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Digital Electronics

Thought for the day

You learn from your mistakes.....

So make as many as you can and you will eventually know everything

Digital Electronics

Analog signal: **Signal is constantly changing levels**

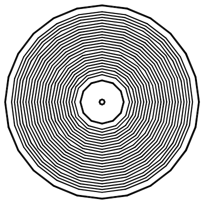
Digital signal: **Signal is either present (1) or not (0)**

Computers

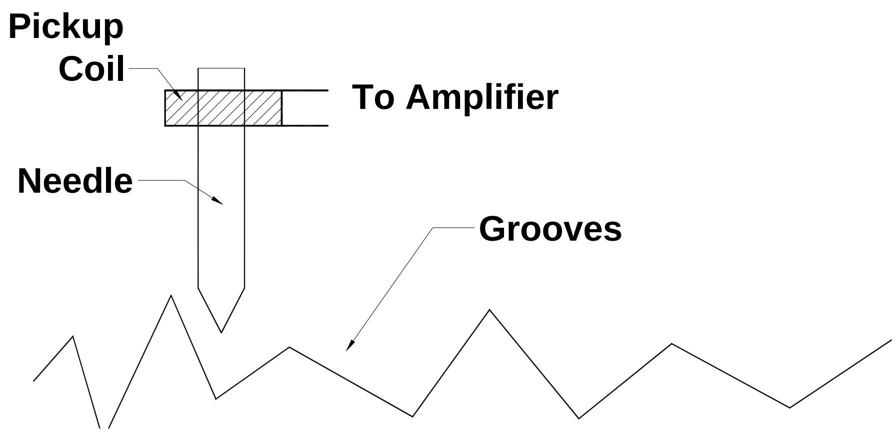
Communications

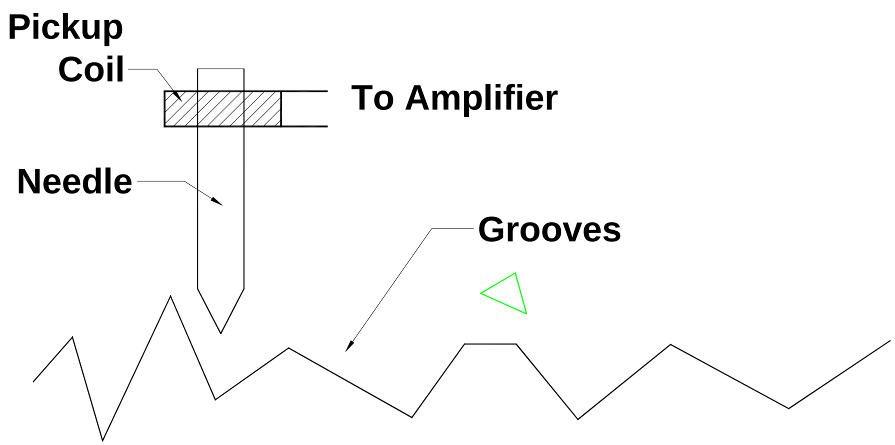
Music

Why Digital?



Phonograph
Record
(1/2 mile of grooves)





Why Digital?

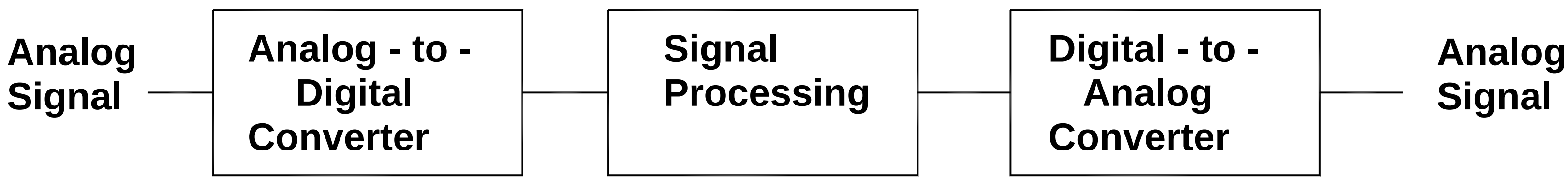
Noise: Clarity of signal

Storage: Real time storage

Programmable: Processing is easier

Precision: Not dependent on component values

Circuit Density: Much higher than analog



Basic Binary Arithmetic

Decimal system	-	Base 10
Binary system	-	Base 2
Octal system	-	Base 8
Hexadecimal System	-	Base 16

