y\bar{z}}$

$\cancel{x+y\bar{z}}$

$\overline{(\overline{x+y})\ (\overline{\bar{z}+x})}+x$

$(\overline{x+y})\ (\overline{\bar{z}+x})+x$

$(x+y)\ (\bar{z}+x)+x$

$(x+y)\ x(\bar{z}+1)$

$(x+y)\ x$

$x+yx$

$x(y+1)$

x

$\overline{(\overline{x+y})\ (\overline{\bar{z}+x})}+x$

$(\bar{x}.\bar{y})\ (z.\bar{x})+x$

$(\bar{x}+\bar{y})\ (\bar{z}+x)+x$

$x+y+\bar{z}+(x.x)$

$x+y+\bar{z}$

6 $(\bar{a}+ab)\ (b+c)\bar{c}$

$(\bar{a}+ab)\ (b\bar{c}+\bar{c}.c)$

$(\bar{a}+ab)\ (b\bar{c})$

$\bar{a}b\bar{c}+ab\bar{c}$

$b\bar{c}\ (\bar{a}+a)$

$b\bar{c}$

* Canonical Form :-

Representing the boolean expression (function) by either in sum of minterm or product of maxterm.

1 Sum of product (Σ - Symbol)

The variable having data zero representing as compliment. and variable having data one represented as it is.

Sum of product searching for minterm that is from the truth table the output is one and excluding zero.

x	y	min	minterm
0	0	$\bar{x}\bar{y}$	
0	1	$\bar{x}y$	
1	0	$x\bar{y}$	
1	1	xy	

$F = \Sigma$ (Sum of product)

m_0, m_1, m_2, m_3

$= \bar{x}\bar{y} + \bar{x}y + x\bar{y} + xy$

Eg :-

x	y	O/P
0	0	0
0	1	1
1	0	1
1	1	0

Find logical function using sum of product (SOP

x	y	~~minterm~~ O/P	minterm
0	0	0	
0	1	1	$\bar{x}y$
1	0	1	$x\bar{y}$
1	1	0	

$F = \Sigma$ (Sum of product)
$= \Sigma (m_1, m_2)$

$F = \bar{x}y + x\bar{y}$
$= x \oplus y$

2] Product of sum (π)

The variable having data one representing as it is compliment and variable having data zero represented as compliment.

Product of sum searching for maxterm that is from the truth table the O/P is zero and excluding 1

x	y	Maxterm
0	0	$x+y$
0	1	$x+\bar{y}$
1	0	$\bar{x}+y$
1	1	$\bar{x}+\bar{y}$

$F = (\pi)$ Product of sum
$= m_0, m_1, m_2, m_3$
$(x+y) \cdot (x+\bar{y}) \cdot (\bar{x}+y) \cdot (\bar{x}+\bar{y})$

Eg :-

x	y	maxterm
0	0	$x+y$
0	1	$x+\bar{y}$
1	0	$\bar{x}+y$
1	1	$\bar{x}+\bar{y}$

$F = (\pi)$ m_2, m_3
$(x+\bar{y}) \cdot (\bar{x}+y)$
$x\bar{x} + xy + \bar{x}\bar{y} + y\bar{y}$
$xy + \bar{x}\bar{y}$

Conversation of SOP to POS and vice versa
$(\Sigma \to \Pi)$ $(\Pi \to \Sigma)$

SOP $\overrightarrow{F(x,y)} = \overline{(\bar{x}.y) + (x\bar{y})}$

$\overline{(\bar{x}.y)} . \overline{(\bar{x}.\bar{\bar{y}})}$

$\bar{\bar{x}} + \bar{y} . \bar{x} + \bar{\bar{y}}$

$(x + \bar{y}) . (\bar{x} + y)$

POS $\overrightarrow{F(x,y)} = \overline{(x + \bar{y}) . (\bar{x} + y)}$

$\overline{(x+\bar{y})} + \overline{(\bar{x}+y)}$

$\bar{x} . \bar{\bar{y}} + \bar{\bar{x}} . \bar{y}$

$(\bar{x}.y) + (x.\bar{y})$

* Conversation of standard logic function to cannonical form.

- Step 1 : Find total no of variables in the standard form.
- Step 2 : Find the variables absent in each term.
- Step 3 : Try to apply operation for converting standard to cannonical form using 1/0 logic i.e $(A+\bar{A}) / (\bar{A}\bar{A})$

