



Introduction to Embedded Systems, Lecture 10

# ES electronic circuits design and prototyping. PCB technology overview

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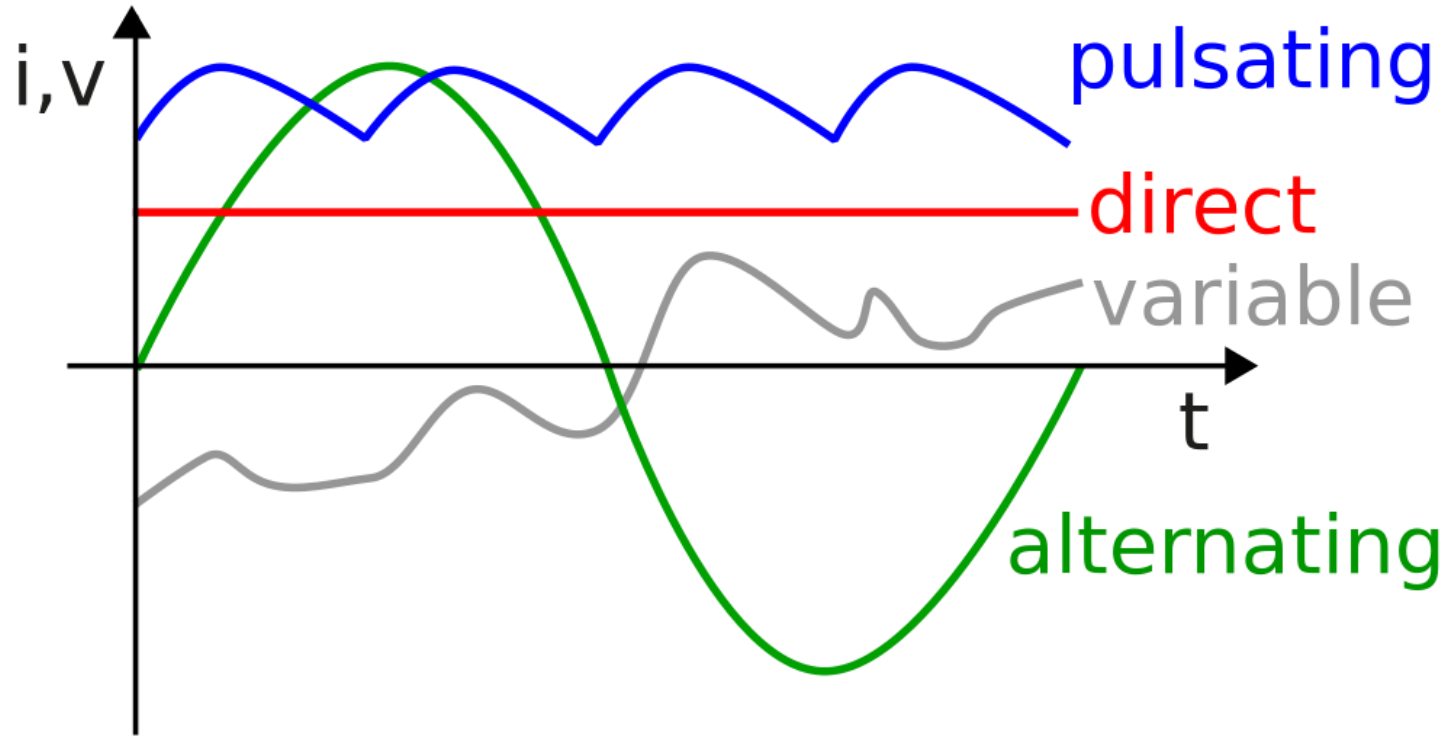
# Electronic circuit

- An electronic circuit is composed of individual electronic components, such as resistors, transistors, capacitors, inductors and diodes, connected by conductive wires or traces through which electric current can flow. It is a type of electrical circuit.

# Electric current

- An electric current is a flow of charged particles such as electrons or ions, moving through an electrical conductor or space. It is defined as the net rate of flow of electric charge through a surface.
- The moving particles are called charge carriers, which may be one of several types of particles, depending on the conductor.
- In electric circuits the charge carriers are often electrons moving through a wire.
- In semiconductors they can be electrons or holes.
- In an electrolyte the charge carriers are ions.
- In plasma, an ionized gas, they are ions and electrons.

# Electric current types



# Ohm's Law

- the voltage across a conductor is directly proportional to the current flowing through it, provided all physical conditions and temperatures remain constant.

- $I = V / R$



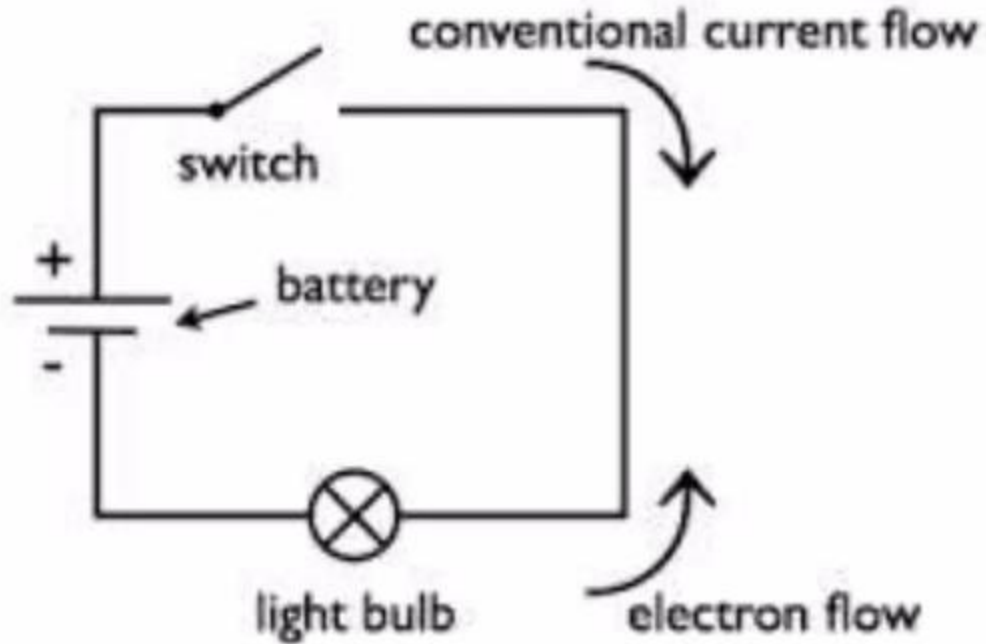
3 V 6  $\Omega$  0.5 A

- Current = Voltage / Resistance

# Direct Current

- Direct current (DC) refers to a system in which the movement of electric charge is in only one direction (sometimes called unidirectional flow).
- Direct current is produced by sources such as batteries, thermocouples, solar cells, and commutator-type electric machines of the dynamo type.
- Alternating current can also be converted to direct current through use of a rectifier.

# Direct current circuit example



# Alternating Current (AC)

- In alternating current (AC) systems, the movement of electric charge periodically reverses direction.
- AC is the form of electric power most commonly delivered to businesses and residences.
- The usual waveform of an AC power circuit is a sine wave, though certain applications use alternative waveforms, such as triangular or square waves.
- Audio and radio signals carried on electrical wires are also examples of alternating current.
- An important goal in these applications is recovery of information encoded (or modulated) onto the AC signal.

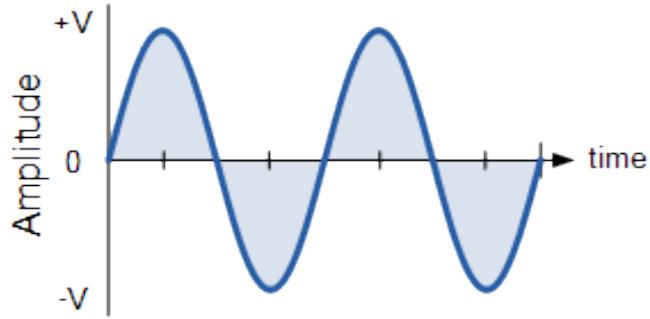


# AC Waveform Characteristics

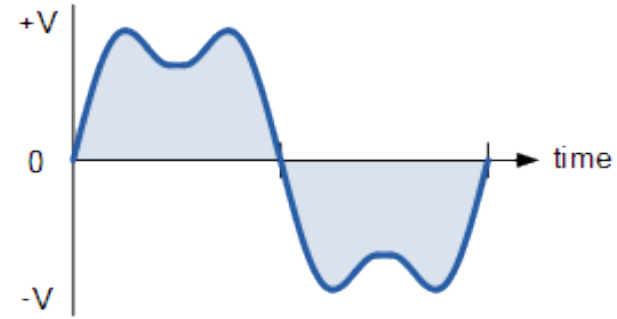
- The Period, (T) is the length of time in seconds that the waveform takes to repeat itself from start to finish. This can also be called the *Periodic Time* of the waveform for sine waves, or the *Pulse Width* for square waves.
- The Frequency, (f) is the number of times the waveform repeats itself within a one second time period. Frequency is the reciprocal of the time period, (  $f = 1/T$  ) with the unit of frequency being the *Hertz*, (Hz).
- The Amplitude (A) is the magnitude or intensity of the signal waveform measured in volts or amps.

