Essentials of Electronics Design From Ohm's Law to EasyEDA

Comprehensive Curriculum

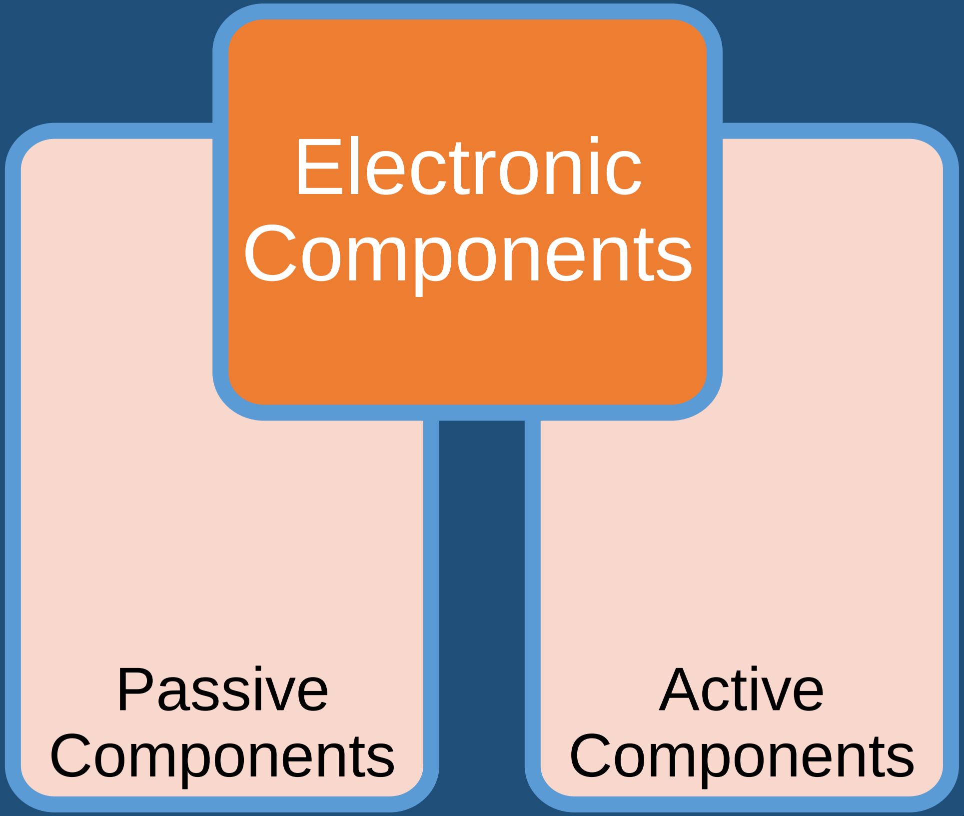
Electronic Components

Passive Components:

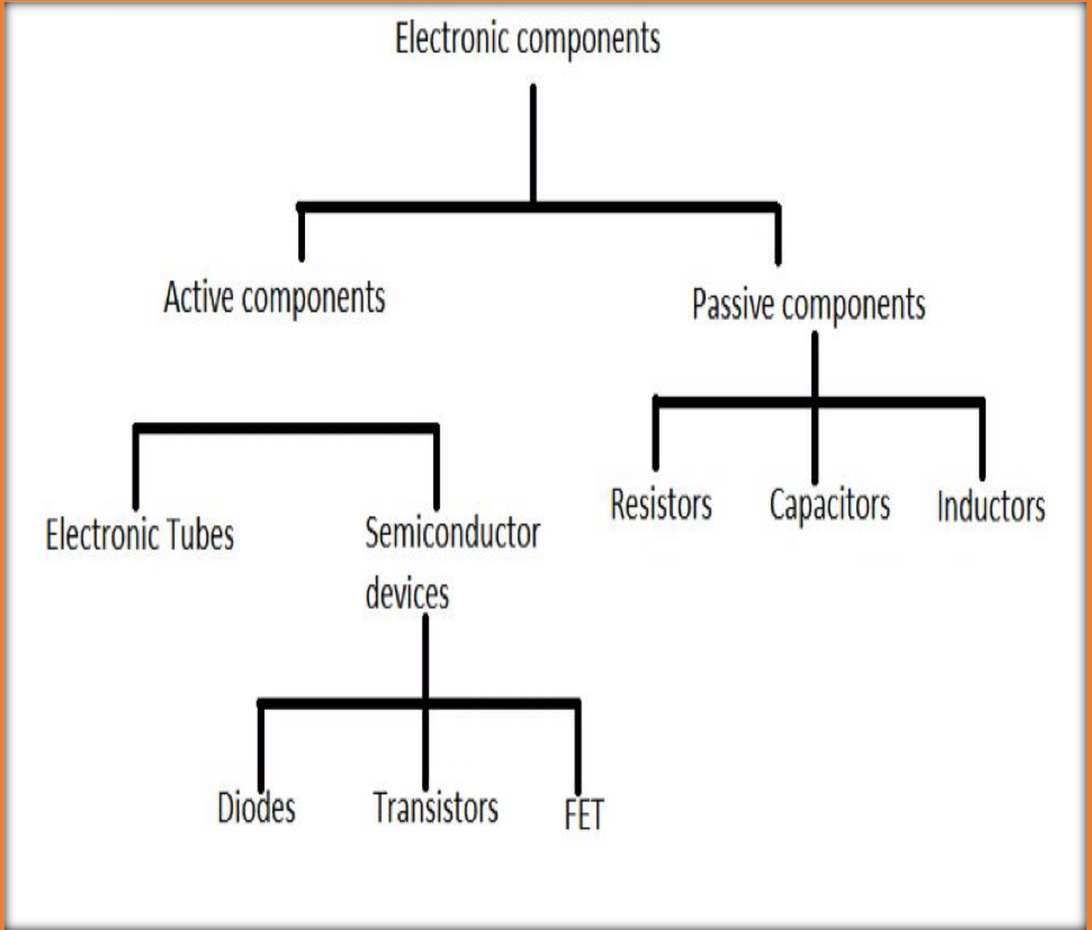
Components that do not require an external power source to operate. They primarily modify or control the flow of electrical signals without amplification. Examples include resistors, capacitors, inductors, and transformers.

Active Components:

Components that require an external power source to operate. They can amplify, rectify, or switch electrical signals. Examples include transistors, diodes, operational amplifiers (op-amps), and integrated circuits (ICs).



Classification of Electronic Components



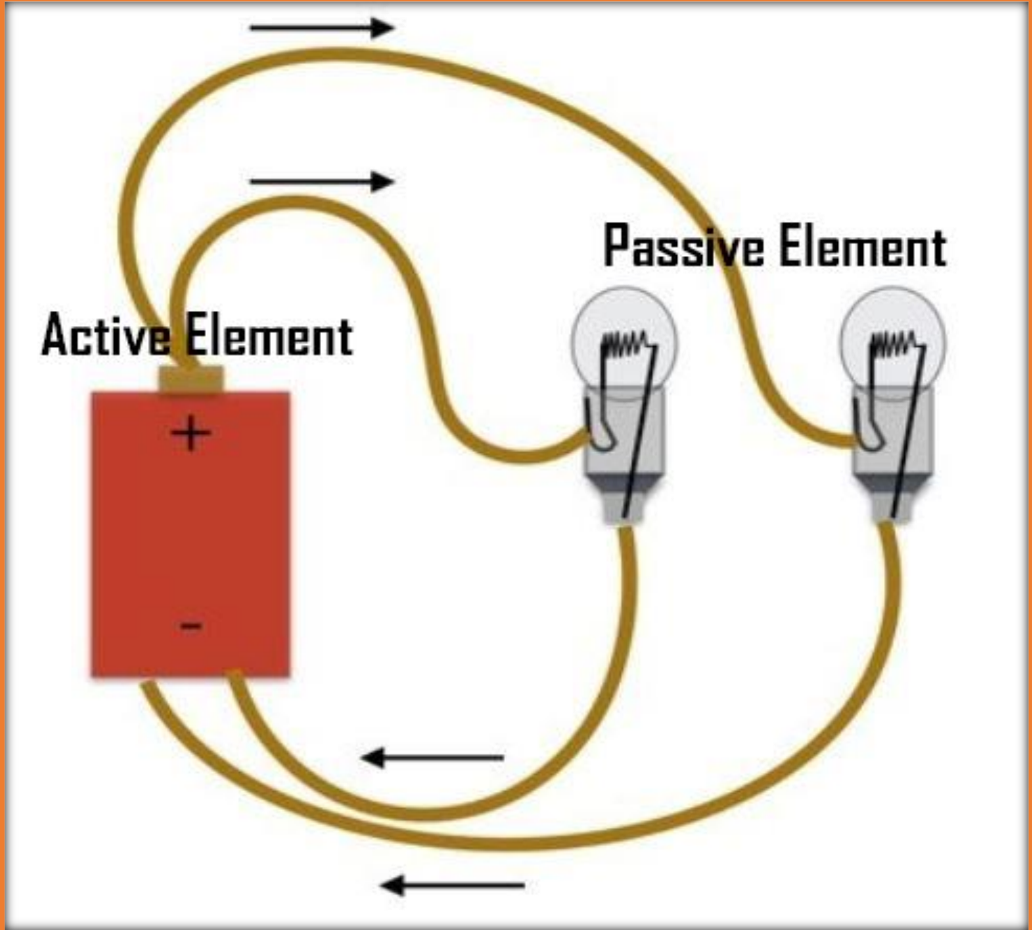


Table of Passive Components

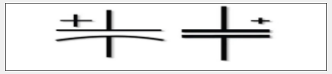
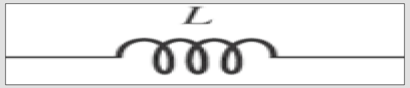
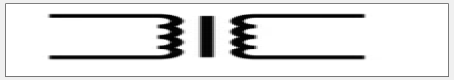
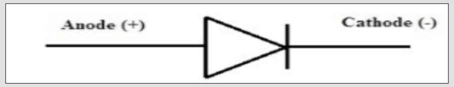
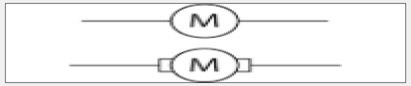
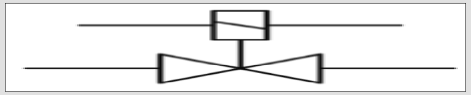
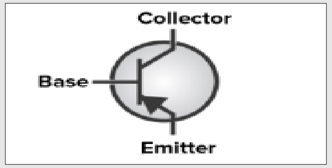
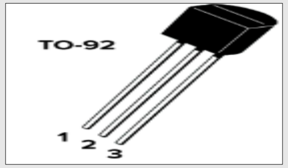
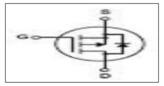
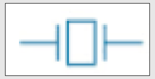
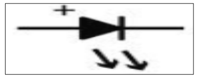
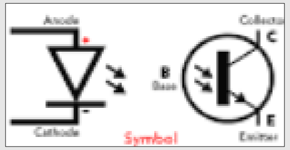
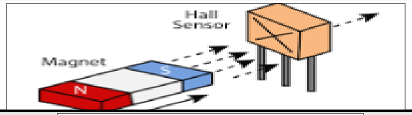
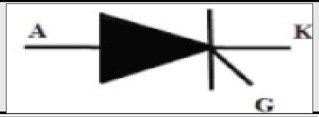
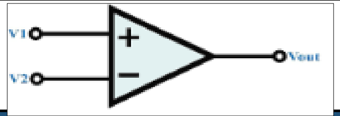
Passive Components	S.I Unit	Symbol
Resistors	Ohm	
Capacitors	farad	
Inductors	henry	
Transformers	kilovolt-amperes	
Diodes	-	
Potentiometer	volt/metre	
Relays	-	
Motors	-	
Solenoid	-	

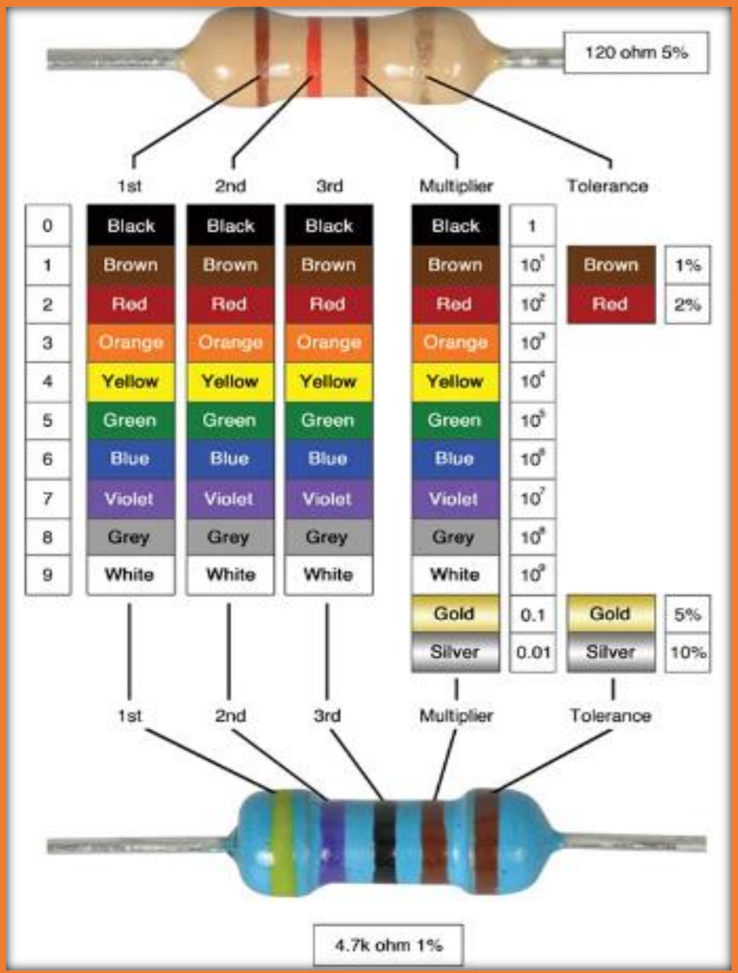
Table of Active Components

Active Components	Relationship/Unit	Symbols
Transistors	Ampere (A), Volt (V), and Ohm (Ω), respectively.	 
MOSFETS	Ampere per Volt	
Crystal Oscillator	Hertz	
Leds	Candela	
Opto Couplers	Volts	
Hall effect sensors	tesla (T)	
Silicon-controlled rectifiers	Volt/Ampere	
Comparators	Voltage (V)	

Passive Components:

➢ Resistors :

Resistors are passive electrical components that resist the flow of electrical current. They are commonly used to limit current, divide voltage, adjust signal levels, terminate transmission lines, and provide biasing in electronic circuits.



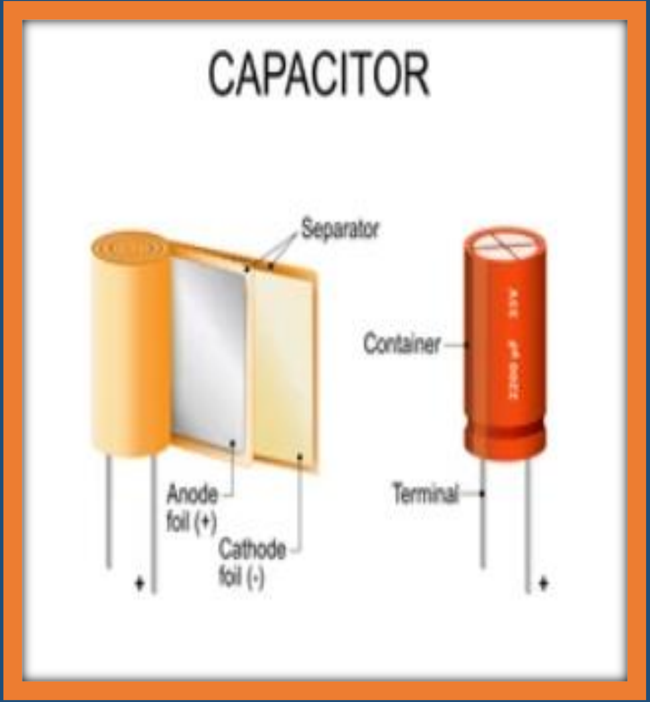
➢ Applications:

- Voltage division: Used in voltage dividers to produce a fraction of an input voltage.
- Current limiting: Protecting components by limiting current flow.
- Biasing: Setting the operating point of active components like transistors.
- Signal conditioning: Shaping or scaling signals in electronic circuits.

Passive Components:

➢ Capacitors:

Capacitors store electrical energy in an electric field. They consist of two conductive plates separated by an insulating material (dielectric).



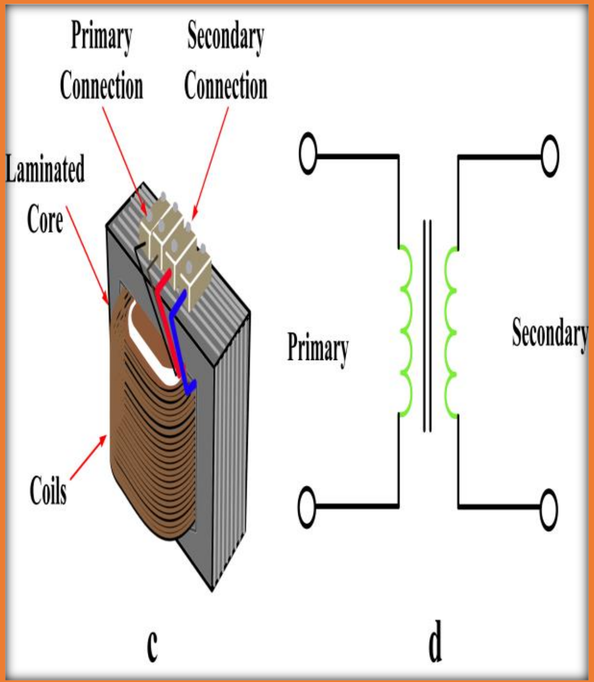
➢ Applications:

- Energy storage: Capacitors store energy in circuits and release it when needed.
- Filtering: Smoothing out voltage variations and filtering noise.
- Timing: Used in combination with resistors to create timing circuits.
- Coupling: Transmitting AC signals while blocking DC.

Passive Components:

➢ Inductors:

Inductors are passive electrical components that store energy in a magnetic field when current flows through them. They consist of a coil of wire wound around a core material.



➢ Applications:

- Filtering: Blocking certain frequencies while allowing others to pass.
- Energy storage: Inductors store energy in magnetic fields and release it when needed.
- Inductive coupling: Transferring energy between circuits without direct electrical connection.
- Signal processing: Used in oscillators, filters, and impedance matching circuits.

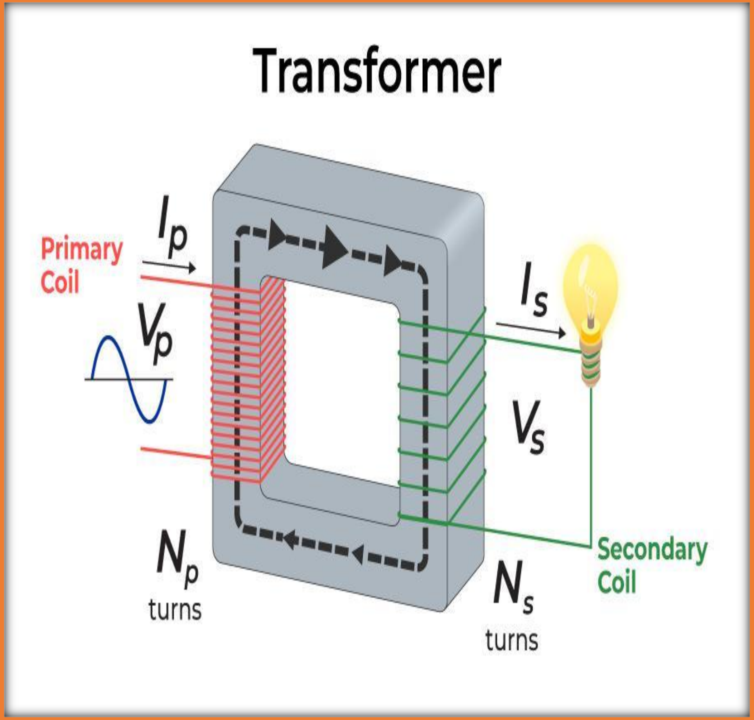
Passive Components

➢ Transformers:

Transformers are passive devices that transfer electrical energy between two or more circuits through electromagnetic induction. They consist of two or more coils of wire wrapped around a magnetic core.

➢ Applications:

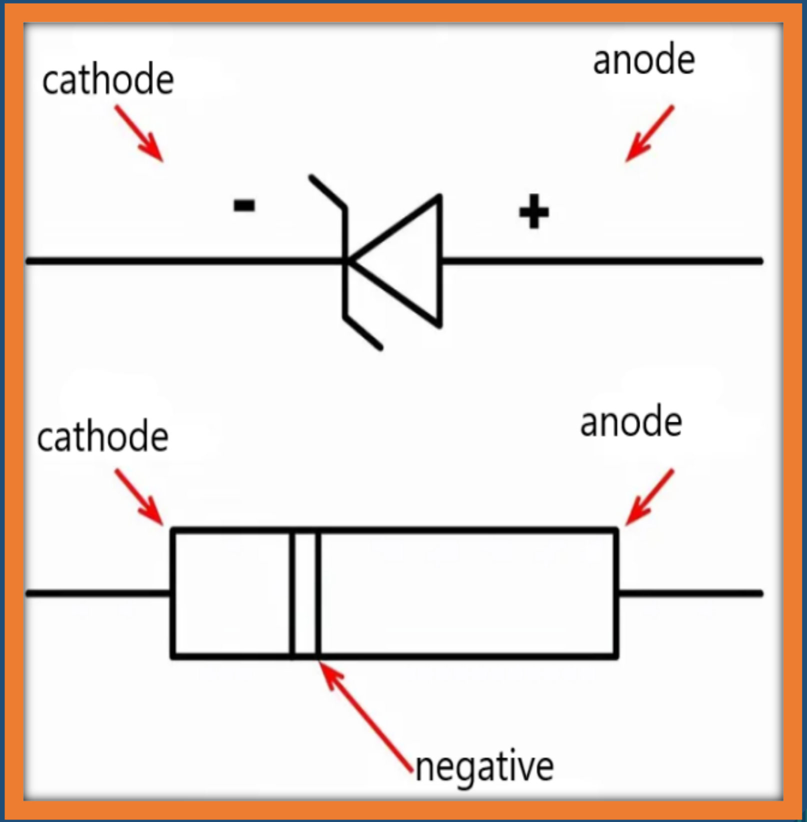
- Voltage transformation: Changing the voltage level between circuits (step-up or step-down).
- Isolation: Electrically isolating circuits while transferring power.
- Impedance matching: Matching the impedance between input and output circuits.
- AC power distribution: Transmitting electricity efficiently over long distances.



Passive Components

- **Diodes:**

Diodes are semiconductor devices that allow current to flow in one direction only. They consist of a PN junction.



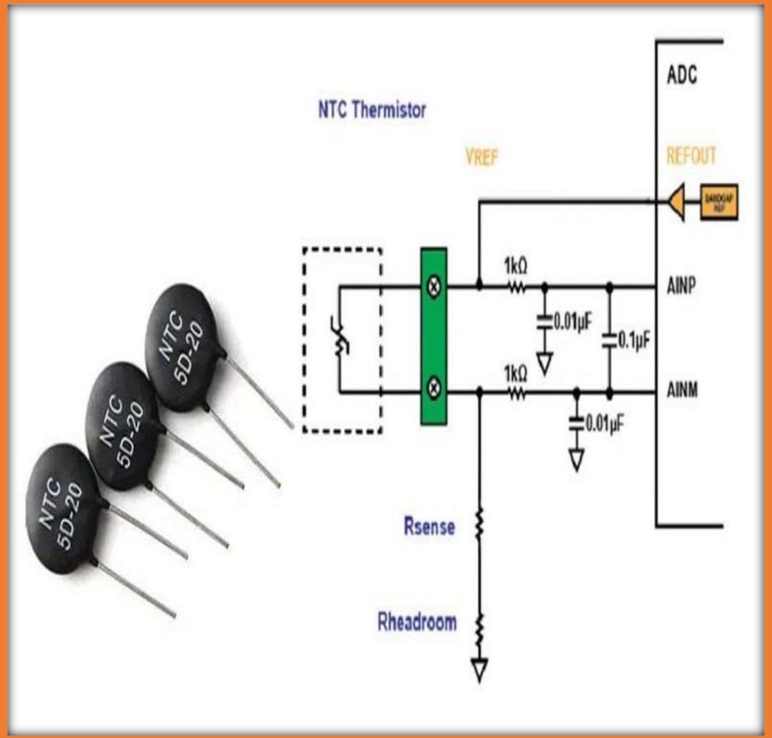
- **Applications:**

- Rectification: Converting AC to DC by allowing current flow in only one direction.
- Voltage regulation: Stabilizing voltage levels in circuits.
- Signal demodulation: Recovering the original signal from modulated signals.
- Protection: Preventing reverse current flow and voltage spikes in circuits.