Eg :- $x + yz$

$x(y+\bar{y}) + yz(x+\bar{x})$

$xy + x\bar{y} + yzx + yz\bar{x}$

$xy(z+\bar{z}) + x\bar{y}(z+\bar{z}) + xyz + \bar{x}yz$

$xyz + xy\bar{z} + x\bar{y}z + x\bar{y}\bar{z} + xyz + \bar{x}yz$

$xyz + xy\bar{z} + x\bar{y}z + x\bar{y}\bar{z} + \bar{x}yz$

111 110 101 100 011

7 6 5 4 3

$\Sigma(7, 6, 5, 4, 3)$

$\Sigma(m_7, m_6, m_5, m_4, m_3)$

POS $x + yz$

$(x+y) \cdot (x+z)$

$(x+y+z\bar{z}) \cdot (x+z+y\bar{y})$

$(x+y+z) \cdot (x+y \cdot \bar{z}) \cdot (x+z+y) \cdot (x+z+\bar{y})$

$(x+y+z) \cdot (x+y+\bar{z}) \cdot (x+\bar{y}+z)$

$(0\ 0\ 0)$ $(0\ 0\ 1)$ $(0\ 1\ 0)$

0 1 2

$f(x,y,z) = \pi(m_0, m_1, m_2)$

(3) $B \cdot \bar{C}$

$B(C+\bar{C}) \cdot \bar{C}(B+\bar{B})$

$BC + B\bar{C} \cdot B\bar{C} + \bar{B}\bar{C}$

$BC + \bar{B}\bar{C}$

$BC(A+\bar{A}) + \bar{B}\bar{C}(A+\bar{A})$

$BC\bar{A} + BCA + \bar{B}\bar{C}A + \bar{B}\bar{C}\bar{A}$

(4) $y + \bar{z}$

$y(z+\bar{z}) + \bar{z}(y+\bar{y})$

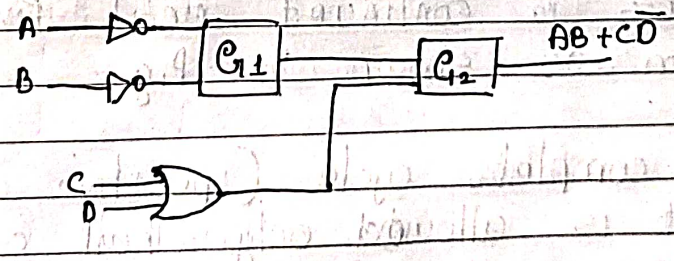
$yz + y\bar{z} + y\bar{z} + \bar{z}\bar{y}$

$yz + \bar{z}\bar{y}$

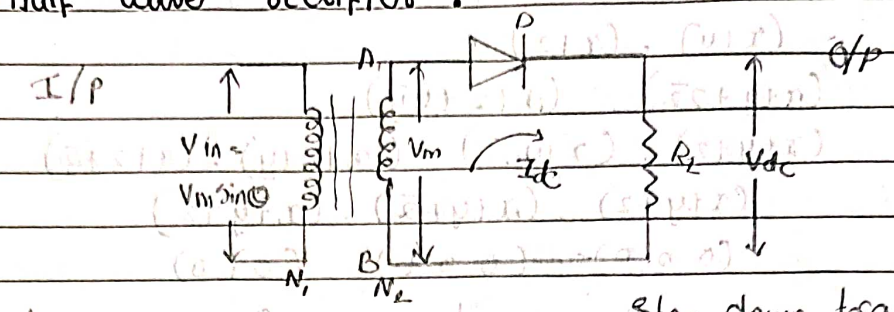
(5) From given fig the output is required to be $y = AB + \overline{CD}$, the gate G_1 & G_2 must be.

(i) NOR, OR (ii) OR, NAND

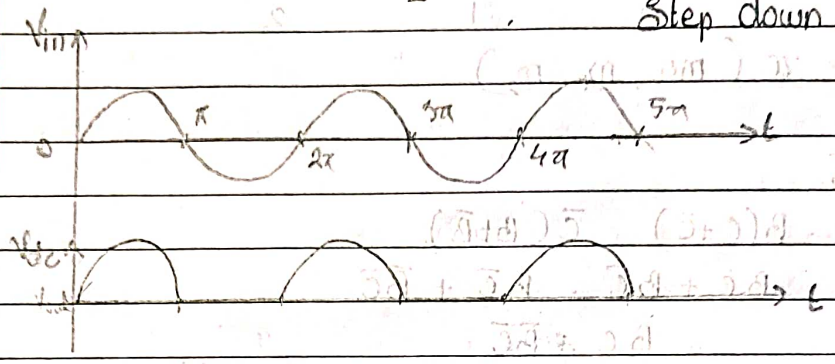
(iii) NAND, OR (iv) AND, NAND



Half wave rectifier :



Step down transformer



- during positive half cycle (0 to t_1) in this time diode act as forward bias [conducting] and the circuit becomes closed. Hence it provide current [I_{dc}] due to $V_{in} = V_m \sin\theta$. Therefore the output voltage across R_L [$V_{dc} = I_{dc} \times R_L$], we obtained output voltage.

- during negative half cycle [b/w t_1 to t_2] in this time diode will be reversed bias [nonconducting] and the circuit becomes open. Hence it does not provide current, which means [$I_{dc} = 0$] the output voltage [$V_{dc} = I_{dc} \times R_L$], $\therefore V_{dc} = 0$, hence there is no output voltage.

This process is continued until further. The wave form as shown in fig.

For one complete cycle (positive & negative) the output is allowed only half cycle, hence the name half wave.

