IxD Theory 2: Telecomunicazioni

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Visual and Multimedia Communication graduate programme

Computation

Why do we need to know?

It’s our ‘medium’ as designers

It’s shaping our world

It’s amazing

Key concepts

1 Digital

2 Code

DIGITAL

To do with discrete amounts (from digit, digitus—counting on fingers—discrete counting).

Contrast with analog (a continuous spectrum).

Computers work by controlling the **flow** of electricity.

Computers use electrical voltages to represent binary numbers (base 2 numbers)

no voltage = 0 voltage = 1

Binary numbers

decimal	*binary*
1 =	1
2 =	1 0
3 =	1 1
4 =	1 0 0
5 =	1 0 1
6 =	1 1 0
7 =	1 1 1
8 =	1 0 0 0
9 =	1 0 0 1
10 =	1 0 1 0
? =	1 1 1 1

Binary numbers

decimal	*binary*	*4-bit code*
1 =	1	
2 =	1 0	
3 =	1 1	
4 =	1 0 0	
5 =	1 0 1	
6 =	1 1 0	
7 =	1 1 1	
8 =	1 0 0 0	
9 =	1 0 0 1	
10 =	1 0 1 0	
? =	1 1 1 1	

Binary numbers

decimal	*binary*	*4-bit code*
1 =	1	0001
2 =	1 0	0010
3 =	1 1	0011
4 =	1 0 0	0100
5 =	1 0 1	0101
6 =	1 1 0	0110
7 =	1 1 1	0111
8 =	1 0 0 0	1000
9 =	1 0 0 1	1001
10 =	1 0 1 0	1010
? =	1 1 1 1	1111

Binary numbers

1 bit of information is the smallest possible unit of information. It has two states: on or off.

Computers use 1 bit of information to represent each binary digit (measuring a voltage on or off).

Binary numbers

1 bit of information is the smallest possible unit of information. It has two states: on or off.

Computers use 1 bit of information to represent each binary digit (measuring a voltage on or off).

A **byte** is 8 bits.

It can represent numbers from 0 to 255.

Binary numbers

decimal		*binary*	*8-bit code*
15	=	1 1 1 1	0000 1111
255	=		1111 1111

Binary numbers: a byte

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
1	**1**	**1**	**1**	**1**	**1**	**1**	**1**

128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255

Binary numbers: a byte

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
128	64	32	16	8	4	2	1	
1	**0**	**1**	**0**	**1**	**0**	**1**	**0**	= ?

Binary numbers: a byte

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1
1	**0**	**1**	**0**	**1**	**0**	**1**	**0**

$128 + 0 + 32 + 0 + 8 + 0 + 2 + 0 = 170$

Binary numbers: a byte

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
128	64	32	16	8	4	2	1	
0	**0**	**0**	**0**	**0**	**1**	**1**	**1**	= ?

Binary numbers: a byte

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
128	64	32	16	8	4	2	1	
0	**0**	**0**	**0**	**0**	**1**	**1**	**1**	
0	0	0	0	0	4	+ 2 + 1		= 7

Adding decimal numbers

1 3

1 9

———

2 carry 1

Adding decimal numbers

1 3

1 9

———

2 carry **1**

Adding decimal numbers

1 3

1 9

---

2 2

1

3 2

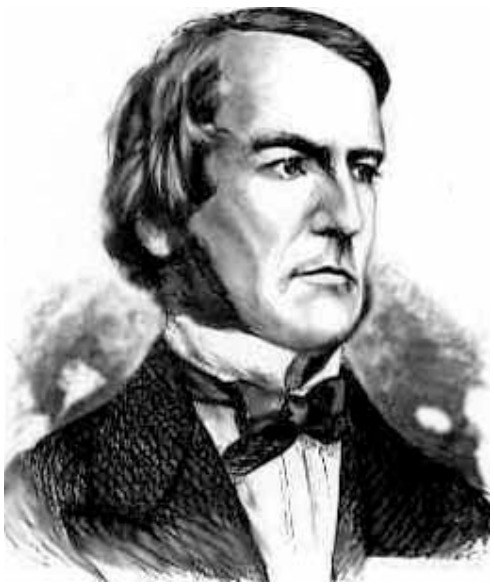
Adding binary numbers

A		*B*		*carry*	
0	+	0 = 0		0	
0	+	1 = 1		0	
1	+	0 = 1		0	
1	+	1 = 0		1	= 10 (binary)

Boolean logic

George Boole (1815–64)

His aim: to make an algebra of logical thought



Boolean logic

Truth table for **AND**

AND	**F**	**T**
F	F	F
T	F	T

B

A

Take two inputs: proposition A **AND** proposition B.