Decimal system:

$2745.214 = 2x10^3 + 7x10^2 + 4x10^1 + 5x10^0 + 2x10^{-1} + 1x10^{-2} + 4x10^{-3}$

Binary system:

$1011.101 = 1x2^3 + 0x2^2 + 1x2^1 + 1x2^0 + 1x2^{-1} + 0x2^{-2} + 1x2^{-3}$

$= 8 + 0 + 2 + 1 + 0.5 + 0 + 0.125$

$= 11.625_{10}$

Each of the binary numbers is called a "bit"

Adding binary numbers

$$\begin{array}{r} 1\ 0\ 1\ 0 \\ \underline{0\ 1\ 1\ 1} \\ 1\ 0\ 0\ 0\ 1 \end{array}$$

$1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 0 \times 2^0 = 10$

$0 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 7$

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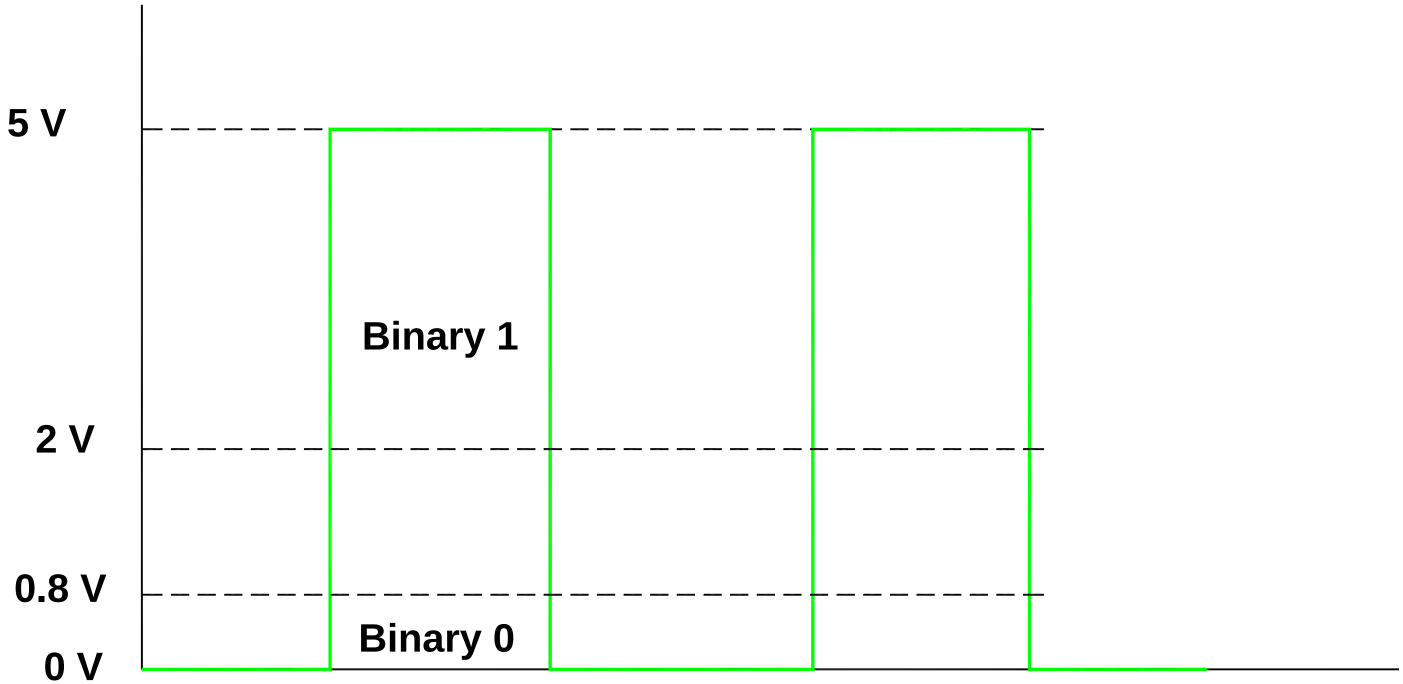
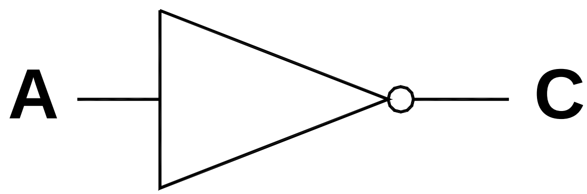
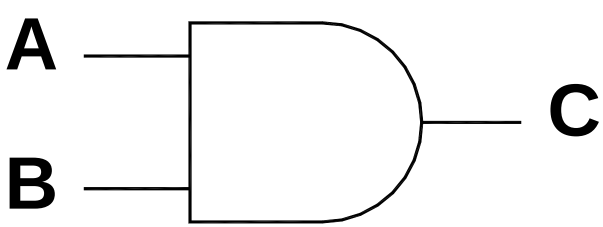
Representation of Binary Signals



