



# Data Storage

Zeros and Ones



# Lecture Contents

- The electronics behind computers
  - Switches (transistors)
  - Logic Gates
  - Flip Flops



# Digital Data

- Computers store data as zeros and ones...
  - each zero or one is referred to as a “**bit**” (**b**inary **d**igit)

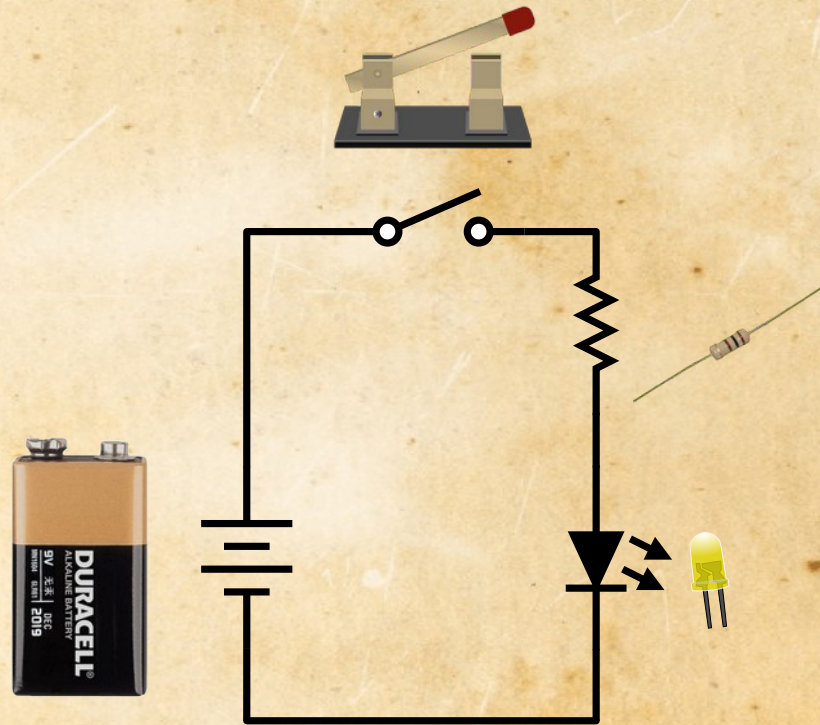


01111110000001111100100110001101110010100111111111110  
101111110000111010111111011000111101111110101011001  
0111111000011100011010100101110100111110001100010001  
0001110111110111111011111111110100011111101110111111  
111001101110111100011110111010111010001111111011111  
001101111111011000100100000010111011101110111111111  
1110001111110001111111111111100111100111111001011111  
1111101100111011110111111101011111011111111011001110  
11111111000111111100101001010001111101111011010011110  
00111111111110110001010000111100100000001111001001000  
0111111001111111110101011111110001011101110000010011111



# Switches

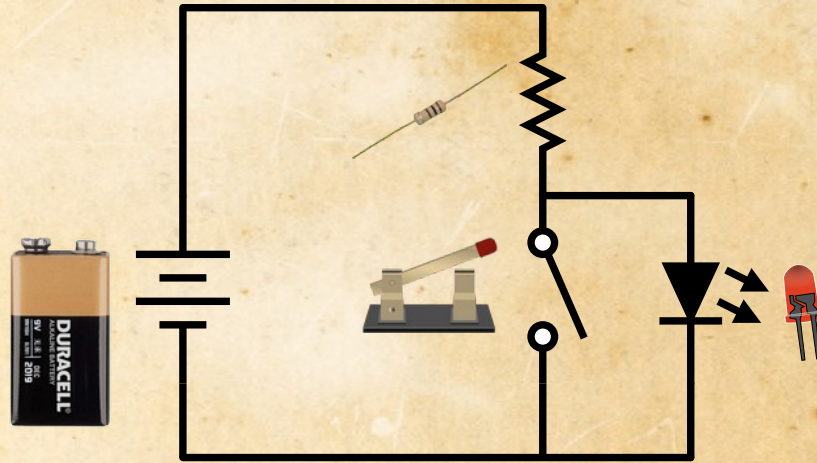
- When will the light turn on?