* Analysis of the circuit :

⇒ Output Voltage (V_{dc}) :-

$$V_{dc} = \frac{1}{2\pi}\int_0^{2\pi} V_{in} \cdot d\theta$$

$$= \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\theta \, d\theta$$

$$= \frac{1}{2\pi}\int_0^{\pi} V_m \sin\theta \, d\theta + \int_{\pi}^{2\pi} V_m \sin\theta \, d\theta$$

$$= \frac{V_m}{2\pi}\left[-\cos\theta\right]_0^{\pi}$$

$$= -\frac{V_m}{2\pi}\left[\cos(180) - \cos(0)\right]$$

$$= -\frac{V_m}{2\pi}\left[-1-1\right]$$

$$= -\frac{V_m}{2\pi} \times -2$$

$$\frac{\cancel{2}V_m}{\cancel{2}\pi}$$

$$\boxed{V_{dc} = \frac{V_m}{\pi}} \quad \text{—— (1)}$$

Current :-

$$I_{dc} = \frac{V_{dc}}{R_L}$$

$$\boxed{I_{dc} = \frac{V_m}{\pi R_L}} \leftarrow \text{Output current}$$

$$\boxed{I_{dc} = \frac{I_m}{\pi}} \quad \text{—— (2)} \qquad \left(\because \frac{V_m}{R_L} = I_m\right)$$

* Efficiency (η) = $\frac{\text{Input power}}{\text{Output power}} = \frac{P_{AC}}{P_{DC}}$

$$\eta = \frac{P_{AC}}{\frac{I_m}{\pi}\frac{V_m}{\pi}} = \frac{P_{AC}}{\frac{I_m V_m}{\pi}} = \frac{I_{rms} V_{rms}}{I_{dc} V_{dc}}$$

$$\eta = \frac{P_{dc}}{P_{ac}} = \frac{V_{dc} I_{dc}}{V_{rms} I_{rms}}$$

$$\text{Efficiency} = \frac{\text{Output Power}}{\text{Input Power}} = \frac{P_{dc}}{P_{ac}} = \frac{I_{dc} V_{dc}}{I_{rms} V_{rms}}$$

$$V_{dc} = I_{dc} \times R_L \quad , \quad I_{dc} = \frac{V_{dc}}{R_L}$$

$$V_{rms} = I_{rms} (r_f + R_L)$$

$$\eta = \frac{I_{dc}^2 . R_L}{I_{rms}^2 (r_f + R_L)}$$

W.K.T $I_{dc} = I_m / \pi$ & $I_{rms} = I_m / 2$

$$\eta = \frac{\left(\frac{I_m}{\pi}\right)^2 . R_L}{\left(\frac{I_m}{2}\right)^2 . (r_f + R_L)}$$

$$\frac{\frac{R_L}{\pi^2}}{\frac{r_f + R_L}{4}}$$

$$\eta = \frac{4 R_L}{\pi^2 (r_f + R_L)}$$

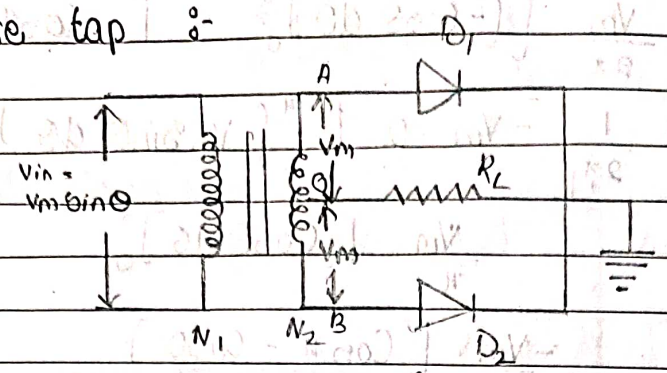
* The efficiency is very much less in HWR hence to increase the efficiency we should use more than one diode, i.e FWR

* Peak Inverse Voltage :- It is the reverse voltage when diode is non-conducting

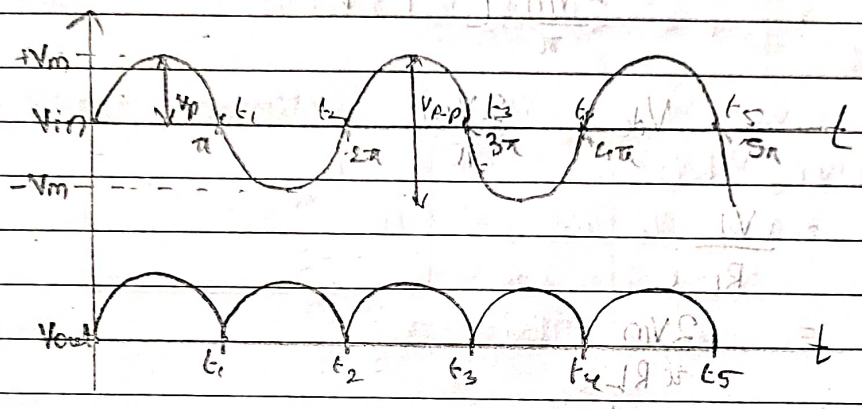
In HWR PIV = V_m [Voltage drop]

* Full wave rectifier (FWR) :

i] Centre tap :-



Step down transformer



$V_p = (+ve) = V_m$

$V_p = (-ve) = -V_m$

$V_{p-p} = (+ve) - (-ve)$

$= 2V_m$

- during positive half cycle diode D_1 is conducting and D_2 is not conducting ∴ i.e A = +ve, O = -ve, D_1 is conducting and O = +ve & B = -ve, diode D_2 is nonconducting, I_{dc} is due to D_1

- during negative half cycle diode D_1 is nonconducting and D_2 is conducting i.e A = -ve, O = +ve, D_1 is nonconducting and O = -ve & B = +ve, D_2 is conducting, I_{dc} is due to D_2