The table shows the different permutations according to the truth of A and B.

Boolean logic

Is this true?:

(A) Phil is a woman **AND** (B) Phil is bald?

Boolean logic

Is it true that both

(A) Phil is a woman **AND** (B) Phil is bald?

False **AND** False = ?

Boolean logic

Is this true?:

(A) Phil is a woman **AND** (B) Phil is bald?

False **AND** False = False

Boolean logic

Is it true that both

AND	F	T
F	F	F
T	F	T

B

A

(A) Phil is a woman **AND** (B) Phil is bald ?

False **AND** False = False

Boolean logic

Is it true that both

AND	F	T
F	F	F
T	F	T

B

A

(A) Phil is a woman **AND** (B) Phil is bald ?

False **AND** False = False

Boolean logic

Is this true?:

(A) Phil is a man **AND** (B) Phil has hair?

Boolean logic

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Boolean logic

Is this true?:

AND	F	T
F	F	F
T	F	T

B

A

(A) Phil is a man **AND** (B) Phil has hair?

True **AND** True = True

Boolean logic

(A) Phil is a woman **AND** (B) Phil is bald

False **AND** False = False

(A) Phil is a woman **AND** (B) Phil has hair

False **AND** True = False

(A) Phil is a man **AND** (B) Phil is bald

True **AND** False = False

(A) Phil is a man **AND** (B) Phil has hair

True **AND** True = True

Boolean logic

AND	F	T
F	F	F
T	F	T

B

A

(A) Phil is a woman **AND** (B) Phil is bald

False **AND** False = False

(A) Phil is a woman **AND** (B) Phil has hair

False **AND** True = False

(A) Phil is a man **AND** (B) Phil is bald

True **AND** False = False

(A) Phil is a man **AND** (B) Phil has hair

True **AND** True = True

Boolean logic: OR

Is it true that

AND	F	T
F	F	F
T	F	T

B

A

(A) Phil is a man **AND** (B) Phil is bald

True **AND** False = False

OR	F	T
F	F	T
T	T	T

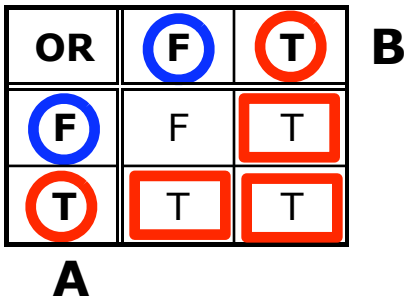
B

A

(A) Phil is a man **OR** (B) Phil is bald

True **OR** False = True

Boolean logic: OR



(A) Phil is a woman **OR** (B) Phil is bald

False **OR** False = False

(A) Phil is a woman **OR** (B) Phil has hair

False **OR** True = True

(A) Phil is a man **OR** (B) Phil is bald

True **OR** False = True

(A) Phil is a man **OR** (B) Phil has hair

True **OR** True = True

Boolean logic: OR is inverse of AND

(A) Phil is a woman **OR** (B) Phil is bald = False

(A) Phil is a man **OR** (B) Phil has hair = True

(A) Phil is a woman **OR** (B) Phil has hair = True

(A) Phil is a man **OR** (B) Phil is bald = True

(A) Phil is a woman **AND** (B) Phil is bald = False

(A) Phil is a man **AND** (B) Phil has hair = True

(A) Phil is a woman **AND** (B) Phil has hair = False

(A) Phil is a man **AND** (B) Phil is bald = False

Boolean logic

Truth tables

AND	F	T
F	F	F
T	F	T

OR	F	T
F	F	T
T	T	T

XOR	F	T
F	F	T
T	T	F

NOT	
F	T
T	F

Boolean logic

Truth tables

AND	F	T
F	F	F
T	F	T

OR	F	T
F	F	T
T	T	T

XOR	F	T
F	F	T
T	T	F

NOT	
F	T
T	F

XOR: Is (A) true or (B) true, but not both?