# Types of Periodic Waveform

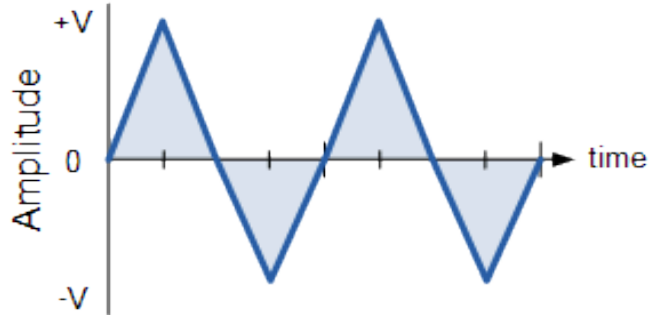
Sine wave



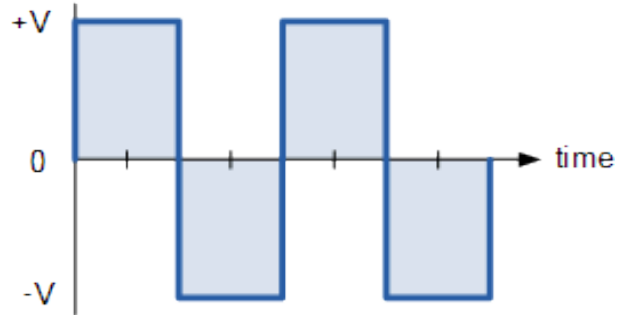
Complex wave



Triangular wave



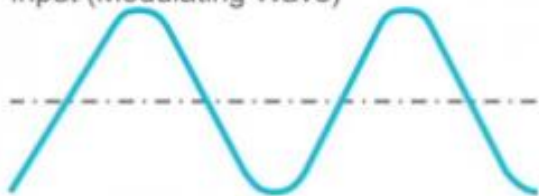
Square wave



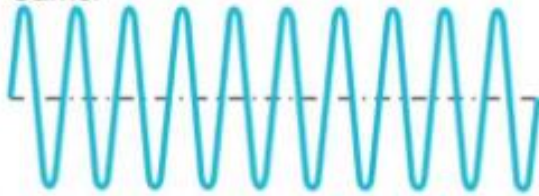
# Modulation

## Amplitude Modulation (AM)

Input (Modulating Wave)



Carrier

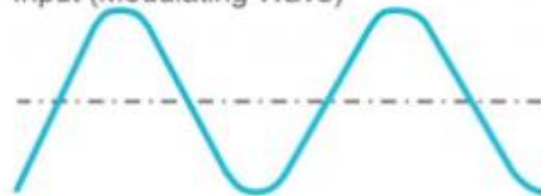


Modulated Result

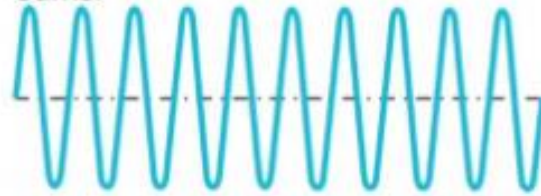


## Frequency Modulation (FM)

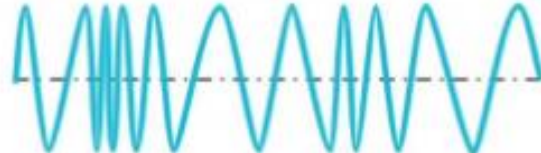
Input (Modulating Wave)



Carrier

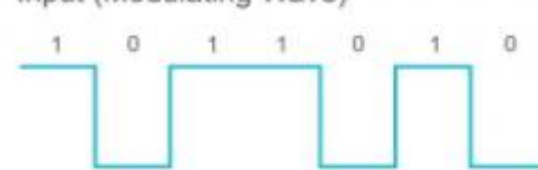


Modulated Result

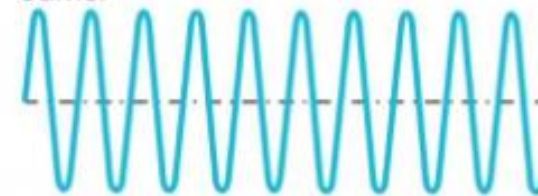


## Digital Modulation

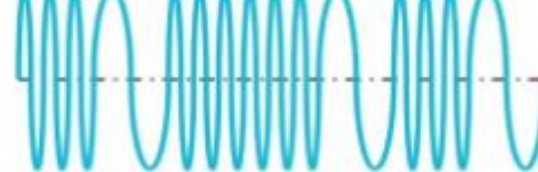
Input (Modulating Wave)



Carrier

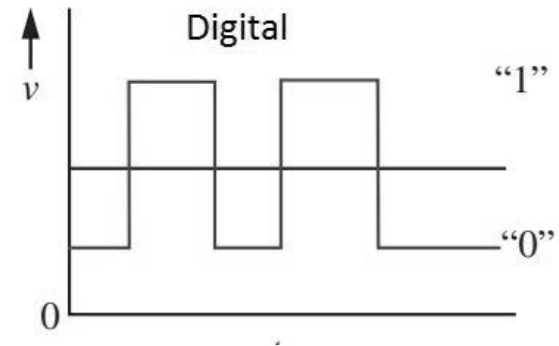
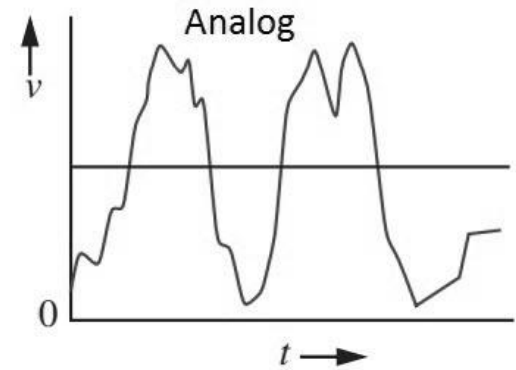


Modulated Result



# Analog and digital circuits

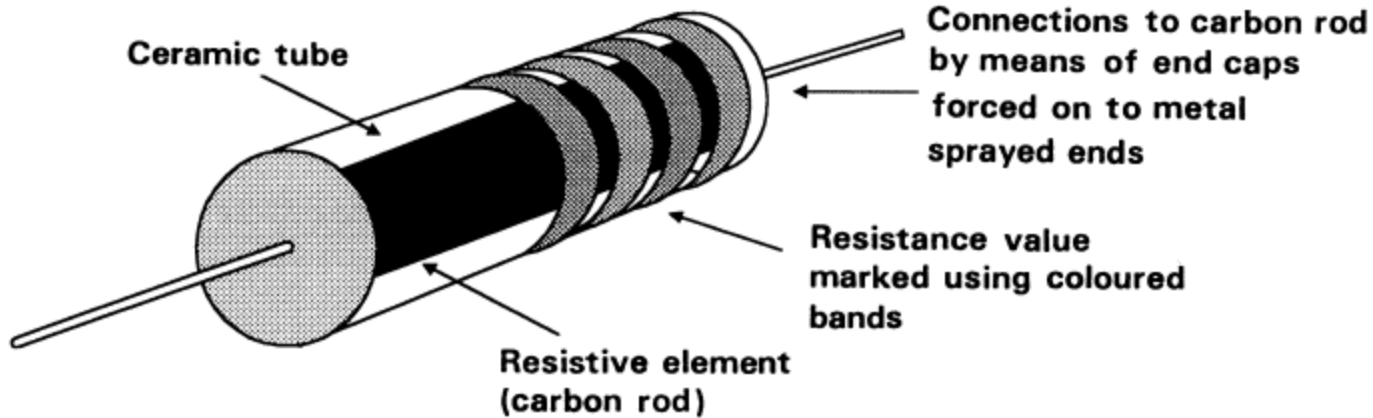
- Analogue circuit is one that uses voltage or current levels that vary continuously with time to represent signal amplitude.
- Digital circuit uses a discrete set of signal levels, usually two voltages or currents, that represent signal amplitude.