Passive Components

Thermistors:

Thermistors are temperature-sensitive resistors whose resistance changes significantly with temperature.



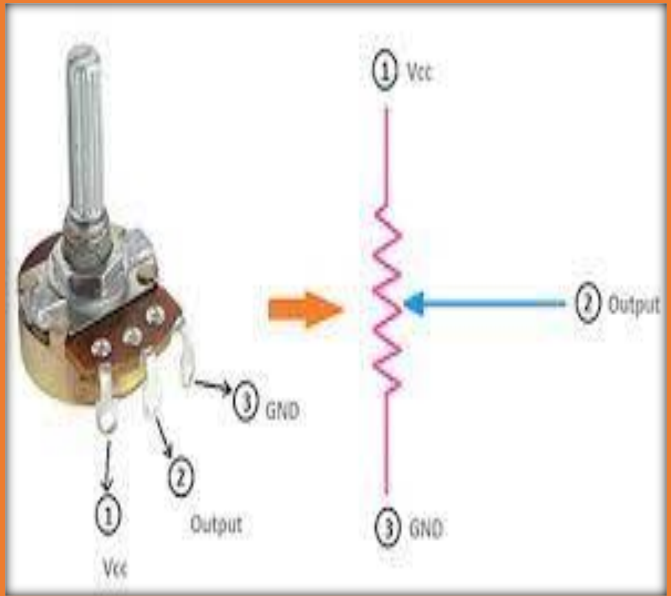
Applications:

- Temperature measurement: Used in thermostats, temperature sensors, and thermal protection circuits.
- Compensation: Providing compensation for temperature-dependent effects in circuits.
- Control: Regulating temperature in heating and cooling systems.
- Current limiting: Protecting circuits from excessive current flow by using their temperature-dependent resistance.

Passive Components

Potentiometers:

Potentiometers, or variable resistors, are resistors with an adjustable tapping point. By adjusting the tapping point, the resistance between the two endpoints can be varied.



Applications:

- Voltage division: Adjusting voltage levels in circuits.
- Volume control: Adjusting the volume in audio equipment.
- Biasing: Setting the operating point in electronic circuits.
- Tuning: Adjusting the frequency in radio circuits.

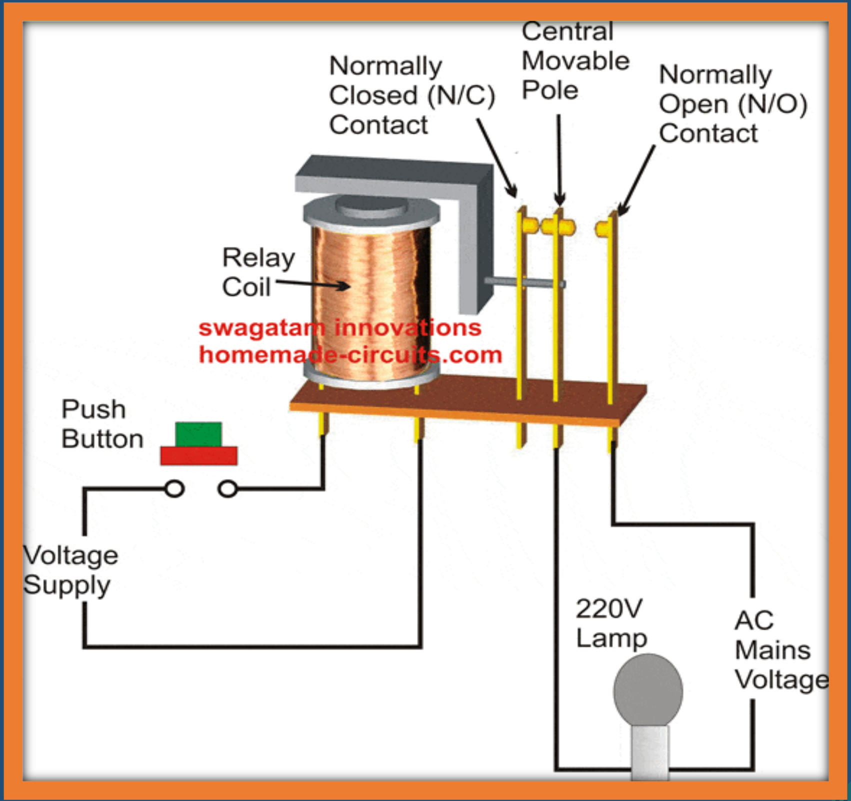
Passive Component

➢ Relays:

Relays are electromagnetic switches, they use an electromagnet to mechanically operate a switch.

➢ Applications:

- Switching high-power circuits: Controlling motors, lights, and heaters.
- Signal routing: Selecting between multiple inputs or outputs in electronic systems.
- Circuit protection: Disconnecting circuits in case of overload or fault conditions.



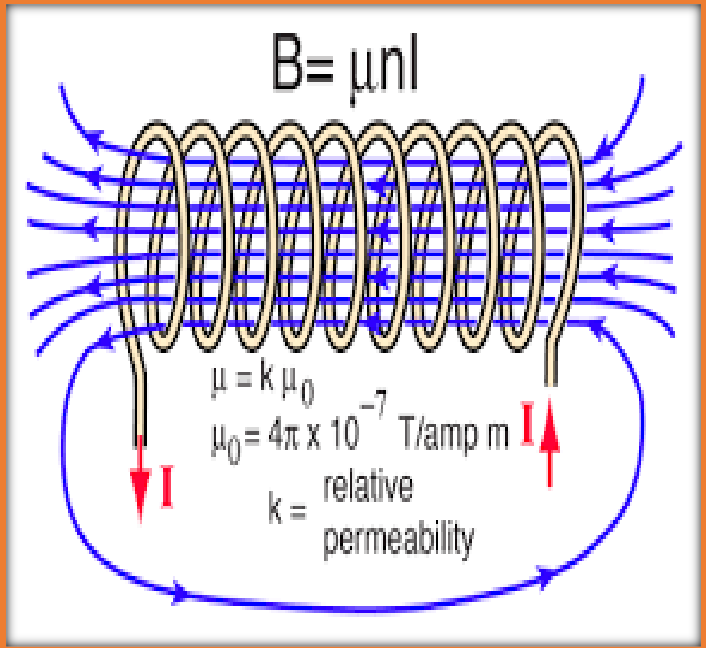
Passive Component

- **Solenoids:**

Solenoids are devices that convert electrical energy into linear motion using an electromagnetic coil.

- **Applications:**

- Actuation: Opening and closing valves, doors, and latches.
- Control systems: Controlling the position of mechanical components in automotive systems, industrial machinery, and consumer electronics.



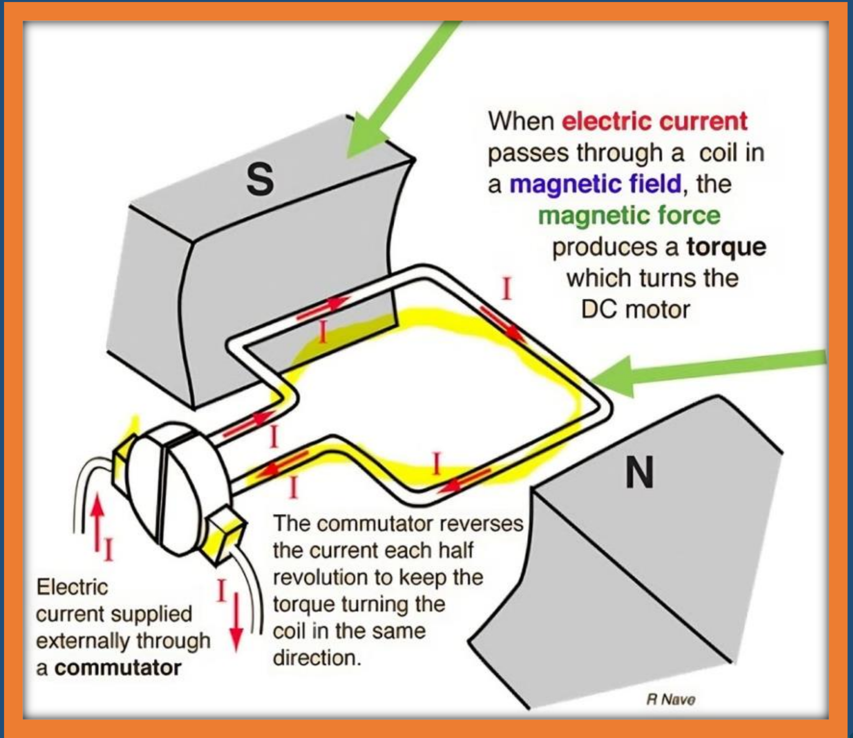
Passive Components

➢ Motors:

- Motors are devices that convert electrical energy into mechanical motion.

➢ Applications:

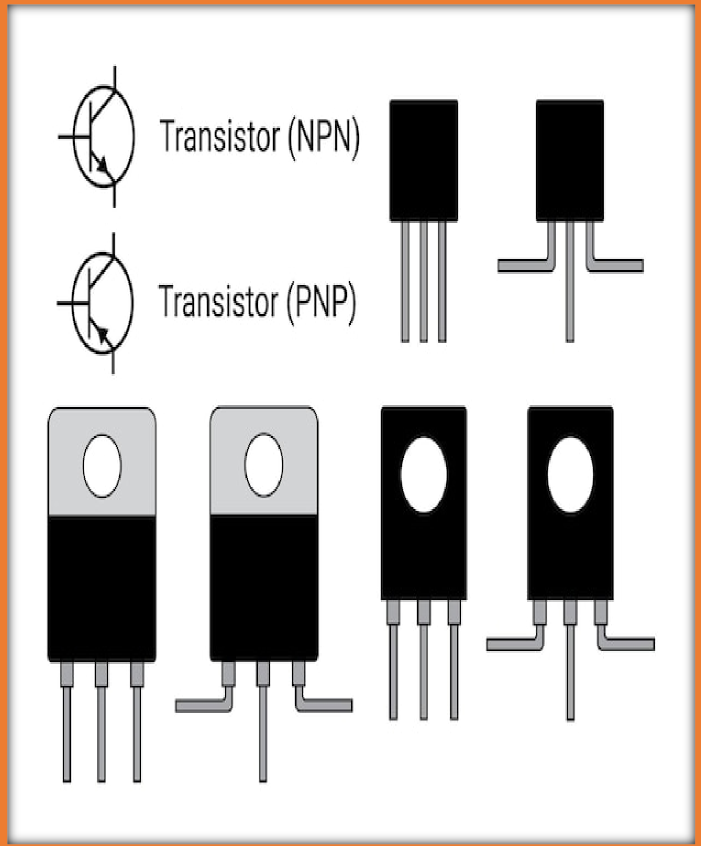
- Motion control: Driving machinery, appliances, and vehicles.
- Actuation: Moving mechanical components in robotics, automation, and industrial systems.
- Energy conversion: Converting electrical energy into rotational or linear motion in generators and actuators.



Active Components

Transistor:

A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power. It comes in various types such as bipolar junction transistors (BJTs) and field-effect transistors (FETs).



Applications

- Amplification: "Transistors amplify weak signals, crucial for applications like audio amplifiers and radio frequency circuits."
- Switching: "Transistors act as electronic switches, controlling current flow in digital circuits for devices like microcontrollers and power switches."
- Voltage Regulation: "They are integral to voltage regulation circuits, ensuring stable output voltages despite varying input or load conditions."
- Signal Modulation: "Used for encoding information onto carrier signals, facilitating communication systems like radio transmission."

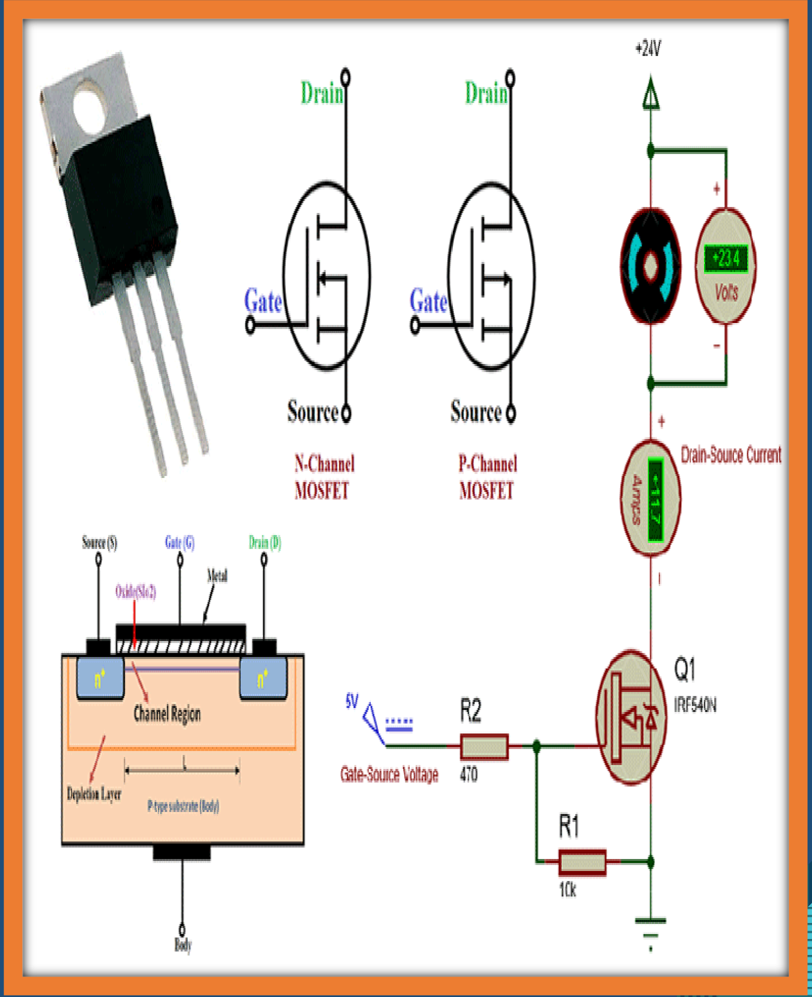
Active Components

MOSFET

MOSFET is a type of field-effect transistor where the flow of charge carriers (electrons or holes) is controlled by an electric field.

Applications

- Power Amplification: "MOSFETs amplify power in applications such as audio amplifiers and motor control."
- Switching: "They swiftly control the flow of power in electronic switches for efficient operation in DC-DC converters and LED drivers."
- Analog Signal Processing: "MOSFETs process analog signals for tasks like voltage amplification and filtering in electronic circuits."
- Memory: "Essential components in non-volatile memory technologies like Flash memory and EEPROM."
- Voltage Regulation: "Utilized in voltage regulator circuits for precise voltage regulation in portable devices and power supplies."



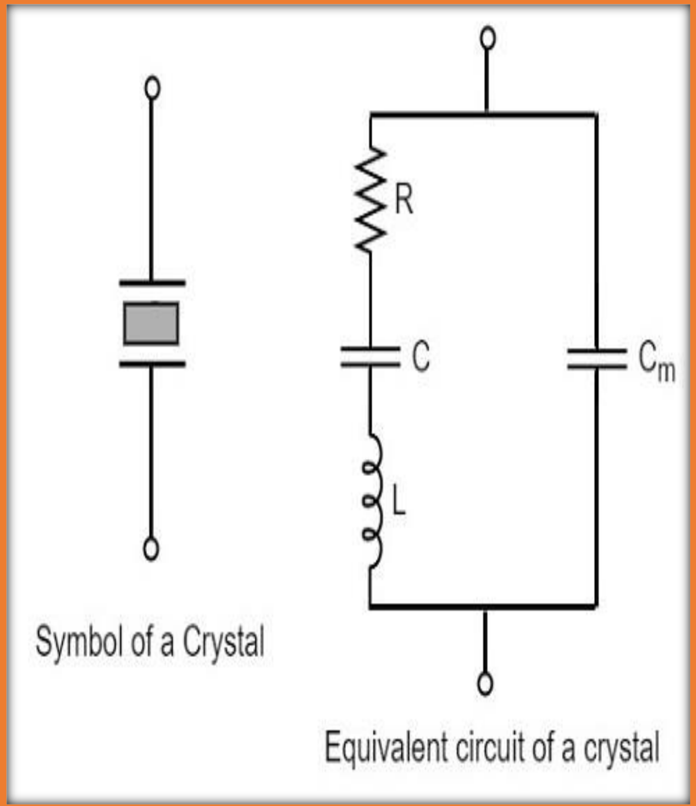
Active Components

Crystal Oscillator

A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a precise frequency.

Applications

- Clock Generation: "Crystal oscillators produce accurate clock signals, vital for synchronization in digital circuits."
- Frequency Synthesis: "They synthesize stable output frequencies for applications like radio transmitters and wireless communication systems."
- Signal Conditioning: "Used in signal conditioning circuits to generate stable reference frequencies for precision measurement instruments."
- Timing Applications: "Applied in various timing applications, including event timing and timekeeping in digital systems."



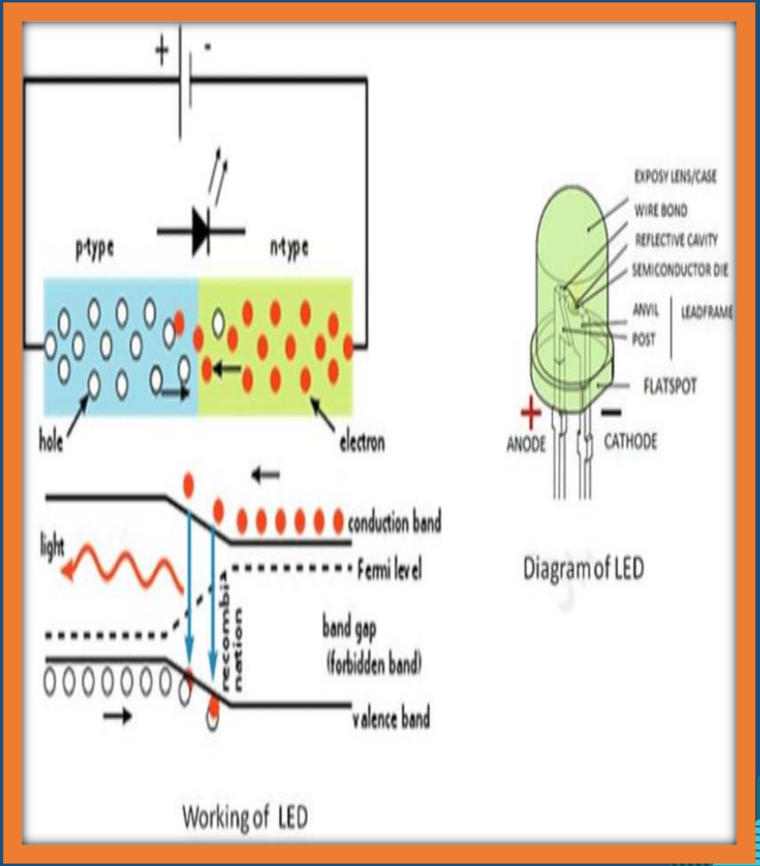
Active Components

LEDs (Light-Emitting Diodes):

LEDs are semiconductor light sources that emit light when an electric current passes through them. They are often used as indicators, illuminators, and in displays.

Applications

- Lighting: "LEDs are energy-efficient light sources widely used in both residential and commercial lighting applications."
- Indicator Lights: "LEDs provide visual indication for device status in electronics, from power on/off to system alerts."
- Automotive Lighting: "They illuminate headlights, taillights, and interior lighting in vehicles, offering durability and efficiency."
- Backlighting: "LEDs backlight LCD panels in electronic displays like smartphones and TVs, ensuring vibrant visuals."



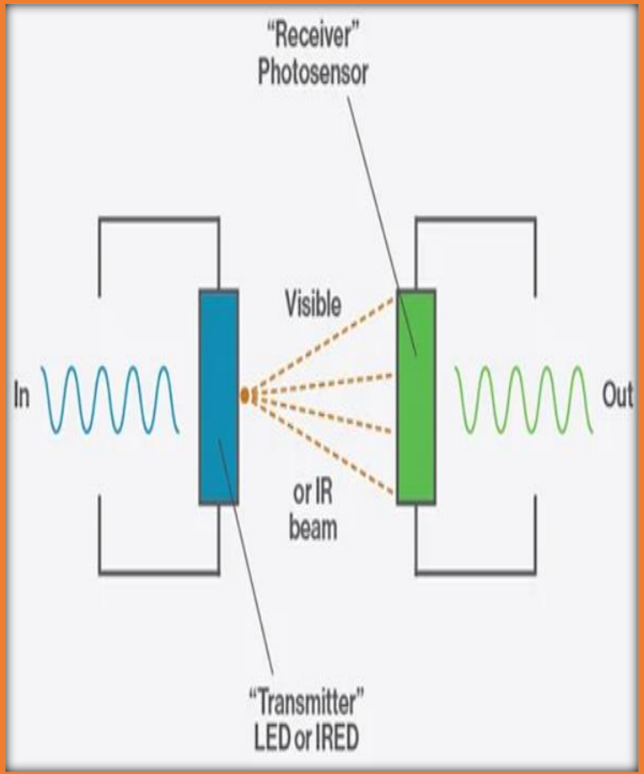
Active Component

- **Optocoupler**:

An optocoupler, also known as an opto-isolator, is a device that transfers electrical signals between two isolated circuits using light waves, typically emitted by an LED and detected by a photosensitive transistor or diode.

- **Application**

- Isolation: "Optocouplers provide electrical isolation between circuits, critical for preventing ground loops and ensuring safety."
- Signal Transmission: "They transmit analog or digital signals between circuits, particularly useful in noisy environments or high-voltage systems."
- Feedback Circuits: "Used in feedback loops to isolate the feedback path, ensuring stability and performance in power supplies and amplifiers."
- Motor Control: "Applied in motor control circuits to provide isolation between control signals and power electronics, minimizing electrical noise."

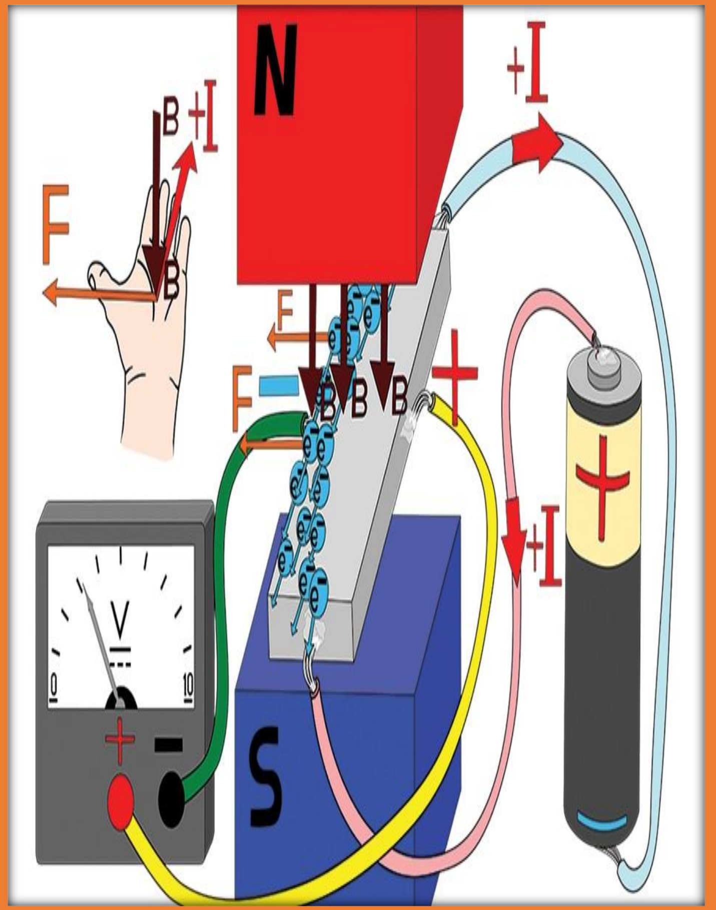


Active Component

- **Hall Effect Sensor**:

  A Hall effect sensor is a transducer that varies its output voltage in response to changes in magnetic field strength. It operates based on the Hall effect phenomenon.

