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$A \odot A \odot A \odot A$

odd $A \Rightarrow A$

(1) $\Leftarrow$ even A

even 0 → 1

even 1 → 1

odd 0 → 0

odd 1 → 1

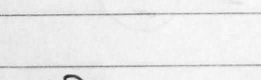
* NAND and NOR as universal gates L-1

NAND as universal gates

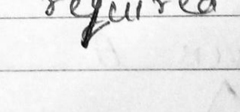
- NOT gate using NAND

NAND ~~goal~~ gate

NOT



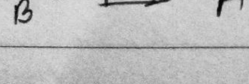
$\overline{A \cdot A} = \overline{A}$



$\overline{AB}$

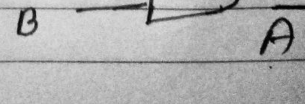
1 NAND gate is required for NOT gate

- AND



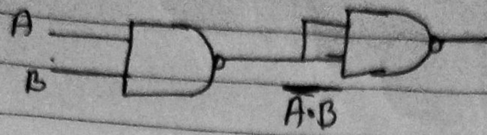
$A \cdot B$

NAND



$\overline{A \cdot B}$

- AND using NAND

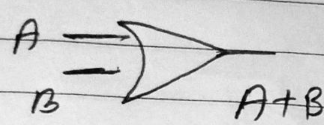


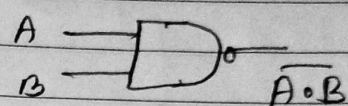
$\overline{\overline{A\cdot B}} \Rightarrow A\cdot B$

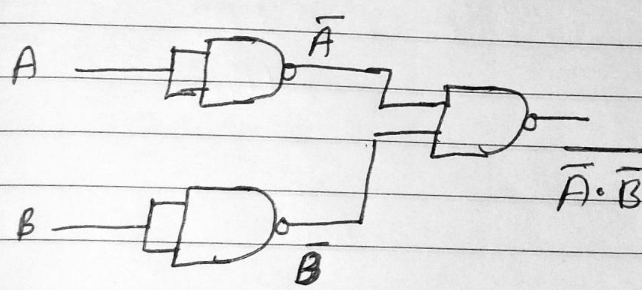
2 NAN gate is used

- OR gate

NAND





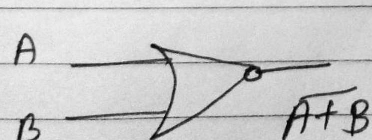


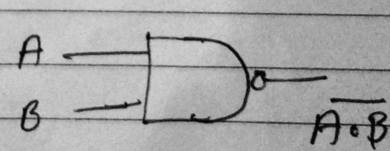
$\overline{\bar{A}\cdot\bar{B}} \Rightarrow A+B$

3 NAND gate is used

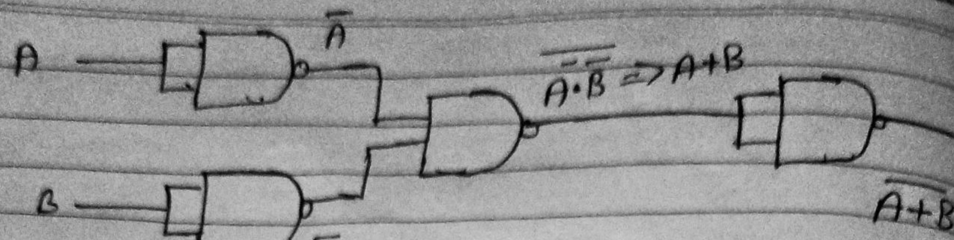
* Nor gate

NAND gate





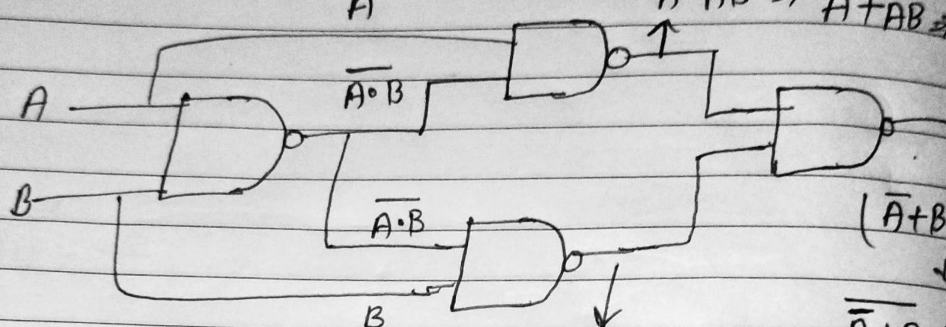
Nor gate using NAND



Ans

(4) NAND gates

- **XOR**



$\overline{A\cdot\overline{AB}} \Rightarrow \bar{A}+AB \Rightarrow \bar{A}+B$

$\overline{B\cdot\overline{AB}}$

$\Downarrow$

$\bar{B}+AB$

$\bar{B}+A$

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

$\Downarrow$

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

$\Downarrow$

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

Ans

(4) NAND gates

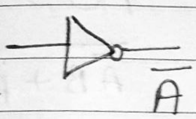
- XNOR

Make XOR and add one NAND gate in the end

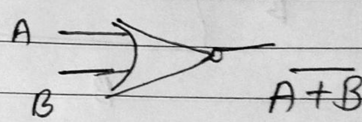
	NAND	NOR
NOT	— 1	1
AND	— 2	3
OR	— 3	2
NAND	— 1	4
NOR	— 4 [3+1]	1
XOR	— 4	5
XNOR	— 4+1 = 5	4