# Basic parts of electronic circuit

- resistors – resistance, Ohms
- capacitors – capacity, Farads
- inductors – inductance, Henrys
- diodes – conducts current primarily in one direction
- transistors – amplifies or switches electrical signals and power

# Resistor



Ohm, kilohm:  $1\text{ k}\Omega = 1,000\ \Omega$

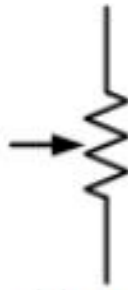
# Resistor Symbols



Fixed Value  
Resistor  
(IEC Symbol)



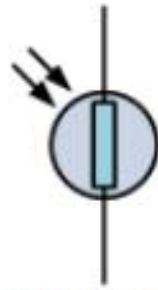
Fixed Value  
Resistor  
(IEEE Symbol)



Variable  
Resistor  
(Potentiometer)

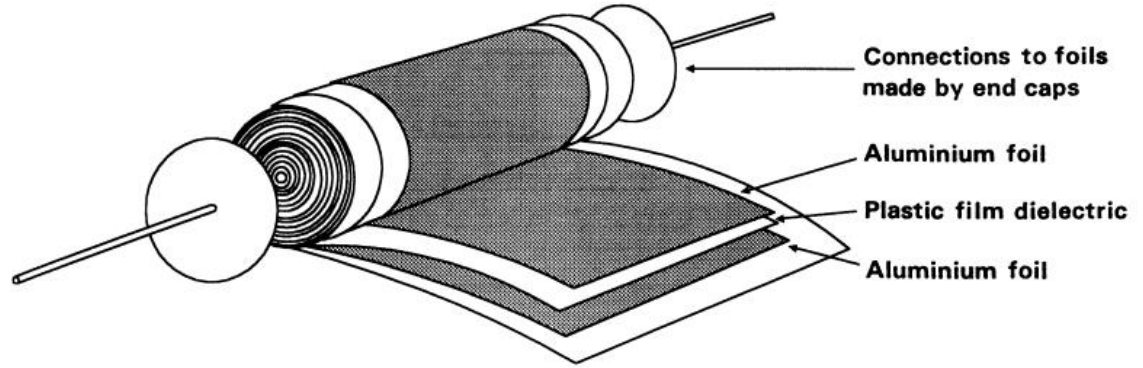
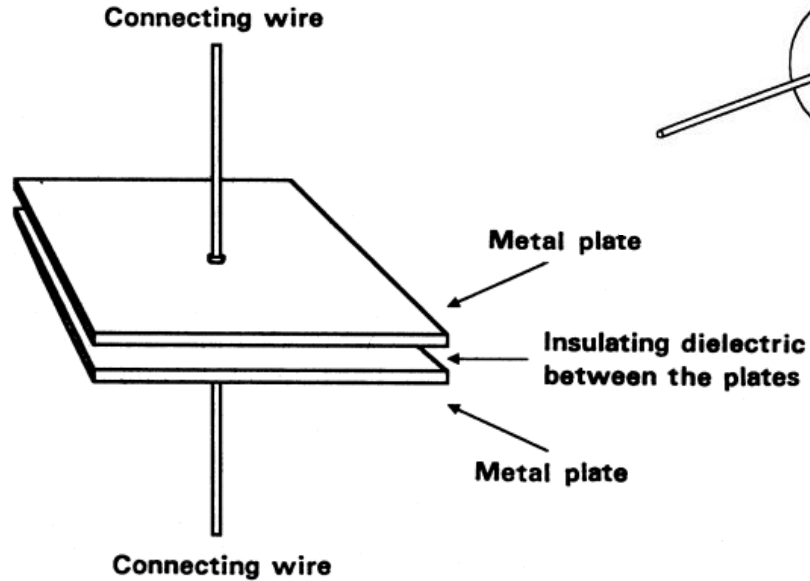
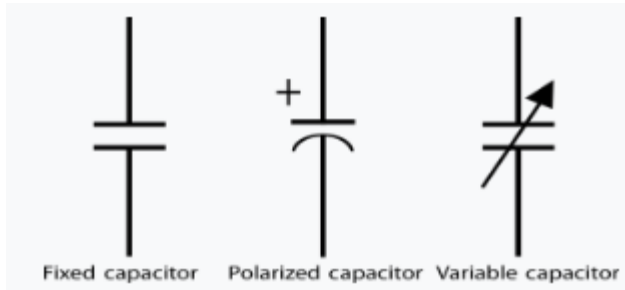


Variable  
Resistor  
(Rheostat)



(LDR) Light  
Dependant  
Resistor

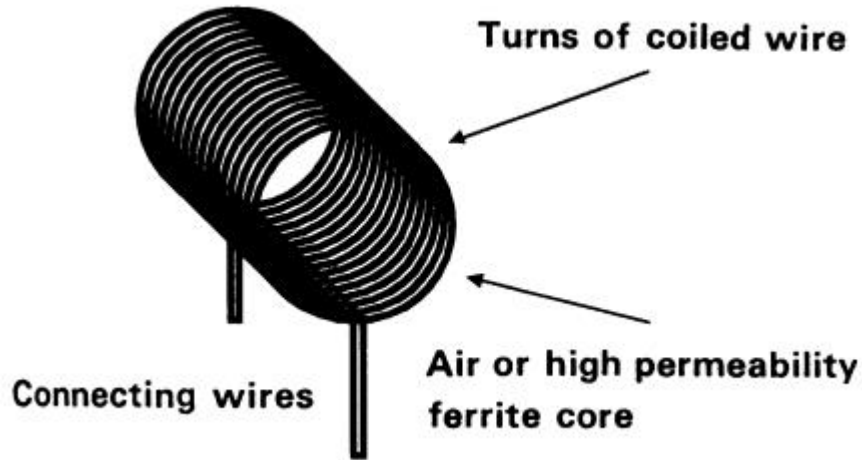
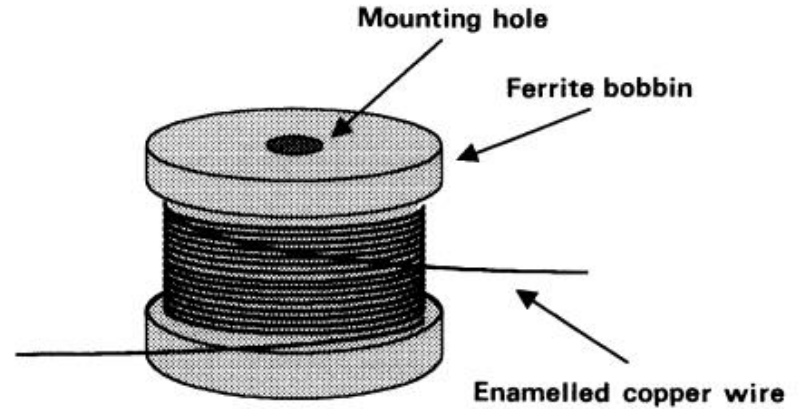
# Capacitor



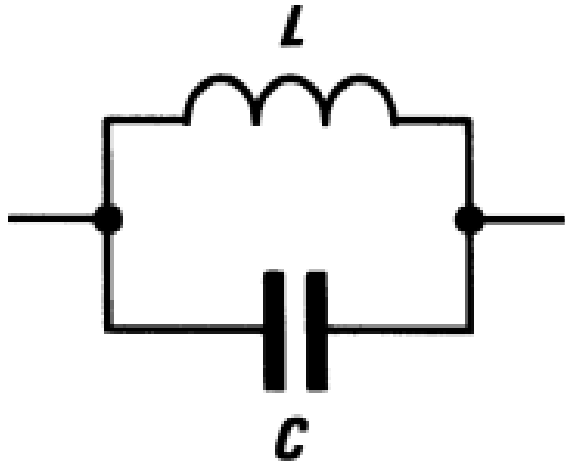
Farad, micro-farad ( $10^{-6}$ ), pico-farad ( $10^{-12}$ )