Analysis of FWR

* Output Voltage :- (V_{dc}) -

$$V_{dc} = \frac{1}{2\pi}\int_0^{2\pi} V_m \sin\theta \, d\theta$$

$$= \frac{1}{2\pi}\int_0^{\pi} V_m \sin\theta \, d\theta + \int_{\pi}^{2\pi} V_m \sin\theta \, d\theta$$

$$= \frac{V_m}{2\pi}\left[\int_0^{\pi} \sin\theta \, d\theta + \int_{\pi}^{2\pi} \sin\theta \, d\theta\right]$$

$$= \frac{V_m}{2\pi}\left[\left[-\cos\theta \, d\theta\right]_0^{\pi} + \left[-\cos\theta \, d\theta\right]_{\pi}^{2\pi}\right]$$

$$\frac{1}{2\pi} \; \cancel{-V_m} \; 2\left[\int_0^{\pi} V_m \sin\theta \, d\theta\right]$$

$$\frac{V_m}{\pi}\left[-\cos\theta \, d\theta\right]_0^{\pi}$$

$$= \frac{-V_m}{\pi}\left[\cos\pi - \cos 0\right]$$

$$= \frac{-V_m}{\pi}\left[-1-1\right]$$

$$V_{dc} = \frac{2V_m}{\pi}$$

$$I_{dc} = \frac{V_{dc}}{R_L}$$

$$= \frac{2V_m}{\pi R_L}$$

$$\boxed{I_{dc} = \frac{2I_m}{\pi}} \qquad I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$\text{Efficiency} = \frac{\text{Output power}}{\text{Input power}} = \frac{P_{dc}}{P_{AC}}$$

$$= \frac{I_{dc} V_{dc}}{I_{rms} V_{rms}}$$

$$= \frac{\frac{2 \cancel{V_m} I_m \cancel{V_m}}{\pi^2}}{\frac{\cancel{I_m} \cancel{V_m}}{\cancel{\sqrt{2}} \cancel{\sqrt{2}}}}$$

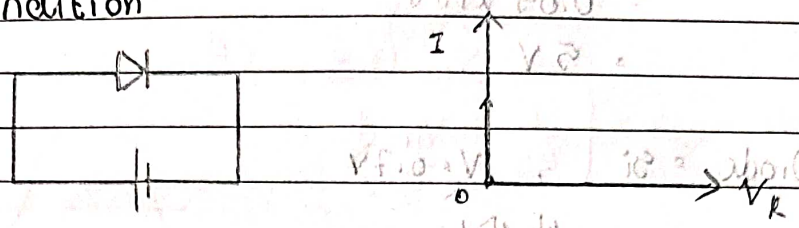
$$\eta = \frac{8}{\pi^2}$$

$$\eta = 0.8102$$

$$\eta\% = 81.02\%$$

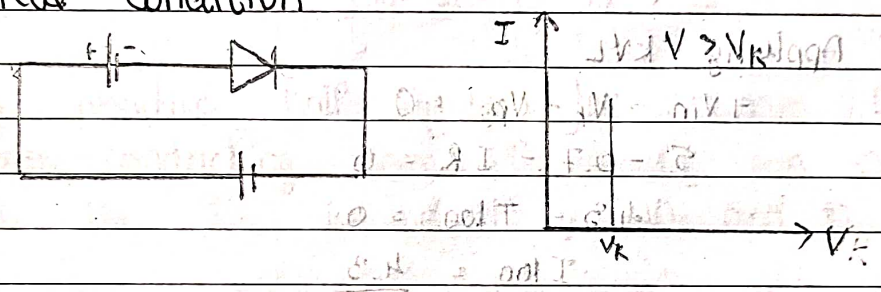
* Ideal and practical characteristics of semiconductor diode :