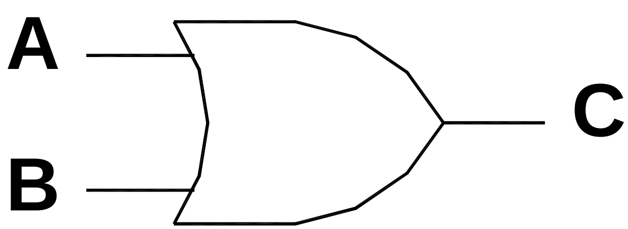
All Logic Circuits can be realized with just three basic building blocks



Inverter



And Gate

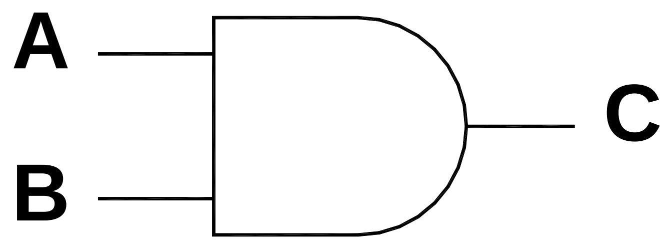


Or Gate

Truth Table

A table that lists all possible outputs for all possible inputs

AND Gate



2^n possible combinations

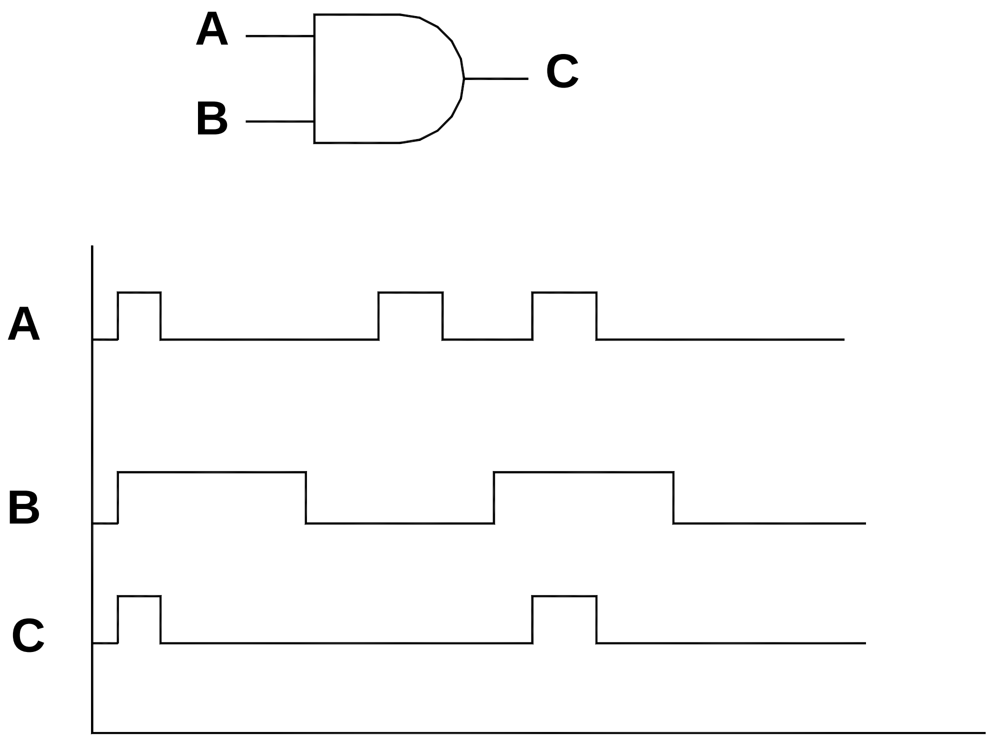
A	B	C
0	0	0
1	0	0
0	1	0
1	1	1

Boolean expression:

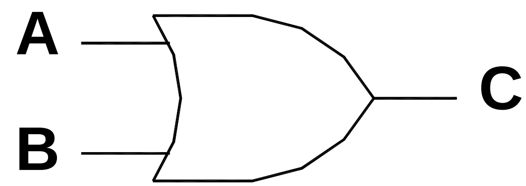
$C = A \bullet B$

“AB”

Operation of AND Gate



OR Gate

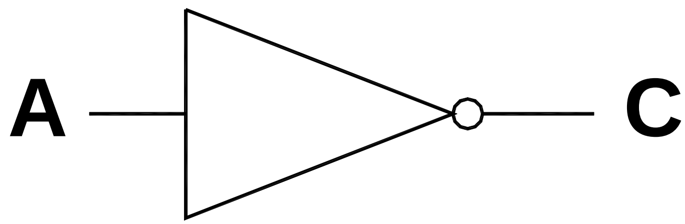


A	B	C
0	0	0
1	0	1
0	1	1
1	1	1

Boolean expression:

C = A + B

Inverter
("Not")

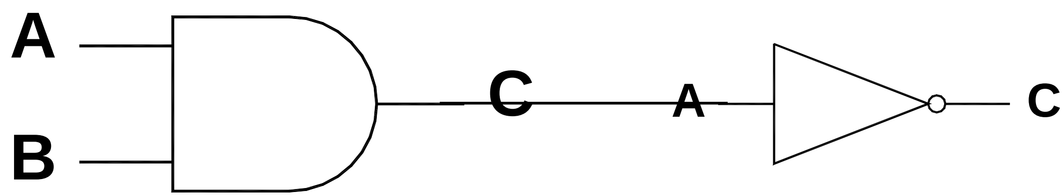


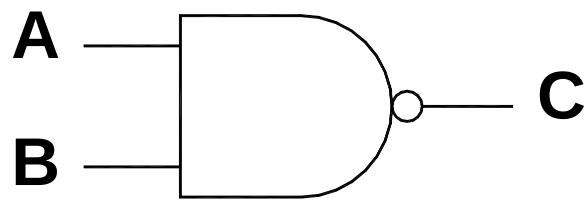
A	C
0	1
1	0

Boolean expression:

$C = \overline{A}$

NAND Gate





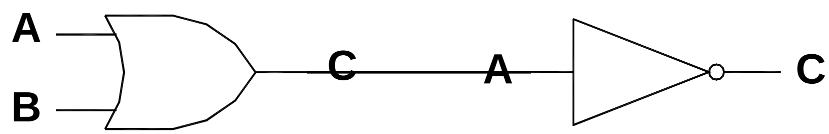
A	B	C
0	0	1
1	0	1
0	1	1
1	1	0

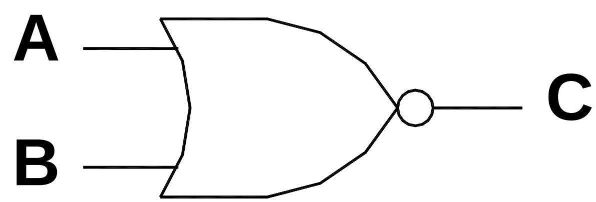
Boolean expression:

$C = \overline{A \bullet B}$

$C = \overline{AB}$

NOR Gate

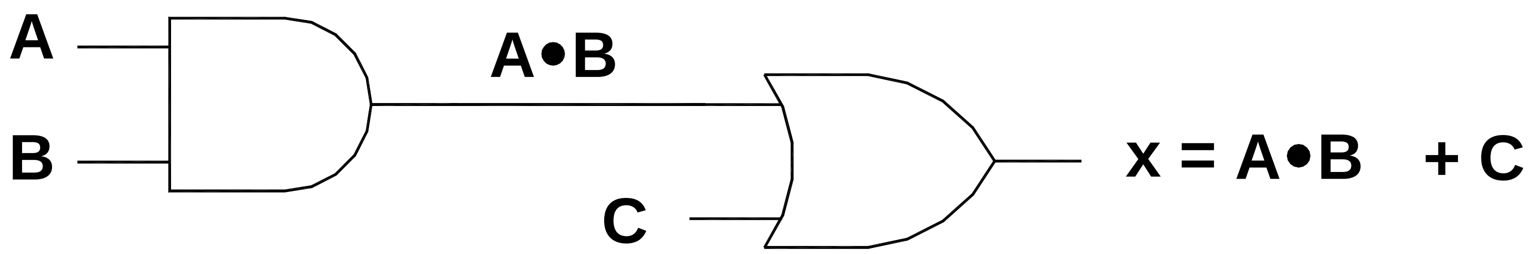




A	B	C
0	0	1
1	0	0
0	1	0
1	1	0

Boolean expression:

$C = \overline{A + B}$



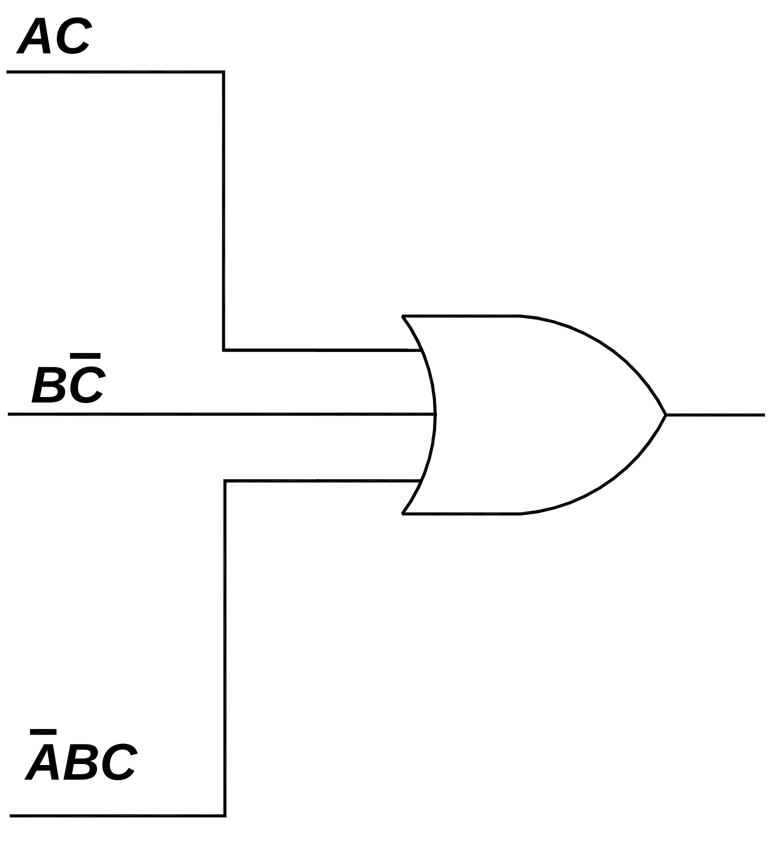
A	B	A•B	C	X = A•B + C
0	0	0	0	0
0	1	0	0	0
1	0	0	0	0
1	1	1	0	1
0	0	0	1	1
0	1	0	1	1
1	0	0	1	1
1	1	1	1	1

To go the other way:

Suppose we want to implement:

$$Y = AC + B\overline{C} + \overline{A}BC$$

Need a three-input OR Gate

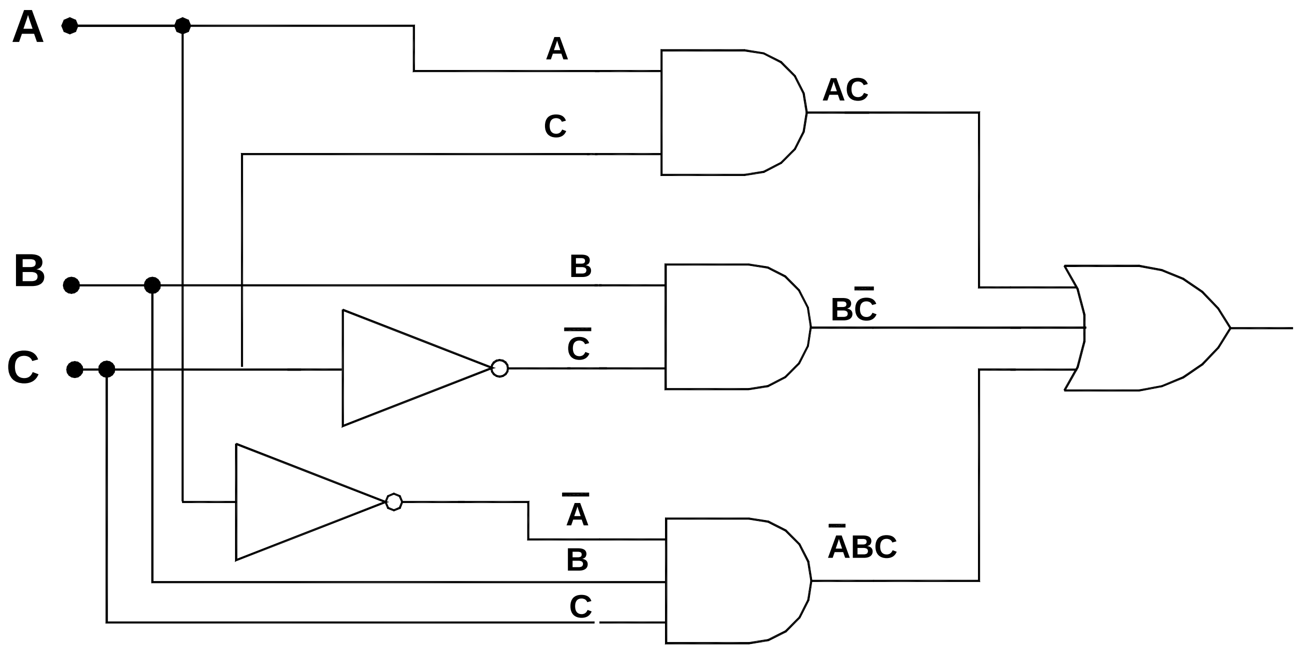


$$Y = AC + B\overline{C} + \overline{A}BC$$

Need two two-input AND Gates

Need one three-input AND Gate

Need two inverters

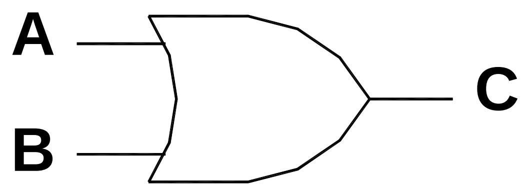


$$Y = AC + B\overline{C} + \overline{A}BC$$

A	*B*	*C*	*A C*	*B $\overline{C}$*	*$\overline{A}$ B C*	*Y*
0	0	0	0	0	0	0
0	0	1	0	0	0	0
0	1	0	0	1	0	1
0	1	1	0	0	1	1
1	0	0	0	0	0	0
1	0	1	1	0	0	1
1	1	0	0	1	0	1
1	1	1	1	0	0	1

Exclusive OR (XOR) Gate

XOR Gate



A	B	C
0	0	0
1	0	1
0	1	1
1	1	0

Boolean expression:

C = A + B

The XOR gate can be used to make a circuit that adds two one - bit binary numbers

0 + 0 = 0 no carry

1 + 0 = 1 no carry

1 + 1 = 0 1 carry

Adding binary numbers

$$
\begin{array}{r}
1\,0\,1\,0 \\
\underline{0\,1\,1\,1} \\
1\,0\,0\,0\,1
\end{array}
$$

$1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 0 \times 2^0 = 10$

$0 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 7$

Boolean Algebra Theorems

Single variable

$x \bullet 0 = 0$

$x \bullet 1 = x$

$x \bullet x = x$

$x \bullet \overline{x} = 0$

$x + 0 = x$

$x + 1 = 1$

$x + x = x$

$x + \overline{x} = 1$

Multiple variables

$x + y = y + x$

$x \bullet y = y \bullet x$

$x + (y + z) = (x + y) + z = x + y + z$

$x (yz) = (xy)z = xyz$

$x(y + z) = xy + xz$

$(w + x)(y + z) = wy + xy + wz + xz$

$x + xy = x$

$x + \overline{x}y = x + y$

Example:

Simplify

$$Y = A\overline{B}D + A\overline{B}\,\overline{D}$$

Factor out $A\overline{B}$

$$Y = A\overline{B}(D + \overline{D})$$

$$D + \overline{D} = 1$$

$$Y = A\overline{B}D + A\overline{B}\,\overline{D} = A\overline{B}$$

DeMorgan's Theorems

$$\overline{(x + y)} = \overline{x} \bullet \overline{y}$$

$$\overline{(x \bullet y)} = \overline{x} + \overline{y}$$

Example: Simplify

$$z = \overline{(\overline{A} + C) + (B + \overline{D})}$$

$$z = (\overline{\overline{A}} \bullet \overline{C}) + (\overline{B} \bullet \overline{\overline{D}})$$

$$\overline{\overline{A}} = A, \quad \overline{\overline{D}} = D$$

$$z = A\overline{C} + \overline{B}D$$