# Inductor

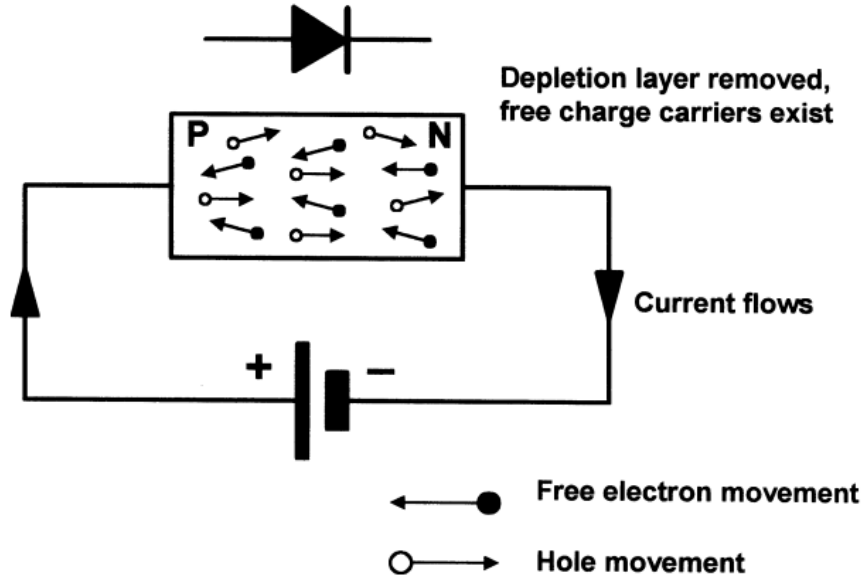


# Resonant circuits



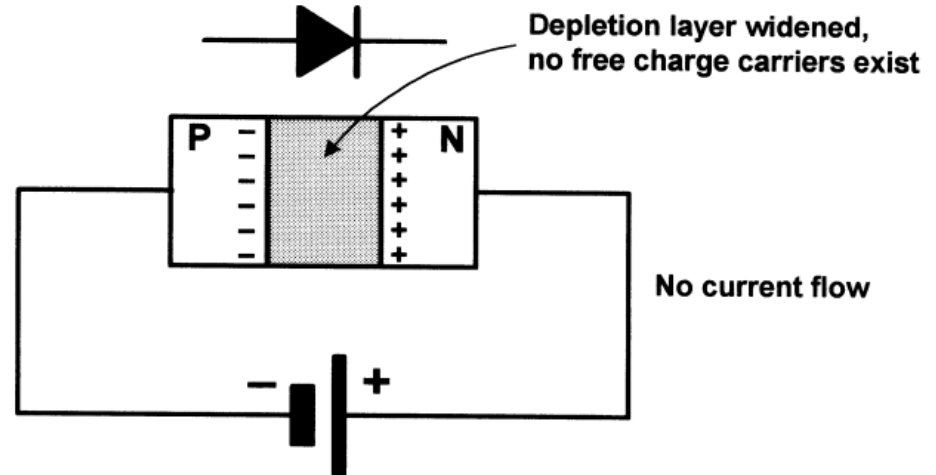
The current in a circuit peaks at the resonant frequency

# Diode



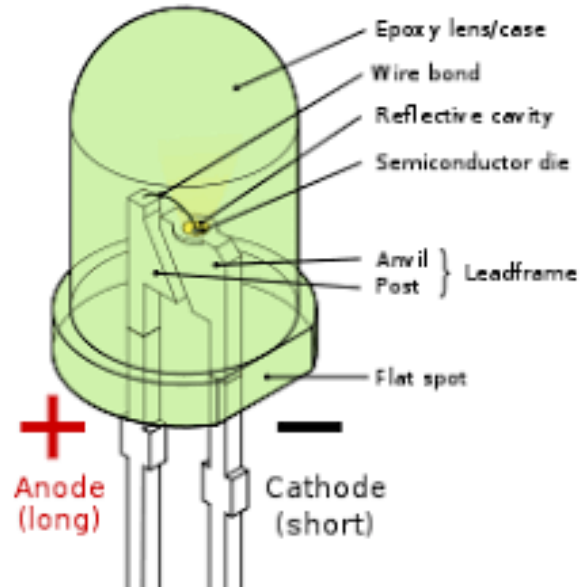
P – positive, excess of holes

N – negative, excess of electrons

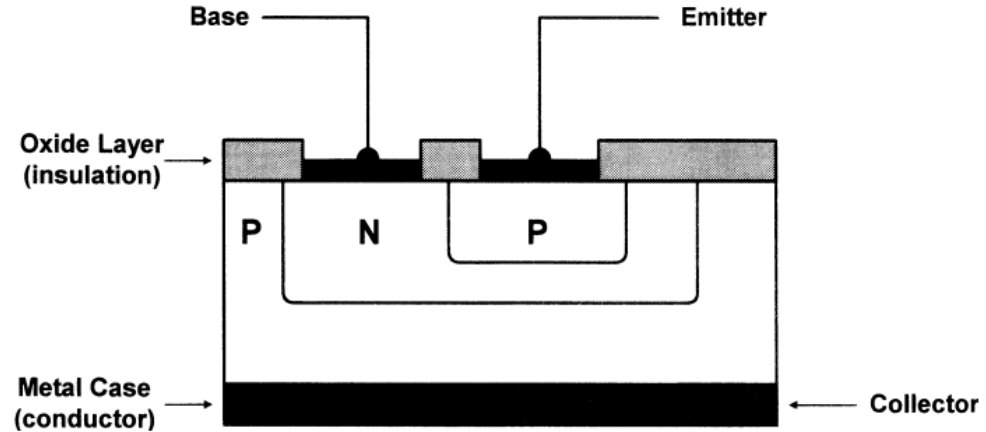
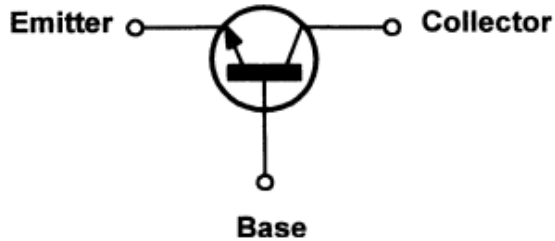
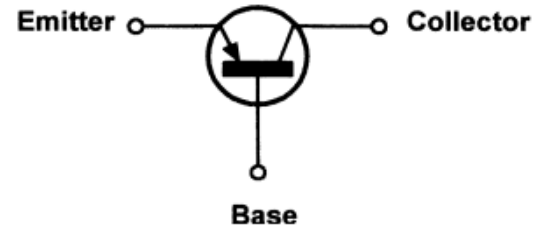
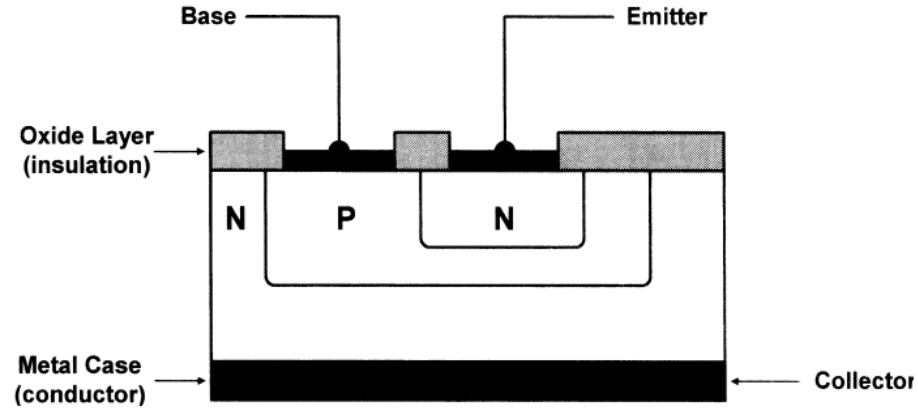


# Light emitting diodes

- A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it.
- When current passes through an LED, the electrons recombine with holes emitting light in the process.