- **Applications**



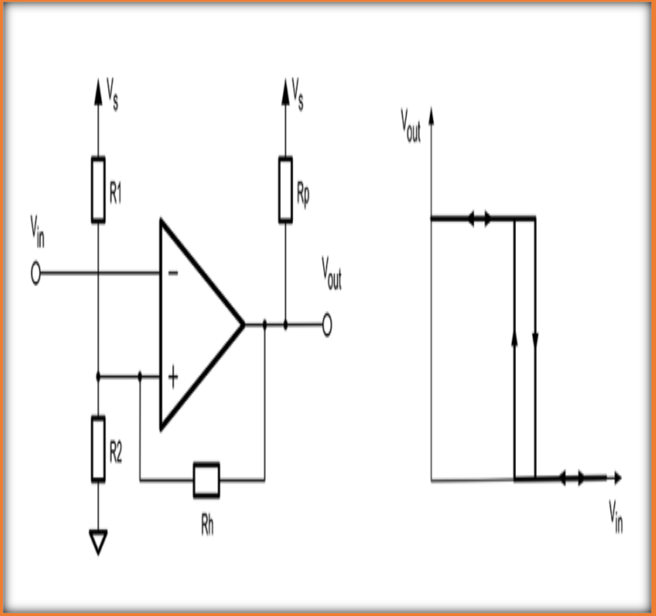
- Position and Proximity Sensing: "Hall effect sensors detect nearby magnetic objects, enabling applications like rotary encoders and proximity sensors."
- Current Sensing: "They measure magnetic fields generated by current flow, providing non-invasive current sensing in motor control and power monitoring."
- Brushless DC Motor Control: "Used with permanent magnets for feedback in brushless DC motors, allowing precise speed and direction control."
- Speed Measurement: "Hall effect sensors measure rotational speed in gears and wheels, vital for automotive speedometers and industrial machinery."

Active Component

- **Comparator**:

A comparator is an electronic circuit that compares two voltage inputs and produces an output based on their relative magnitudes.

- **Applications**

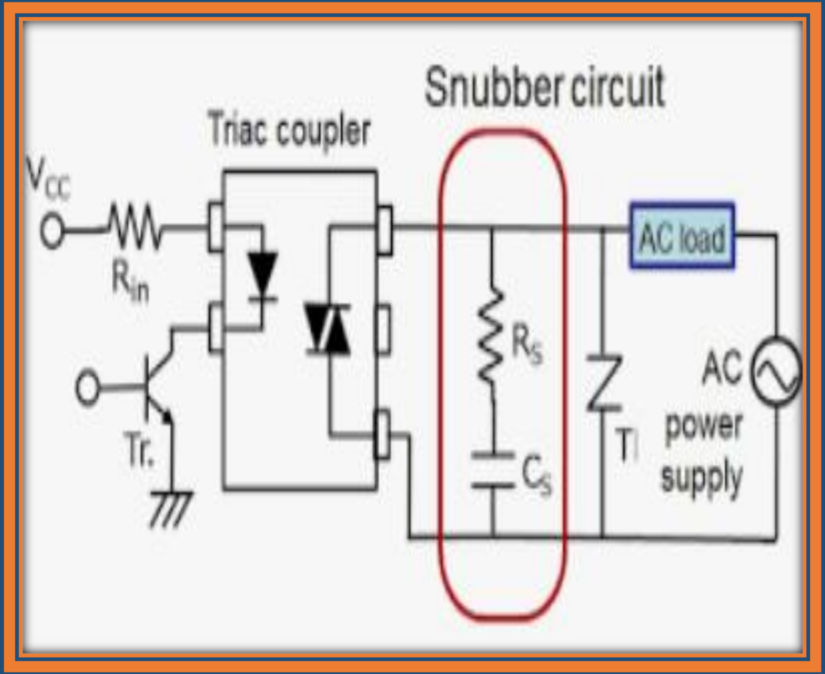


- Voltage Level Detection: "Comparators detect voltage levels against references, crucial for threshold detection and voltage monitoring."
- Window Detection: "They trigger events based on voltage within predefined ranges, used in temperature control and alarm systems."
- Zero Crossing Detection: "Comparators detect zero-crossing points in AC signals, vital for synchronization and phase control in power electronics."
- Pulse Width Modulation (PWM): "Used in PWM circuits to generate variable-width pulses based on comparison, applied in motor control and power supplies."

Snubber Circuits

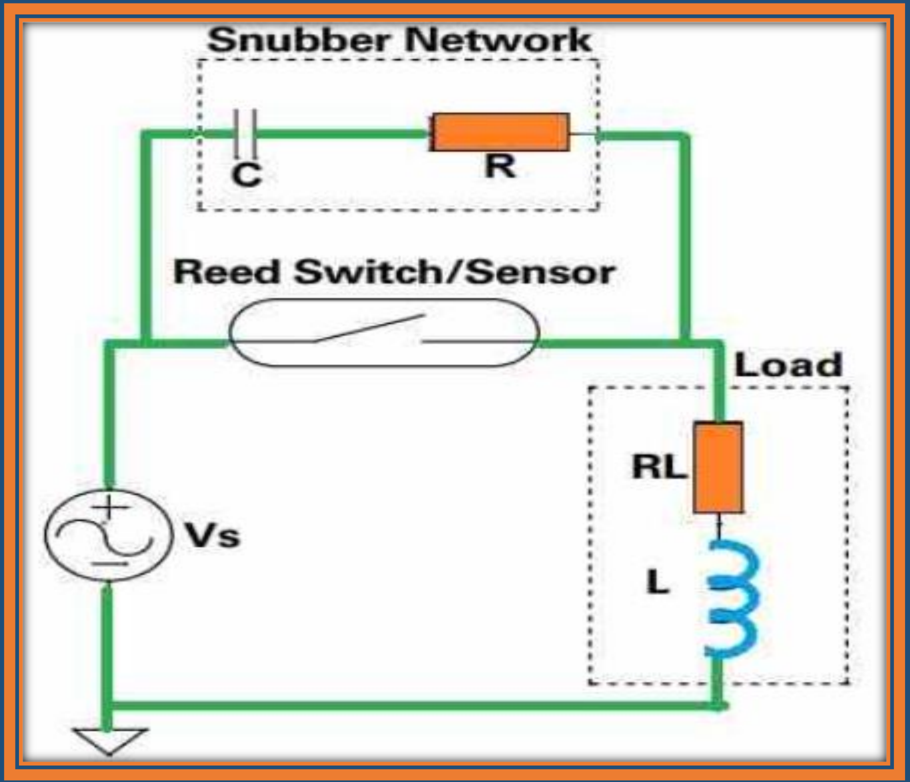
What is a Snubber Circuit?

A snubber circuit is like a bodyguard for electronic devices, especially diodes. It's made of a resistor and a capacitor, which are connected together and placed near the device they're protecting. Their job is to absorb any sudden spikes in voltage that can happen when the device switches on or off. These spikes can damage the device, but the snubber circuit absorbs them, keeping everything safe.



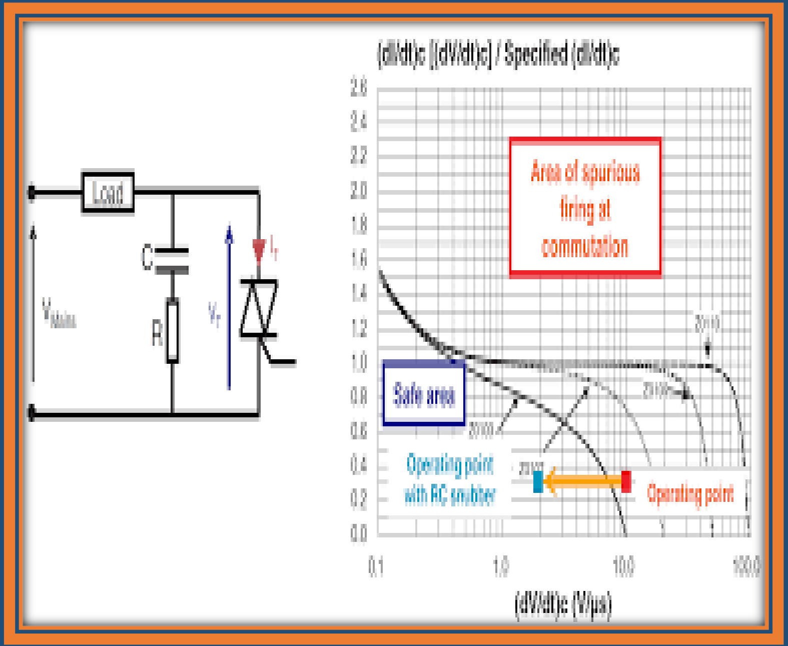
How Does it Work?

Imagine you have a water hose and you suddenly turn off the tap. The water in the hose keeps moving and can cause a big splash at the end. The resistor in the snubber circuit acts like a valve, slowing down this "splash" of electricity. The capacitor is like a sponge, soaking up the extra energy from the splash.



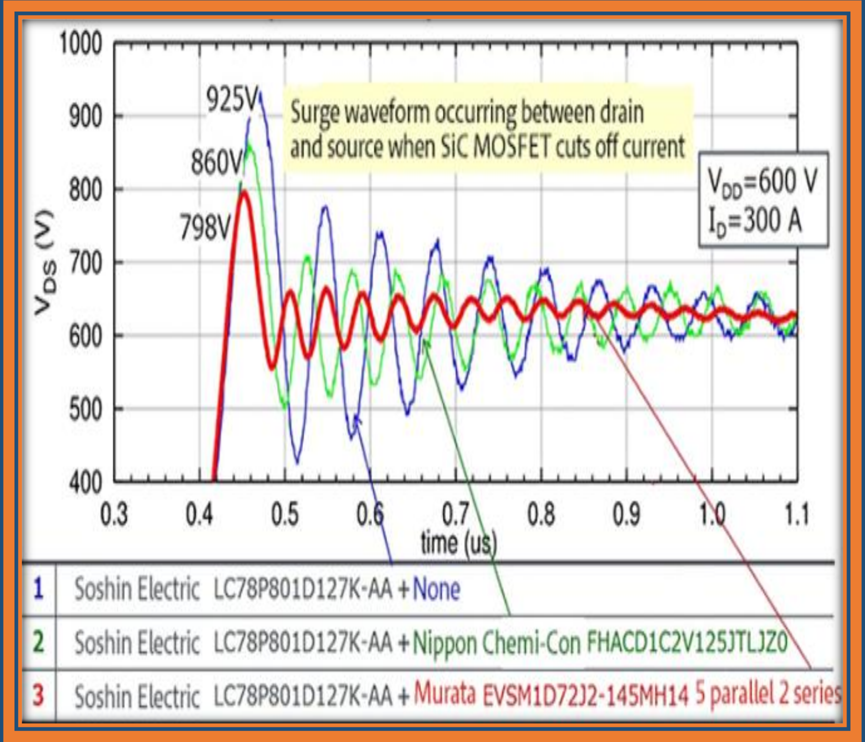
Advantages:

Keeps devices safe from voltage spikes.
Reduces the risk of things breaking unexpectedly.
Lessens annoying electromagnetic interference.
Helps regulate voltage in power supplies.
Stops devices from making unwanted noise.



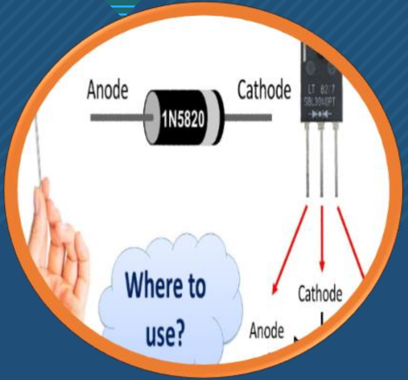
Disadvantages:

Adds some complexity and cost to the circuit.
Might not work perfectly in all situations.
Can cause some extra energy loss.
Choosing the right size of components can be tricky.
Works better in some situations than others.

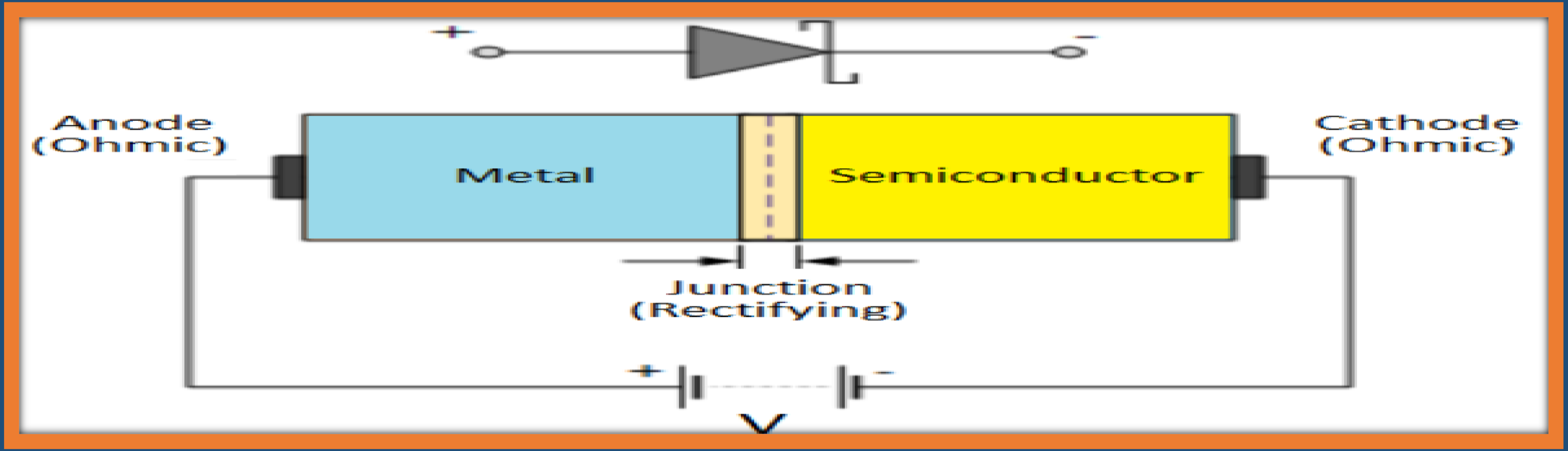


Applications:

Protecting motors from damage in machines.
Keeping audio systems stable and quiet.
Safeguarding solar power systems from sunlight changes.
Ensuring UPS systems switch smoothly.
Helping power converters work well, like in chargers.



Detailed Explanation On Diodes



What is Diode ?

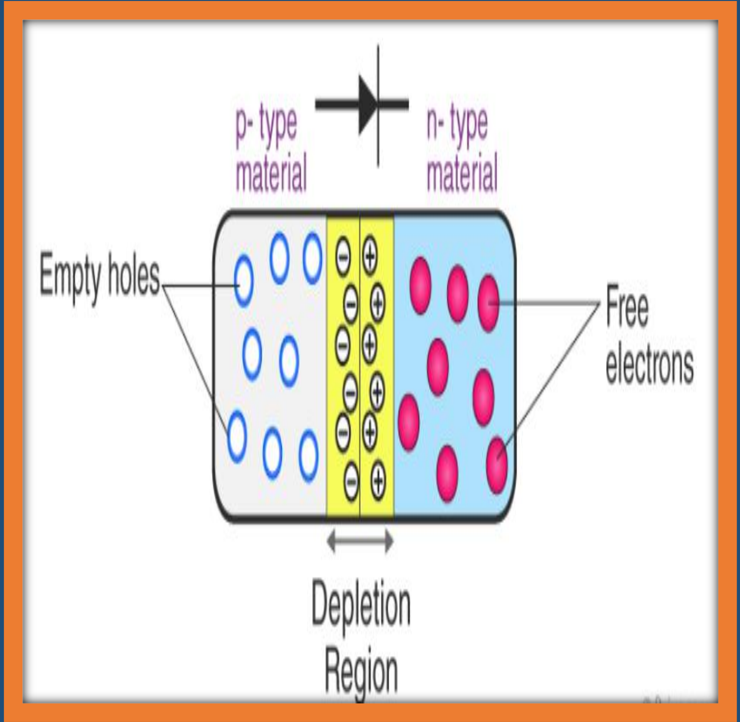
- A **diode** is a semiconductor device that essentially acts as a one-way switch for current. It allows current to flow easily in one direction, but severely restricts current from flowing in the opposite direction.

- Diodes are also known as **rectifiers** because they change alternating current (ac) into pulsating direct current (dc). Diodes are rated according to their type, voltage, and current capacity.

- Diodes have polarity, determined by an **anode** (positive lead) and **cathode** (negative lead). Most diodes allow current to flow only when positive voltage is applied to the anode.

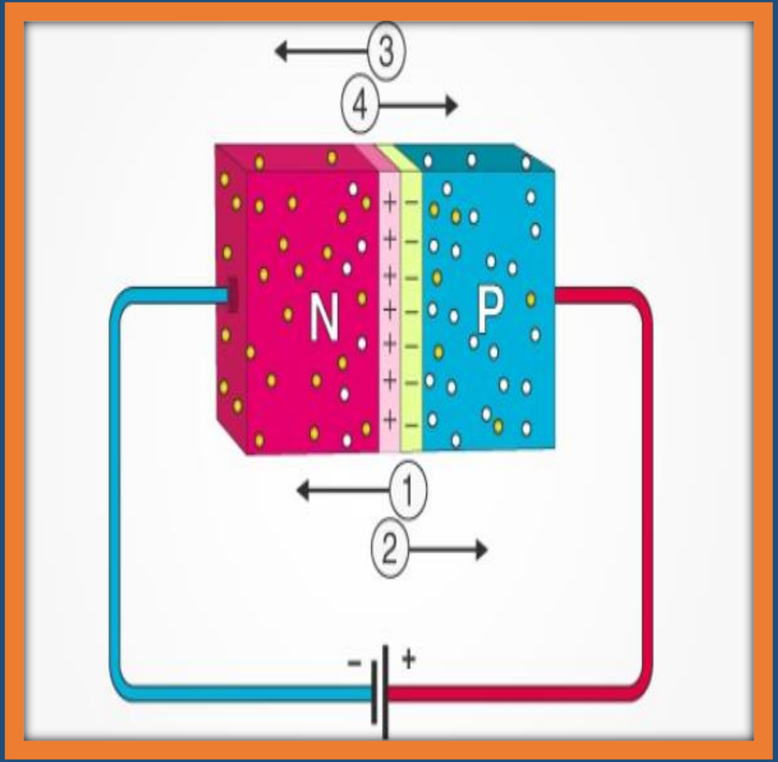
Formation of P-N Junction

To create a P-N junction, we start with a thin p-type silicon semiconductor sheet and introduce a small amount of pentavalent impurity, transforming part of the material into n-type silicon. This process establishes both p-type and n-type regions within the sheet, delineated by the junction between them. Subsequently, two fundamental processes ensue: diffusion and drift. During diffusion, holes from the p-side and electrons from the n-side migrate across the junction, driven by disparities in their concentrations, thereby generating a diffusion current. As this occurs, an accumulation of ionized donors on the n-side and acceptors on the p-side gives rise to a depletion region. In this region, a layer of positive charge forms on the n-side, while a negative charge layer forms on the p-side, establishing an electric field. This electric field induces drift, whereby electrons move from the p-side to the n-side against the diffusion current, maintaining equilibrium within the junction.



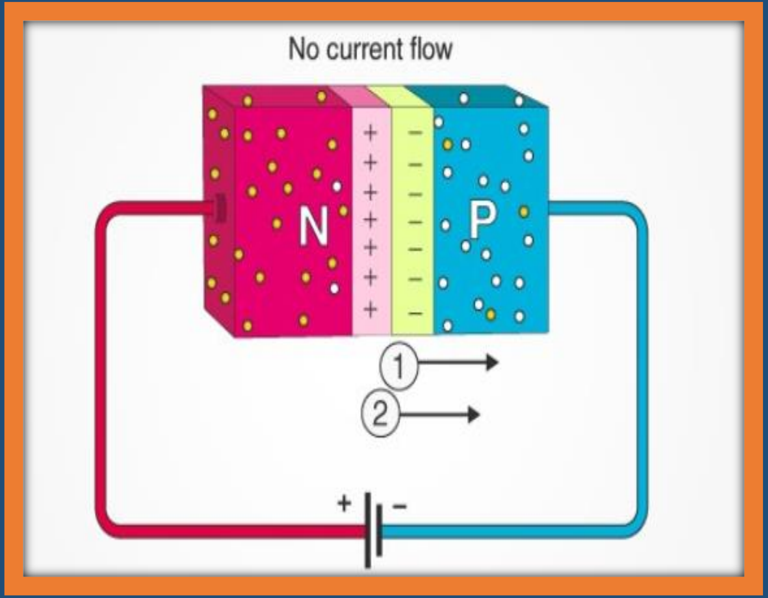
Forward Bias

When the p-type is connected to the battery's positive terminal and the n-type to the negative terminal, then the P-N junction is said to be forward-biased. When the P-N junction is forward biased, the built-in electric field at the P-N junction and the applied electric field are in opposite directions. When both the electric fields add up, the resultant electric field has a magnitude lesser than the built-in electric field. This results in a less resistive and thinner depletion region. The depletion region's resistance becomes negligible when the applied voltage is large. In silicon, at the voltage of 0.6 V, the resistance of the depletion region becomes completely negligible, and the current flows across it unimpeded.



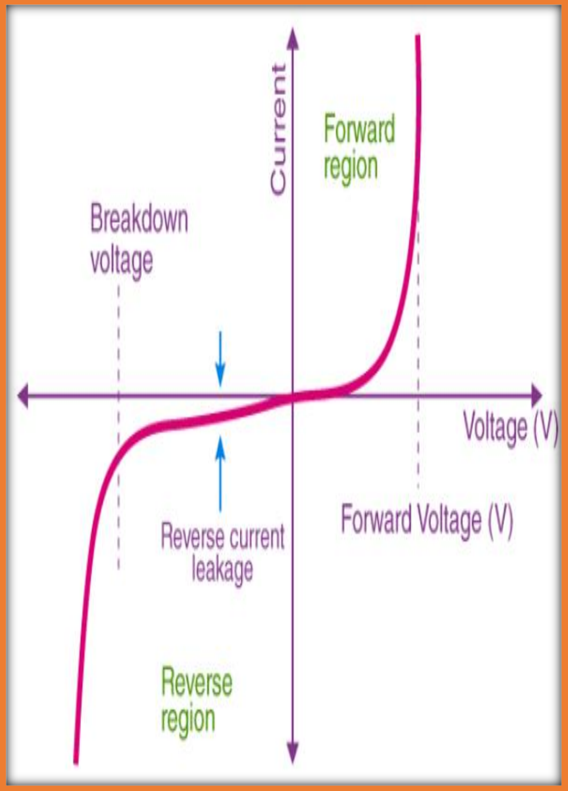
Reverse Bias

- When the p-type is connected to the battery's negative terminal and the n-type is connected to the positive side, the P-N junction is reverse biased. In this case, the built-in electric field and the applied electric field are in the same direction. When the two fields are added, the resultant electric field is in the same direction as the built-in electric field, creating a more resistive, thicker depletion region. The depletion region becomes more resistive and thicker if the applied voltage becomes larger.



V-I Characteristics of P-N Junction Diode:

- The V-I characteristics of a P-N junction diode depict its behavior concerning voltage and current. It is represented as a curve with voltage on the x-axis and current on the y-axis. The curve delineates three operating regions:
- **Zero Bias:** In this state, no external voltage is applied, and the potential barrier at the junction prevents current flow.
- **Forward Bias:** When the diode is forward biased, the p-type terminal connects to the positive voltage, reducing the potential barrier. For silicon diodes, this occurs at around 0.7 V, and for germanium diodes, at approximately 0.3 V, enabling current flow.
- **Reverse Bias:** Here, the p-type terminal connects to the negative voltage, increasing the potential barrier, hindering current flow. Initially, a reverse saturation current flows due to minority carriers present in the junction.
- During forward bias, the current gradually increases, initially non-linearly as the voltage overcomes the barrier, then sharply linearly. In reverse bias, the potential barrier increases, and excessive voltage may lead to breakdown, potentially damaging the diode.

