# Transistors & Number systems

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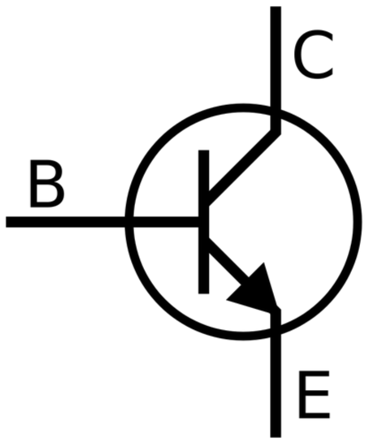
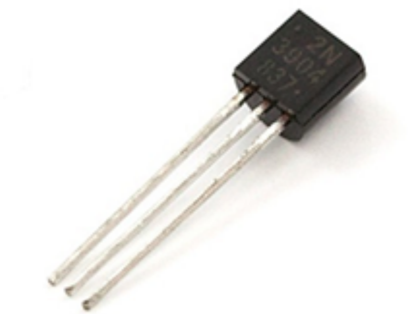
# What is transistor?



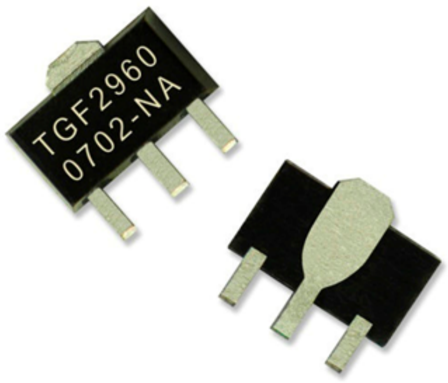

- Semiconductor element with three terminals
  - Base: This is responsible for activating the transistor.
  - Collector: This is the positive lead
  - Emitter: This is the negative lead
- Regulates current or voltage flow and acts as a switch or gate for signals.

# Types of transistors

- Two types of transistors:
  - bipolar junction transistors (BJT)
  - field effect transistors (FET)




Bipolar Junction Transistor




Field Effect Transistors

# Application of transistors

- Transistors are applied in:
  - Motherboards
  - Video cards
  - Power supplies, etc.
- CPUs and microcontrollers are consists of millions of transistors and used for various calculations

# Application of transistors (cont.)

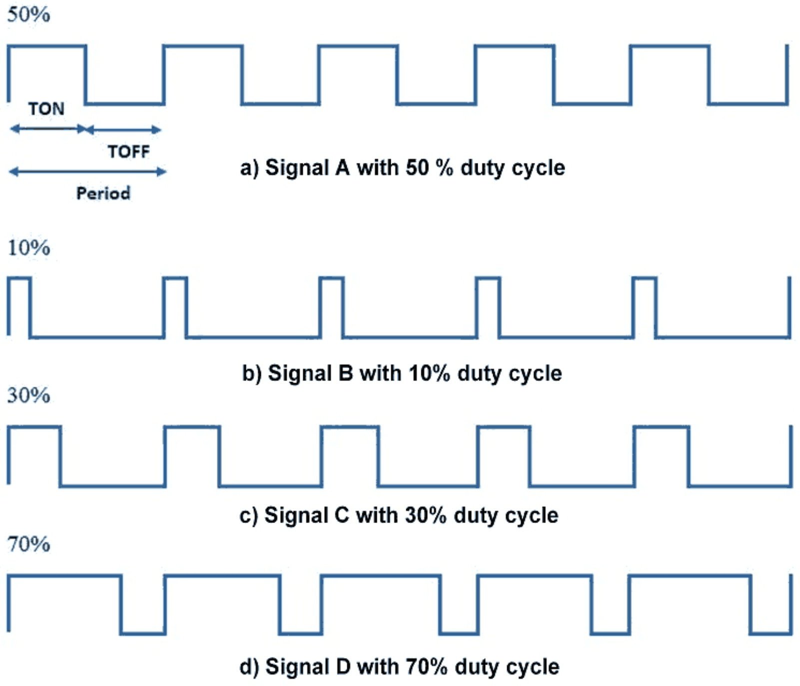
- Transistors are also used in:
  - Lamps
  - Electric motors
  - Other devices where a rapid change in the current is needed
- The transistor can limit the current either smoothly or by pulse-pause method
- Pulse-pause method is widely used in PWM Signals

# PWM Signal

- PWM - Pulse Width Modulation
- A method for generating an analog signal using a digital source
- Consists of two main components:
  - duty cycle
  - frequency

# PWM Signal (cont.)

- Duty cycle
  - Describes the amount of time the signal is in a high (on) state as a percentage of the total time of it takes to complete one cycle
- Frequency
  - how fast the PWM completes a cycle
  - how fast it switches between high and low states



# Number systems

- Four number systems:
  - Decimal (10)
  - Binary (2)
  - Octal (8)
  - Hexadecimal (16)

# Decimal Number System

- We use in out day-to-day life
- Has base 10 as it uses 10 digits from 0 to 9
- Each position represents a specific power of the base (10)
- Example:

**Hundreds Position**

**Units Position**

2 0 1 8

Thousands Position

**Tens Position**

# Binary Number System

- Characteristics
  - Uses two digits, 0 and 1
  - Also called as base 2 number system
  - The last position in a binary number represents a **0 power of the base (2).**

    Example $2^0$
  - The first position in a binary number represents a x power of the base (2).