# Transistors



# Integrated circuits (ICs)

- Complex circuits fabricated on a small slice of silicon
- Packages example: Single-in-line (SIL), Dual-in-line (DIP), Quad-in-line (QID)
- Analog: amplifiers, generators, filters, radio
- Digital:
  - Gates
  - Microprocessors
  - SoC

# IC Packages



Single-in-line (SIL)

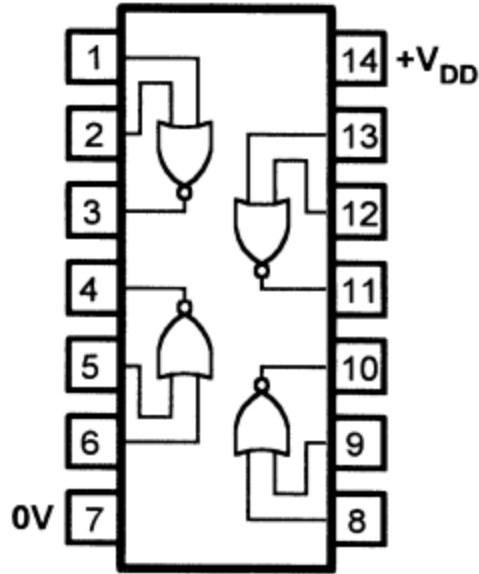


Dual-in-line (DIP)

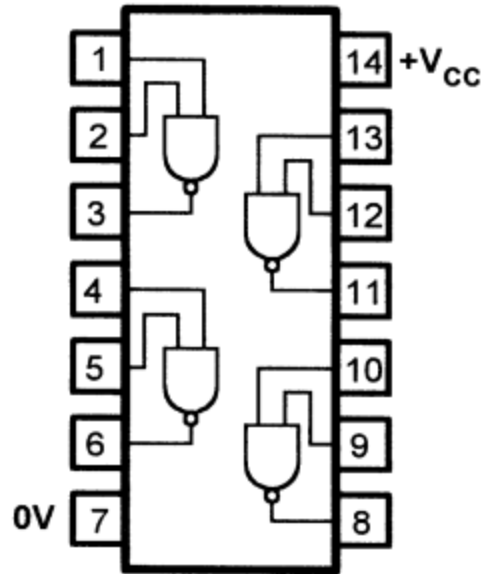


Quad-in-line (QID)

# IC schemes

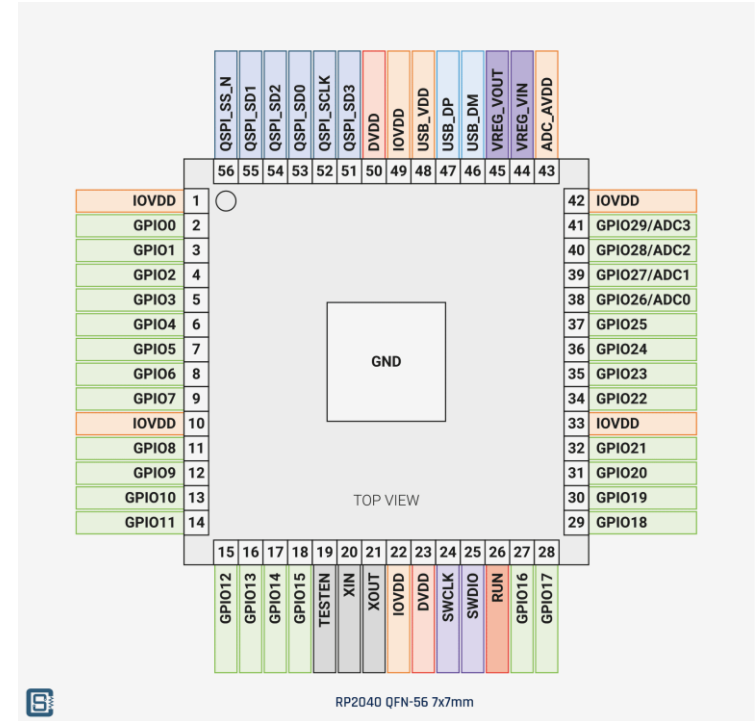


**4001UBE**



**74LS00**

gates

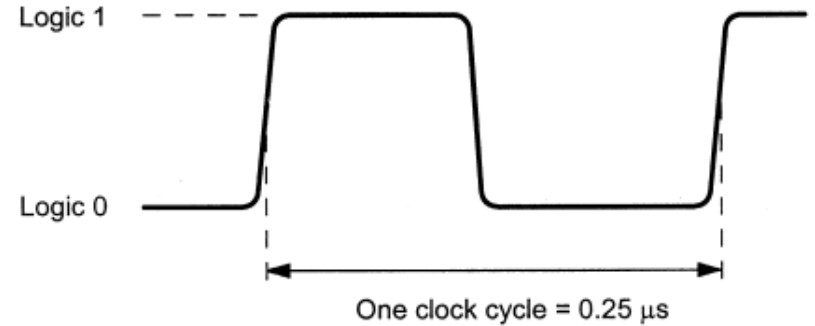
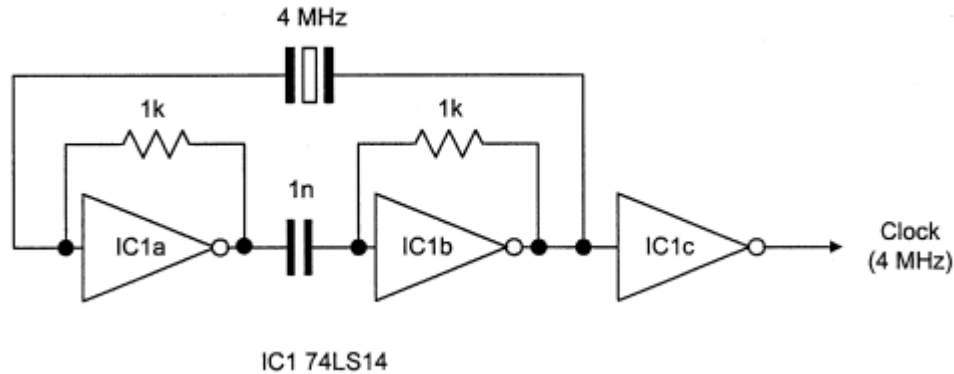


