Intro to Computer Science and Software Engineering

Gates and Circuits

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Computer and computation

A electronic computer is a tool that can carry out the computation we have discussed.

- the processor unit or chip

Binary (base 2)

One bit addition

A			0
B	+		0
		0	0
		carry	sum

A			
B	+		
		carry	sum

A			
B	+		
		carry	sum

A			
B	+		
		carry	sum

Arithmetic operations

- **Addition**
- Subtraction
- Multiplication
- division

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B	+		0
		0	0

		0
+		1
	0	1

A			1
B	+		0
		0	1
		carry	sum

		1
+		1
	1	0
	carry	sum

Arithmetic operations

- **Addition**
- Subtraction
- Multiplication
- division

How addition of Binary system can be implemented by electronic units?

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Binary (base 2)

Boolean algebra

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- division

Operations:
NOT
AND
OR
XOR
NAND
NOR

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Arithmetic operations

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Boolean algebra

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NOR

How addition of Binary system can be implemented by Boolean Algebra?

Computer and computation

"A + B" expression, A and B are variables

A + B

A and B are decimal integers in [0,9]

+: addition

A ● B

A and B can be true (1) or false (0)

● : AND

Algebra

A + B

A and B are binaries in [0,1]

+: addition

Boolean algebra

Three different, but equally powerful ways

- Boolean expressions
- Logic diagrams (Gates and Circuits)
- Truth tables

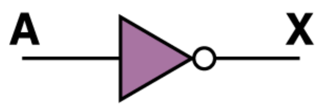
Gates

NOT

Boolean Expression

$X = A'$

Logic Diagram Symbol



Truth Table

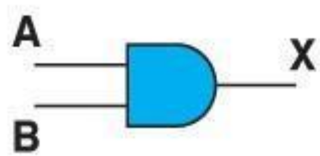
A	X
0	1
1	0

AND

Boolean Expression

$X = A \cdot B$

Logic Diagram Symbol



Truth Table

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

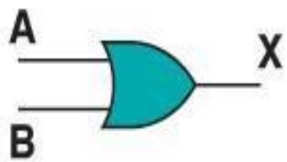
Gates

OR

Boolean Expression

$X = A + B$

Logic Diagram Symbol



Truth Table

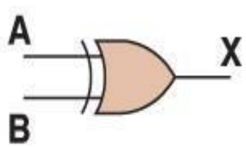
A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

XOR

Boolean Expression

$X = A \oplus B$

Logic Diagram Symbol



Truth Table

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

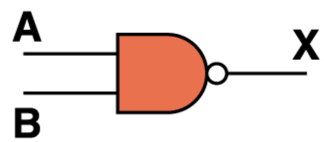
Gates

NAND

Boolean Expression

$X = (A \cdot B)'$

Logic Diagram Symbol



Truth Table

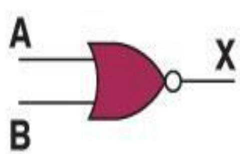
A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

NOR

Boolean Expression

$X = (A + B)'$

Logic Diagram Symbol



Truth Table

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

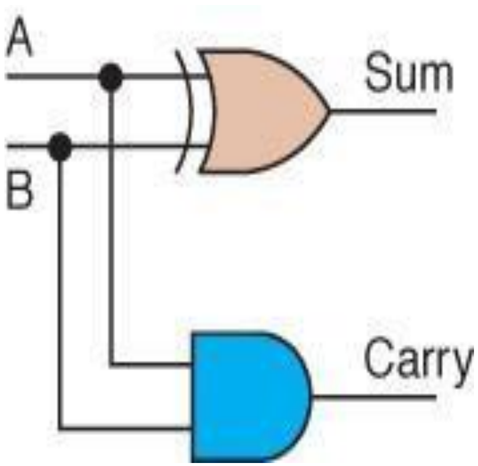
Boolean algebra

Boolean expression

sum $= A \oplus B$

Carry $= A \bullet B$

Logical diagram



Truth table

		sum	carry
A	B	$A \oplus B$	$A \bullet B$
0	0		
0	1		
1	0		
1	1		

Boolean algebra

Binary (base 2)

