Representation

- Data & instructions
- Numeric data
  - Integer
  - Real value
- Integer arithmetic
  - Unsigned
  - Signed
    - Sign-magnitude
    - 1's complement
    - 2's complement

$n = 4$

Hamacher 2.1 Decimal values 5, −2, 14, −10, 26, −19, 51 and −43

→ Signed 7-bit numbers

- Sign-magnitude
- 1's complement
- 2's complement.

	Sign-Magnitude	1's Complement	2's complement
5	0000101	0000101	0000101
−2	1000010	1111101	1111110
14			
−10			

1111101 + 1 = 1111110

26

-19

51

-43

Electronic logic gates

2 logic levels: 0 1

0V 5V Supply voltage.

3.3

2.3

1.8

1.1

0.5

Power consumption $\propto$ Square of supply voltage.

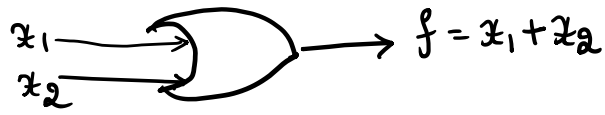
- Power consumption ↓
  → Smaller transistor → Length of transistor ↓

  ⇒ Pack more components on a given area

- Hand-held devices, sensors.

- Transistors → Logic gates

OR gate

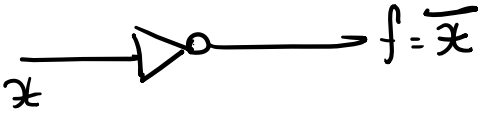


x_1	x_2	$f = x_1 + x_2$
0	0	0
0	1	1
1	0	1
1	1	1

AND

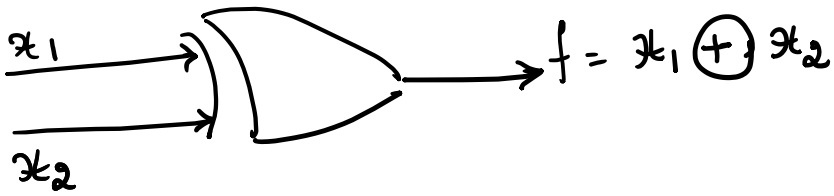
x_1	x_2	$f = x_1 . x_2$
0	0	0
0	1	0
1	0	0
1	1	1

NOT gate



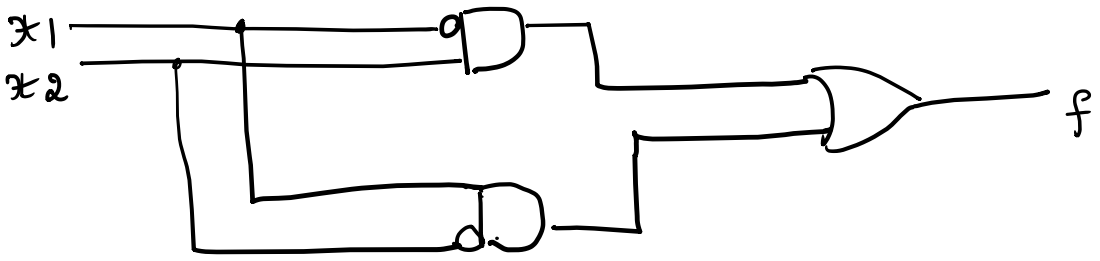
x	$f = \bar{x}$
0	1
1	0

XOR gate



x_1	x_2	$f = x_1 \oplus x_2$
0	0	0
0	1	1
1	0	1
1	1	0

Synthesize — logic functions



x_1	x_2	$\overline{x_1} \cdot x_2$	$x_1 \cdot \overline{x_2}$	$f =$
0	0	0	0	0
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

XOR

$$f = \overline{x_1} \cdot x_2 + x_1 \cdot \overline{x_2}$$ SoP

DESIGN OF ADDERS

Unsigned Addition

$$\begin{array}{r} X \\ +\ Y \\ \hline Z \\ \hline \end{array}$$

$$\begin{array}{r} 7 \\ +\ 6 \\ \hline 13 \\ \hline \end{array}$$

$$\begin{array}{r} \overset{\times}{1}\ 1\ 0\ 0 \\ 0\ 1\ 1\ 1 \\ 0\ 1\ 1\ 0 \\ \hline 1\ 1\ 0\ 1 \\ \hline \end{array}$$

Signed 2's complement Addition

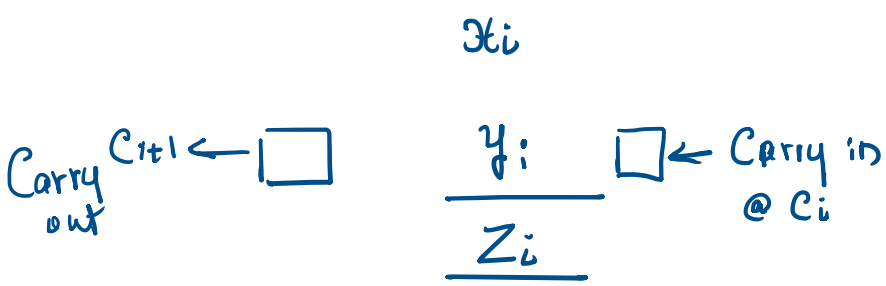
$$\begin{array}{r} X \\ +\ Y \\ \hline Z \\ \hline \end{array}$$

$$\begin{array}{r} (+7) \\ +\ (-3) \\ \hline +4 \\ \hline \end{array}$$

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

C_i x_i y_i z_i

C_{i+1} C_i x_i y_i z_i



INPUT			OUTPUT		
x_i	y_i	C_i	S_i / Z_i		C_{i+1}
0	0	0	0	$x_i y_i C_i$	0
0	0	1	1	$\bar{x}_i \bar{y}_i C_i$	0
0	1	0	1	$\bar{x}_i y_i \bar{C}_i$	0
0	1	1	0	$x_i \bar{y}_i \bar{C}_i$	1
1	0	0	1	$x_i \bar{y}_i C_i$	0
1	0	1	0	$\bar{x}_i y_i \bar{C}_i$	1
1	1	0	0	$\bar{x}_i \bar{y}_i C_i$	1
1	1	1	1	$x_i y_i C_i$	1

At one bit position

$S_i = (\downarrow) + () + ()$

→ 1-bit adder.