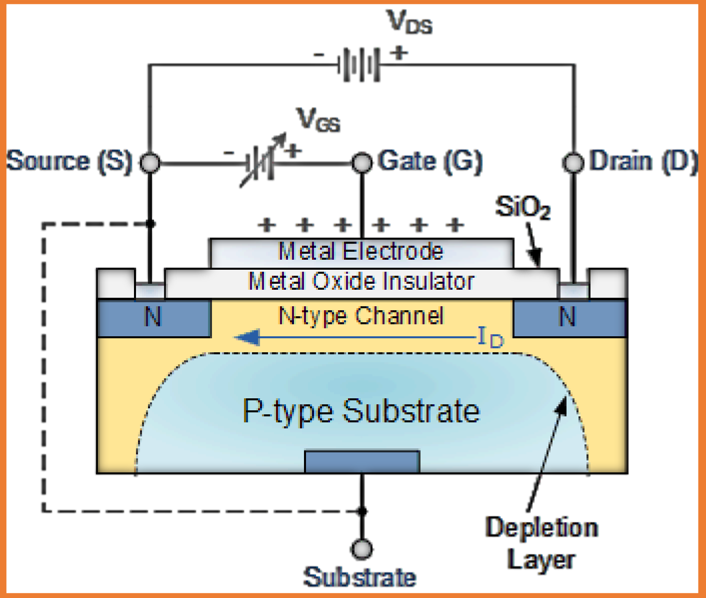


Metal-Oxide-Semiconductor Field-Effect Transistors)

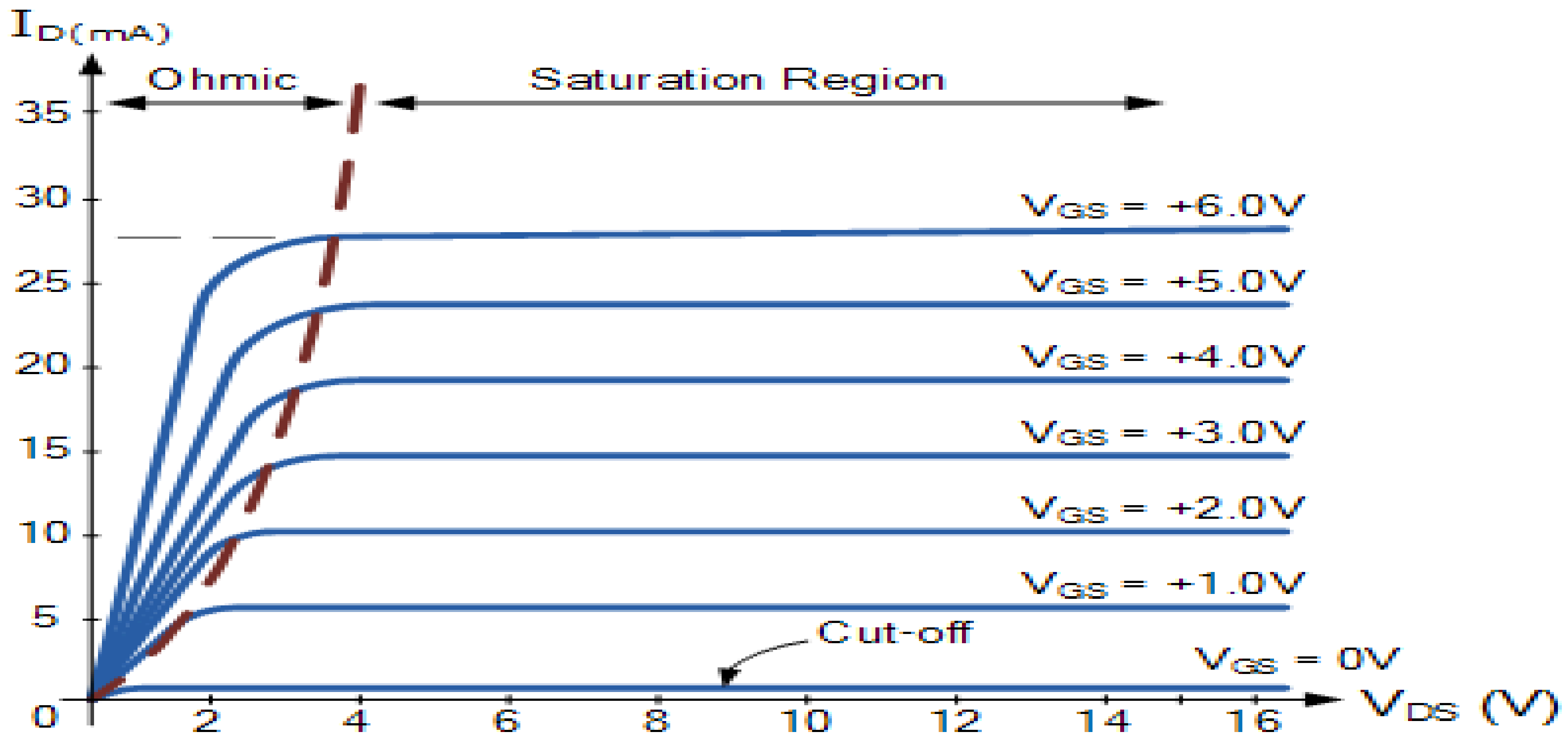
MOSFETs are semiconductor devices with three terminals: source, drain, and gate. They function as voltage-controlled switches or amplifiers and are crucial components in electronic circuits. MOSFETs come in depletion-type or enhancement-type, and can be p-channel or n-channel, depending on charge carrier type. Despite structural differences, all MOSFETs modulate an electric field within the semiconductor to control current flow between the terminals.

➢ Regions Of MOSFETS:

- Cut-Off Region: The MOSFET is off with no current flow, acting as an open switch suitable for electronic switching applications.
- Ohmic or Linear Region: In this region, the MOSFET operates as an amplifier, with current (IDS) increasing linearly with voltage (VDS).
- Saturation Region: MOSFETs maintain constant IDS despite increasing VDS, behaving like a closed switch after reaching pinch-off voltage (VP). Used for switching operations requiring saturated current flow.



Operating regions of MOSFET



n-channel Enhancement-type MOSFET

For n-channel Enhancement-type MOSFETs, the biasing conditions determine the operational regions experienced. Figure 1a illustrates the transfer characteristics (IDS vs. VGS), showing that current flow begins only when VGS exceeds the threshold voltage (VT). Below this threshold, no channel exists between drain and source, resulting in zero current flow—a state known as the cut-off region. Even with an increase in VDS, no current flows, as shown in Figure 1b.

Once VGS surpasses VT, current starts to flow, initially increasing linearly with IDS in the Ohmic region, then saturating as determined by VGS in the saturation region. Increasing VGS leads to higher saturation current, as depicted in Figure 1b, where IDSS2 exceeds IDSS1 when VGS2 > VGS1, and so on. The locus of pinch-off voltage (VP), indicated by the discontinuous curve in Figure 1b, shifts upward with increasing VGS.

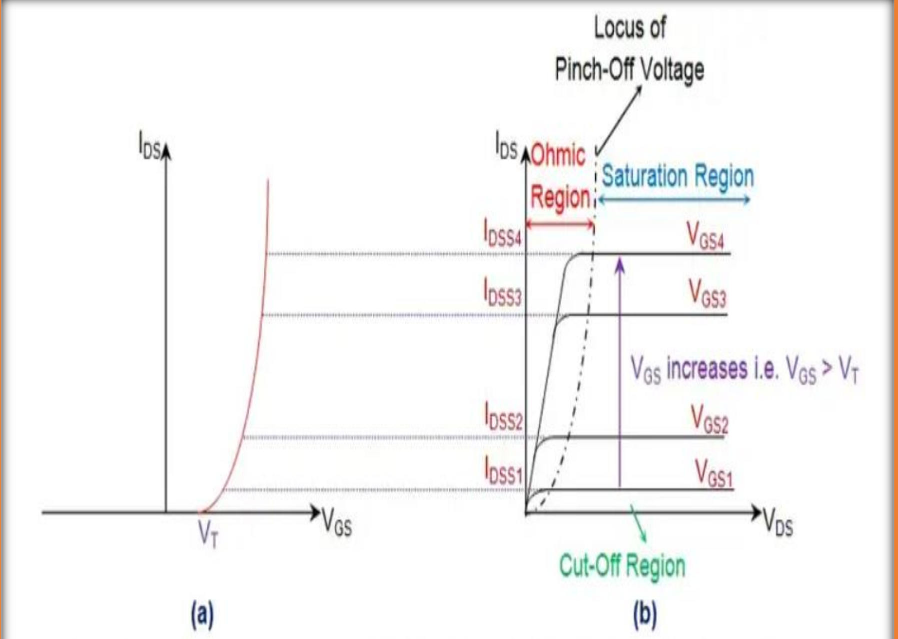


Figure 1 *n*-Channel Enhancement type MOSFET (a) Transfer Characteristics (b) Output Characteristics

P-channel Enhancement-type MOSFET

Figure 2a displays the transfer characteristics of p-type enhancement MOSFETs, revealing that IDS remains zero until VGS equals -VT, signifying the cutoff state. Only then does a channel form between drain and source terminals, allowing current flow. Subsequently, IDS increases in the reverse direction as VDS decreases, indicating operation in the ohmic region, where current rises with applied voltage (VSD).

As VDS reaches -VP, the device enters saturation, characterized by a saturated current (IDSS) flowing through it, determined by VGS. Notably, the saturation current increases with more negative VGS values, with IDSS for VGS3 surpassing that for VGS2 and significantly exceeding both for VGS4, reflecting their increasing negativity. Additionally, the locus of the pinch-off voltage shows that as VGS becomes more negative, VP also increases in negativity.

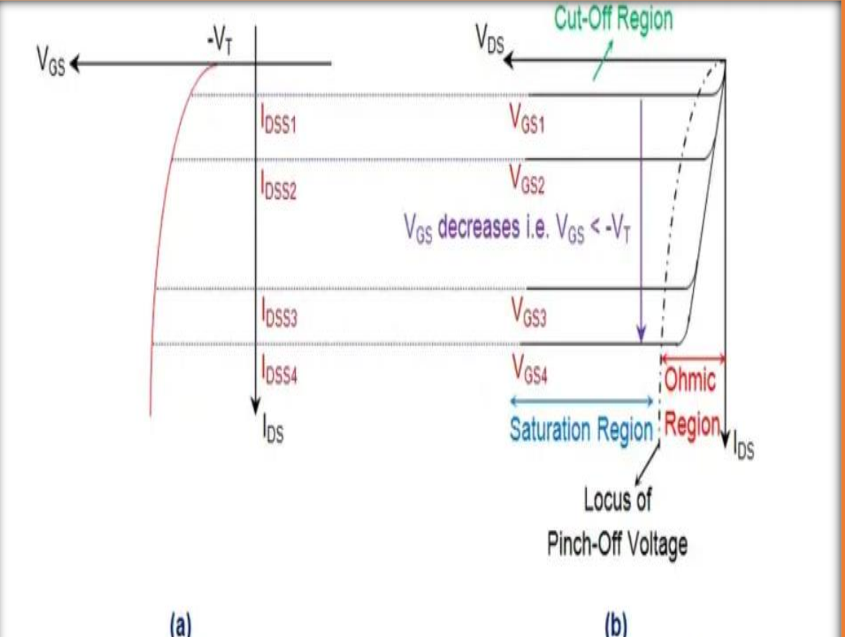
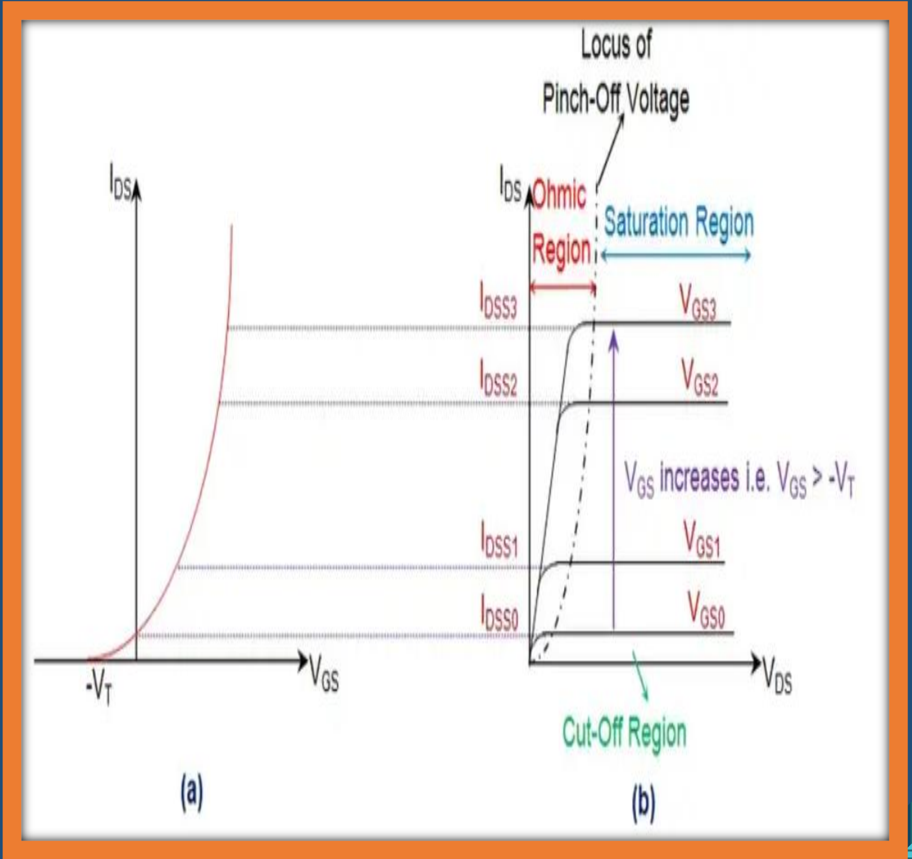


Figure 2 p-Channel Enhancement type MOSFET (a) Transfer Characteristics (b) Output Characteristics

n-channel Depletion-type MOSFET

- The transfer characteristics of n-channel Depletion-type MOSFETs depicted in Figure 3a reveal that the device conducts current even with VGS at 0V. This indicates that these MOSFETs can conduct even without biasing the gate terminal, as evidenced by the VGS0 curve.
- Under this unbiased condition, the current through the MOSFET increases with rising VDS, representing the Ohmic region, until VDS reaches the pinch-off voltage VP. Beyond this point, IDS saturates to a specific level, IDSS, in the saturation region, which increases with higher VGS values—illustrated by IDSS3 > IDSS2 > IDSS1 as VGS3 > VGS2 > VGS1.
- Moreover, the locus of the pinch-off voltage demonstrates that VP increases with increasing VGS. However, to operate these devices in a cut-off state, a negative VGS is required. Once VGS becomes equal to -VT, conduction through the device ceases (IDS = 0) as the n-type channel is depleted.



p-channel Depletion-type MOSFET

- The transfer characteristics of p-channel Depletion-type MOSFETs, illustrated in Figure 4a, demonstrate that these devices are normally ON, conducting even without a gate-to-source voltage (VGS). This is due to the presence of a default channel, resulting in a non-zero IDS for VGS = 0V, as shown by the VGS0 curve.
- Initially, the current through the MOSFET increases with rising VDS, representing the ohmic region of operation. However, once VDS surpasses VP, the current saturates, entering the saturation region. The saturation current is determined by VGS and increases in the negative direction as VGS becomes more negative.
- For instance, the saturation current for VGS3 exceeds that for VGS2, which in turn surpasses that for VGS1. This is because VGS2 is more negative than VGS1, and VGS3 is much more negative than either of them.
- Additionally, the locus of the pinch-off point shows that VP becomes increasingly negative with higher negativity associated with VGS.

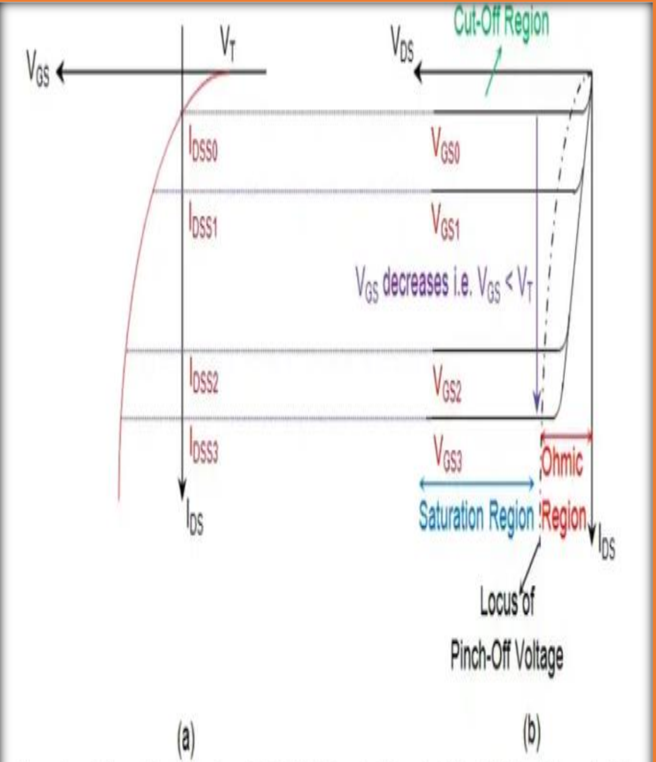


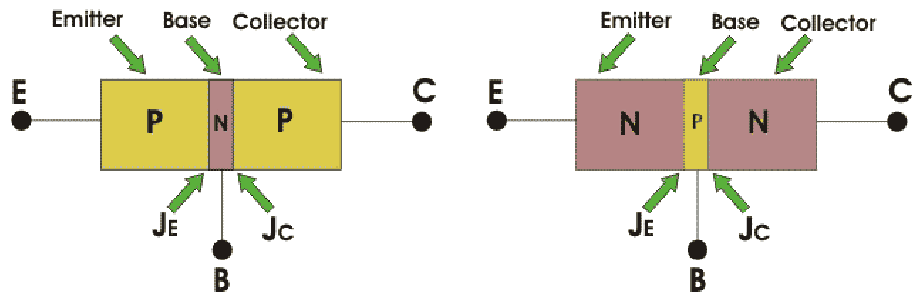
Figure 4 p-Channel Depletion type MOSFET (a) Transfer Characteristics (b) Output Characteristics

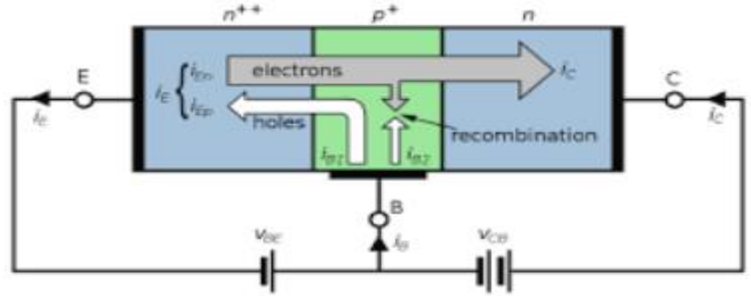
Region Of Operation

Kind of MOSFET	Region of Operation		
	Cut-Off	Ohmic/Linear	Saturation
n-channel Enhancement-type	$V_{GS} < V_T$	$V_{GS} > V_T$ and $V_{DS} < V_P$	$V_{GS} > V_T$ and $V_{DS} > V_P$
p-channel Enhancement-type	$V_{GS} > -V_T$	$V_{GS} < -V_T$ and $V_{DS} > -V_P$	$V_{GS} < -V_T$ and $V_{DS} < -V_P$
n-channel Depletion-type	$V_{GS} < -V_T$	$V_{GS} > -V_T$ and $V_{DS} < V_P$	$V_{GS} > -V_T$ and $V_{DS} > V_P$
p-channel Depletion-type	$V_{GS} > V_T$	$V_{GS} < V_T$ and $V_{DS} > -V_P$	$V_{GS} < V_T$ and $V_{DS} < -V_P$

What is a BJT?

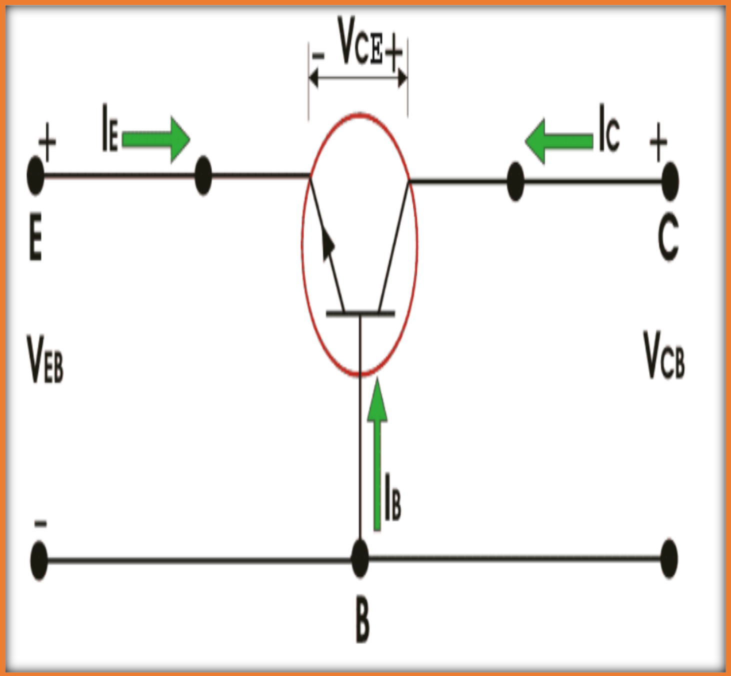
A Bipolar Junction Transistor (BJT) is a three-terminal semiconductor device with two p-n junctions that amplify signals. It operates based on current control and has terminals named base, collector, and emitter. BJTs use both electrons and holes as charge carriers. When a small signal is applied to the base, it gets amplified at the collector. BJTs require an external DC power supply for amplification. There are two types: NPN and PNP transistors, distinguished by the arrangement of their layers.





NPN Bipolar Junction Transistor

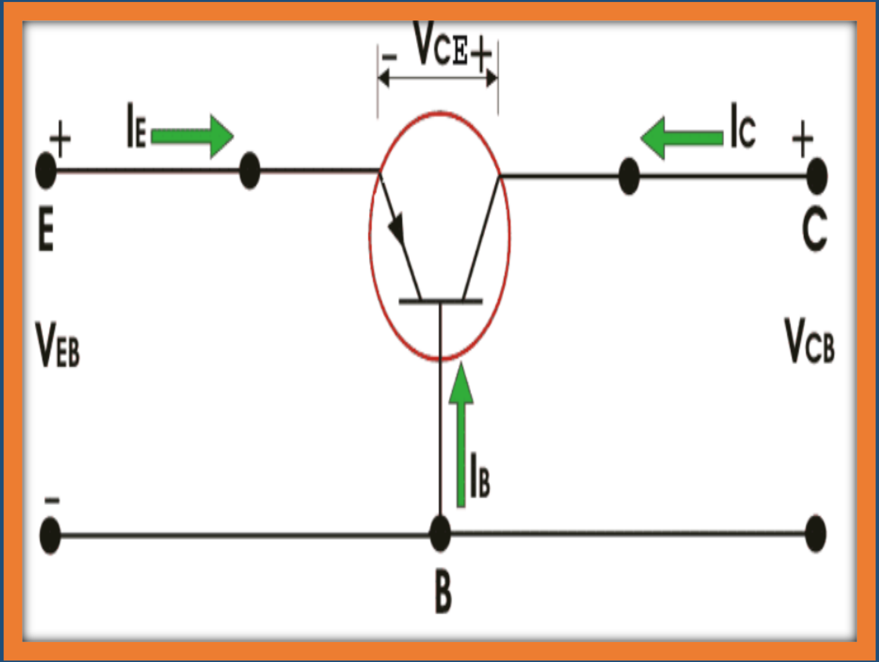
- In an n-p-n bipolar transistor, a layer of p-type semiconductor material is sandwiched between two layers of n-type semiconductor material. The diagram below illustrates the configuration of an n-p-n transistor.
- Now, referring to the transistor, IE and IC denote the emitter current and collector current respectively, while VEB and VCB represent the emitter-base voltage and collector-base voltage.
- Following convention, when currents IE, IB, and IC flow into the transistor, their signs are considered positive. Conversely, when currents flow out from the transistor, their signs are taken as negative.