i Ideal Condition

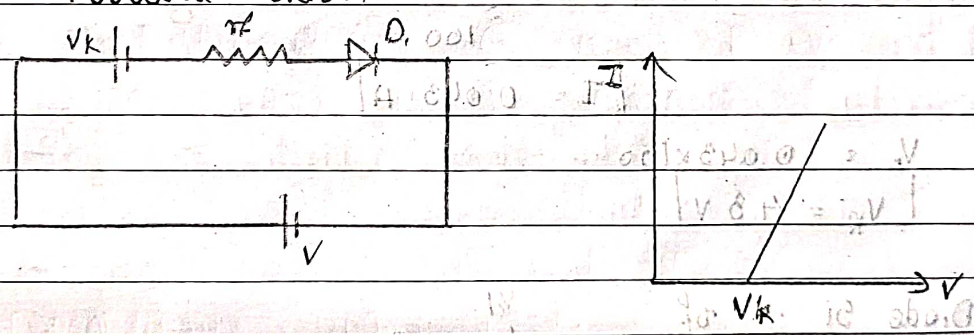


Here r_f = Absent

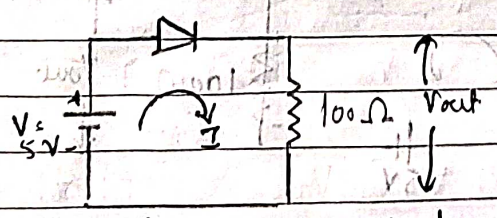
ii) Practical condition



iii) V_K + Forward bias

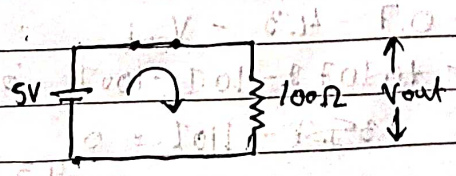


Q.1 Find I & V_0



at (i) Ideal (ii) Diode is Si (iii) Diode is Si and r_f = 10Ω

→



$$I = \frac{V_{in}}{R} = \frac{5}{100}$$

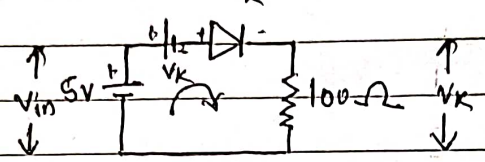
$$= 0.05\ A$$

$$V_R = IR$$

$$= 0.05 \times 100$$

$$= 5\ V.$$

2] Diode = Si , $V_K = 0.7V$



Applying KVL

$$+V_{in} - V_K - V_R = 0$$

$$5 - 0.7 - IR = 0$$

$$4.3 - I100 = 0$$

$$I100 = \frac{4.3}{100}$$

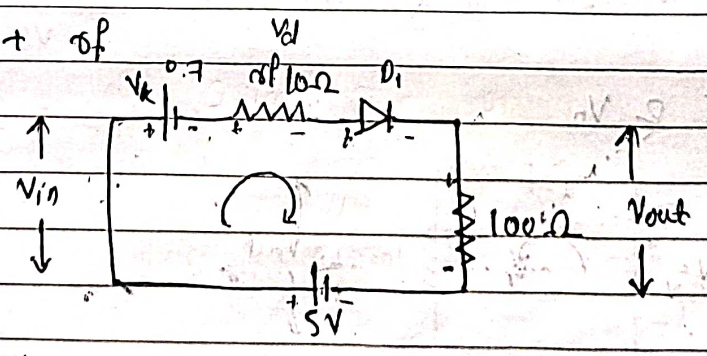
$$I = \frac{4.3}{100}\ A$$

$$\boxed{I = 0.043\ A}$$

$$V_R = 0.043 \times 100$$

$$\boxed{V_R = 4.3\ V}$$

3] Diode Si + rf



Applying KVL

$$V_{in} - V_K - V_d - V_{out} = 0$$

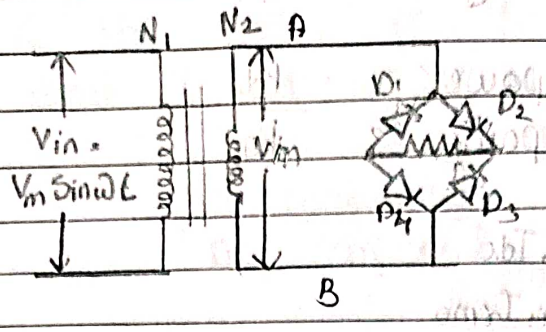
$$5 - 0.7 - 4.3 - V_{out}$$

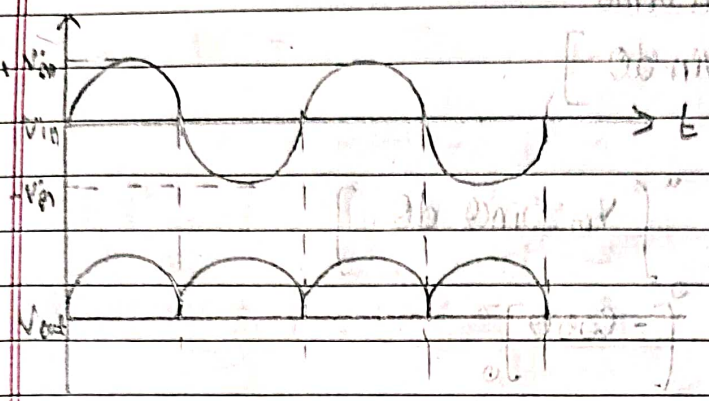
$$5 - 0.7I - 10I - 100I = 0$$

$$4.3 - 110I = 0$$

$$I = \frac{4.3}{110} = 0.039\ A$$

* Bridge rectifier.





During positive half cycle the diodes D_2 and D_4 are conducting and D_1 & D_3 are non conducting hence the I_{dc} is due to D_2 and D_4

During negative half cycle the diodes D_1 and D_3 are conducting and D_2 & D_4 are non conducting hence the current I_{dc} is due to D_1 and D_3

* Efficiency of bridge rectifier

During positive half cycle

SONA ROOPA Page No.
Date

* Efficiency of Bridge rectifier:

$$\eta = \frac{\text{Output power}}{\text{Input power}} = \frac{P_{dc}}{P_{AC}}$$

$$= \frac{V_{dc} I_{dc}}{V_{rms} I_{rms}}$$

$$V_{dc} = 2 \times \left[\frac{1}{2\pi} \int_0^{\pi} V_m \, d\theta \right]$$

$$= 2 \times \left[\frac{1}{2\pi} \int_0^{\pi} V_m \sin\theta \, d\theta \right]$$