(A) Phil is a man **XOR** (B) Phil has hair

True **XOR** True = False

Boolean logic

What has Boolean logic to do with computers?

Boolean logic

Truth tables: false = 0, true = 1

AND	F	T
F	F	F
T	F	T

OR	F	T
F	F	T
T	T	T

XOR	F	T
F	F	T
T	T	F

NOT	
F	T
T	F

Boolean logic

Truth tables: false = 0, true = 1

AND	F	T
F	F	F
T	F	T

OR	F	T
F	F	T
T	T	T

XOR	F	T
F	F	T
T	T	F

NOT	
F	T
T	F

AND	0	1
0	0	0
1	0	1

OR	0	1
0	0	1
1	1	1

XOR	0	1
0	0	1
1	1	0

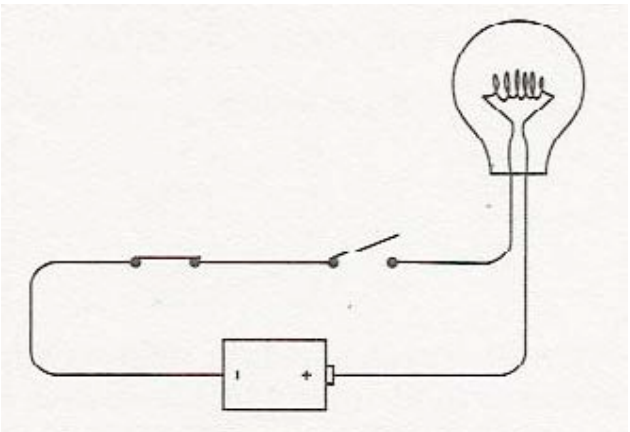
NOT	
0	1
1	0

Boolean logic

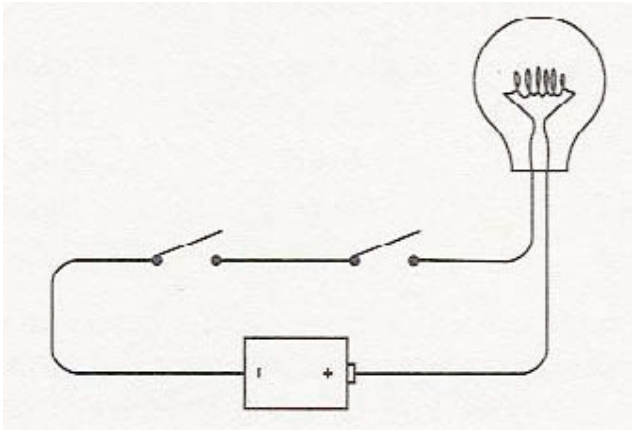
The next step is to do this physically, with electricity.