# Switches

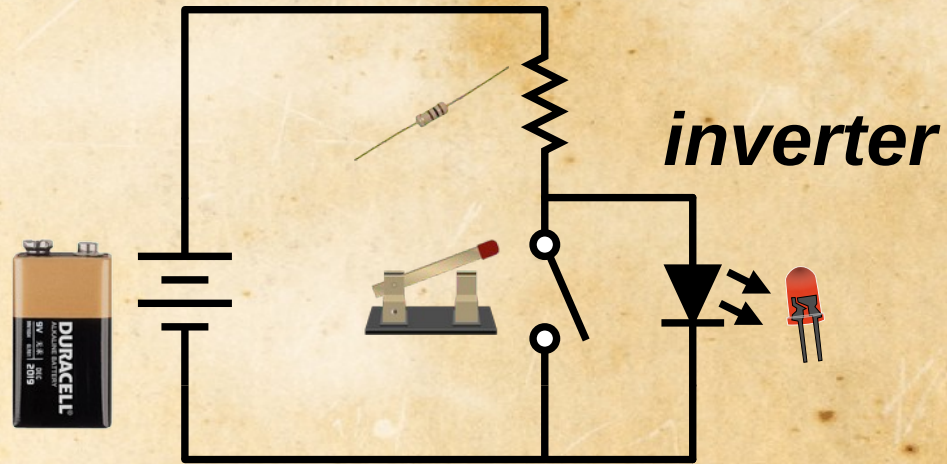
- When will the light turn on?





# Switches

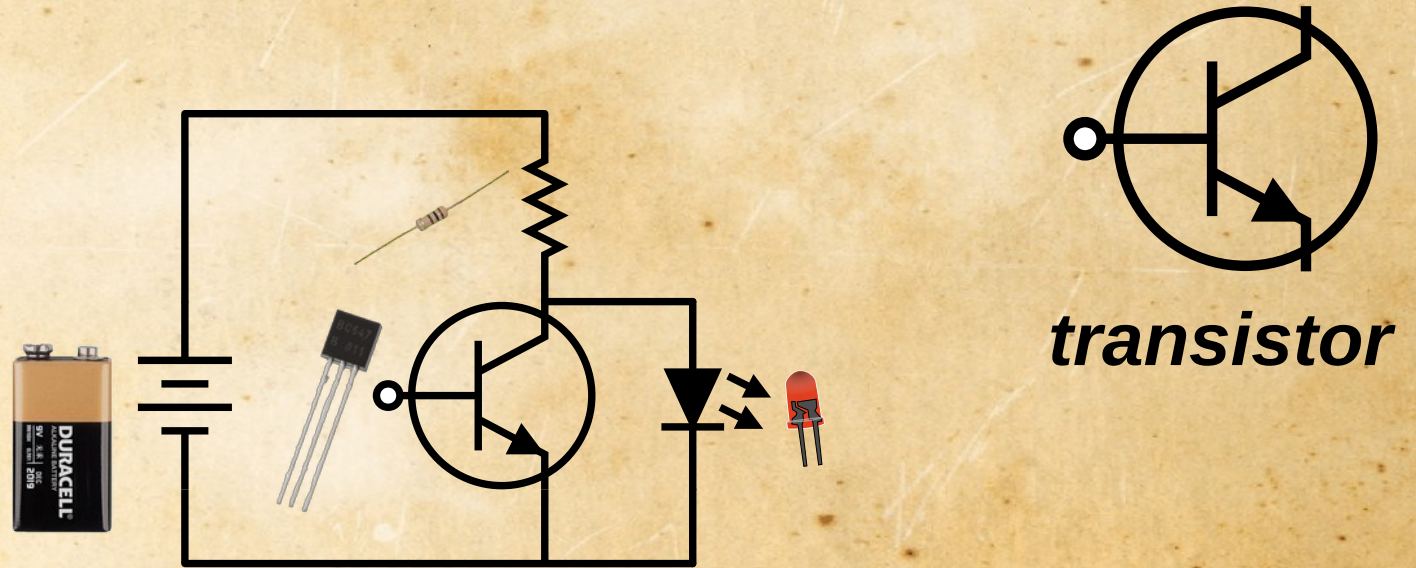
- When will the light turn on?