$$= 2 \times \frac{V_m}{2\pi} \left[-\cos\theta \right]_0^{\pi}$$

$$= \frac{-V_m}{\pi} \left[\cos\pi - \cos 0 \right]$$

$$= \frac{-V_m}{\pi} \left[-1 - 1 \right]$$

$$V_{dc} = \frac{2V_m}{\pi}$$

$$I_{dc} = \frac{2V_m}{\pi R_L} \qquad I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$I_{dc} = \frac{2 I_m}{\pi} \qquad V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$\eta = \frac{\frac{2V_m}{\pi} \times \frac{2I_m}{\pi} R_L}{\frac{I_m V_m}{2} (r_f + R_L)}$$

$$= \frac{\frac{4 \cancel{V_m I_m} \cancel{R_L}}{\pi^2}}{\frac{\cancel{I_m V_m}}{2} \cancel{R_L}} \qquad (r_f + R_L) \sim R_L$$

$$= \frac{8}{\pi^2}$$

$$\eta\% = 81.05\%$$

* Ripple factor :
It is the ratio of AC component present in the output to DC component.

$$RF = \frac{\text{AC component}}{\text{DC component}}$$

$$RF = \frac{I_{ac}}{I_{dc}}$$

$$I_{rms}^2 = I_{ac}^2 + I_{dc}^2$$

$$I_{ac}^2 = I_{rms}^2 - I_{dc}^2$$

$$\frac{I_{ac}^2}{I_{dc}^2} = \frac{I_{rms}^2 - I_{dc}^2}{I_{dc}^2}$$

$$\frac{I_{ac}^2}{I_{dc}} = \sqrt{\frac{I_{rms}^2}{I_{dc}^2} - 1}$$

$$RF = \sqrt{\frac{I_{rms}^2}{I_{dc}^2} - 1}$$

1] Half wave rectifier

$$RF = \sqrt{\frac{\left(\frac{I_m}{2}\right)^2}{\left(\frac{I_m}{\pi}\right)^2} - 1}$$

$$= \sqrt{\frac{\frac{1}{4}}{\frac{1}{\pi^2}} - 1}$$

$\frac{1}{4} \times \frac{\pi^2}{1}$

$$RF = \sqrt{\frac{\pi^2}{4} - 1}$$

$$RF = 1.2113$$

Centre-tap & bridge

$$RF = \sqrt{\frac{I^2_{rms}}{I^2_{dc}} - 1}$$

$$= \sqrt{\frac{\left(\frac{I_m}{\sqrt{2}}\right)^2}{\left(\frac{2I_m}{\pi}\right)^2} - 1}$$

$$= \sqrt{\frac{\frac{\pi^2}{2}}{\frac{4}{\pi^2}} - 1}$$

$$\sqrt{\frac{\pi^2}{8} - 1}$$

$$RF = 0.48$$

lesser the value of RF more effective designing the rectifier.

larger the value of η more " " rectifier

Q Assertion :- Half way rectifier has less efficiency and has ~~less~~ one diode efficiency.

Reason :- FWR have two diode and has more efficiency

Comparision between HWR & FWR

Parameter	HWR	Centre tap	Bridge
Diodes	1	2	4
I_{dc} & V_{dc}	$\frac{I_m}{\pi}$ $\frac{V_m}{\pi}$	$\frac{2I_m}{\pi}$ $\frac{2V_m}{\pi}$	$\frac{2I_m}{\pi}$ $\frac{2V_m}{\pi}$
I_{rms} & V_{rms}	$\frac{I_m}{2}$ $\frac{V_m}{2}$	$\frac{I_m}{\sqrt{2}}$ $\frac{V_m}{\sqrt{2}}$	$\frac{I_m}{\sqrt{2}}$ $\frac{V_m}{\sqrt{2}}$

	HWR	Centretap	Bridge
η	40.5	81.05	81.05
PIV	V_m	$2V_m$	V_m
RF	1.211	0.48	0.48
Cost	Low	High	Very High

Q1 Determine average current, voltage, efficiency, Ripple factor and PIV of HWR $V_{in} = 35 \sin\omega t$ resistance $= 10\Omega$ and $R_L = 500\Omega$

→

$V_{in} = 35 \sin\omega t$

$V_{in} = V_m \sin\omega t$

$V_m = 35$

$$V_{dc} = \frac{V_m}{\pi} = \frac{35}{\pi} = 11.1408 \text{ V}$$

$$I_{dc} = \frac{I_m}{\pi} = \frac{V_{dc}}{R_L} = \frac{11.140}{500} = 0.022 \text{ A}$$

$$\eta = \frac{\text{Output Power}}{\text{Input Power}} = \frac{V_{dc} \times I_{dc}}{V_{rms} \times I_{rms}}$$

$$\eta = \frac{\left(\frac{I_m}{\pi}\right)^2 \cdot R_L}{\left(\frac{I_m}{2}\right)^2 (r_f + R_L)} = \frac{\left(\frac{0.022}{\pi}\right)^2 \times 500}{\left(\frac{0.022}{2}\right)^2 \times 510}$$

$$0.0612 = \frac{\frac{R_L}{\pi}}{\frac{r_f + R_L}{2}}$$

$$= \frac{\frac{500}{\pi}}{\frac{510}{4}}$$

$\eta = 39.7\%$

$$= \frac{11.14 \times 22 \times 10^{-3}}{17.5 \times 34 \times 10^{-3}}$$

$\eta = 41\%$

$V = IR$

SONA ROOPA Page No.
Date

* Ripple factor

$$RF = \sqrt{\frac{I^2_{rms}}{I^2_{dc}} - 1}$$

$$= \sqrt{\frac{\left(\frac{I_m}{\sqrt{2}}\right)^2}{\left(\frac{I_m}{\pi}\right)^2} - 1}$$