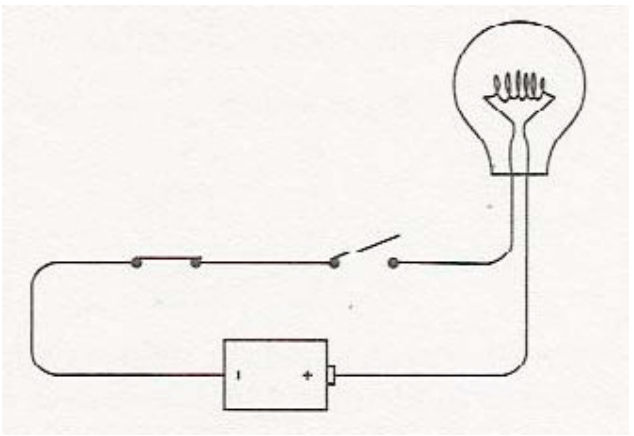
Boolean logic with electricity

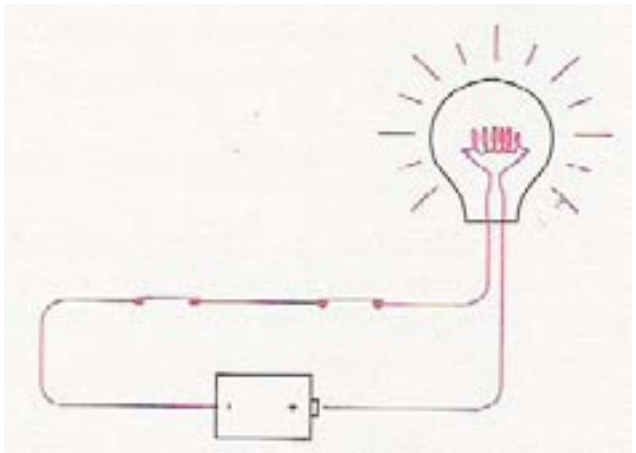
The principle is this (in a computer there are microscopic switches in the silicon of a chip):



Boolean logic with electricity







AND 0 0 = **0**
1 0 = **0**
0 1 = **0**
1 1 = **1**

(from Charles Petzold: *Codice: il linguaggio segreto dei computer*)

Adding binary numbers—remember?

A		*B*		*carry*	
0	+	0	= 0	0	
0	+	1	= 1	0	
1	+	0	= 1	0	
1	+	1	= 0	1	= 10 (binary)

Truth tables meet binary arithmetic

A	B	sum	carry
0 + 0 = 0		**0**	**0**
0 + 1 = 1		**1**	**0**
0 + 1 = 1		**1**	**0**
1 + 1= 10		**0**	**1**

Truth tables meet binary arithmetic

A	B	sum	carry
0	0 = 0	**0**	**0**
0	1 = 1	**1**	**0**
0	1 = 1	**1**	**0**
1	1= 10	**0**	**1**

XOR

0 0 = **0**
1 0 = **1**
0 1 = **1**
1 1 = **0**

AND

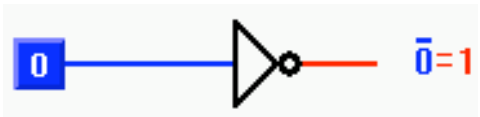
0 0 = **0**
1 0 = **0**
0 1 = **0**
1 1 = **1**

Electronic notation

AND gate

OR gate

NOT (inverter)