Transistor type	I_E	I_B	I_C	V_{EB}	V_{CB}	V_{CE}
n-p-n	–	+	+	–	+	+

PNP Bipolar Junction Transistor

- Similarly for **p-n-p bipolar junction** transistor (or pnp transistor), an n-type semiconductor is sandwiched between two p-type semiconductors. The diagram of a p-n-p transistor is shown below.
- For p-n-p transistors, current enters into the transistor through the emitter terminal. Like any bipolar junction transistor, the emitter-base junction is forward biased and the collector-base junction is reverse biased. We can tabulate the emitter, base and collector current, as well as the emitter-base, collector base and collector-emitter voltage for p-n-p transistors also.



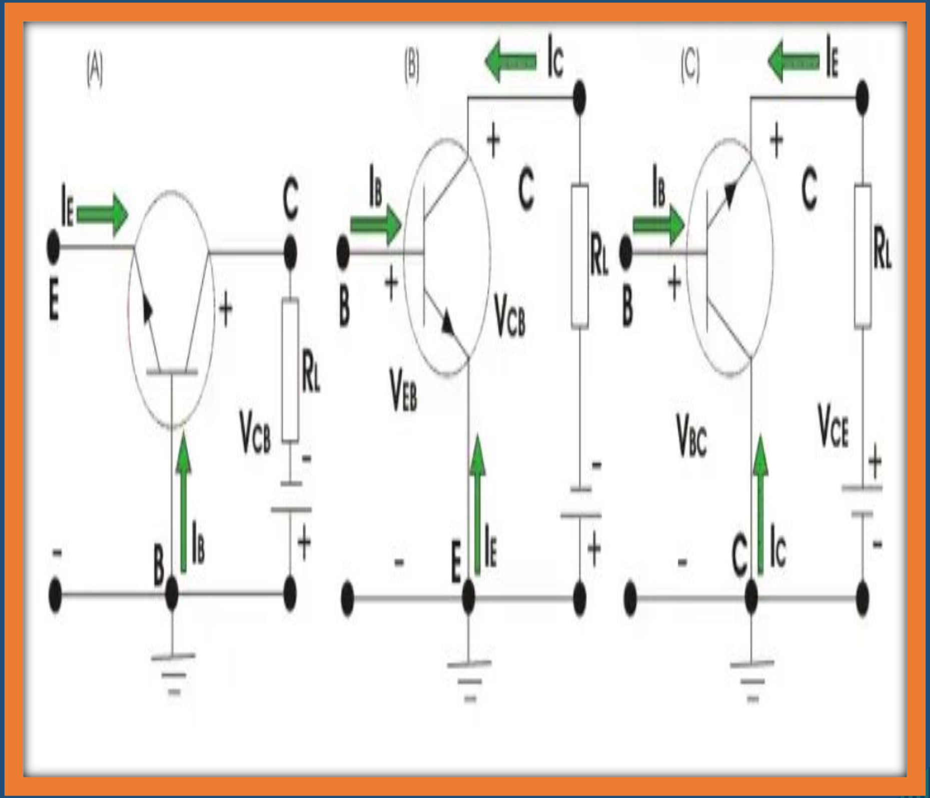
Transistor type	I_E	I_B	I_C	V_{EB}	V_{CB}	V_{CE}
p – n – p	+	–	–	+	–	–

Working Principle of BJT

- An n-p-n transistor operates with the BE junction forward biased and the CB junction reverse biased. Electrons flow from emitter to base due to reduced barrier potential. Base current is small due to electron-hole recombination, while most electrons constitute collector current. BJT operates on minority carrier conduction, hence termed as minority carrier devices.

- Equivalent Circuit: A BJT is analogous to two diodes back to back due to its two p-n junctions.

- BJT Characteristics: BJT has three parts: collector, emitter, and base. It operates in Common Base (CB), Common Emitter (CE), and Common Collector (CC) modes, each with distinct characteristics depicted graphically. Characteristics vary for different modes and parameters in both n-p-n and p-n-p transistors.



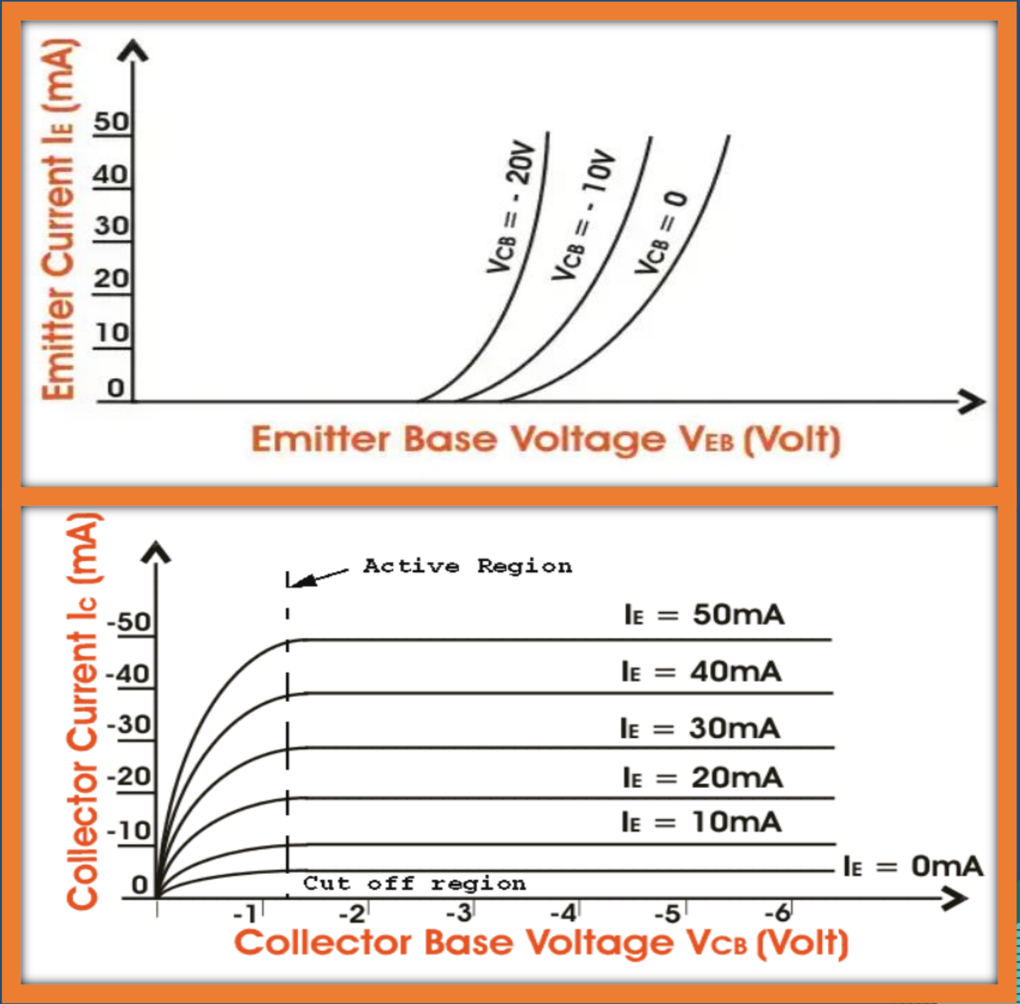
Common Base Characteristics

➢ Input Characteristics

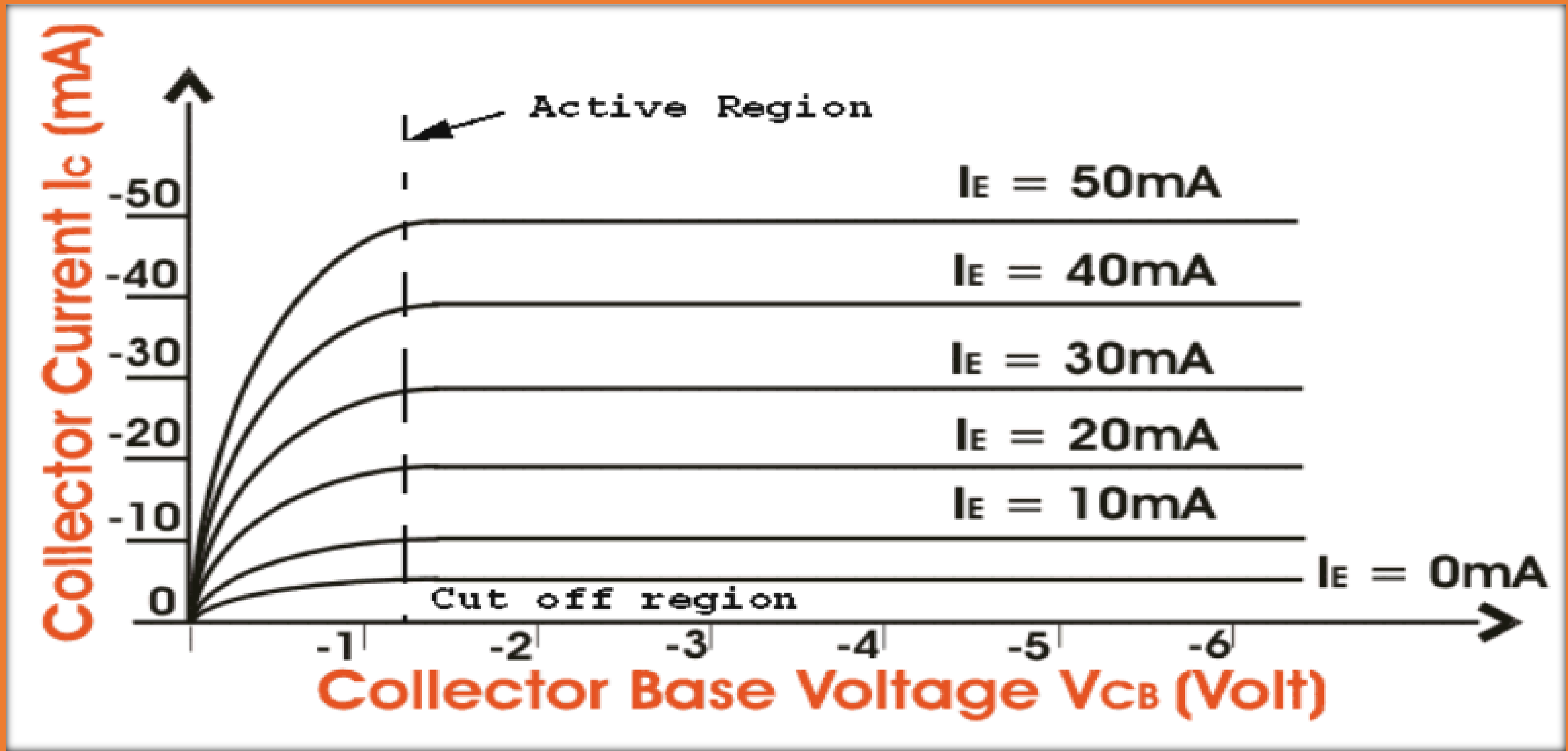
- For p-n-p transistor, the input current is the emitter current (I_E) and the input voltage is the collector base voltage (V_{CB}).
- As the emitter-base junction is forward biased, therefore the graph of I_E Vs V_{EB} is similar to the forward characteristics of a p-n diode. I_E increases for fixed V_{EB} when V_{CB} increases.

➢ Output Characteristics

- The output characteristics show the relation between the output voltage and output current I_C is the output current and collector-base voltage and the emitter current I_E is the input current and works as the parameters. The figure below shows the output characteristics for a p-n-p transistor in CB mode.



Common Base Characteristics



Common Emitter Characteristics

Input characteristics

I_B (Base Current) is the input current, V_{BE} (Base – Emitter Voltage) is the input voltage for CE (Common Emitter) mode. So, the input characteristics for CE mode will be the relation between I_B and V_{BE} with V_{CE} as a parameter.

The typical CE input characteristics are similar to that of a forward-biased of p-n diode. But as V_{CB} increases the base width decreases.

Output Characteristics

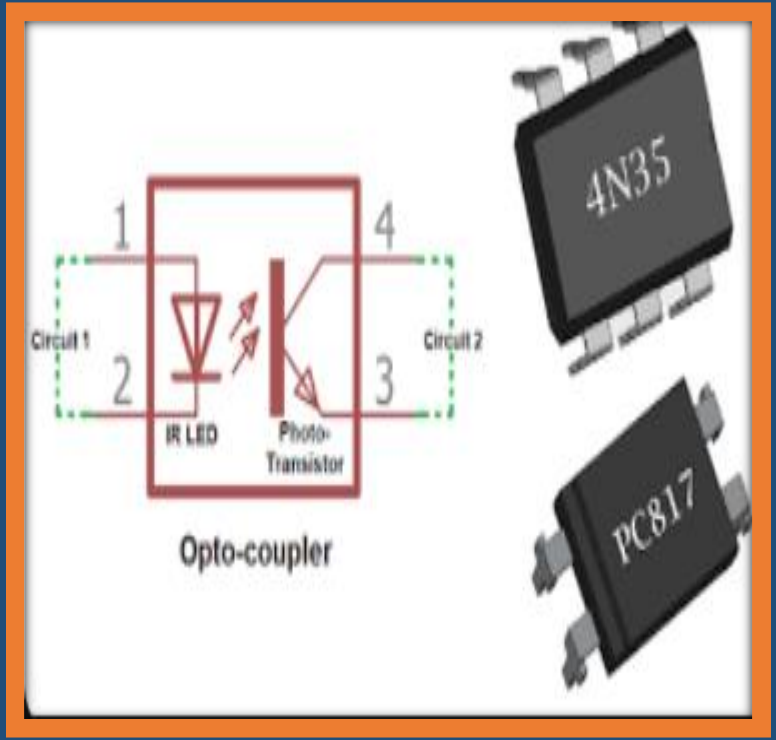
Output characteristics for CE mode is the curve or graph between collector current (I_C) and collector-emitter voltage (V_{CE}) when the base current I_B is the parameter.

Like the output characteristics of common – base transistor CE mode has also three regions named (i) Active region, (ii) cut-off regions, (iii) saturation region. The active region has collector region reverse biased and the emitter junction forward biased.

For cut-off region, the emitter junction is slightly reverse biased and the collector current is not totally cut-off. And finally for the saturation region both the collector and the emitter junction are forward biased.

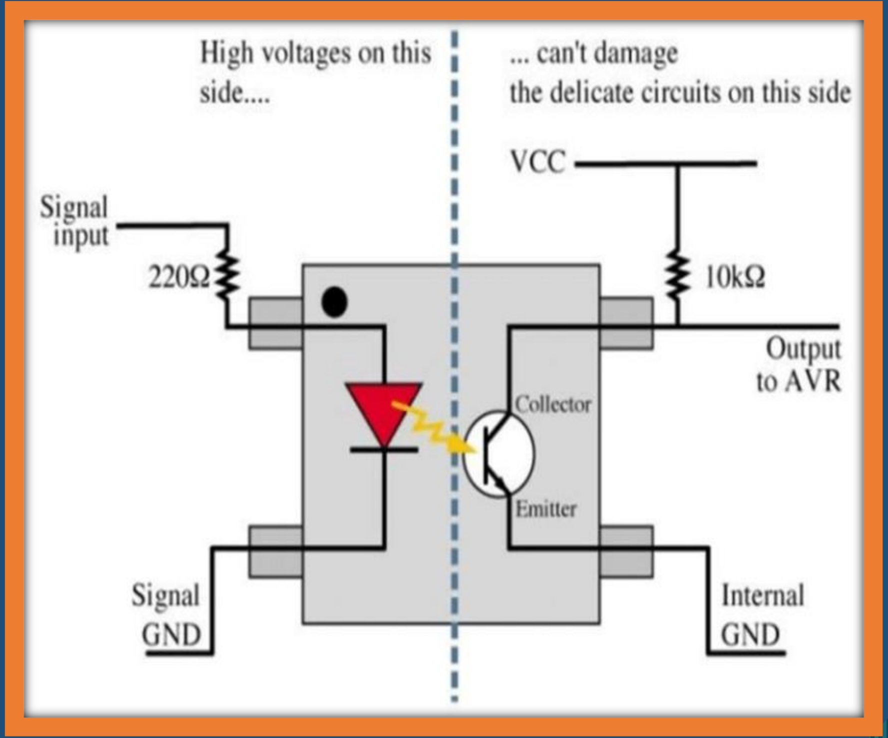
Optocoupler

Optocoupler is a device that couples an input control signal to output or load, via using light energy, in such a manner that electrical isolation also remains intact between input signals and load (output). The basic function of an Optocoupler is the coupling of input and output circuits through light energy (due to which it is called Optocoupler) and to provide complete isolation between input and output circuits, therefore Optocoupler is also sometimes known as Opto isolator. The objective of providing electrical isolation between input and output circuits is to protect them against high voltage transients or high voltage short waves, surge voltage (i.e. sudden sharp increase in voltage), and low-level noise. Moreover, the interfacing of different voltage level circuits and different grounds by means of an Optocoupler (that's different voltage circuits and different grounds can also be set apart or isolated by means of its use). Remember that this device provides isolation up to 2500 volts.



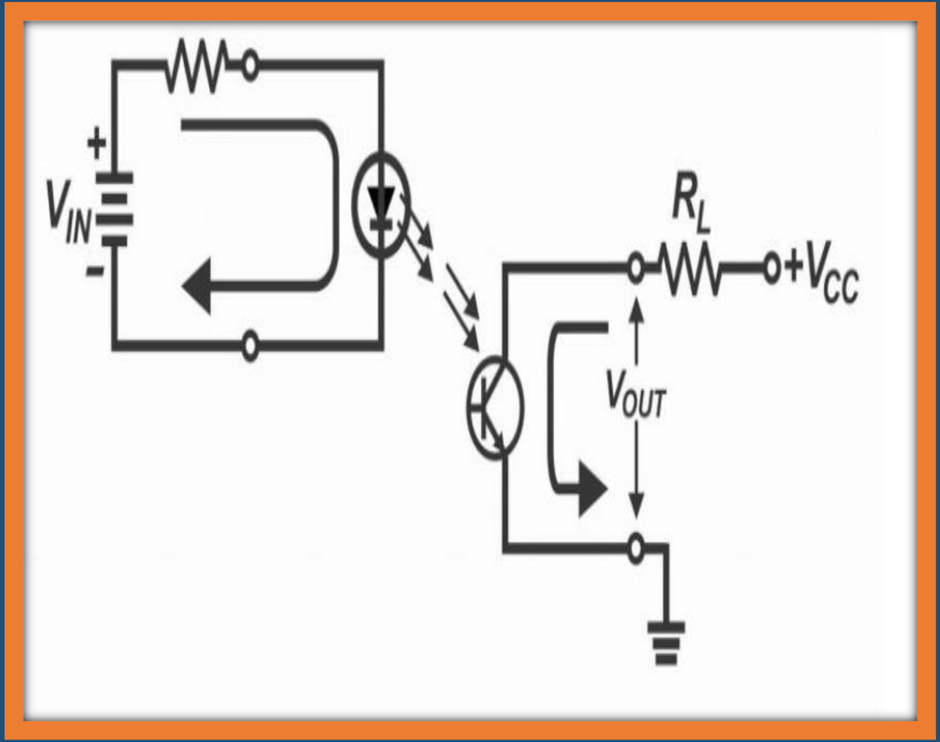
Construction

The input circuit of an Optocoupler or optical coupler comprises an atypical light-emitting diode (LED) and its output circuit a phototransistor. In other words, an Optocoupler consists of a combination of a light-emitting device (i.e. a device which emits light) and a light-sensitive device (a device that is sensitive to light). The LED fixed in Optocoupler is actually a gallium arsenide (GaAs) infra-red emitter, which produces light of about 0.9×10^{-6}m wavelengths. For the purpose of an excellent coupling medium, an infrared glass and for best electrical isolation an air gap is used. Remember that apart from LED and phototransistor combination, Optocoupler is also available in LED and photo Darlington packages or LED and LASCR packages.



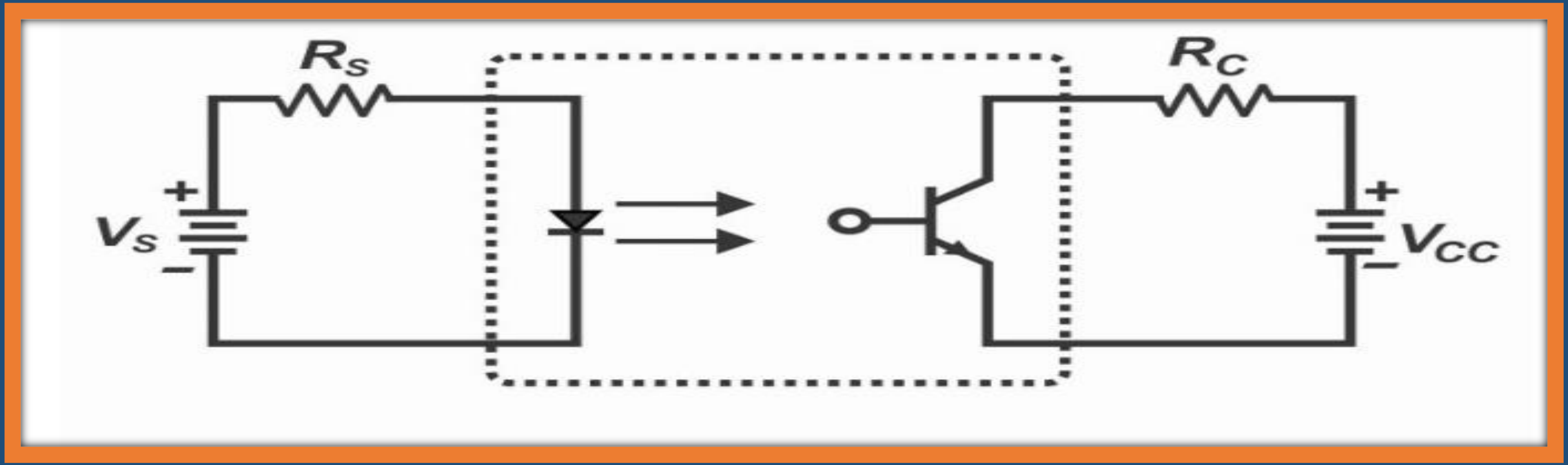
Working

- In figure , an Optocoupler has been illustrated along with its connections. When the input circuit of an Optocoupler is supplied input voltage $V_{in,}$ the circuit becomes forward biased. Thus, LED irradiates and starts emitting light. As input and output circuits are inter-coupled via light energy, therefore when LED light transmits to phototransistor fixed in the output circuit, it turns on. Thus, the flow of current from the extrinsic load circuit starts. The greatest advantage of this series is that the best type of electrical isolation exists between input and output circuits (i.e. low power control circuit and high-power load circuit).
- Figure – Optocoupler with external connections



OptoCoupler

In the figure, a simple optocoupler has been demonstrated for further clarification. The LED fitted in it operates the transistor. A small change in input circuit voltage or VS brings about a change in LED current. As a result, the current passing through the phototransistor also changes. Thus, variable voltages are created parallel to the collector-emitter terminals. Thus, the signal voltage of the input circuit is coupled with the output circuit.



Important Parameters for an Optocoupler

Important parameters of an Optocoupler are as follows:

- **Isolation Voltage**

The maximum voltage which can sustain without any die-electric breakdown between input and output terminals is called isolation voltage Viso. Their specific values are up to 7500 AC volts.

- **Current Transfer Ratio or CTR**

The ratio between output (phototransistor) current and input (LED) current is known as current transfer ratio which is denoted as a percentage. The output CTR values of a phototransistor may be between 50 to 150 percent. While in the case of photo darling ton output its specific values are between 50 to 500 percent.

- **Response Time**

It is divided between rising time (tr) and toll time (tl). The tr and tl output stage of a phototransistor is near to about 2-5 microseconds.