Truth table

One bits addition

		0
+		0
	0	0

		0	A
+		1	B
	0	1	

		1
+		0
	0	1

carry sum

		1	A
+		1	B
	1	0	

carry sum

		sum	carry
A	B	$A \oplus B$	$A \bullet B$
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Boolean algebra

Binary (base 2)

One bits addition

		0	A
+		0	B
	0	0	

		0	A
+		1	B
	0	1	

		1	A
+		0	B
	0	1	

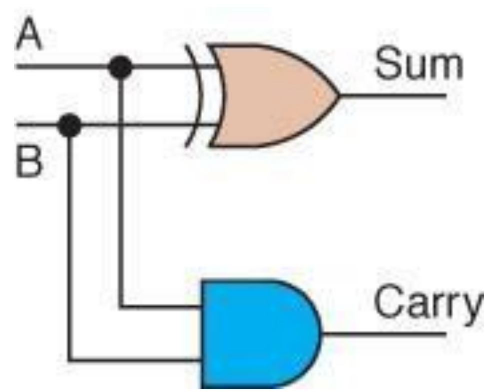
carry sum

		1	A
+		1	B
	1	0	

carry sum

$$\text{sum} = A \oplus B$$

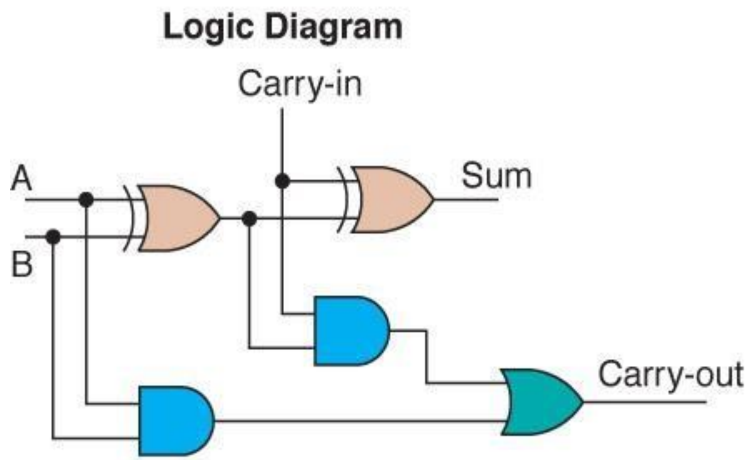
$$\text{Carry} = A \bullet B$$



Half Adder
(two gates)

Boolean algebra

Full Adder (five gates)