SoC RP 2040

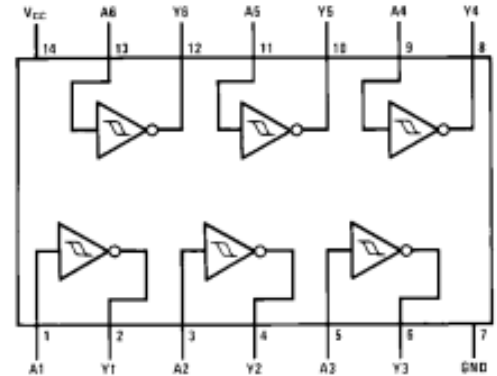


# Clock circuit

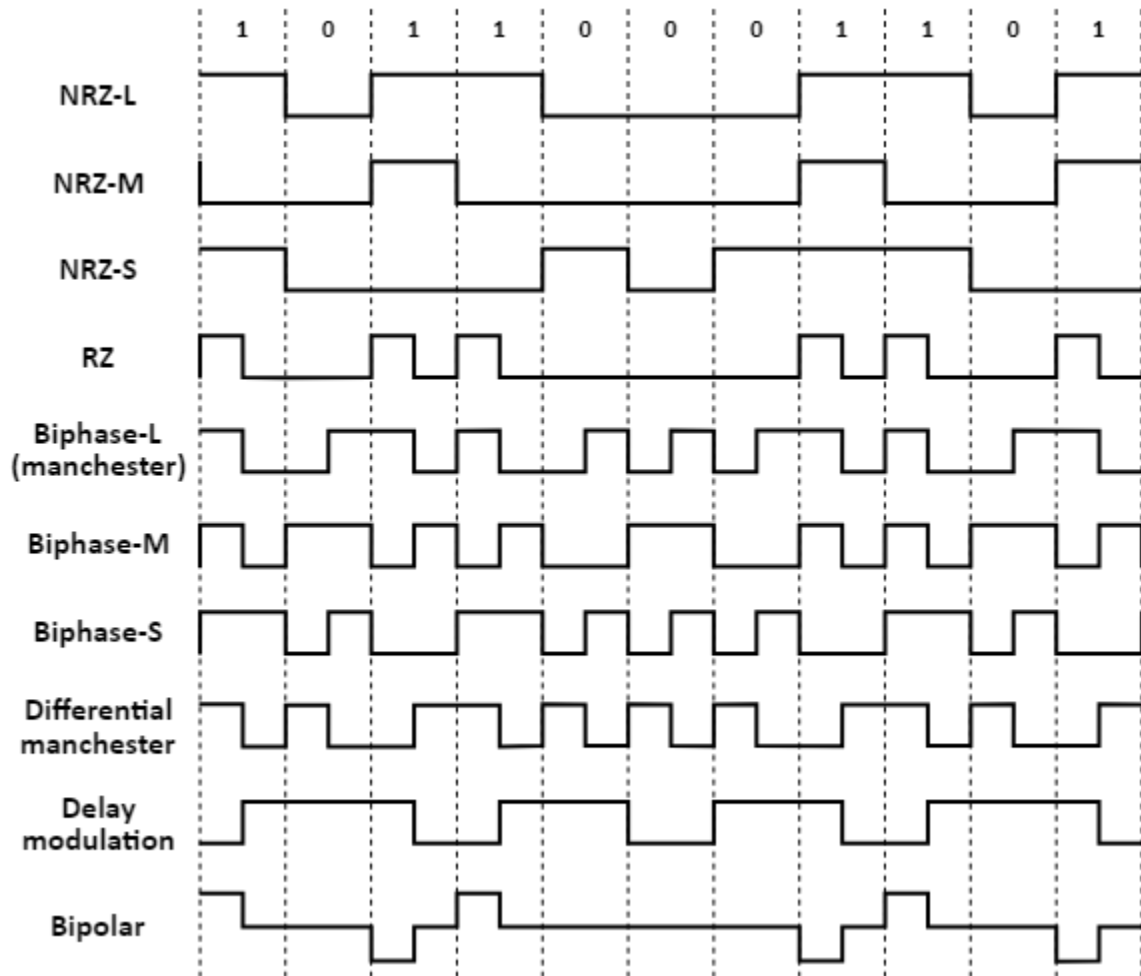
quartz generator



inverter: six independent gates  
each of which performs the logic  
INVERT function

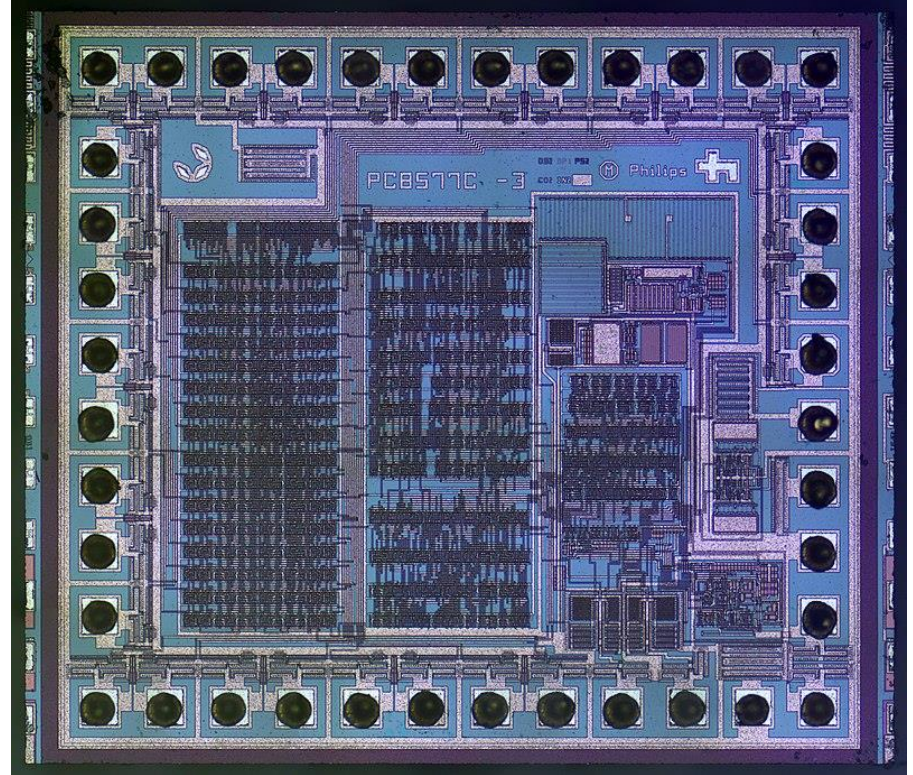


# Digital encoding



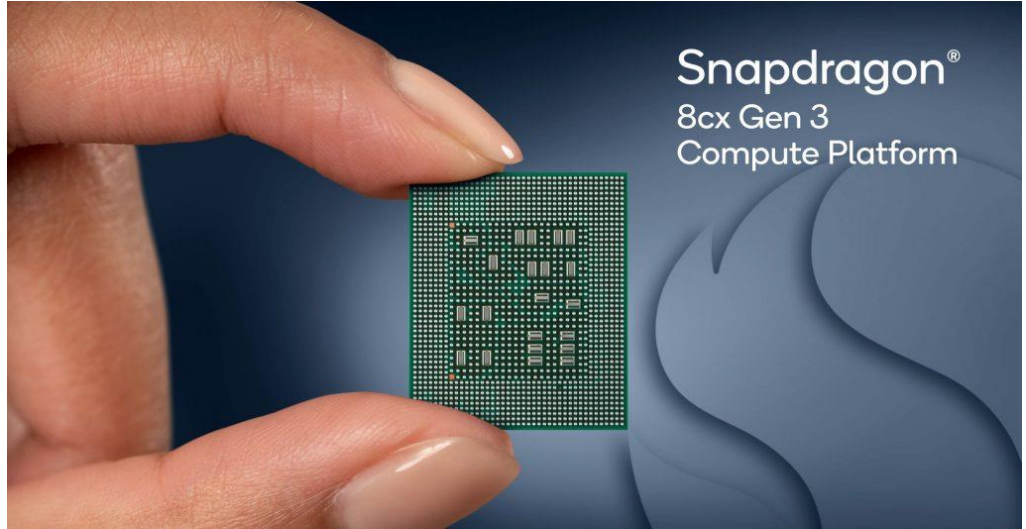
# IC view

- An integrated circuit is a small electronic device made up of multiple interconnected electronic components such as transistors, resistors, and capacitors. These components are etched onto a small piece of semiconductor material, usually silicon.



# IC technology

- NM technology, also known as nanometer technology, refers to the measurement of the size of transistors and other electronic components on a microchip. It represents the distance between two adjacent transistors and is used to determine the density and performance of integrated circuits.

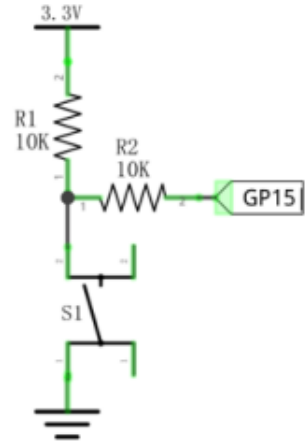
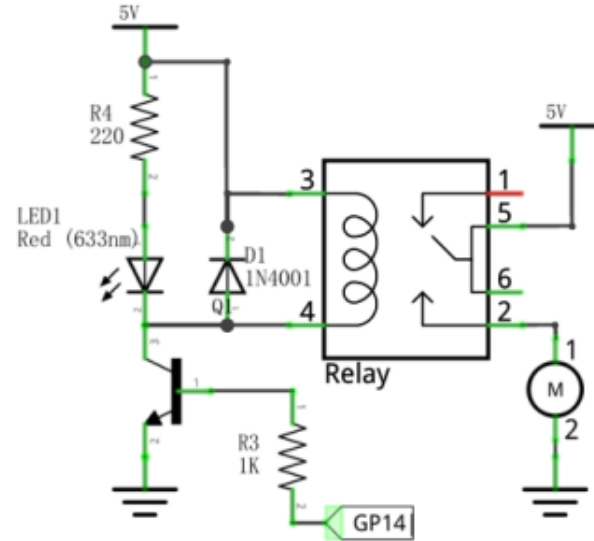
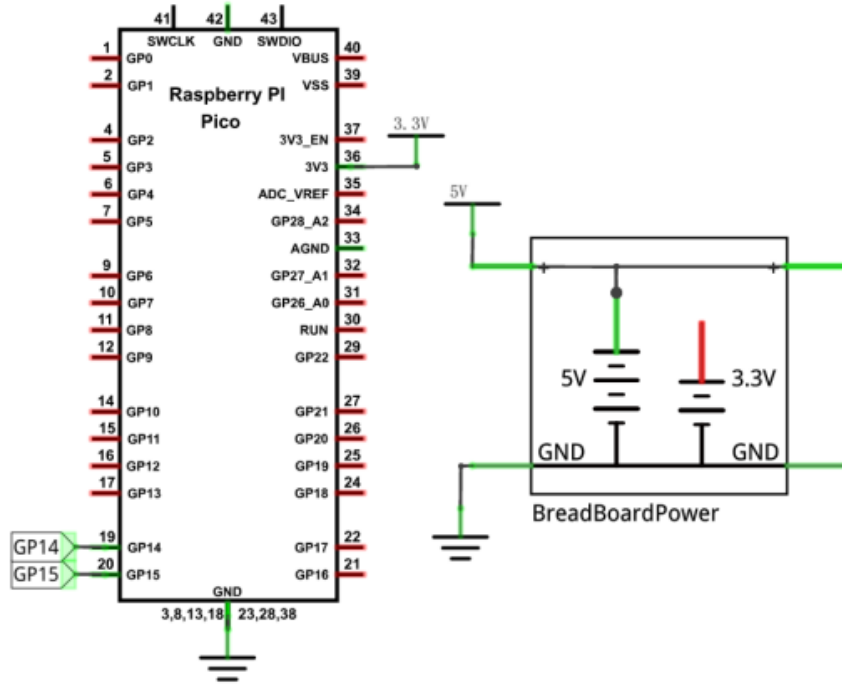


