Digital Electronics

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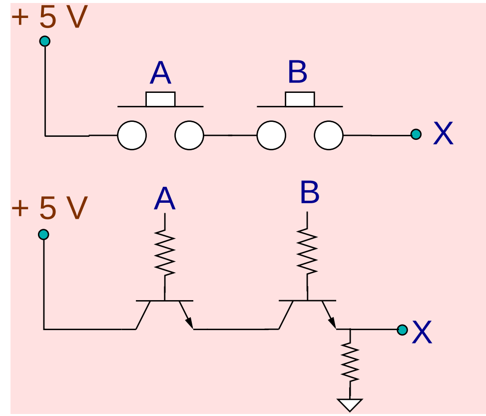
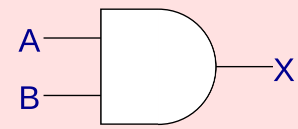
ME 361: Instrumentation & Measurement

AND Gate

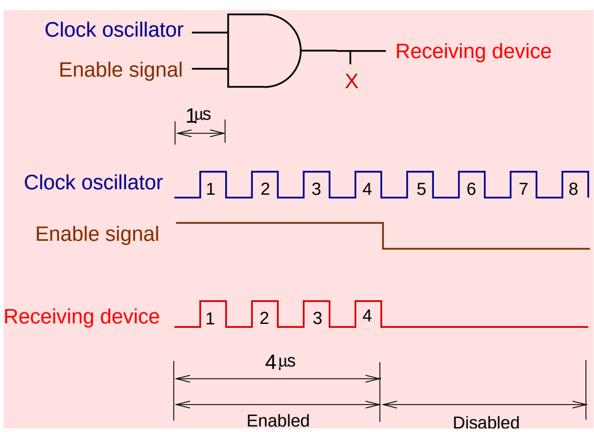




Inputs		Output
A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

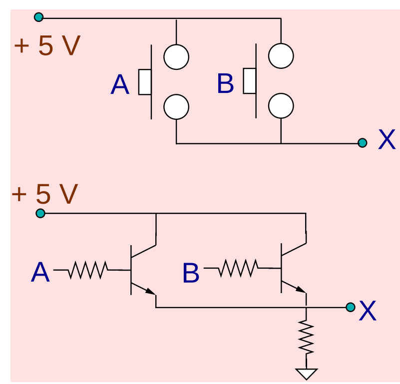
- Output, X, is HIGH only if inputs A and B are both HIGH.
- Boolean Equation: $X = A \text{ AND } B = A \cdot B = AB$

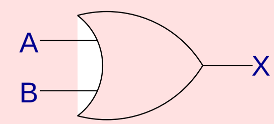
. . . contd.



- AND gate can be used to **enable** a waveform to transmit from one point to another. The LOW value disables the clock from reaching the X-output.

OR Gate

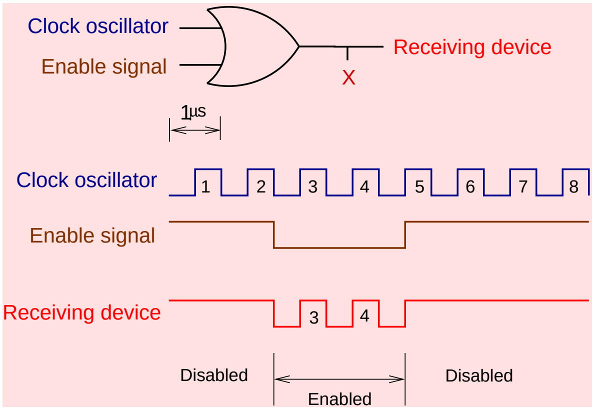




Inputs		Output
A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

- Output, X, is HIGH if input A or input B is HIGH or both are HIGH.
- Boolean Equation: $X = A \text{ OR } B = A + B$

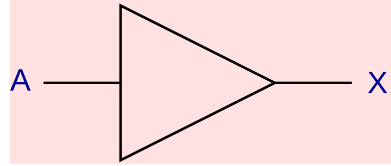
. . . contd.



- OR gate can be used to **disable** a waveform from transmitting from one point to another.

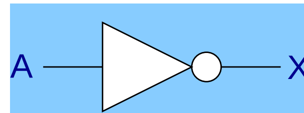
Buffer & Inverter ICs

- **Buffer IC**: Boolean Equation: $X = A$



A	X
0	0
1	1

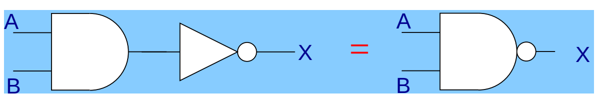
- **Inverter IC**: Boolean Equation: $X = \overline{A}$



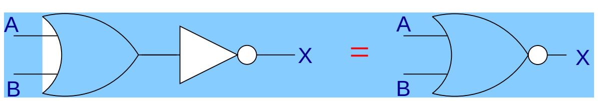
A	X
0	1
1	0

NAND & NOR Gates

- **NAND**: Boolean Equation: $X = \overline{AB}$
- Output is always HIGH unless both inputs are HIGH.