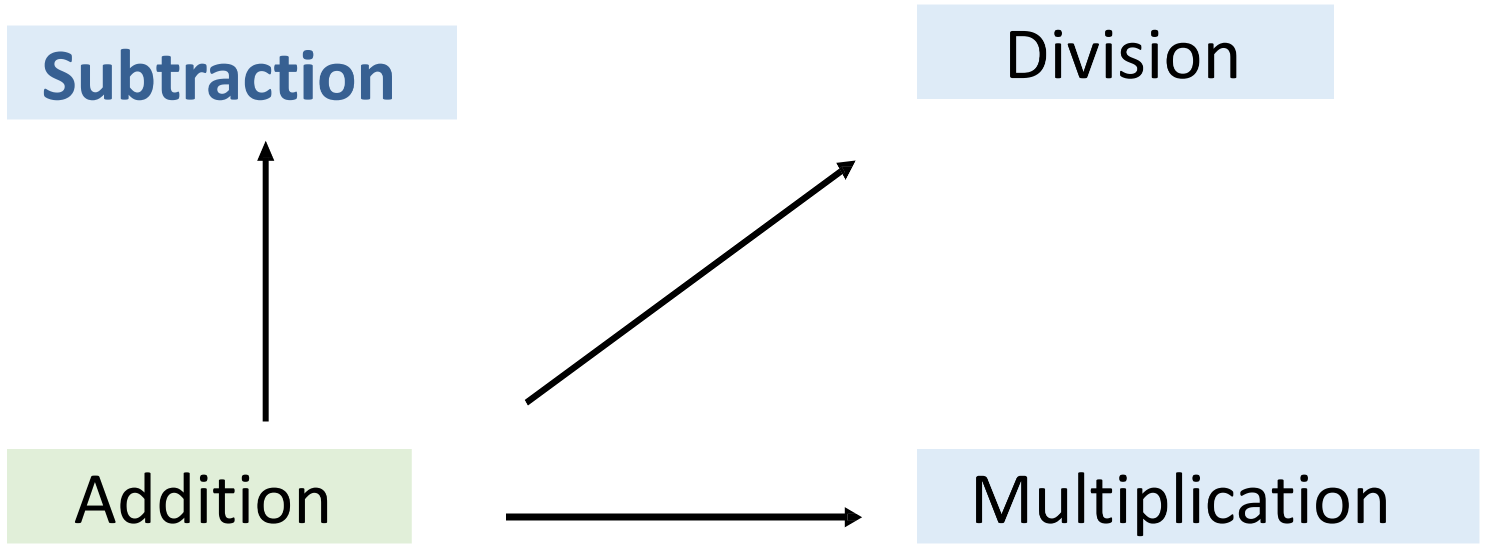
Truth Table

A	B	Carry-in	Sum	Carry-out
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

A circuit is a combination of integrated gates.

- More gates for two-bit addition
- Chips (Integrated Circuits) use many gates
  - Very-Large-Scale Integration (VLSI): more than 100, 000

Computer and computation



How about a circuit can add two 64-bit binary numbers?

- 64-bit chip

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Binary (base 2)

Boolean algebra

Gates and Circuits using transistors

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- **Subtraction**
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- **division**

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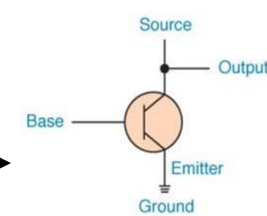

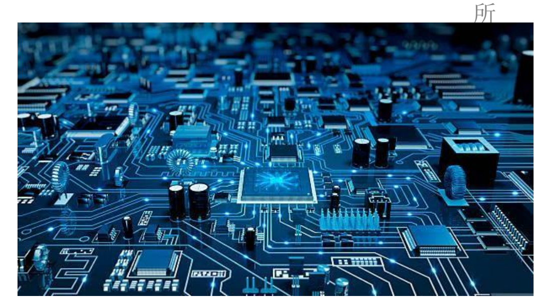

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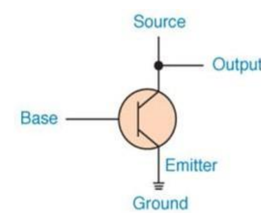
Binary
(base 2)

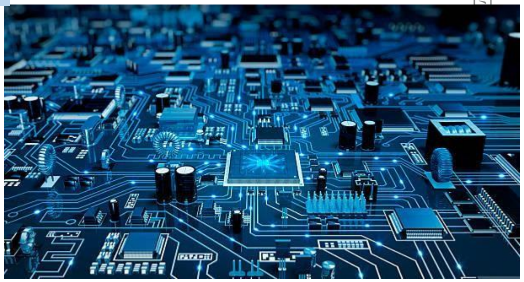
Boolean
algebra

Gates and Circuits
using transistors



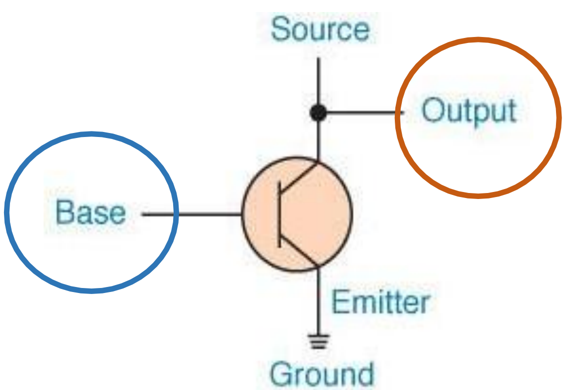
How Boolean Algebra can be implemented by electronic units?