$$= \sqrt{\frac{\left(\frac{0.022}{\sqrt{2}}\right)^2}{\left(\frac{0.022}{\pi}\right)^2} - 1}$$

$$\sqrt{2.42\times10^{-4} - 1}$$

$$\sqrt{4.903\times10^{-5} - 1}$$

$$= \sqrt{\frac{(34\times10^{-3})^2}{(22\times10^{-3})^2} - 1}$$

$$RF = 1.196 \sim 1.2$$

* $PIV = 1 \times V_m = 35\,V$

Q-2 For FWR with 4 diodes uses transformer with turns ratio 2:1 load resistance is 500 Ω and primary voltage is 240V, 50 Hz. Calculate dc voltage and current efficiency and PIV.

$N_1 > N_2$
step down →

$V_m = N_1 : N_2$
$2 : 1$

$$\frac{V_s}{V_p} = \frac{N_2}{N_1}$$

$$V_s = \frac{N_2}{N_1} \times V_p$$

$$V_{rms} = V_s = \frac{1}{2} \times 240$$

$$V_{rms} = 120\,V$$

$$V_m = \sqrt{2} \times V_{rms}$$

$$= 169.70 \sim 170\,V$$

$I_m = \frac{V_m}{R_L}$

$= \frac{170}{500}$

$= 0.34\ A$

$I_{dc} = \frac{2 I_m}{\pi} = 0.216\ A$

$V_{dc} = \frac{2 V_m}{\pi} = 108.22\ V$

$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.240$

$\eta = \frac{\text{Output Power}}{\text{Input Power}}$

$= \frac{I_{dc} \times V_{dc}}{I_{rms} \times V_{rms}}$

$= \frac{0.216 \times 108.22}{120 \times 0.240}$

$\eta = 0.8116$

$\eta\% = 81.16\ \%$

$PIV = V_m = 170\ V$

$R.F = \sqrt{\frac{I_{rms}^2}{I_{dc}^2} - 1}$

$= \sqrt{\frac{(0.240)^2}{(0.216)^2} - 1}$

$R.F = 0.484$

Centre tap

$V_m = \sqrt{2}\ V_{rms}$

$= \sqrt{2} \times 240$

$= 170$

$\frac{V_m}{2} = \frac{170}{2} = 85$

$\frac{I_m}{2} = \frac{V_m}{R_L} = \frac{85}{500} = 0.17\ A$

$I_{dc} = \frac{2 \times I_m}{\pi} = 0.1082$ $\quad V_{rms} = \frac{V_m}{\sqrt{2}}$

$V_{dc} = \frac{2 \times V_m}{\pi} = 54.11$

$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.120$

$$\eta = \frac{\text{Output power}}{\text{Input power}}$$

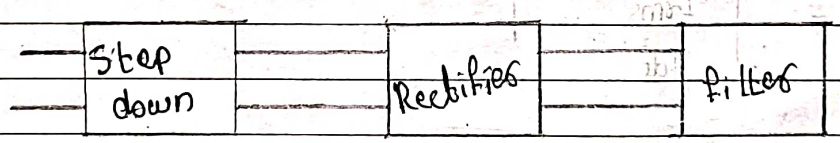
$$= \frac{I_{dc} \times V_{dc}}{I_{rms} \times V_{rms}}$$