* NOR as universal gate

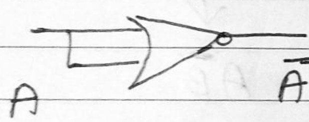
1. NOT gate



NOR gate



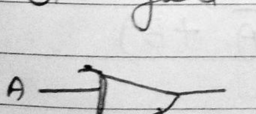
Not gate using NOR



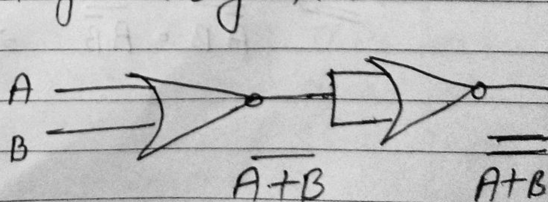
$\overline{A+A} = \bar{A}$ Ans

① NOR gate used

2. OR gate



OR gate using NOR



② NOR used

A+B
Ans

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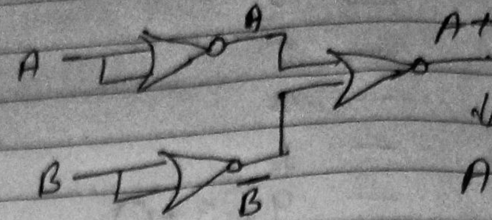
~~AND~~NOR gate

$\overline{A+B}$

$\Downarrow$

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

AND gate using NOR



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

$\Downarrow$

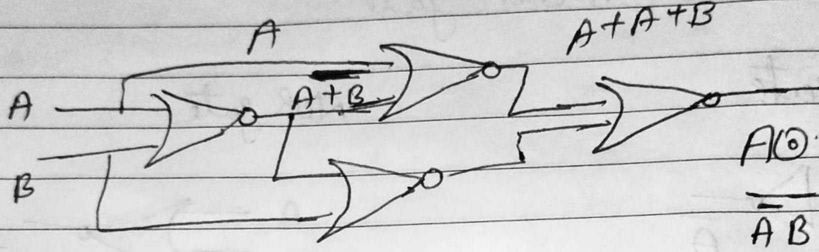
$A\cdot B$

Ans

③ NOR gate used

- XNOR

$A+\overline{A+B} \Rightarrow \bar{A}\cdot(A+B) \rightarrow \bar{A}B$



$A\odot B$

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

$\Downarrow$

$A\odot B$

~~B+~~

$AB+\bar{A}B$

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

$\downarrow$

$A\bar{B}$

④ NOR gate used

XOR		XNOR
$\bar{A}B+A\bar{B}$	$\Rightarrow$	$AB+\bar{A}\bar{B}$

*

$\Downarrow$

Proof

$\overline{\bar{A}B}\cdot\overline{A\bar{B}} \Rightarrow (A+\bar{B})\cdot(\bar{A}+B)$

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

XNOR $\quad\quad\quad\quad$ XOR

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

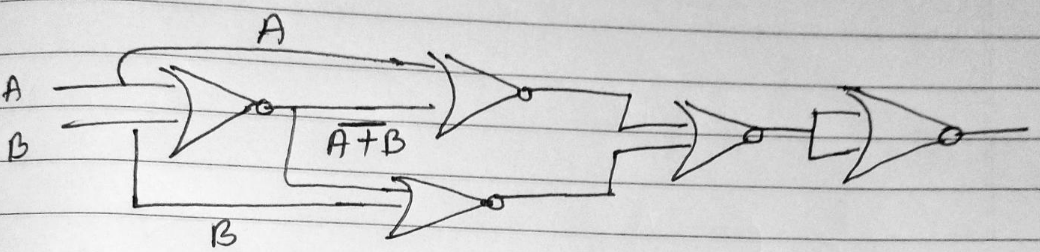
Proof: ↓

$\overline{AB} \cdot \overline{\bar{A}\bar{B}} \Rightarrow (\bar{A}+\bar{B}) \cdot (A+B)$

$\bar{A}B + A\bar{B}$ $\quad$ Ans

* XOR

* Make ~~XNOR~~ ~~XOR~~ XNOR and add "one" NOR in the end



5 NOR gate used

* Principal of duality

$+ \rightarrow \cdot$

$\cdot \rightarrow +$

$1 \rightarrow 0$

$0 \rightarrow 1$

OR → AND
AND → OR

NAND → NOR
NOR → NAND

They are dual of each other

XOR → XNOR
XNOR → XOR

NOR → NOT

Not is self dual

$A + \overline{A} = 1 \longrightarrow$ Tautology

$A \cdot \overline{A} = 0 \longrightarrow$ Tautology

Expression is ~~not~~ tautology iff its dual is tautology