所有图



Constructing gates using transistors

High
voltage



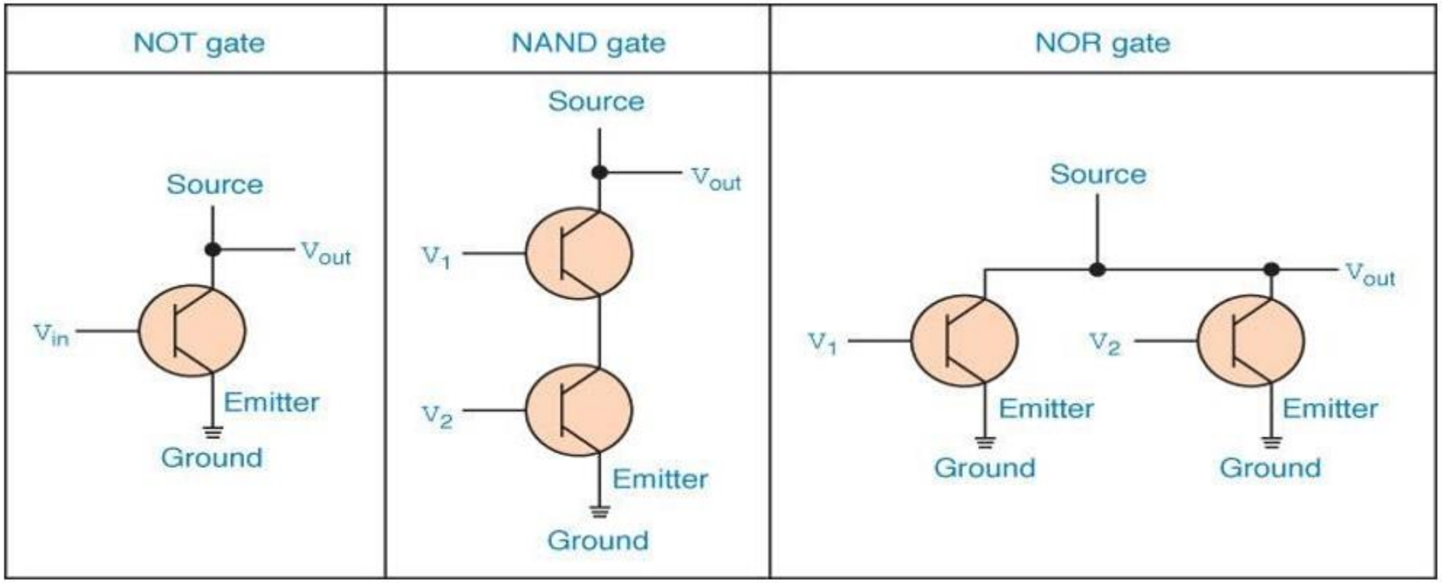
0 voltage

- A transistor has three terminals
  - A source
  - A base (input)
  - An emitter, typically connected to a ground wire

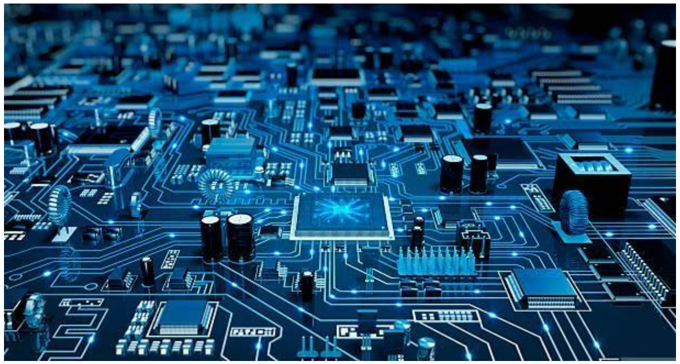
Base	Output
High 1	Low 0
Low 0	High 1

It is made of semiconductor material, usually silicon.

Constructing gates using transistors



Integrated Circuits (IC)



CPU chips

Abbreviation	Name	Number of Gates
SSI	Small-Scale Integration	1 to 10
MSI	Medium-Scale Integration	10 to 100
LSI	Large-Scale Integration	100 to 100,000
VLSI	Very-Large-Scale Integration	more than 100,000

所有图片均来自网络

More about transistors

https://baike.baidu.com/item/%E6%99%B6%E4%BD%93%E7%AE%A1/569042?fr=aladdin#13

https://www.bilibili.com/video/av65427291/

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