# Switches

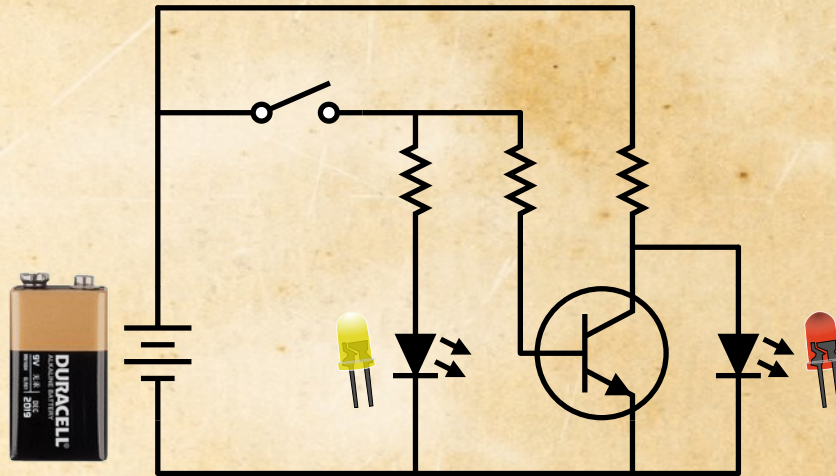
- *Transistors* are electrically controlled switches





# Digital Data

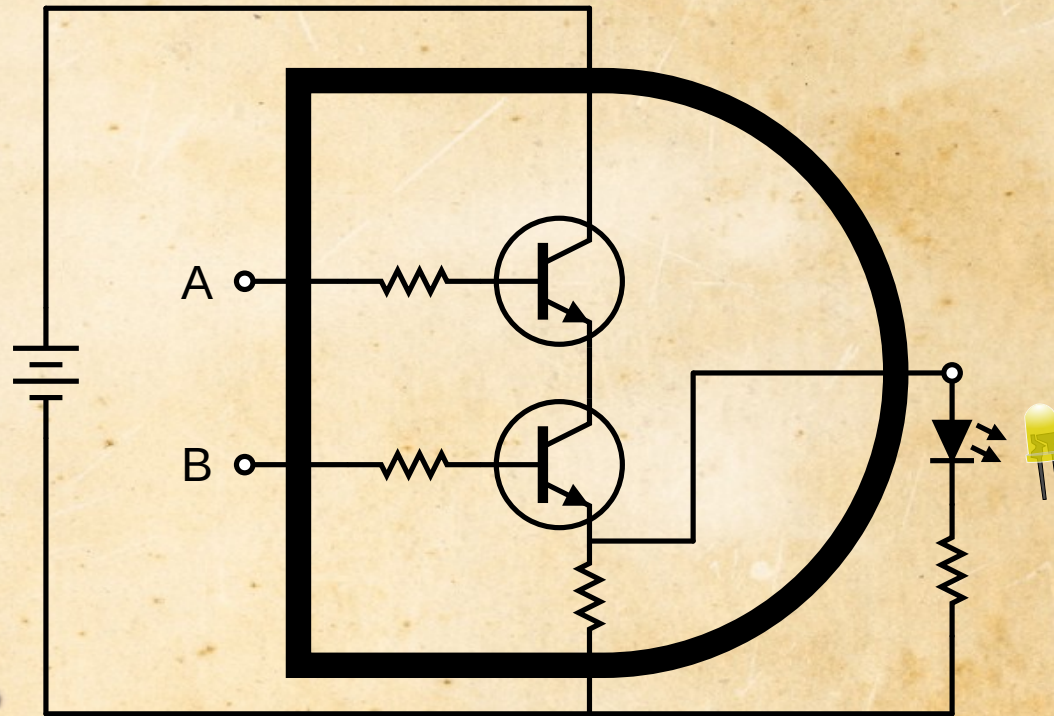
- Which will light?