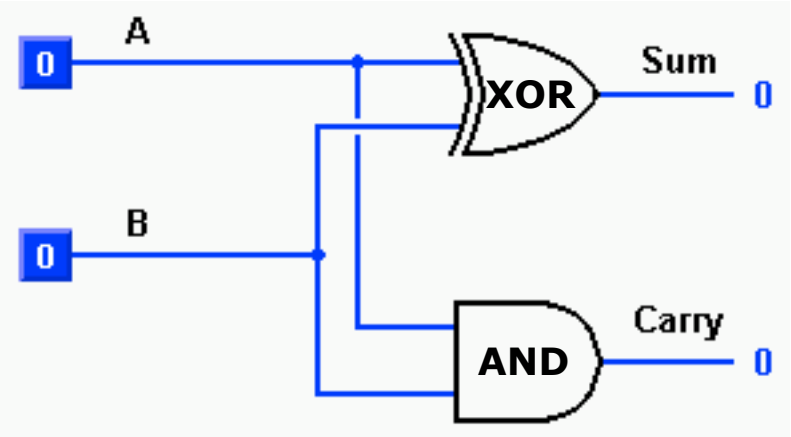
XOR gate

Binary logic: adder

XOR gate

+

AND gate



A *B* *carry*

0 + 0 = 0 **0**

Boolean logic

Truth tables: false = 0, true = 1

AND	F	T
F	F	F
T	F	T

XOR	F	T
F	F	T
T	T	F

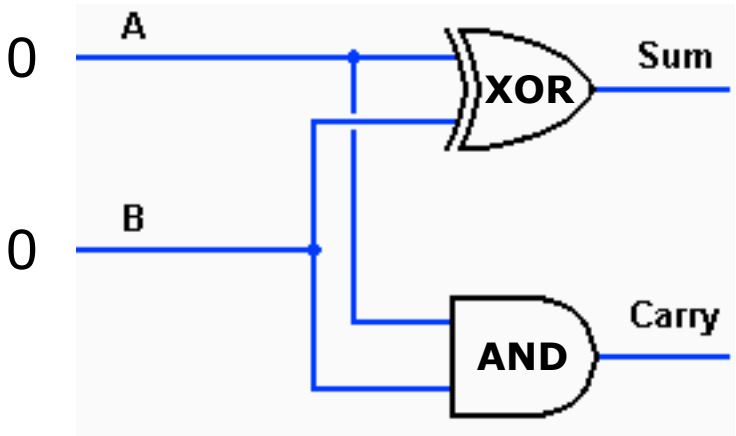
AND	0	1
0	0	0
1	0	1

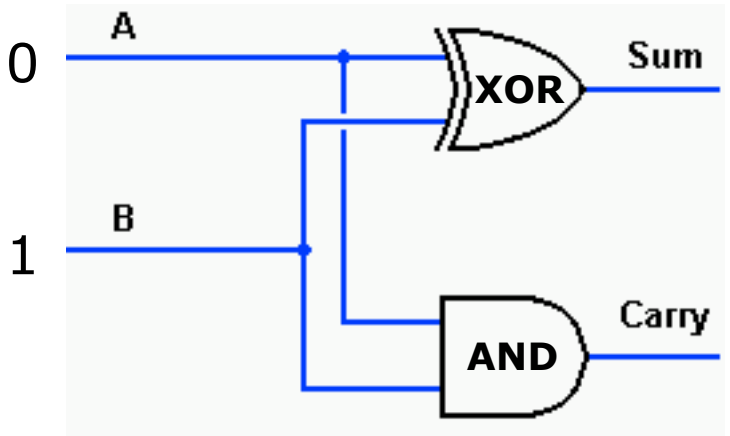
XOR	0	1
0	0	1
1	1	0

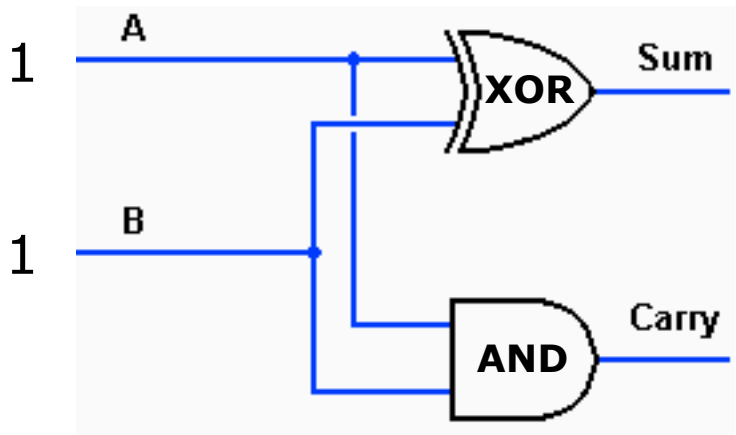
EXERCISE!

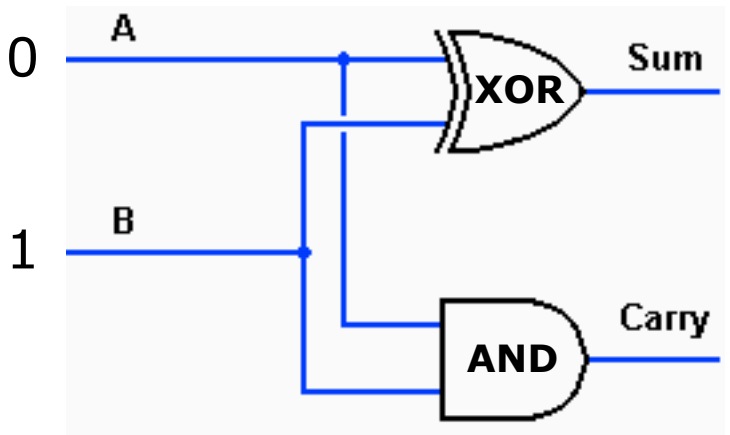
Write down the AND and the XOR truth tables

Binary logic: adder









Adding a byte

When we add two bytes we need to be able to carry over a digit to the next column:

128	64	32	16	8	4	2	1	
0	**0**	**0**	**0**	**1**	**0**	**1**	**1**	**+**
1	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**=**
1	**0**	**1**	**1**	**0**	**1**	**0**	**0**	
			1			**1**	**1**	