**First 5nm Chip for Windows-Based Arm Laptops**

# How to implement electronic circuit layout

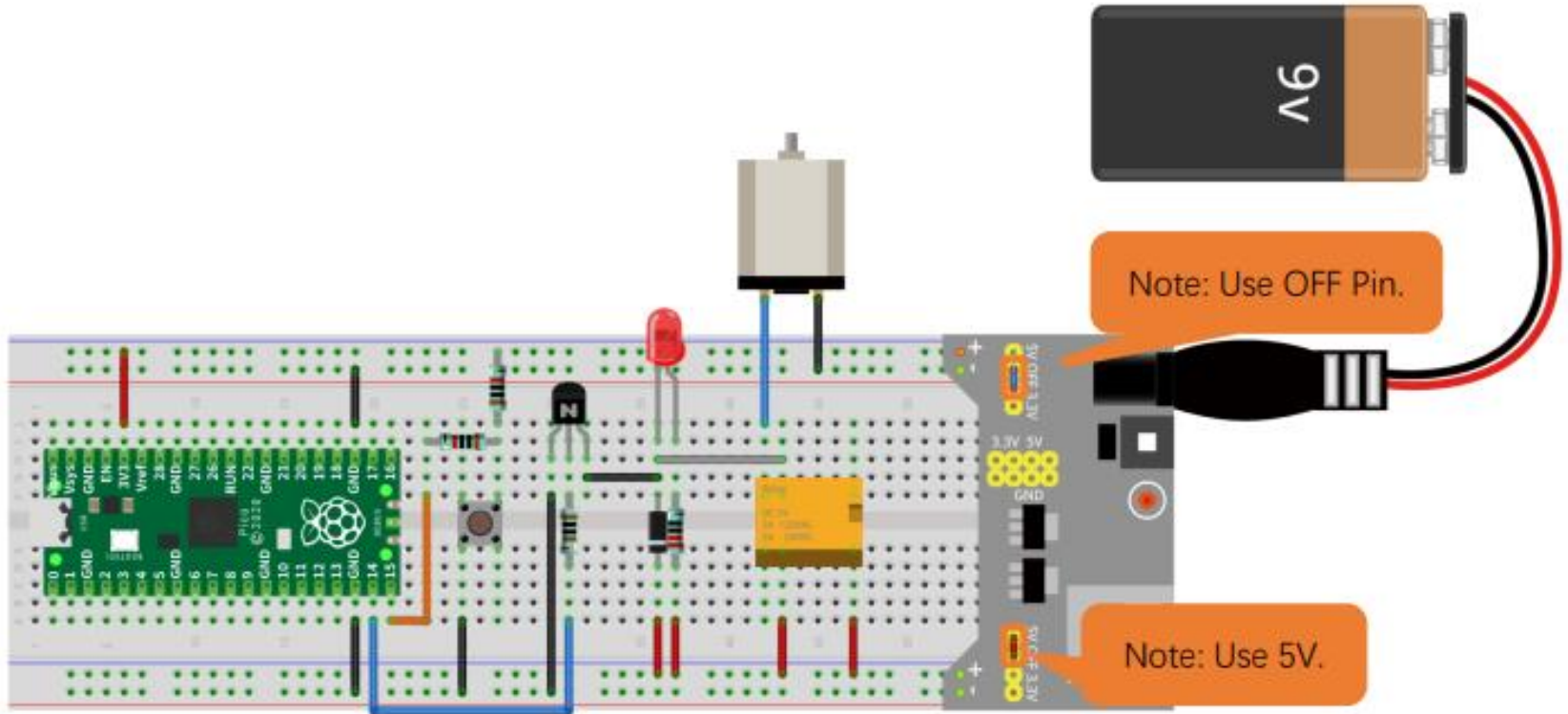
- point to point twisted wires (possibly using clamps)
- point-to-point wiring (soldering)
- breadboard and jumpers solderless prototyping
- printed circuit board (PCB)

# Digital circuit layout example



Relay and motor

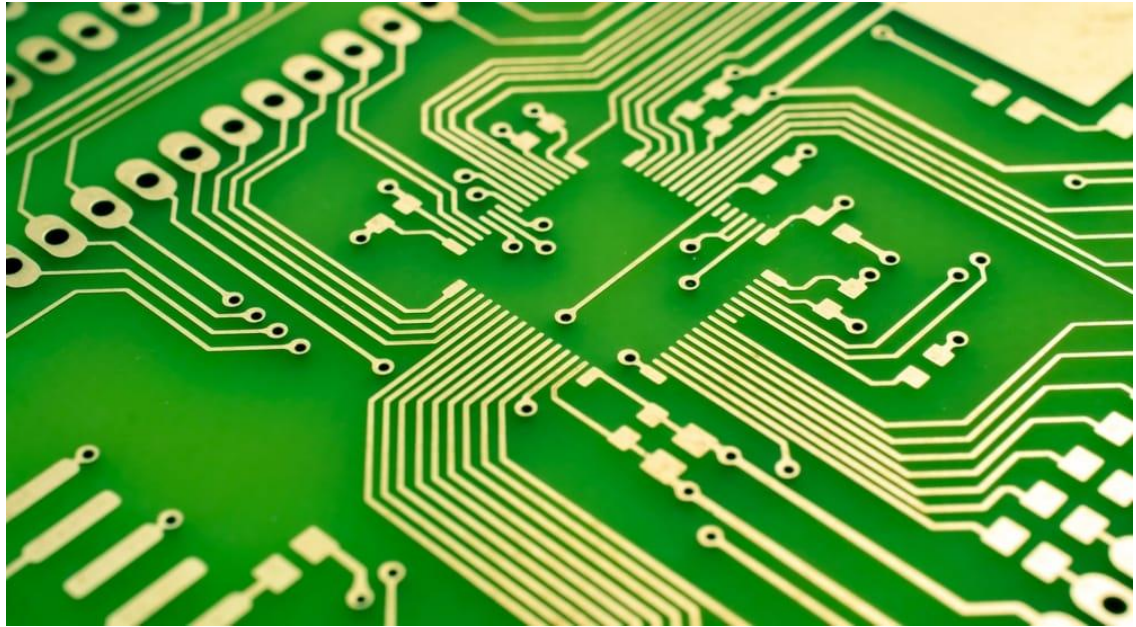
# Solderless prototyping – breadboards, holes, and jumpers





# Printed Circuit Board (PCB)

- a medium used to connect or "wire" components to one another in a circuit
- an electronic assembly that uses copper conductors to create electrical connections between components
- are built from alternating layers of conductive copper with layers of electrically insulating material





# PCB production



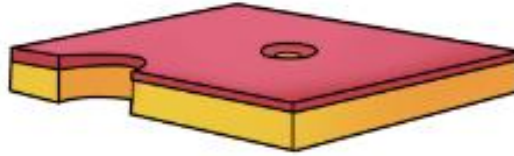
# PCB production process

- Conductive features on printed circuit boards include copper traces, pads, and conductive planes.
- The mechanical structure is made up of the insulating material laminated between the layers of conductors.
- The overall structure is plated and covered with a non-conductive solder mask, and silk screen is printed on top of the solder mask to provide a legend for electronic components.
- After these fabrication steps are completed, the bare board is sent into printed circuit board assembly, where components are soldered to the board and the PCBA can be tested.