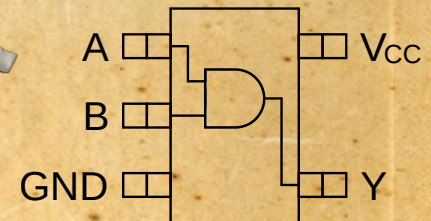
# Gates

- AND gate



Truth Table

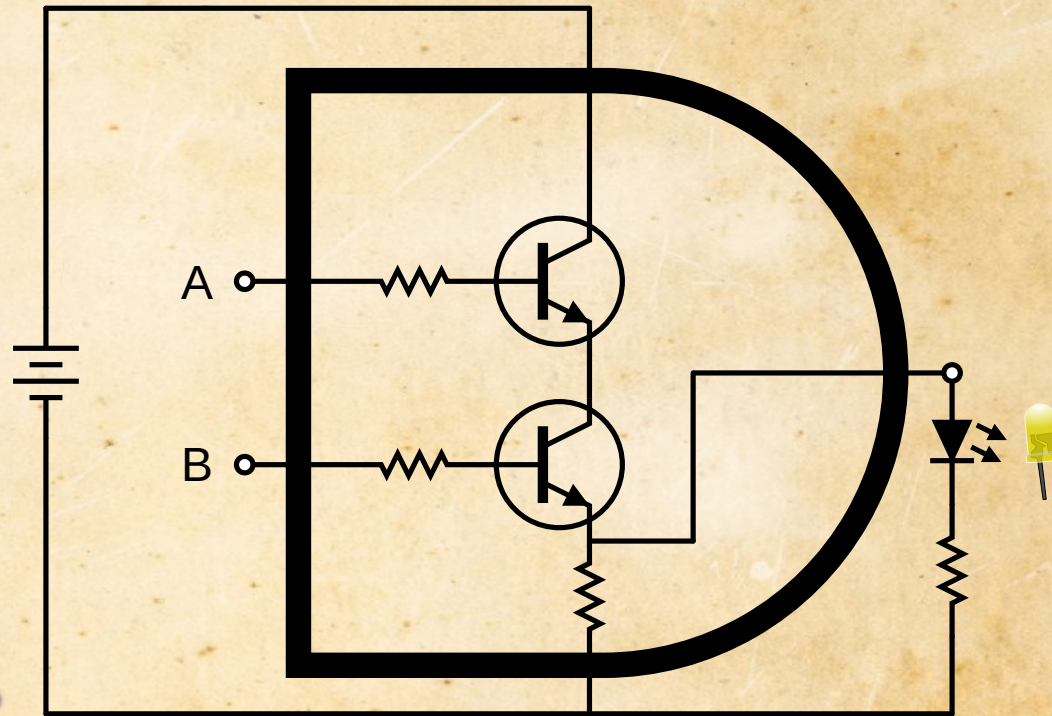
| A | B | Y |
|---|---|---|
| 0 | 0 |   |
| 0 | 1 |   |
| 1 | 0 |   |
| 1 | 1 |   |





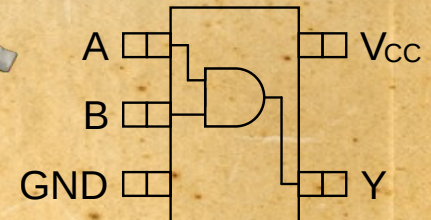
# Gates

- AND gate



Truth Table

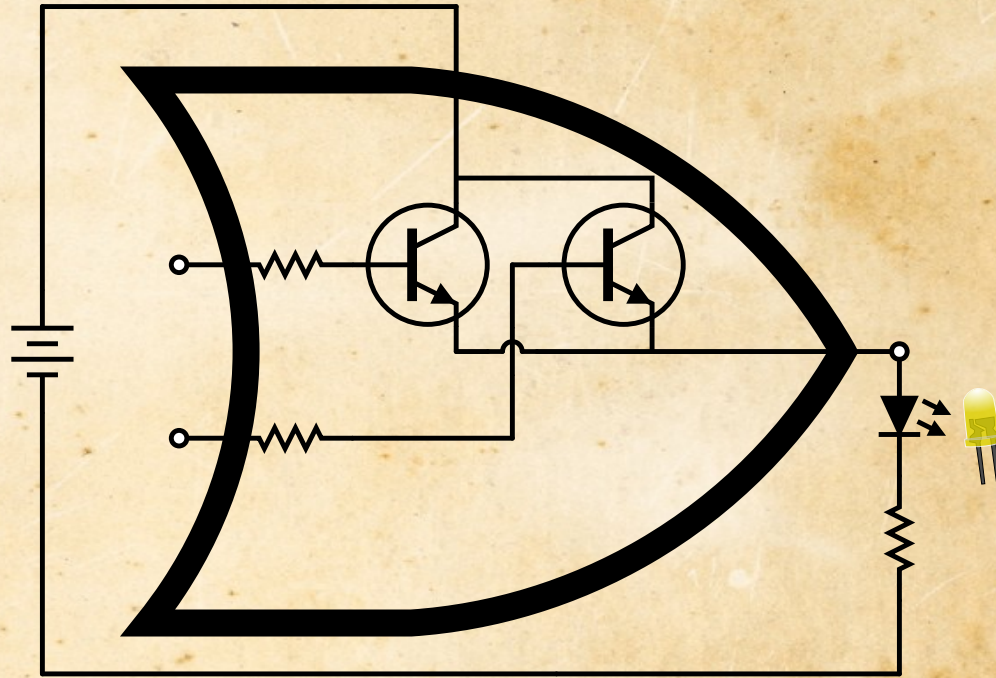
| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |





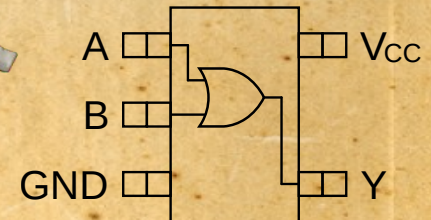
# Gates

- OR gate



Truth Table

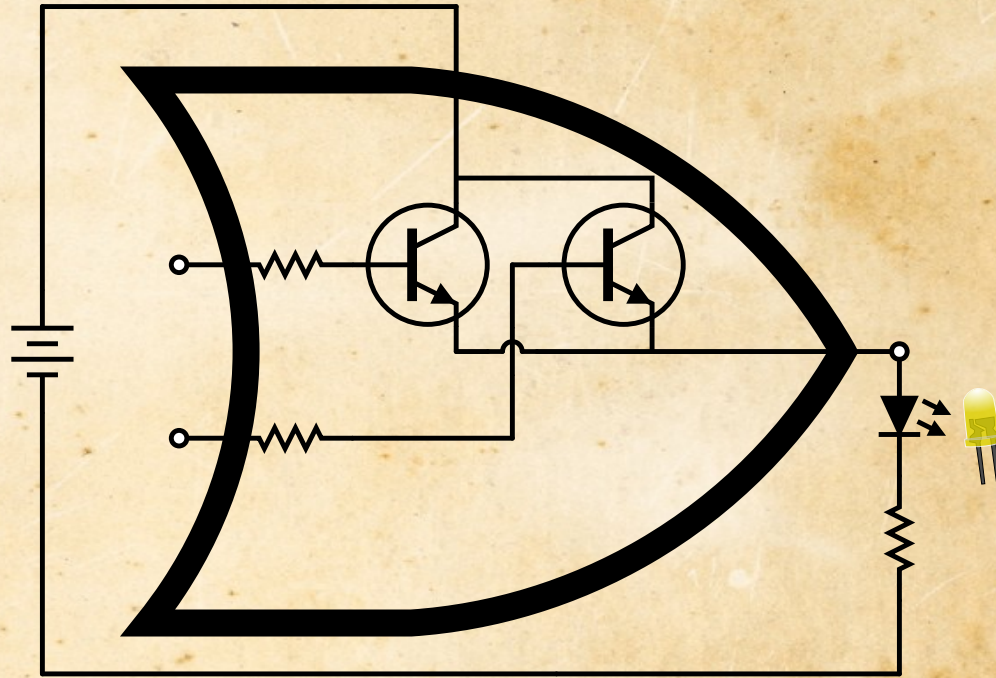
| A | B | Y |
|---|---|---|
| 0 | 0 |   |
| 0 | 1 |   |
| 1 | 0 |   |
| 1 | 1 |   |