Adding a byte

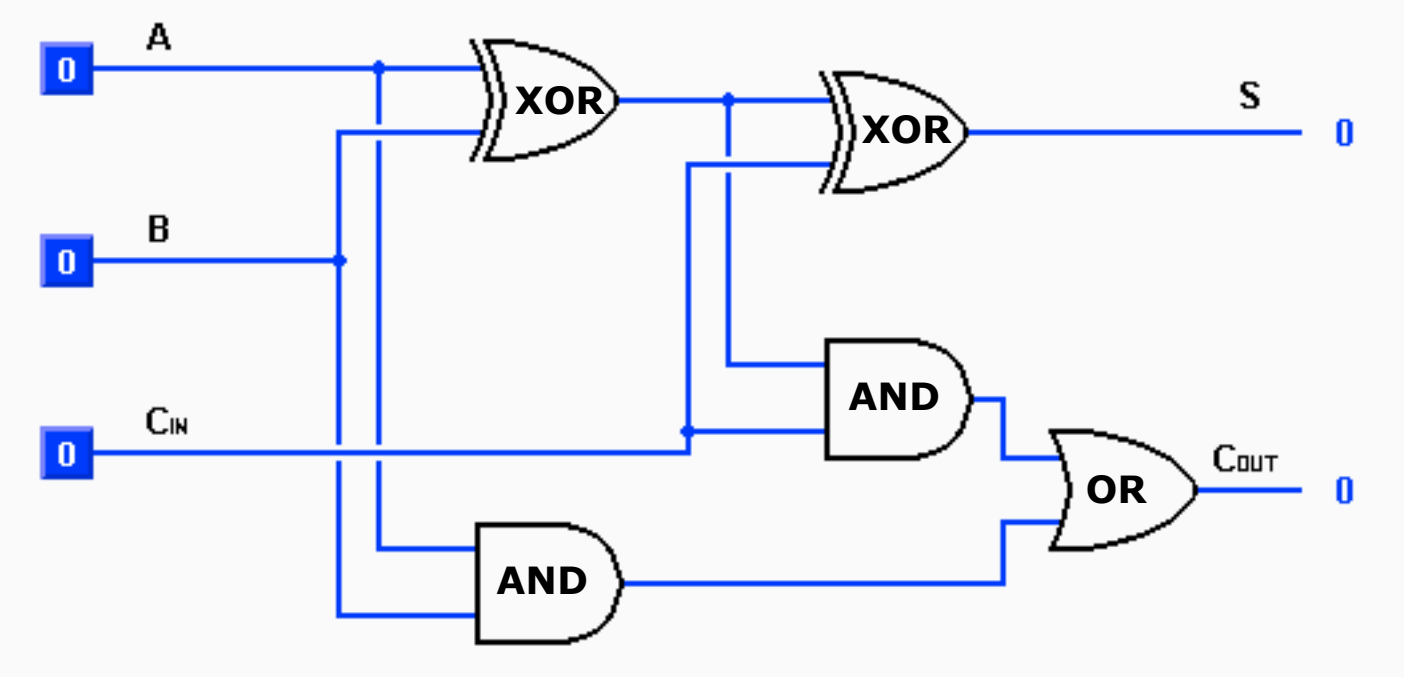
When we add a byte we need to be able to carry over a digit to the next column:

128	64	32	16	8	4	2	1		
0	**0**	**0**	**0**	**1**	**0**	**1**	**1**	**+**	**A**
1	**0**	**1**	**0**	**1**	**0**	**0**	**1**	**=**	**B**
1	**0**	**1**	**1**	**0**	**1**	**0**	**0**		
			1			**1**	**1**		**C**

In order to add numbers more than 0 or 1 we need a circuit that will take in three inputs: (A) (B) and (C), the carry from the previous column.

Electronic notation: full adder

Three inputs: number (A), number (B) and a carry from the previous addition



http://www.play-hookey.com/digital/basic_gates.html

DIGITAL: summary

- Computers use binary numbers
- To add numbers they use electronic circuits to represent Boolean logic
- More complicated circuits allow addition of 8-, 32- and 64-bit numbers as well as multiplication, subtraction and division
- These tiny elements are combined into the very complex systems we use today