- **NOR**: Boolean Equation: $X = \overline{A + B}$
- Output is always LOW unless both inputs are LOW.



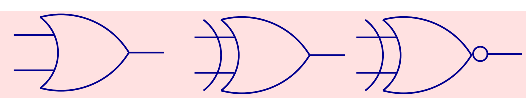
Ex-OR/Ex-NOR Gates

- Exclusive-OR (Ex-OR) gate provides a HIGH output if one input or the other input is HIGH, <u>but not the both</u>.

Ex-OR:	$X = A \oplus B = \overline{A}\ B + A\ \overline{B}$

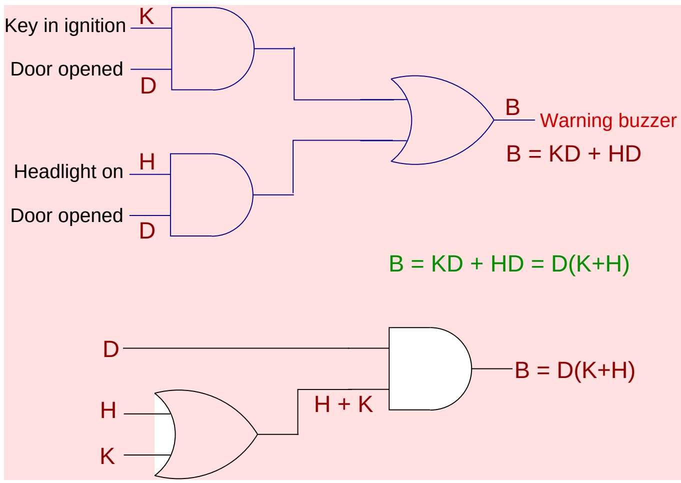
- Ex-NOR is the compliment of the Ex-OR. It provides a HIGH output for both inputs HIGH or both inputs LOW.

Ex-NOR:	$X = \overline{A \oplus B} = AB + \overline{A}\ \overline{B}$



A	B	X(OR)	X(Ex−OR)	X(Ex−NOR)
0	0	0	0	1
0	1	1	1	0
1	0	1	1	0
1	1	1	0	1

Combinational Logic Example



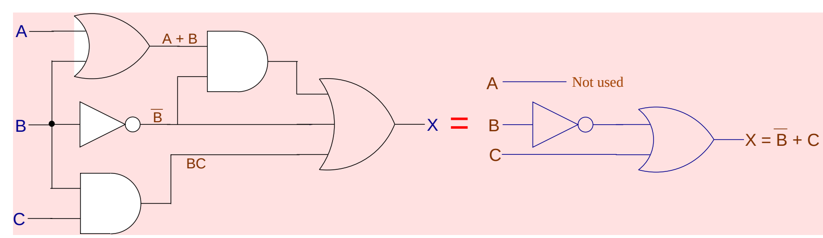
Boolean Algebra Laws

1. Commutative law of addition: $A + B = B + A$, and multiplication: $AB = BA$.
   These laws mean that the order of ORing and ANDing does not matter.
2. Associative law of addition: $A + (B + C) = (A + B) + C$, and multiplication: $A(BC) = (AB)C$.
   These laws mean that the grouping of several variables ORed or ANDed together does not matter.
3. Distributive law: $A(B + C) = AB + BC$, and $(A + B)(C + D) = AC + AD + BC + BD$.
   These laws show methods for expanding and equation containing ORs and ANDs.

Boolean Algebra Rules

1. Anything ANDed with a 0 is equal to 0 ($A \cdot 0 = 0$).
2. Anything ANDed with a 1 is equal itself ($A \cdot 1 = A$).
3. Anything ORed with a 0 is equal itself ($A + 0 = A$).
4. Anything ORed with a 1 is equal to 1 ($A + 1 = 1$).
5. Anything ANDed with itself is equal itself ($A \cdot A = A$).
6. Anything ORed with itself is equal itself ($A + A = A$).
7. Anything ANDed with its own compliment equals 0 ($A \cdot \overline{A} = 0$).
8. Anything ORed with its own compliment equals 1 ($A + \overline{A} = 1$).
9. A variable that is complemented twice will return to its original logic level ($\overline{\overline{A}} = A$) .
10. (a) $A + \overline{A}B = A + B$
    (b) $\overline{A} + AB = \overline{A} + B$