    Example $2^x$ where **x** represents the length - 1.

# Binary -> Decimal

- Technique:
  - Multiply each bit by $2^x$, where $x$ is the "weight" of the bit
  - The weight is the position of the bit, starting from 0 on the right
  - Add the results

- Binary number: 10101
  - Step 1:
    - **$1 \times 2^4 + 0 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$**
  - Step 2:
    - **$16 + 0 + 4 + 1 + 1 = 21$**

# Octal Number System

- Characteristics
  - Uses eight digits, 0,1,2,3,4,5,6,7
  - Also called as base 8 number system
  - Last position in an octal number represents a **0 power of the base (8).**

    Example $8^0$
  - The first position in an octal number represents a **x power of the base (8).**

    Example $8^x$ where **x** represents the length - 1

# Octal -> Decimal

- Technique:
  - Multiply each bit by $8^x$, where *x* is the "weight" of the bit
  - The weight is the position of the bit, starting from 0 on the right
  - Add the results

- Octal number: 12570
  - Step 1:
    - **$1 \times 8^4 + 2 \times 8^3 + 5 \times 8^2 + 7 \times 8^1 + 0 \times 8^0$**
  - Step 2:
    - **$4096 + 1024 + 320 + 56 + 0 = 5496$**

# Hexadecimal Number System

- Characteristics
  - Uses 10 digits and 6 letters, 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
  - Letters represent the numbers starting from 10. A = 10. B = 11, C = 12, D = 13, E = 14, F = 15
  - Also called as base 16 number system
  - Last position in a hexadecimal number represents a **0 power of the base (16).** Example, $16^0$
  - The first position in a hexadecimal number represents a **x power of the base (16).** Example $16^x$ where **x** represents the length - 1

# Hexadecimal -> Decimal

- Technique:
  - Multiply each bit by $16^x$, where $x$ is the "weight" of the bit
  - The weight is the position of the bit, starting from 0 on the right
  - Add the results

- Octal number: 19FDE
  - Step 1:
    - **$1 \times 16^4 + 9 \times 16^3 + F\ (15) \times 16^2 + D\ (13) \times 16^1 + E\ (14) \times 16^0$**
  - Step 2:
    - **65536+ 36864+ 3840+ 208 + 14 = 106462**

# Purpose of octal and hexadecimal

- Ease of use and conversion
- Three bits make one octal digit

  111 010 110 101

  **7 2 6 5** => 7265 in octal
- Four bits make one hexadecimal digit

  1110 1011 0101

  **E B 5** => EB5 in hex

# Decimal -> Binary

- Technique:
  - Divide by 2 until 0
  - Keep track of remainder
- Decimal number: 21
  - Step 1:
    - **21 ÷ 2 = 10 (rem. 1) -> 10 ÷ 2 = 5 (rem 0) -> 5 ÷ 2 = 2 (rem 1)**
    - **2 ÷ 2 = 1 (rem 0) -> 1 ÷ 2 = 0 (rem 1)**
  - Step 2:
    - **Remainders -> 1 0 1 0 1**

# Decimal -> Octal

- Technique:
  - Divide by 8 until 0
  - Keep track of remainder
- Decimal number: 5496
  - Step 1:
    - **5496 ÷ 8 = 687 (rem. 0) -> 687 ÷ 8 = 85 (rem 7) -> 85 ÷ 8 = 10 (rem 5)**
    - **10 ÷ 8 = 1 (rem 2) -> 1 ÷ 8 = 0 (rem 1)**
  - Step 2:
    - **Remainders -> 1 2 5 7 0**

# Decimal -> Hexadecimal

- Technique:
  - Divide by 16 until 0
  - Keep track of remainder

- Decimal number: 106462
  - Step 1:
    - **5496 ÷ 16 = 6653 (rem. 14 => E) -> 6653 ÷ 16 = 415 (rem 13 => D)**
    - **415 ÷ 16 = 25 (rem 15 => F)**
    - **25 ÷ 16 = 1 (rem 9) -> 1 ÷ 16 = 0 (rem 1)**
  - Step 2:
    - **Remainders -> 1 9 F D E**

# Binary Addition

- Technique
  - Add individual bits
  - Propagate carries

```
  10101      21
+ 11001    + 25
 101110      46
```

| A | B | A + B |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 10 |

# Binary Multiplication

- Technique
  - Multiply individual bits
  - Continue as in decimal multiplication

```
    1110
  x 1011
    1110
   1110
  0000
 1110
10011010
```

| A | B | A x B |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

# Fractions

- Binary -> Decimal

$$
\begin{array}{lll}
10.1011 & \Rightarrow & 1 \times 2^{-4} = 0.0625 \\
 & & 1 \times 2^{-3} = 0.125 \\
 & & 0 \times 2^{-2} = 0.0 \\
 & & 1 \times 2^{-1} = 0.5 \\
 & & 0 \times 2^{0} = 0.0 \\
 & & 1 \times 2^{1} = 2.0 \\
 & & \qquad\qquad 2.6875
\end{array}
$$

# Fractions (cont.)

- Decimal -> Binary