- **Transfer Gain**

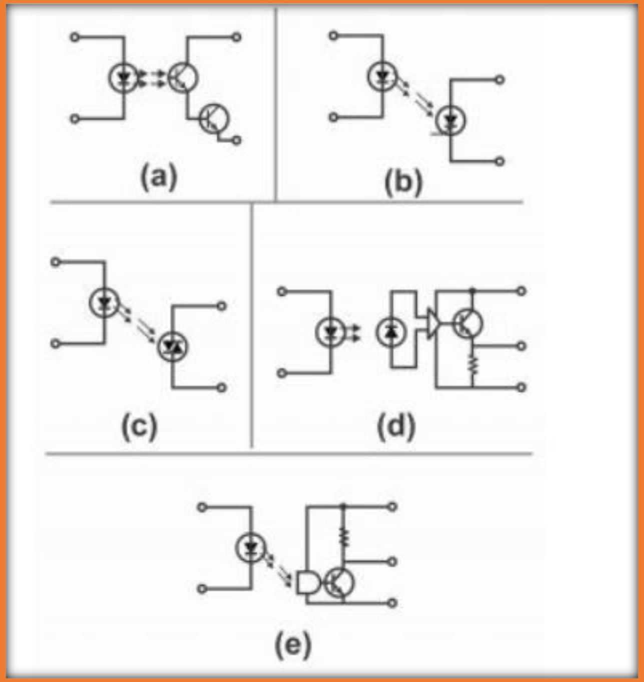
This parameter is associated with an optically isolated AC linear coupler. The ratio between the output voltage and the input current is called transfer gain. Its defined value is 200mV/mA.

Types of Optocoupler

Optocouplers are normally of the following types

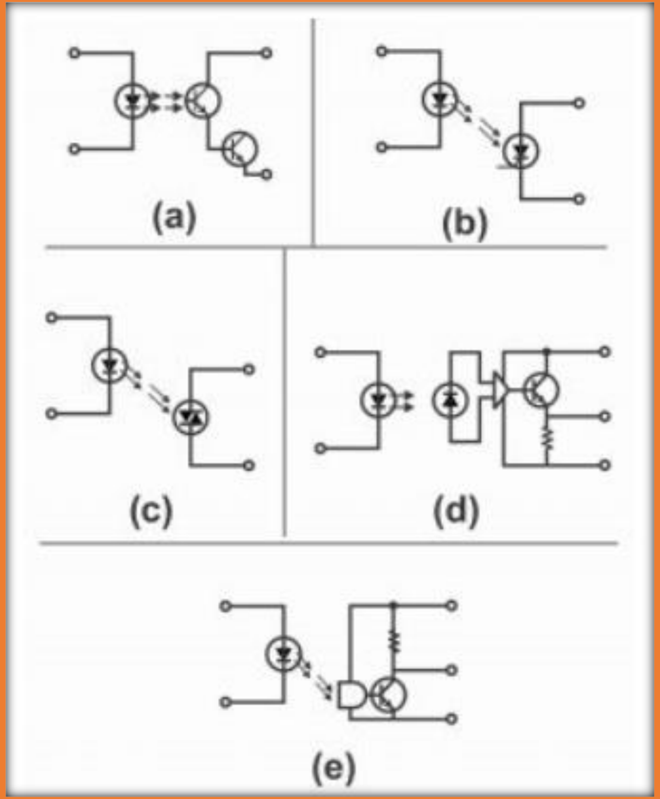
- Darlington Transistor
- SCR output coupler
- Photo Triac Output Coupler
- Optically Isolated AC Linear Coupler
- Digital Output Coupler

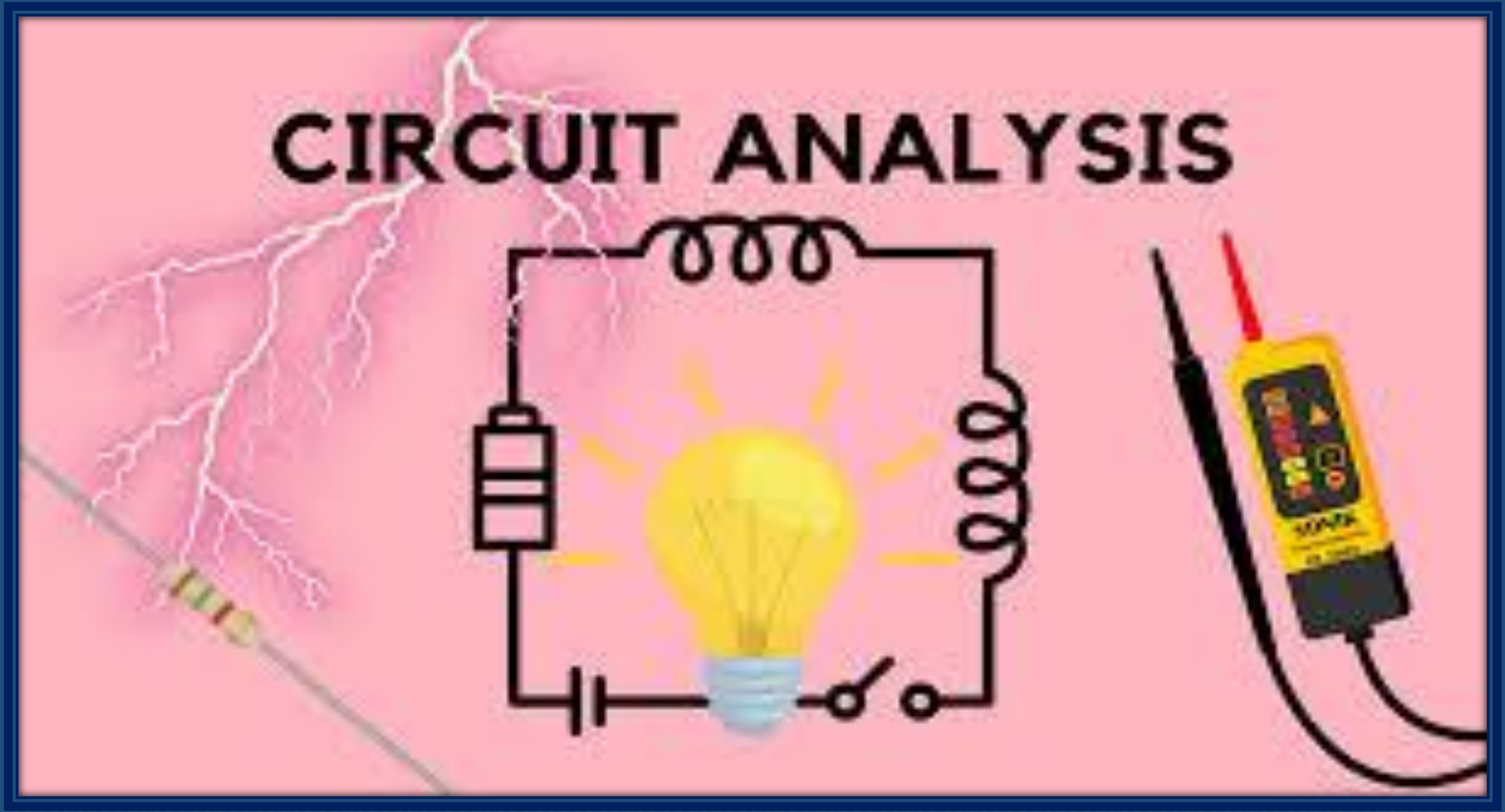
In figure (a), daring ton output or darling ton transistor coupler has been displayed. As compared to the output of an ordinary phototransistor, an extremely high output current is received from a Darlington coupler. Therefore, these couplers are commonly used with high loads. However, it drawback is that its switching speed is less compared to a phototransistor. These types of couplers are used for DC power switching (or such types of couplers are used for supplying DC power on a load).



OptoCoupler

- In figure (b) SCR output coupler has been depicted. As the output stage of this coupler comprises a light-activated SCR, therefore it is also known as the LASCR coupler. This device is used in such a circuit, where a high voltage relay is required to be latched via input voltages. After getting latched, this relay moves onto some other electro-mechanical device.
- In figure (c) a photo Triac output coupler has been exemplified. This device is used for isolated Triac triggering e.g. switching a low-level input to 110-volt AC line.
- In (d), an optically isolated linear coupler uses input current changes to vary output voltage through an amplifier. A photodiode detects LED light changes, feeding signals to the amplifier, with an emitter follower stage. Used in telephone lines and audio.
- In (e), a digital output coupler features a high-speed detector circuit and a transistor stage. The detector activates the output transistor with light, resulting in low collector voltage. Absence of LED light maintains high voltage. Commonly used in digital circuits.




CIRCUIT ANALYSIS

Importance of Circuit Analysis

Foundation of Electronics Engineering:

Circuit analysis, rooted in electrical engineering principles, focuses on ensuring that selected components can handle the anticipated voltages and currents in a circuit. It involves mathematical analysis to calculate unknown elements like voltage or current, typically after simplifying the circuit.

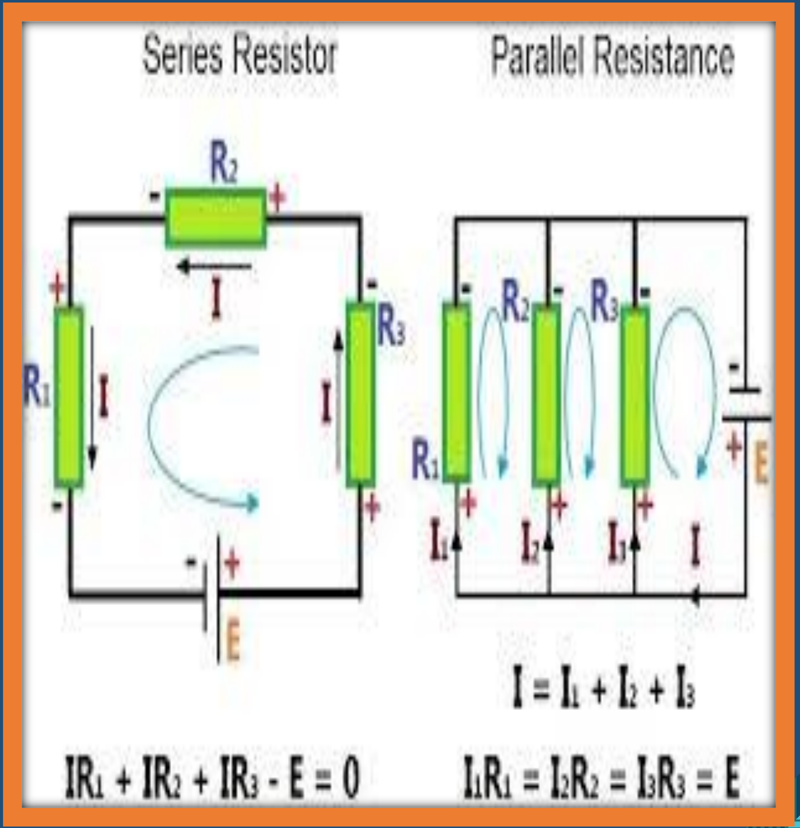
To perform a circuit analysis, you'll need the following tools:

Circuit Schematics:

- Understand the circuit's schematics, visualizing it on paper.
- Draw a comprehensive circuit diagram, including all components.

Resistor Simplification:

- Simplify resistors into a single equivalent resistor.
- Combine resistors in series or parallel into one value.



Circuit Analysis

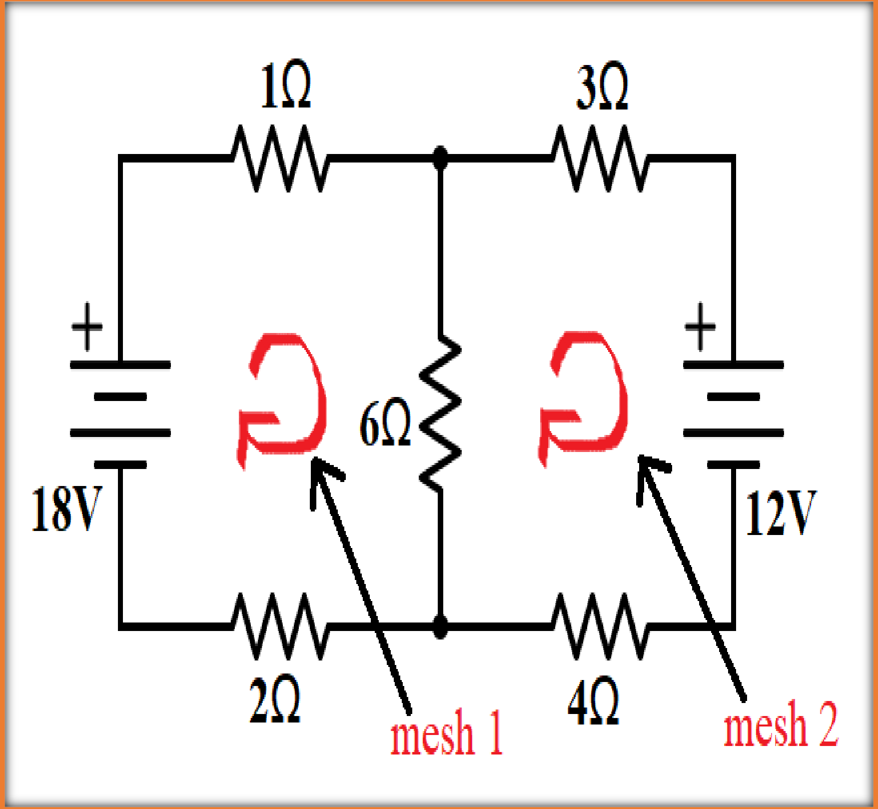
- **Fundamental equations and laws of physics:**

Familiarize yourself with fundamental equations and laws governing physics.

- Ohm's law
- Power / energy definitions and equations

Understand the relationships involving voltage, current, and resistance.

- **Measurement Tools (Real-life Applications):**
  - In real-life applications, utilize a voltmeter and an ammeter.
  - Measure voltage and current to obtain initial values for further calculations.

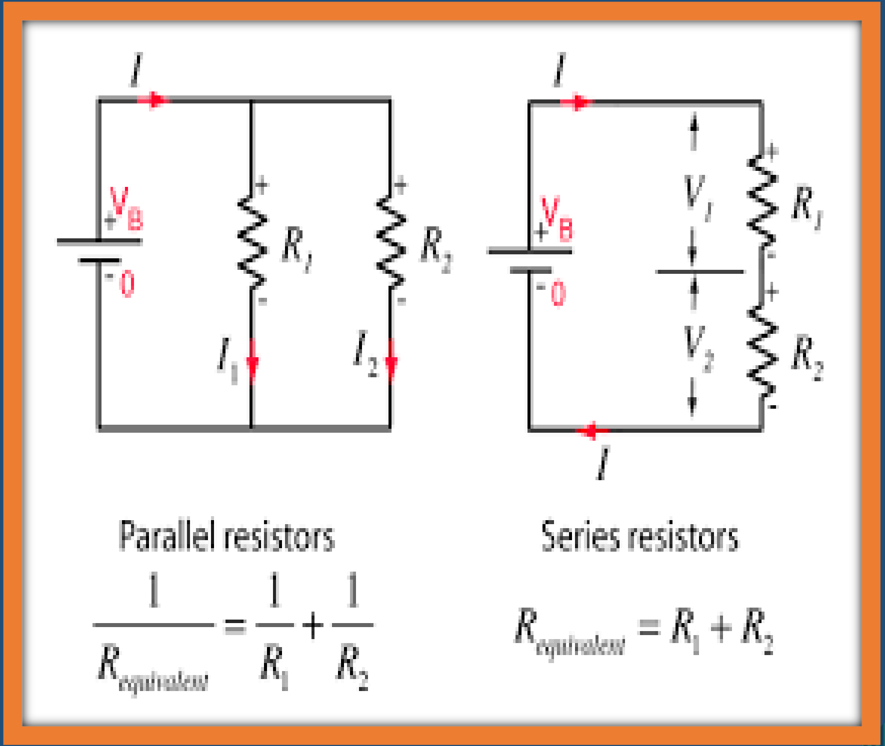


Circuit Analysis

In circuit analysis, various tools play a crucial role in understanding and evaluating electronic systems. Here's a brief overview of essential tools:

Circuit Schematics:

- **Definition:** A circuit schematic, often called a circuit diagram, is a visual representation of a circuit, displaying its connections and components.
- **Purpose:** Engineers use circuit schematics to plan circuits before physical implementation, helping in the identification of necessary components.
- **Representation:** Components are depicted by symbols, connected by vertical and horizontal lines indicating conductors.



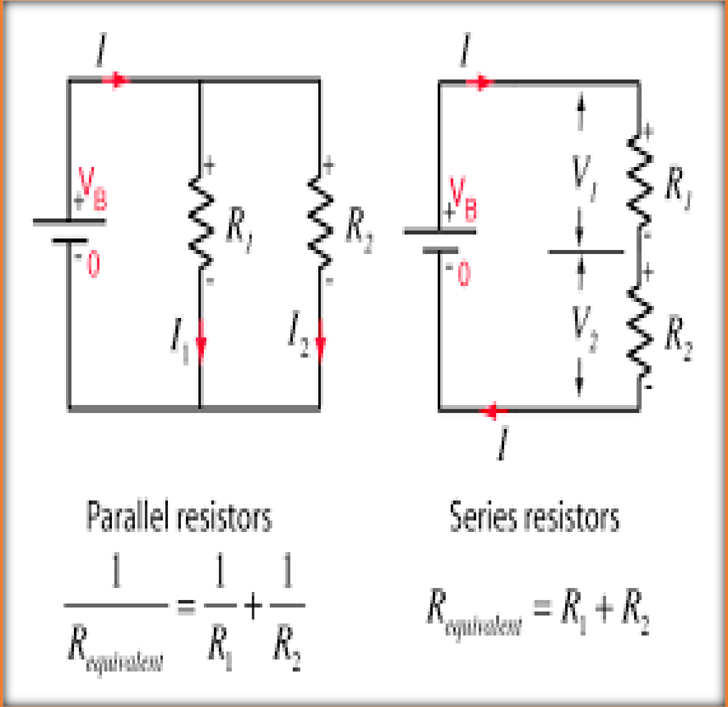
Circuit Analysis

Resistor Simplification:

Resistor simplification involves condensing multiple resistors within a circuit to a single equivalent resistor.

- **Method:**
  - Start with the resistor farthest from the main circuit.
  - Replace groups of resistors in a loop with a single resistor, considering series or parallel connections.
  - Repeat until only one resistor remains in the circuit.

Analogy: Analogous to simplifying fractions in mathematics, this process aids in streamlining circuit analysis.



Fundamental Equations

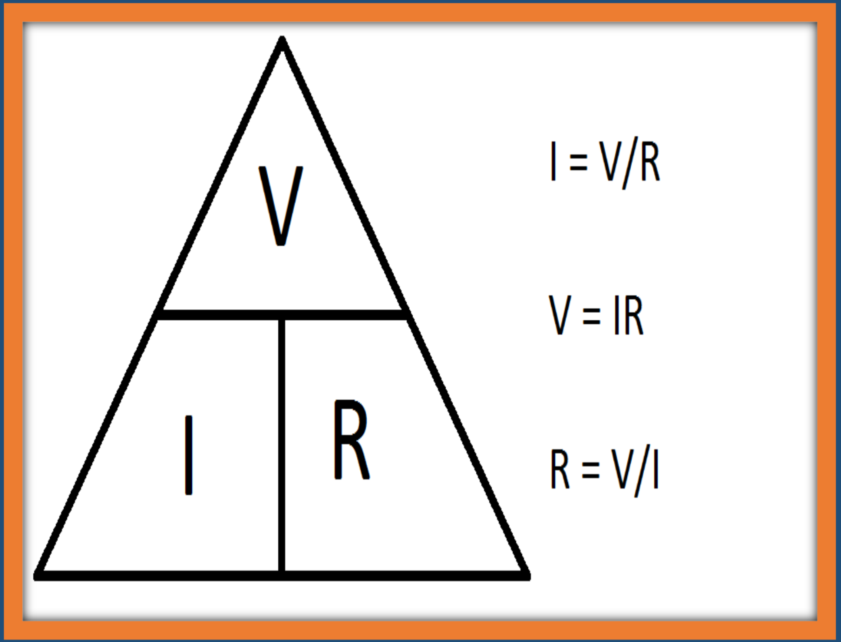
In circuit analysis, understanding fundamental equations is crucial for evaluating ideal circuits. Here are key equations to remember

Ohm's Law:

- Equation: $V = I \cdot R$
- Explanation: Ohm's law relates voltage (V), current (I), and resistance (R), allowing calculation of resistance at a specific point in a circuit.

Power in a Resistor:

- Equation: $P = I^2 \cdot R$
- Explanation: This equation determines the power (P) in watts, considering current (I) and resistance (R).



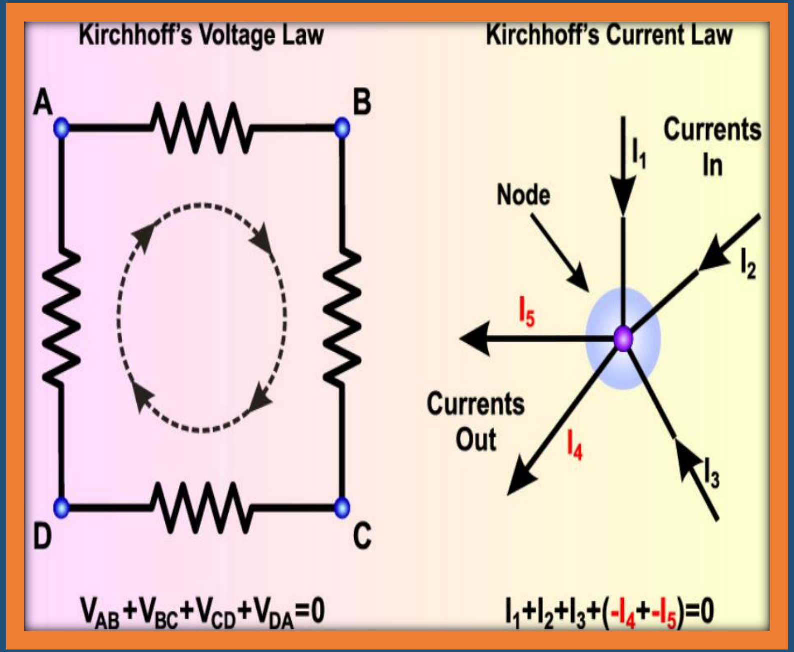
Kirchhoff's Laws:

Kirchhoff's Current Law:

Statement: The total current entering a circuit equals the total current leaving the circuit.

Mathematical Expression: ∑in=∑out∑in=∑out

Application: Used for calculating current in branches of a parallel circuit.



Kirchhoff's Laws:

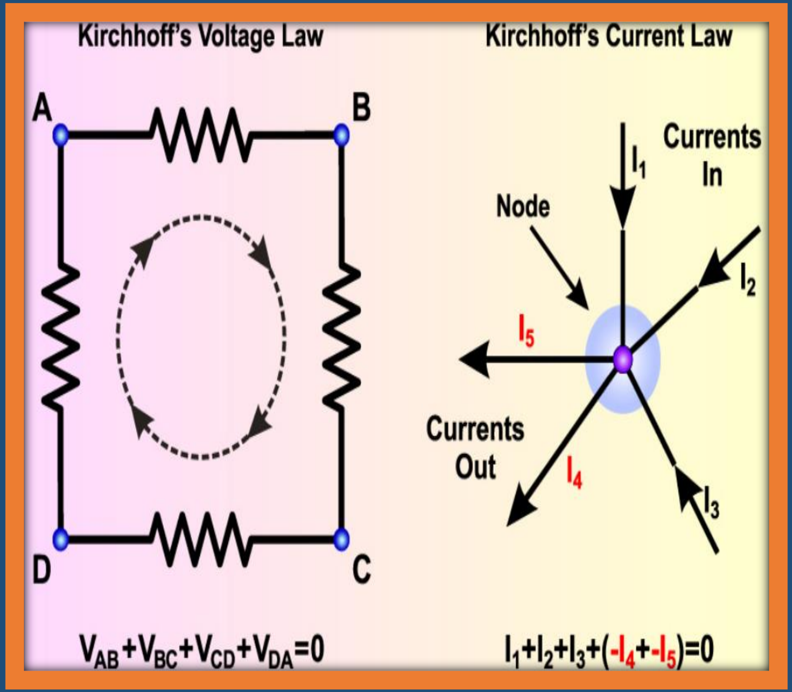
Kirchhoff's Voltage Law:

Statement: The sum of potential differences in a loop equals zero.

Mathematical Expression: ∑loop=∑Vloop=0

Explanation: Describes the distribution of total voltage within a circuit loop.