$$= \frac{0.1082 \times 54.11}{0.120 \times 60.104}$$

$\eta = 0.8117$

$\eta\% = 81.17\%$

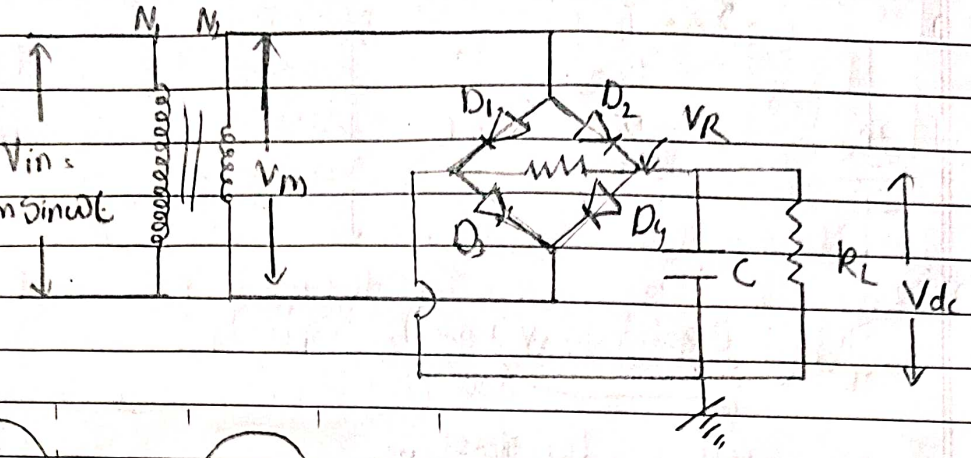
* Power supply design :-

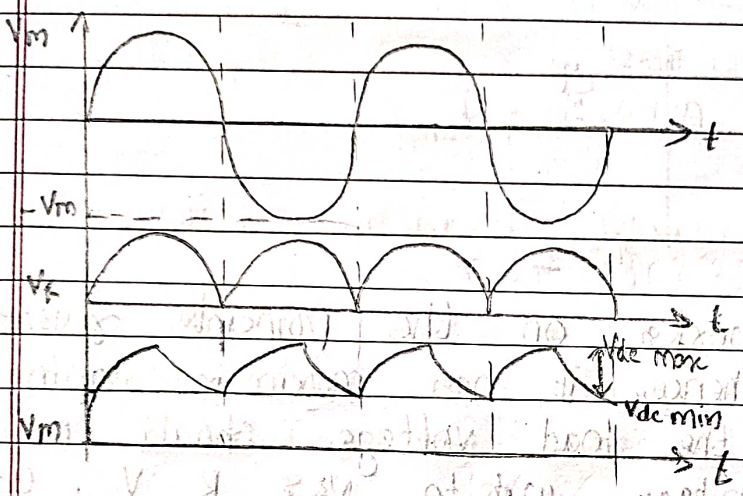


The main purpose of filter design is to remove the AC component i.e frequency >0.
The capacitor would be the best choice as a filter. (Based on the reactance)

Robert Boylsted

* Filter design for bridge rectifier



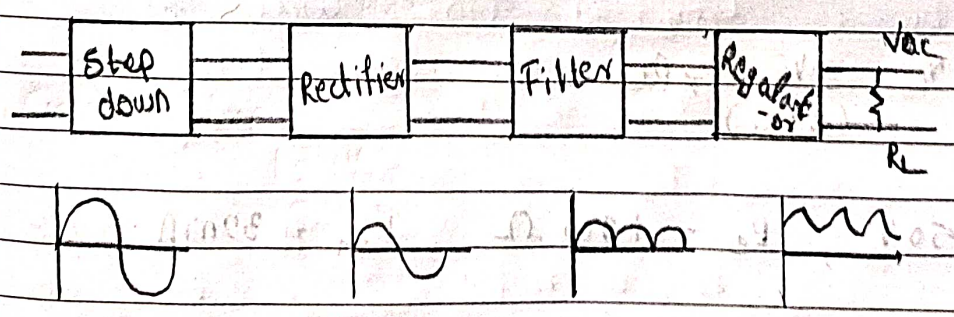


* Ripple factor for filter design

i] HWR = RF = $\frac{1}{2\sqrt{3}\,fCR_L}$

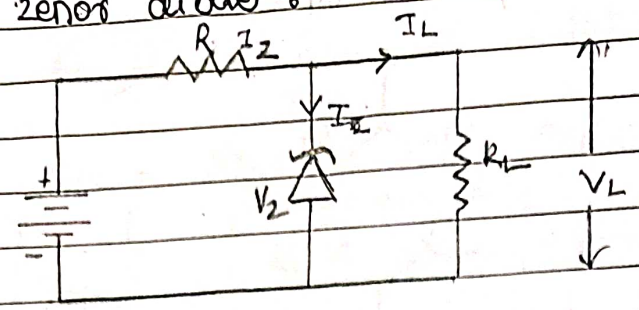
ii] FWR : RF = $\frac{1}{4\sqrt{3}\,fCR_L}$

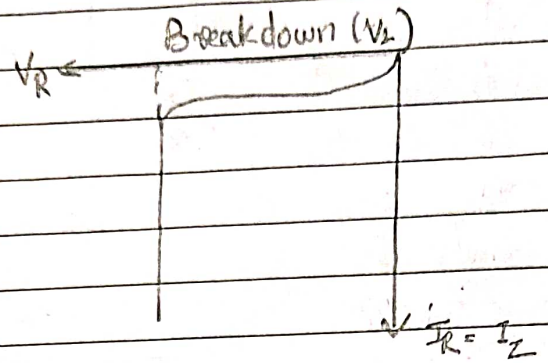
* Design of power supply



Date

zenor diode :





Zenor diode works on the principle reverse bias condition hence it has maximum doping.
· To observe the load voltage should maintain the constant voltage w.r.to V_I, R, V_Z, as per following equn

① To identify wheater zener diode is on or off state

$V_L > V_Z$ → Zener diode is ON

$V_Z > V_L$ → zener diode is OFF

① If $V_I = 16V$, $R = 1k\Omega$, $V_Z = 10V$. Find V_L, V_R, I_Z, P_Z [Power of Zener]

i) When $R_L = 1.2k\Omega$ ii] When $R_L = 3k\Omega$

→ $$V_L = \frac{V_i}{(R+R_L)} \times R_L$$

→ $V_1 = 50V$, $R_S = 1000\Omega$, $I_{SM} = 32mA$

$$R_{Lmin} = \frac{V_{ZR}}{V_{in} - V_{Zm}}$$

$$= \frac{10 \times 1000}{50 - 10}$$

$$= \frac{250000}{40}$$

$$\boxed{R_{Lmin} = 250\ \Omega}$$

$$R_{Lmax} = I_{Lmax} = \frac{V}{R_{Lmax}}$$

$$= \frac{10}{250}$$

$$I_{Lmax} = 0.04\ A$$