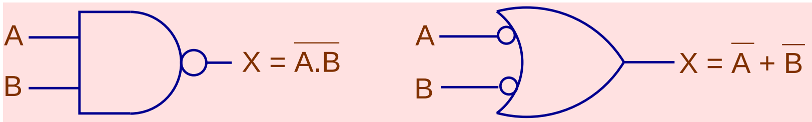
Reduction of Logic Circuits: Example



$$
\begin{aligned}
X &= (A + B)\overline{B} + \overline{B} + BC & \\
&= A\overline{B} + B\overline{B} + \overline{B} + BC & \text{Law 3} \\
&= A\overline{B} + 0 + \overline{B} + BC & \text{Rule 7} \\
&= A\overline{B} + \overline{B} + BC & \text{Rule 3} \\
&= \overline{B}(A + 1) + BC & \text{Factorisation} \\
&= \overline{B} \cdot 1 + BC & \text{Rule 4} \\
&= \overline{B} + BC & \text{Rule 2} \\
&= \overline{B} + C & \text{Rule 10(b)}
\end{aligned}
$$

De Morgan's Theorem 1

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



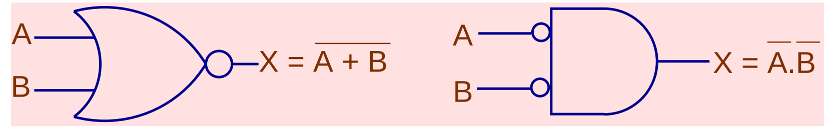
A	B	X = $\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

A	B	X = $\overline{A}$ + $\overline{B}$
0	0	1
0	1	1
1	0	1
1	1	0

Equivalent Result

De Morgan's Theorem 2

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

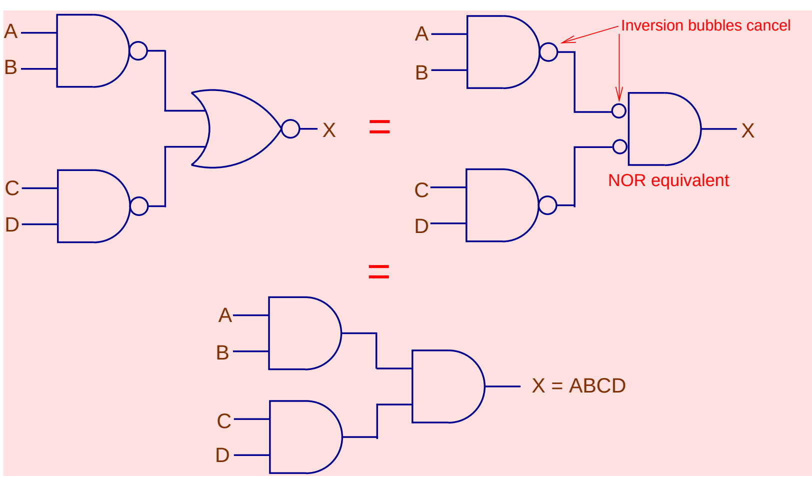


A	B	X = $\overline{A + B}$
0	0	1
0	1	0
1	0	0
1	1	0

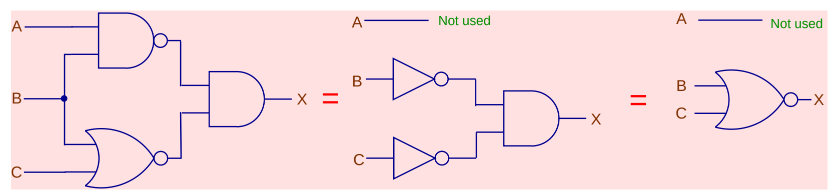
A	B	X = $\overline{A}$.$\overline{B}$
0	0	1
0	1	0
1	0	0
1	1	0

Equivalent Result

De Morgan's Theorem: Application



De Morgan's Theorem: Application



$$\begin{aligned}
X &= \overline{AB} \cdot \overline{B + C} \\
&= (\overline{A} + \overline{B}) \cdot \overline{B}\;\overline{C} && \text{De Morgan's theorem} \\
&= \overline{A}\;\overline{B}\;\overline{C} + \overline{B}\;\overline{B}\;\overline{C} \\
&= \overline{A}\;\overline{B}\;\overline{C} + \overline{B}\;\overline{C} \\
&= \overline{B}\;\overline{C}(\overline{A} + 1) \\
&= \overline{B}\;\overline{C} \\
&= \overline{B + C}
\end{aligned}$$