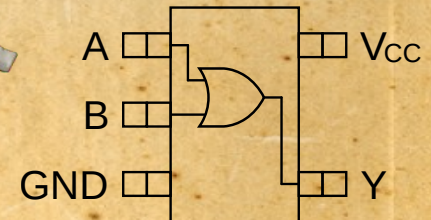
# Gates

- OR gate



Truth Table

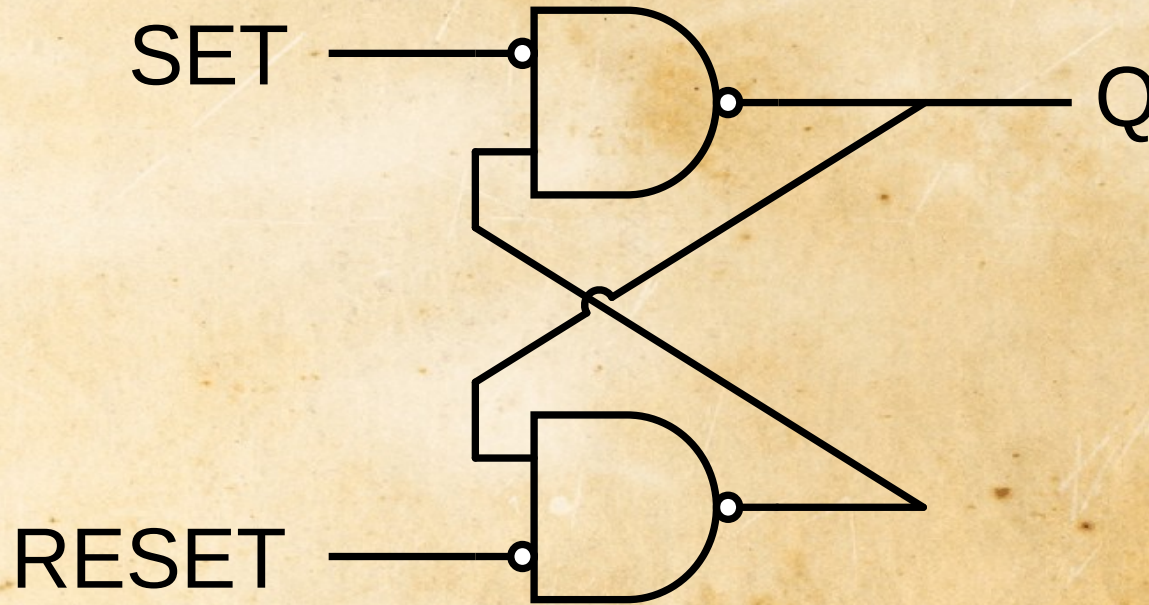
| A | B | Y |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |





# Flip Flops

- A *latch*, also called a *flip flop* will store a value

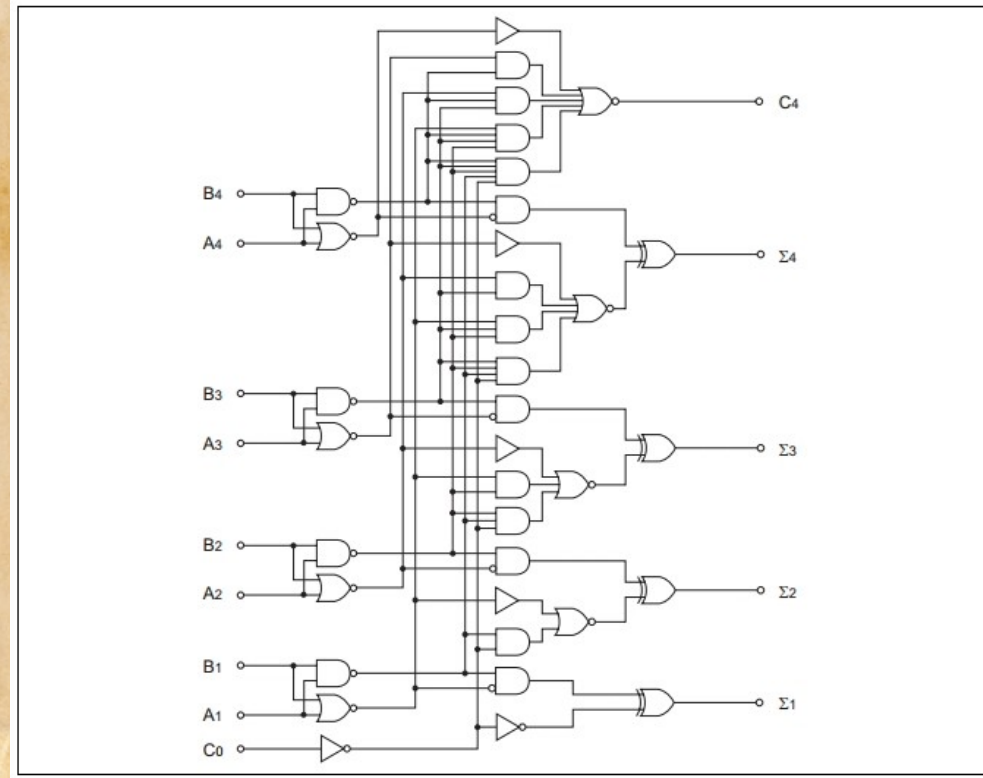




# Binary

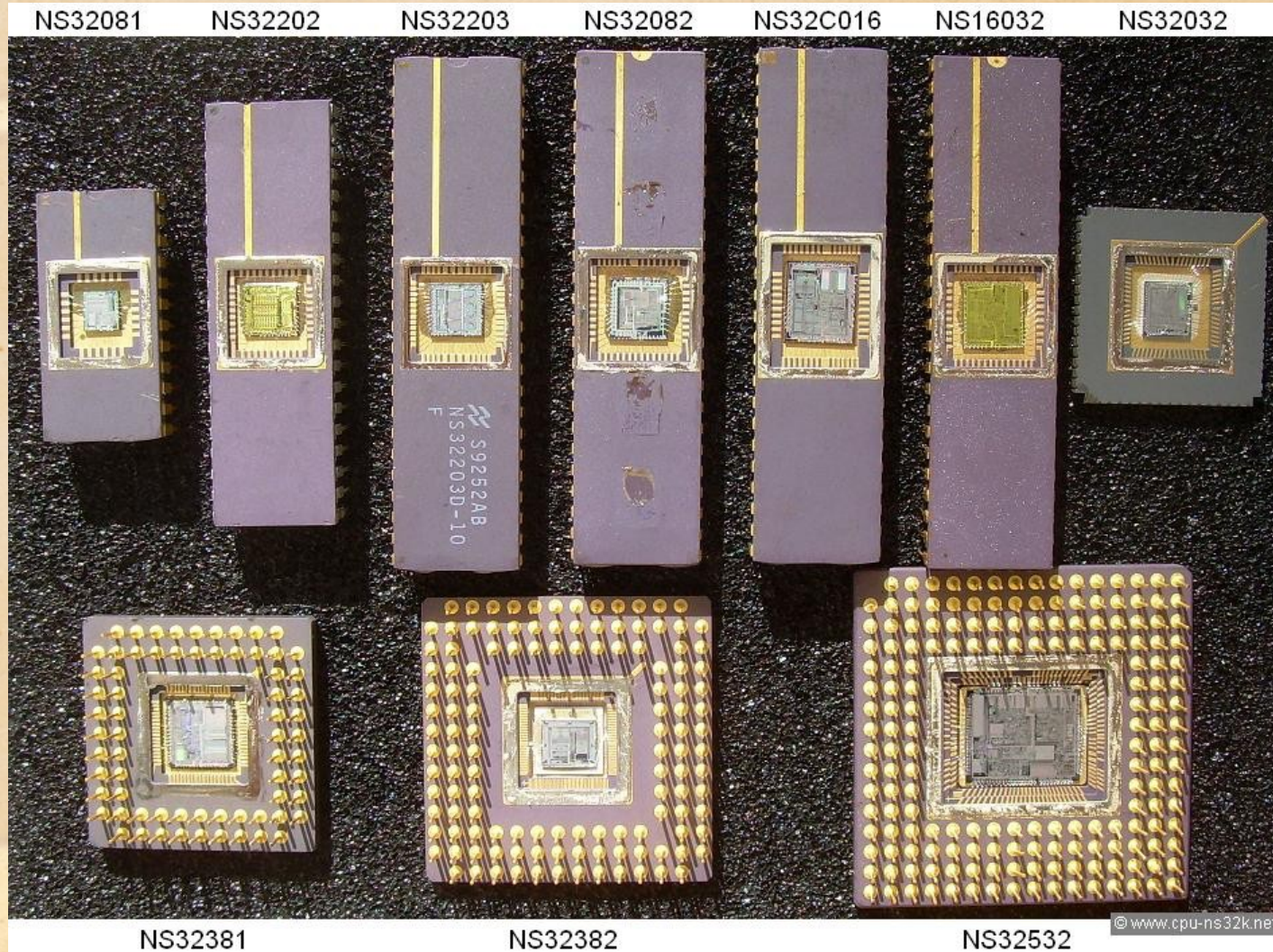
- Binary addition

$$\begin{array}{r} 1011 \\ + 1101 \\ \hline 11000 \end{array}$$





# 1980's CPUs with up to 370k transistors





# Intel i9: 16 (8+8) Core processor





# 128kB Dynamic Random Access Memory







# Data Storage

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