Understanding these fundamental equations and laws forms the basis for effective circuit analysis.



Basic Measuring Instruments

In the realm of electrical circuits, measuring instruments are indispensable for assessing critical quantities.Two fundamental tools, voltmeters and ammeters, play a pivotal role in this domain. Here's a concise exploration:

➢ Types of Basic Measuring Instruments:

Voltmeters:

A voltmeter gauges the voltage across any two points within an electric circuit.

Voltage is measured in volts (V), and the instrument takes the form of a meter.

DC Voltmeters: Gauge direct current (DC) voltage.

AC Voltmeters: Assess alternating current (AC) voltage.

Example:

An analogy could be a thermometer measuring temperature, where the DC voltmeter is akin to measuring a constant temperature, and the AC voltmeter is like measuring temperature variations.

Basic Measuring Instruments

Ammeters:

- *Definition:* An ammeter quantifies the flow of current through any two points in an electric circuit.
- *Unit:* Current is quantified in amperes (A), and the instrument adopts the structure of a meter.

Varieties:

- DC Ammeters: Evaluate direct current (DC) current.
- AC Ammeters: Assess alternating current (AC) current.

Example:

- Think of an ammeter like a flowmeter in a pipeline, where the DC ammeter measures a steady flow, and the AC ammeter measures fluctuations in the flow.

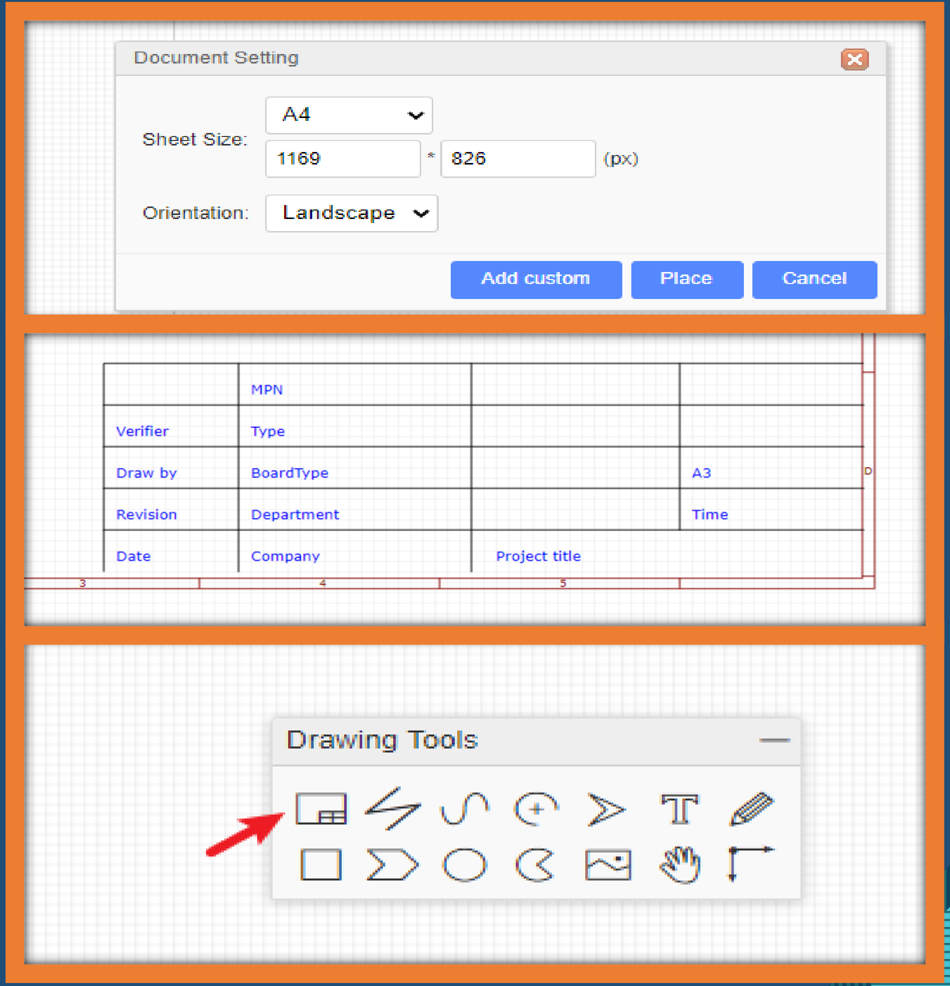
EasyEDA

Custom Sheet

EasyEDA supports the schematic diagram drawing frame required by custom. At present, custom drawings need to be placed manually, and automatic reference of custom drawings is not supported when creating new schematic diagram.

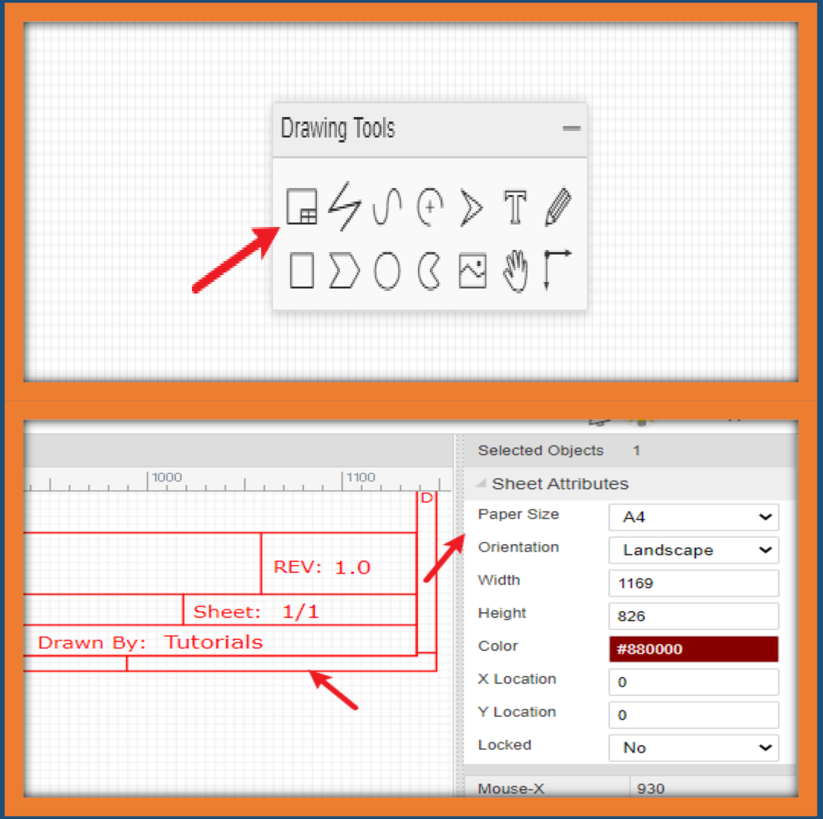
How to create?

- Click the “Sheet Setting” button at “Drawing Tool”.
- Click “Add Custom” button.
- It will create a new symbol editor, you can edit the table by line as you want.



Easyeda tool

- Sheet Setting
- It is now possible to add design notes to the frame and the frame selection, for example A4, which can assist in aligning and improve the look of printed schematics and PCB designs.
- Click the frame/drawing/document button like in the image below
- And you can edit the blue text when you've selected the text attributes or double clicked it.
- The bottom right zone can be selected and dragged or the frame can be dragged and deleted.
- When you've selected the bottom right zone, you can edit the sheet attributes

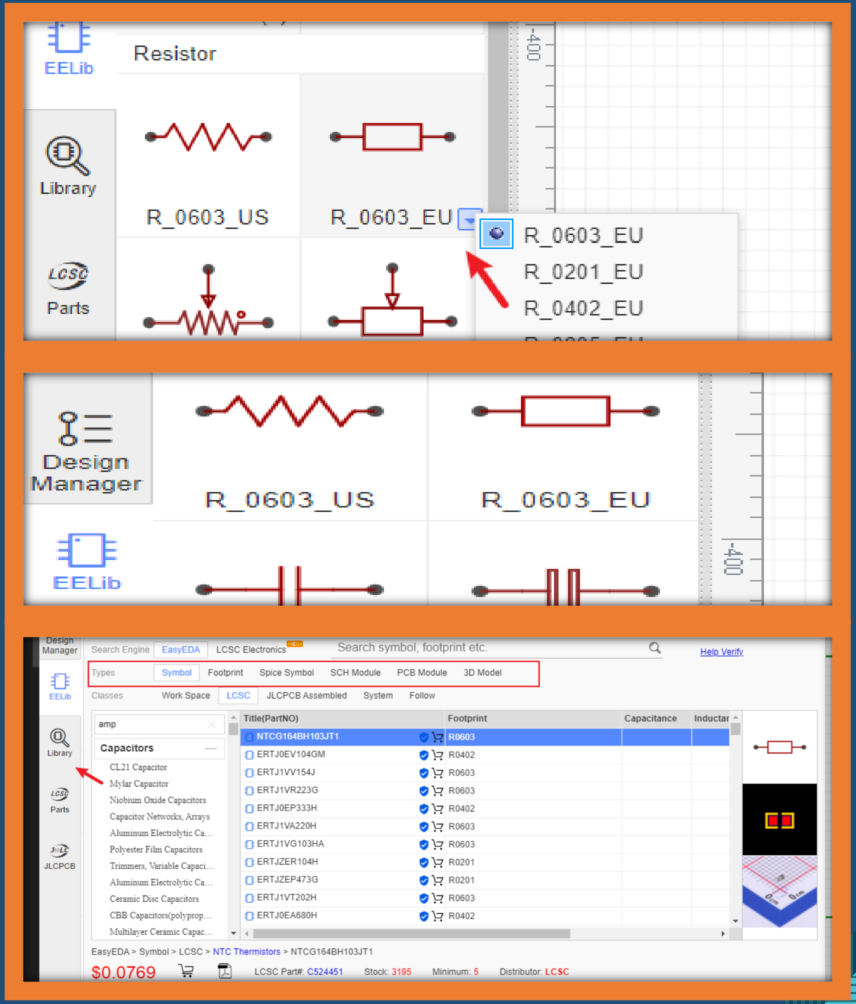


Commonly Library

That contains ready made symbols for a wide range of components and which can be simulated.

EasyEDA provide a lot of libraries, you can find them at “Left-hand Panel - Library”, hotkey “SHIFT+F”, at here you can search library from LCSC, system, user contributed etc.

Many of these components have optional US and EU style symbols, we split them, so you can select those you like. Click on the drop down list or right click to popup the context menu, it contains many footprints or parameters. EasyEDA will remember your choices for the next time.Don’t forget to use Filter to locate a component fastly. For example, you just need to type 0603 to find all of resistors.



Easyeda class

Symbol: Schematic symbols

Spice Symbol: Symbols for spice simlation

Footprint: PCB footprints, PCB pattern.

SCH Modules: Schematic modules, a part of the circuit design. It can not assign the PCB module, doesn’t like the schematic Symbol can assign the footprint . when it be placed on the schematic, it will be separated.

PCB Modules: As like as Schematic modules.

3D Model: It is bind with footprint via “3D Model Manager”. Simply type your part number or symbol’s name to Search. before searching, you must choose the “Type” first.

and then click the “Table of contents” to open the categories list to choose your components.

from there you can scroll up and down to browse parts from each category.

If you know the component’s name

Suppose you want to find the MAX232 (which converts signals from an RS-232 serial port to signals suitable for use in TTL compatible digital logic circuits). Simply type Max232 into the Search box and press Enter.

Classes

Work Space: It include your personal parts and your teams' parts.

LCSC: EasyEDA online part store LCSC.com parts(Officail Parts). It will add new libraries everyday

LCSC Assembled: JLCPCB Assembled parts. All JLCPCB assembly parts will contain a SMT icon, that means this part can be JLCPCB assemble.

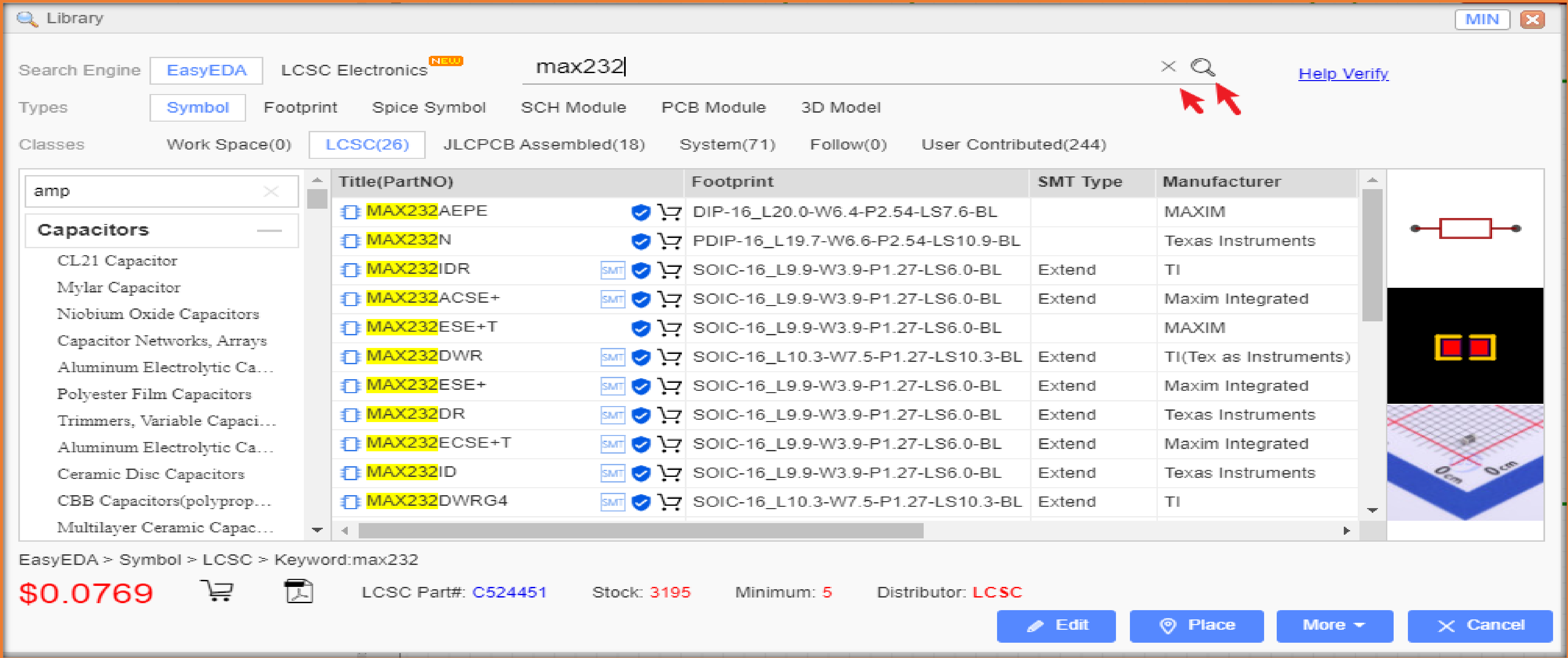
System: EasyEDA system parts, it comes from open source libraries, such as Kicad libraries, company public libraries, user contributions.

Follow: If you follow a user at EasyEDA(You can follow a user at him/her user page), you can view and use his/her libraries.

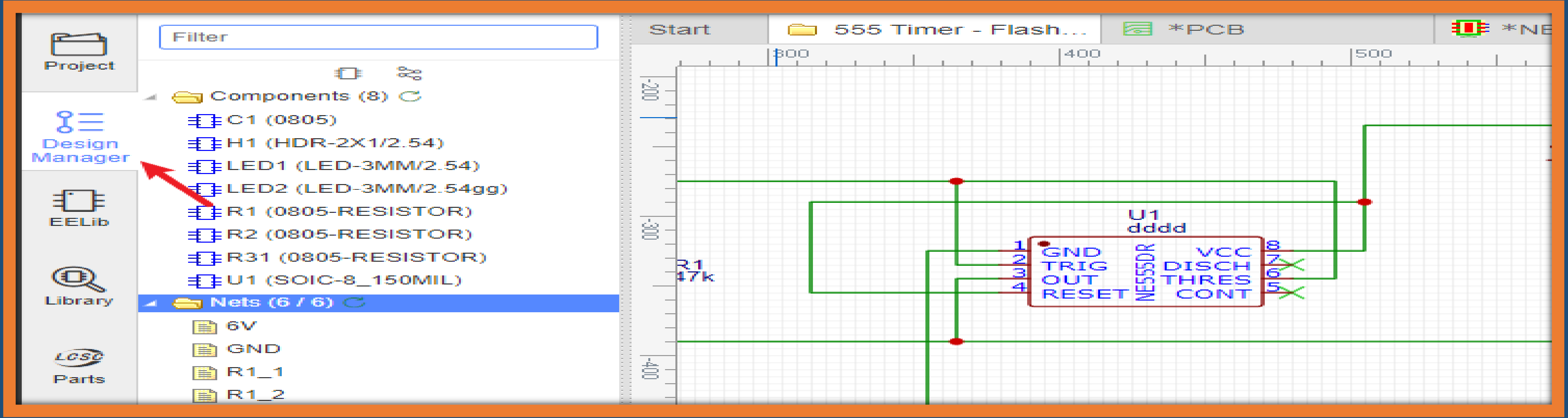
User Contributed: When you searching a part, maybe you can find it at this class. At EasyEDA, all libraries are public. the detail you can refer at: Contribute

We add an "JLCPCB Assembled" Components option of the Parts, It's easy to choose which component can be assembled by JLCPCB. Yes, JLCPCB will provide the assembly service. the more information please refer at: How to order a SMT order

Easyeda classes



Easyeda Nets

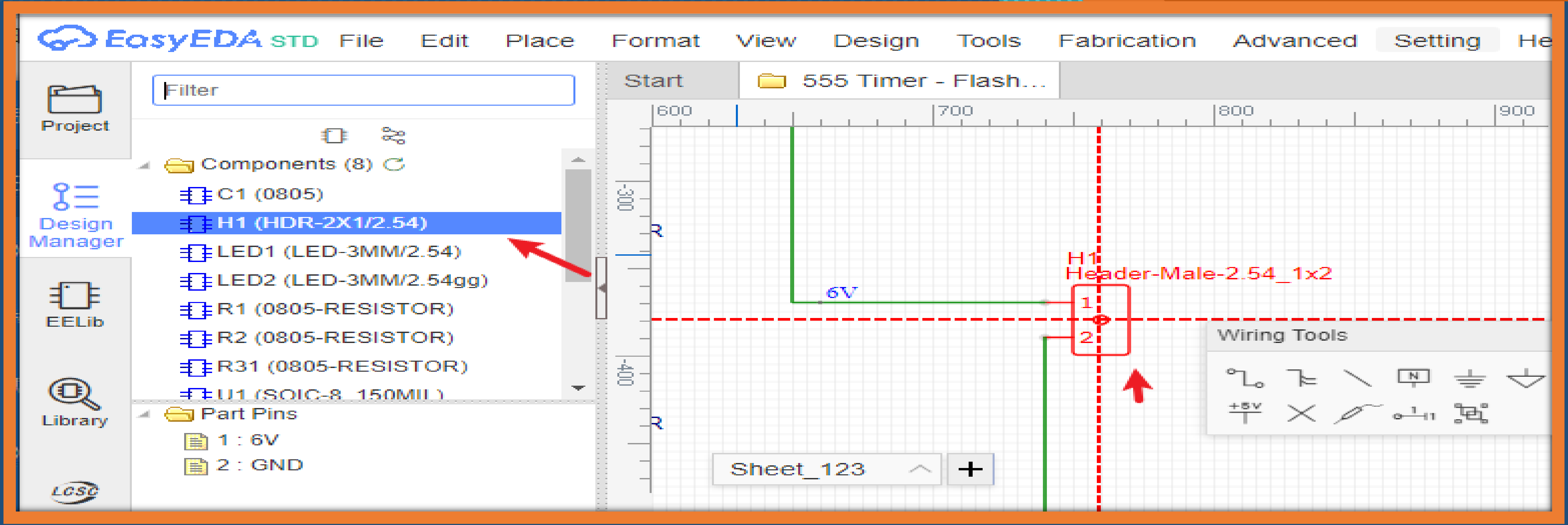


With large schematics it can be hard to find the components quickly. Sometimes, you may make a mistake such as wiring to a wrong component pin. So you need a tool to help you out. Design Manager is just the tool.

Just press the CTRL+D hotkey to open the Design Manager.

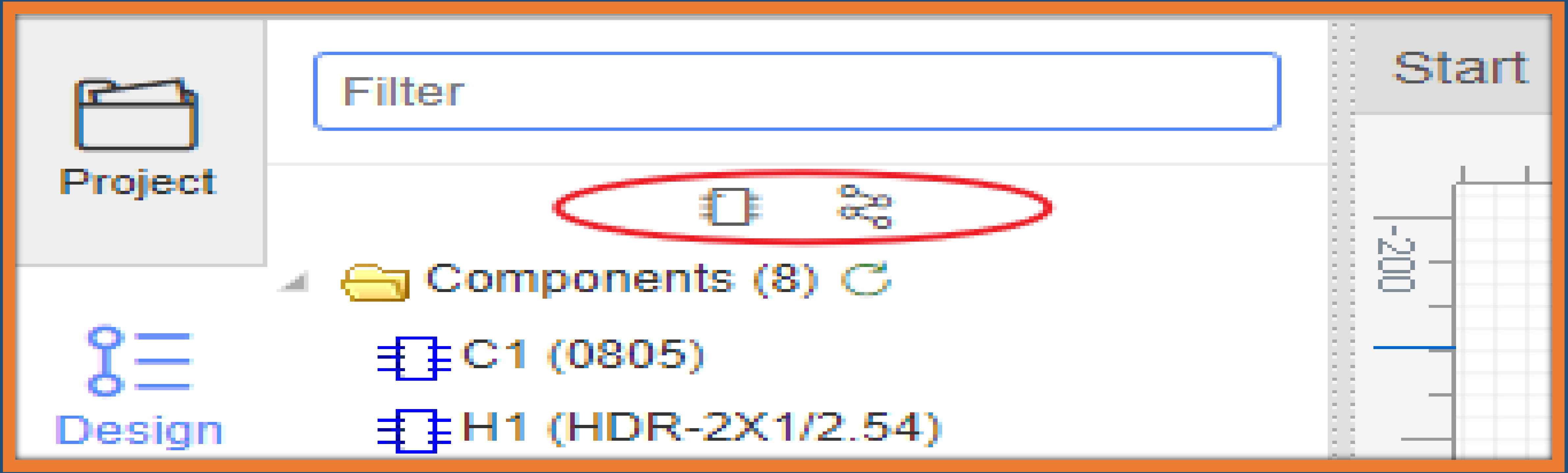
or click it via on the left navigation panel

Easyeda Nets



Nets: Lists all the nets in this schematic. A net must connect at least two Pins, or the net name will be marked as a red error. When click the net name, the canvas wire will highlight and being large, when you click the empty space to unhighlight:

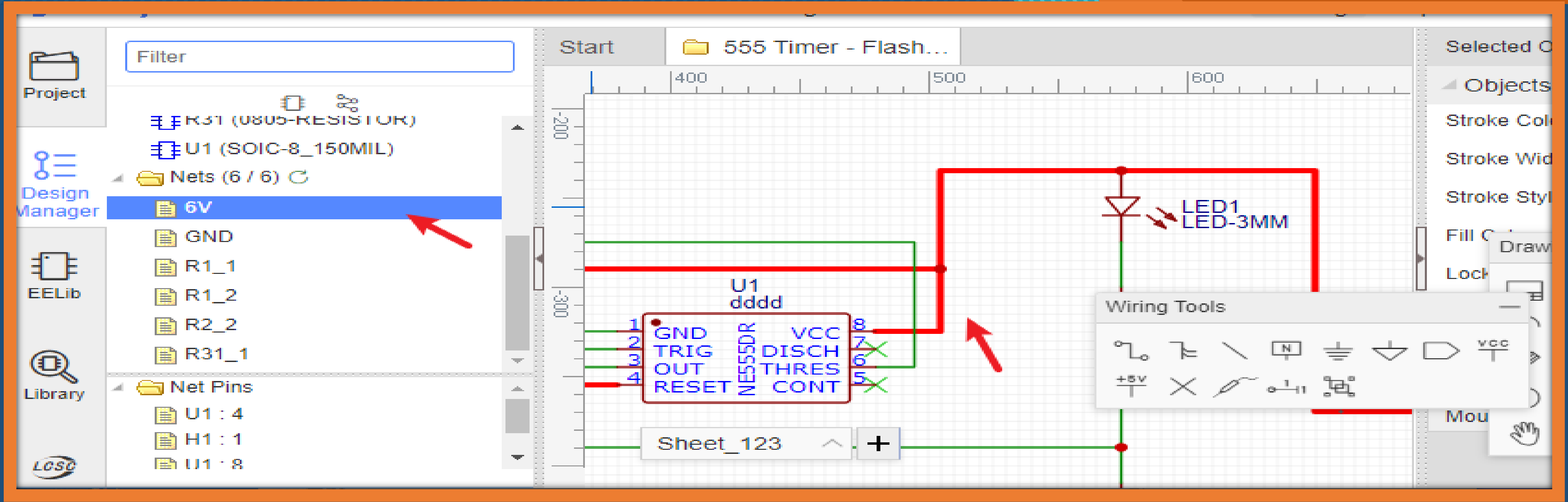
Components



Filter: You can find your components or net name easily: for example, if you want to find all capacitances, you just need to type C;

Components: Lists all the components in this schematic. Clicking on a Component item highlights that component and pans it to the center of the window.