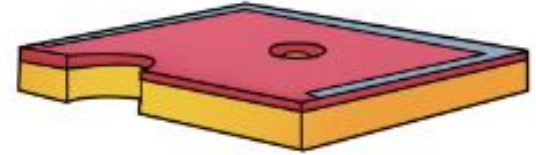
# Basic stages of production



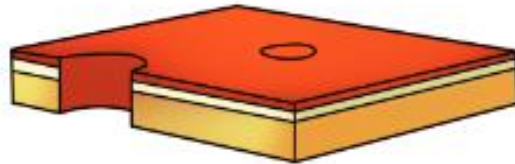
**Copper Clad**



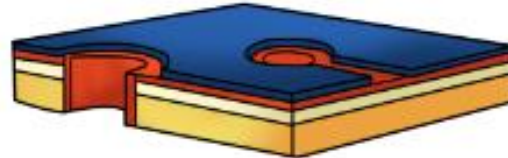
**1. Drilling  
2. Deburr**



**3. Sensitization  
4. Activation**



**5. Electroless  
Copper (2 microns)**



**6. Brushing - Drying  
7. Apply Photoresist**



**8. Copper  
Pattern Plate**

# Manufacturing PCB

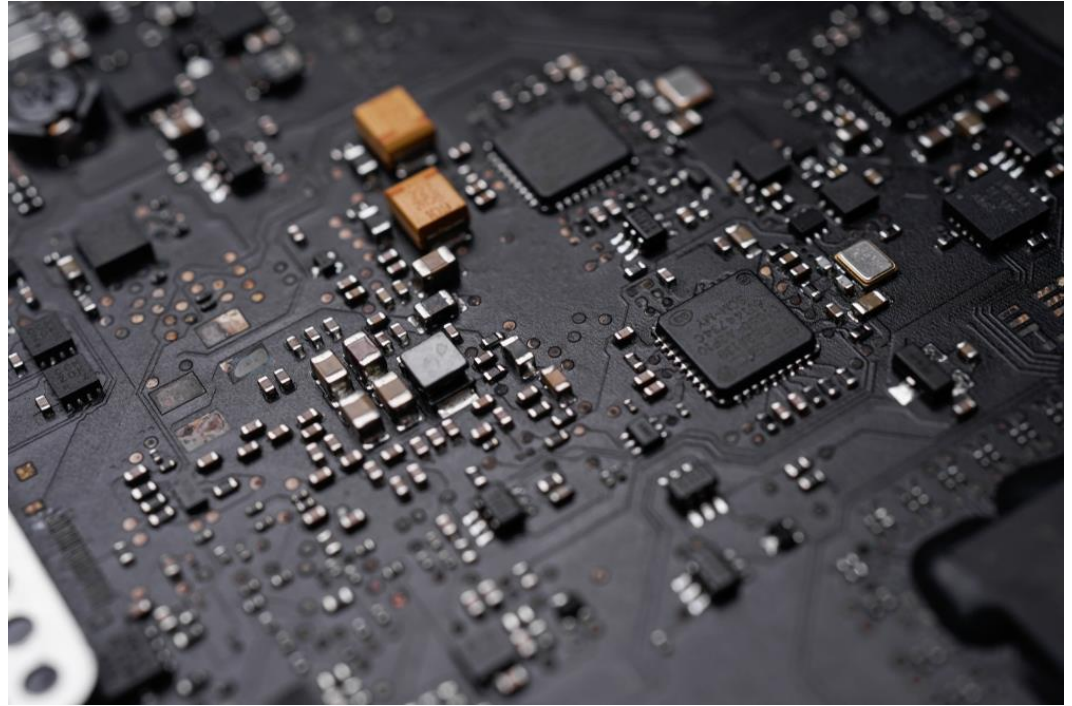
- During manufacturing, the inner copper layers are etched, leaving the intended traces of copper for connecting components in the circuit board.
- Multiple etched layers are laminated in succession until the printed circuit board stack-up is complete.
- This is the overall process used in PCB design fabrication, where the bare board is formed before passing through a printed circuit board's assembly process.

# Types of PCBs

- Single-sided - components are mounted on one surface. The back surface is typically fully copper (ground) and coated with a solder mask.
- Double-sided - components are mounted on both surfaces. Each surface is defined as a signal layer in the PCB stack-up, so the surfaces will contain traces that carry signals between components.
- Multi-layer PCBs - these boards have conductors on internal layers that carry electrical signals between components, or the internal layers could be conductive plane layers. Multi-layer PCBs may be single-sided or double-sided.
- ...

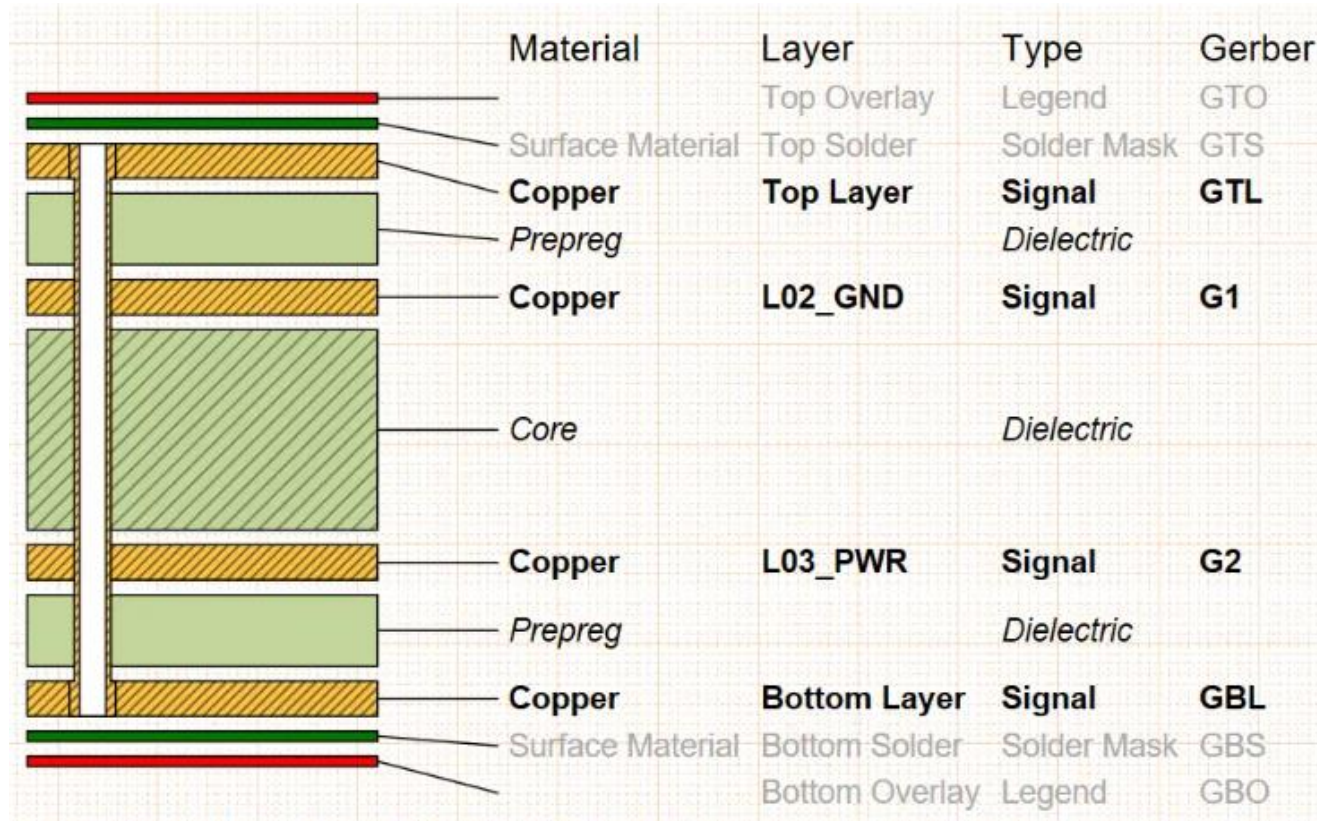
# Modern trends

- Older PCBs:  
through-hole  
technology
- *Modern PCBs:  
tend to surface-  
mount  
technology  
(SMT)*





# PCB stack example



# PCB assembly

- Apply solder paste to the circuit board
- Pick and place the machine
- Let the solder paste solidify
- Inspect the PCB assembly
- Insert the plated through-hole component, wave soldering
- Complete a final inspection