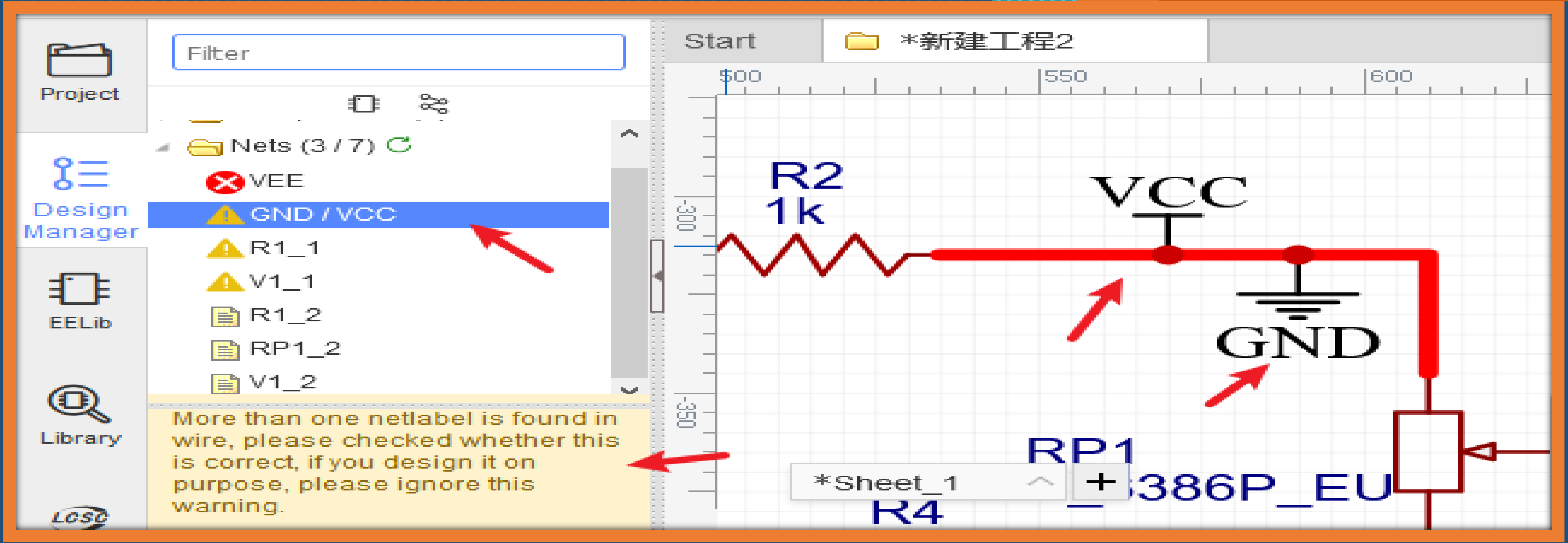
Easyeda nets



When you click the net name, you will see the tip at the bottom-left corner.

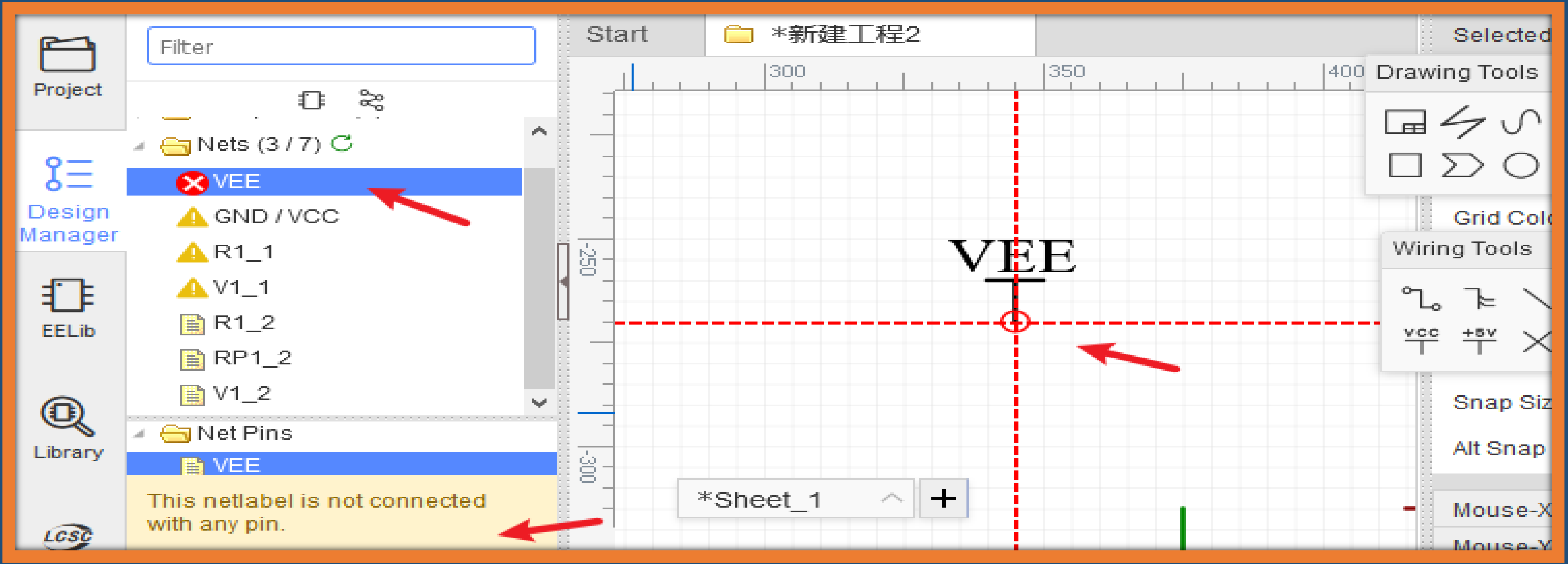
Net warning: It will show a prompt exclamation point icon. When multiple net labels on one wire, please check whether if it is correct or just connected by mistake. You need to click this net and find it out. If your net flag or net label only connect one pin, it will show warning.

Net Label



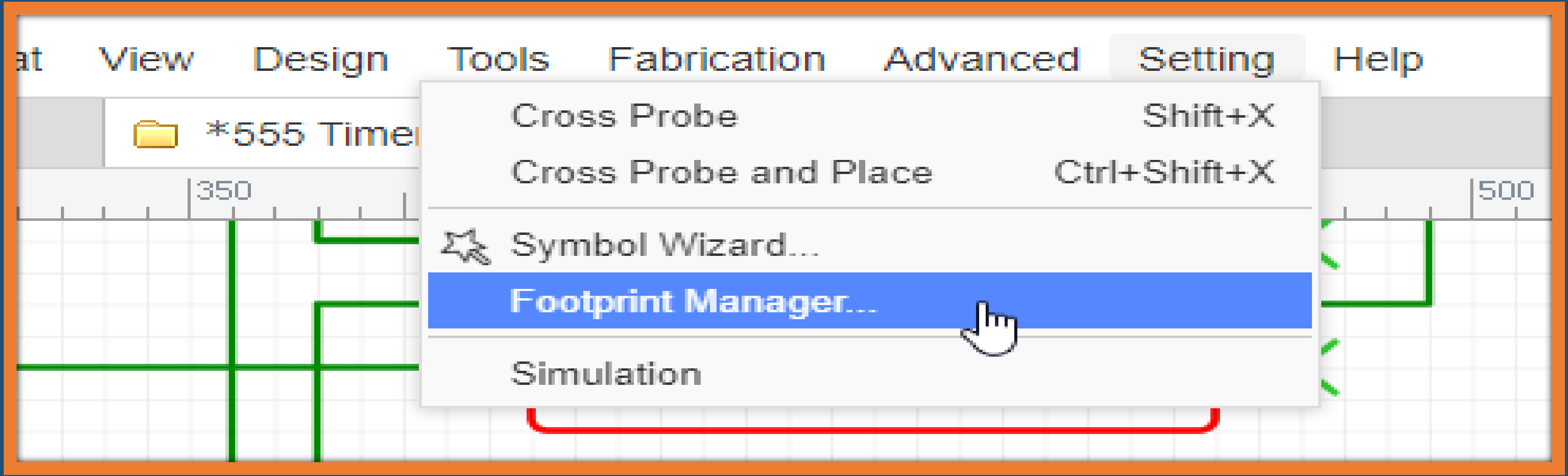
The part's pin doesn't place the netlabel, or doesn't connect other pins, or doesn't place No Connect Flag. A completed net must connects two and more pins, so that, you need to modify your net connection. If you don't need to use this pin, please place a No Connect Flag on the pin.

Net Label



Net error: Prompts a red error icon.
When Netlabel haven't connected any pins

Footprint manager



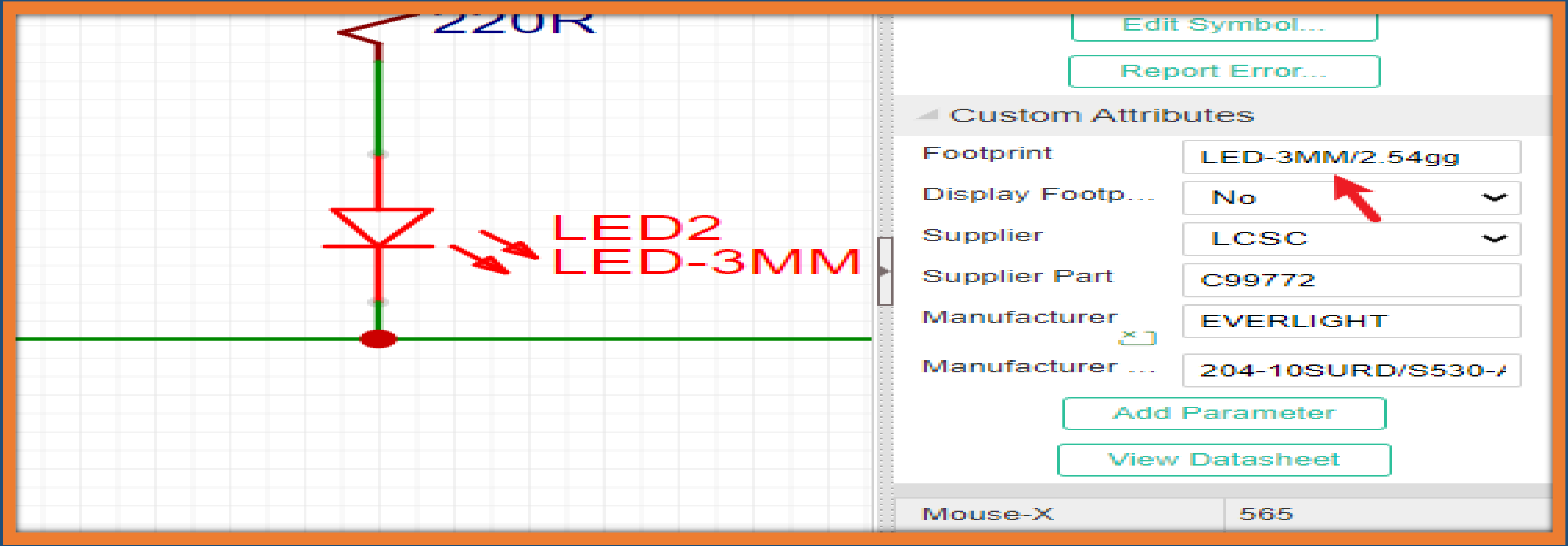
Click the footprint input box of custom attributes when you've selected a component:

Want to batch modify components? Can't identify the corresponding relationship between component pins and footprint pins? Don't worry, EasyEDA can do this.

There are two ways to open the footprint manager:

Click top menu, via: Top Menu - Tools - Footprint Manager

Footprints



EasyEDA's Footprint Manager instantly checks and alerts with a red background if a part's footprint is missing, nonexistent in EasyEDA Libraries, or if there's a mismatch between the part's pins and the footprint's pads.

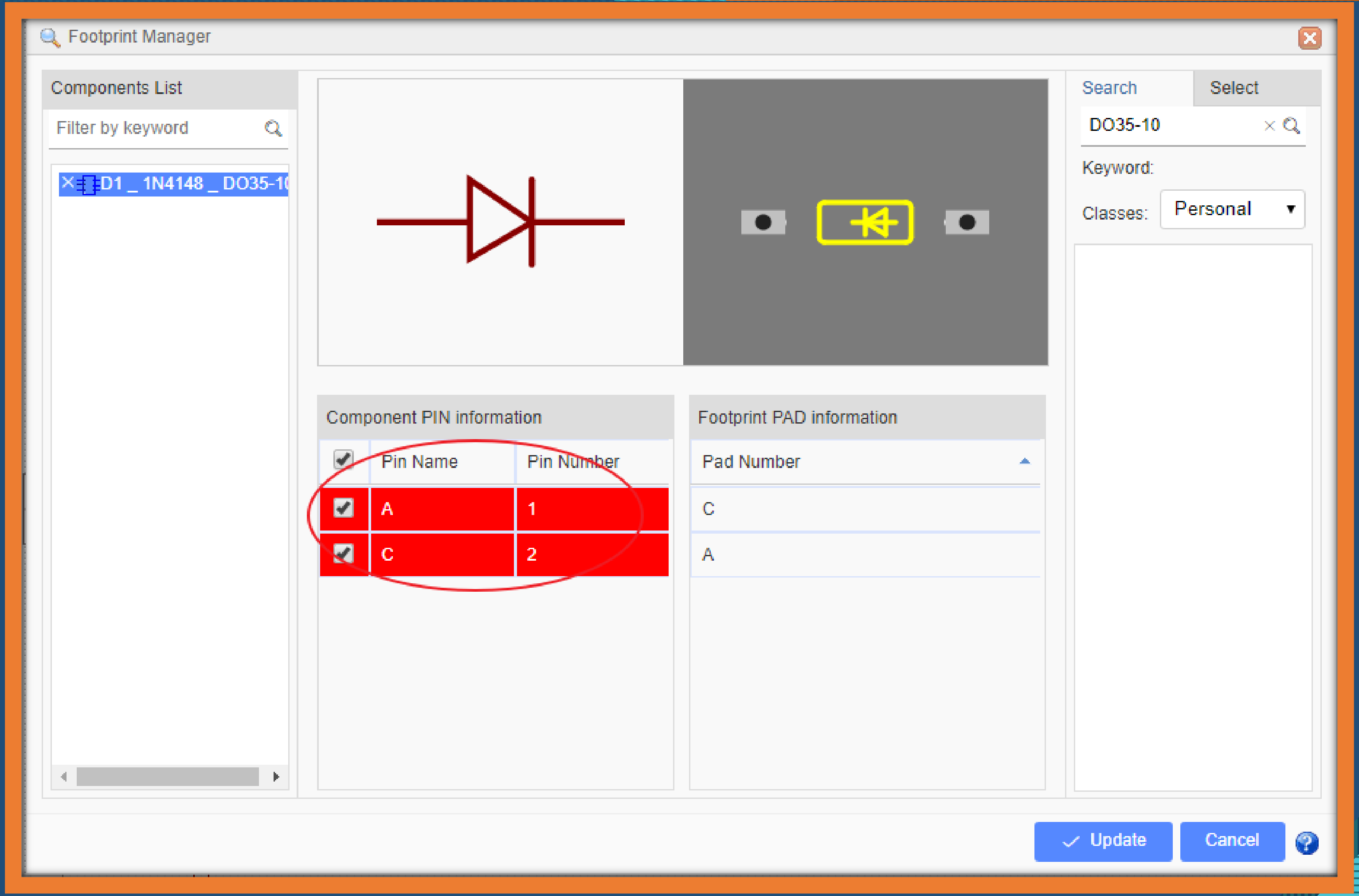
Footprint

In order to solve this:

method 1: change part's pin number from 1 and 2 to A and C.

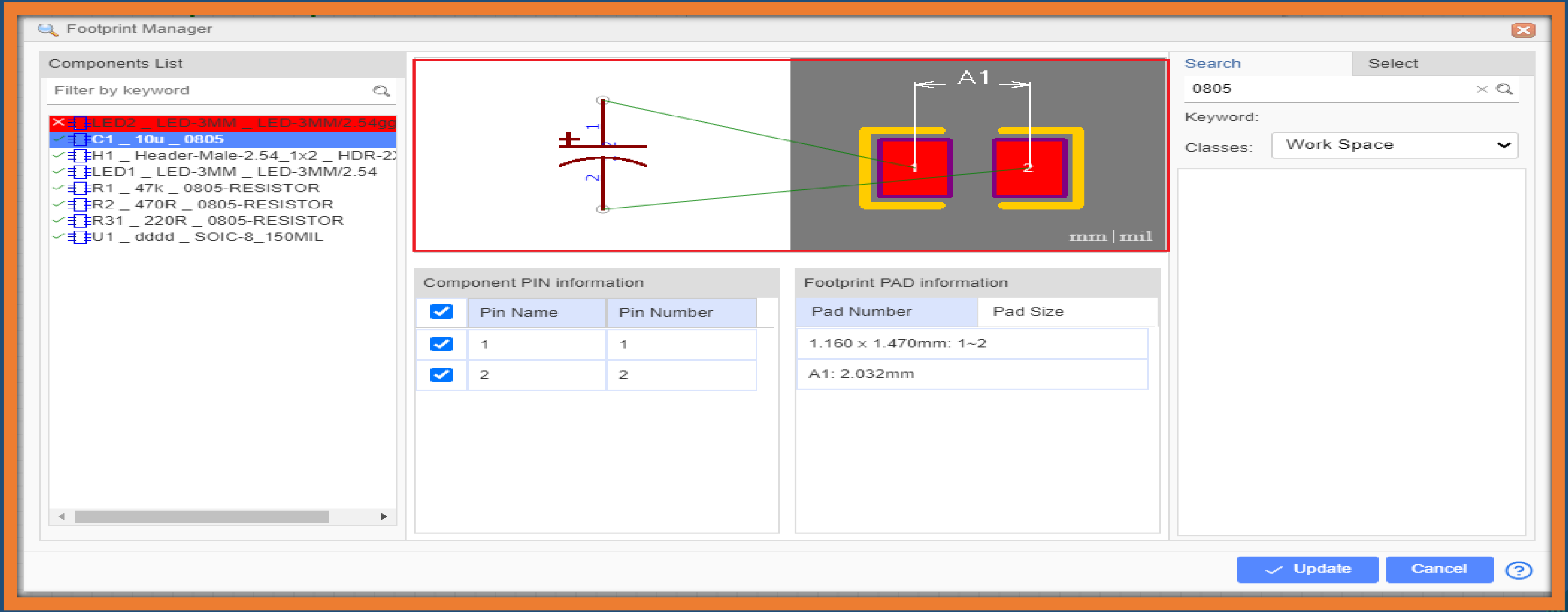
method 2: change footprint's pad number as 1 and 2. That needs the footprint is created by you. And you can't change the Pad number in footprint manager, you need to find out the footprint at "Library > Footprints > Work Space", and then edit it.

method 3: find an other footprint and update.



PCB PAD

In the preview area, you can zoom in, zoom out and pan with mouse scroll button.

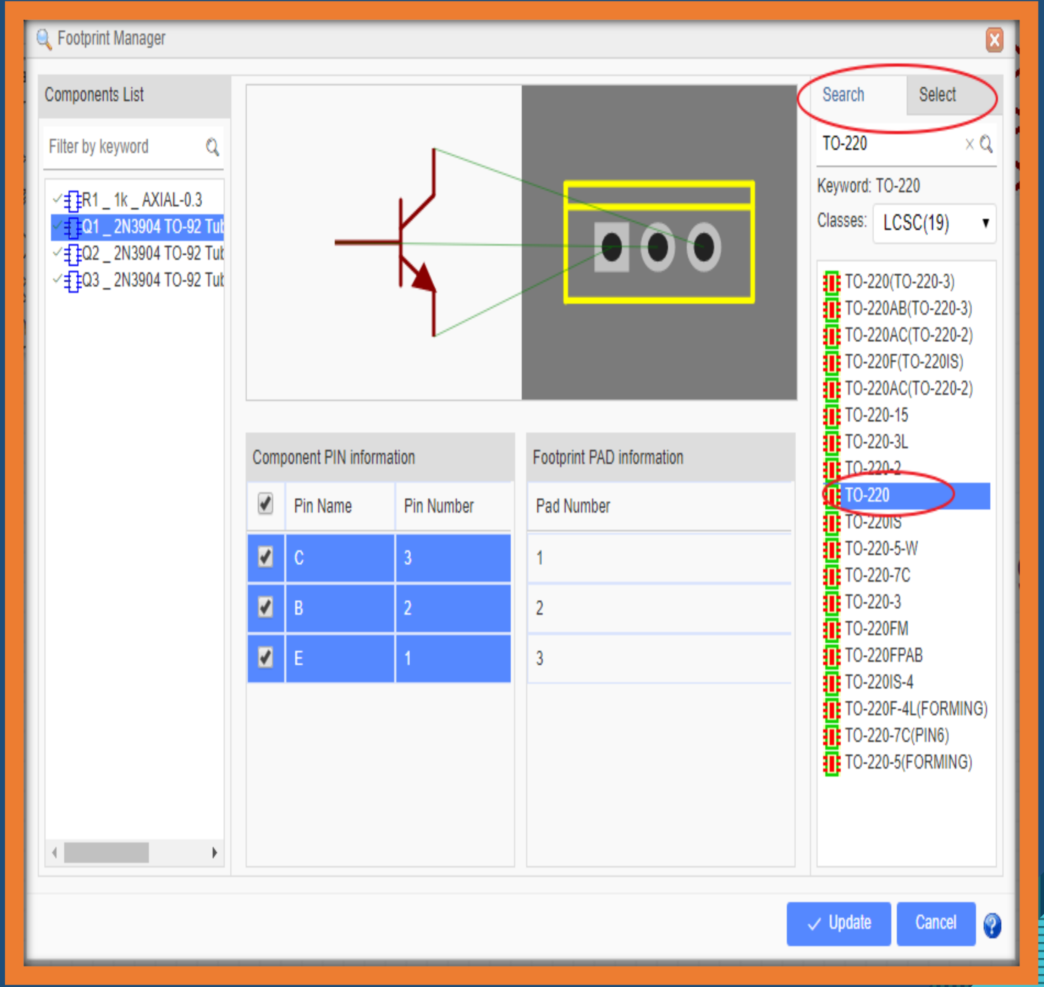


PCB PAD

you can modify component’s pin map information in here.

PCB PAD Information:

- **Pad Number**: You can check the footprint’s pad number, but you can’t modify it. when you select the component on the left side, it shows component’s footprint pad number, if you selected a footprint which is searched or selected from the classes, it will show the selected footprint’s pad number.
- **Pad Size**: You can check the footprint’s pads size and distance, it same as “Check Dimension” tool of footprint editor. Click the preview area unit text to change size unit.



FOOTPRINT

Update footprint

If you want to change the footprint, for example, select a component such as Q1, from **TO-92** TO **TO-220**, you just need to click in the footprint input box. EasyEDA will popup the footprint manager dialog. You can follow the instructions.

Type **TO-220** into the search box and search, Or change to Select tab,

Select the classes you want and select **TO-220** footprint,

Verify it in the preview box,

then press the **Update** button.

After that you will find you have changed the footprint to **TO-220**.

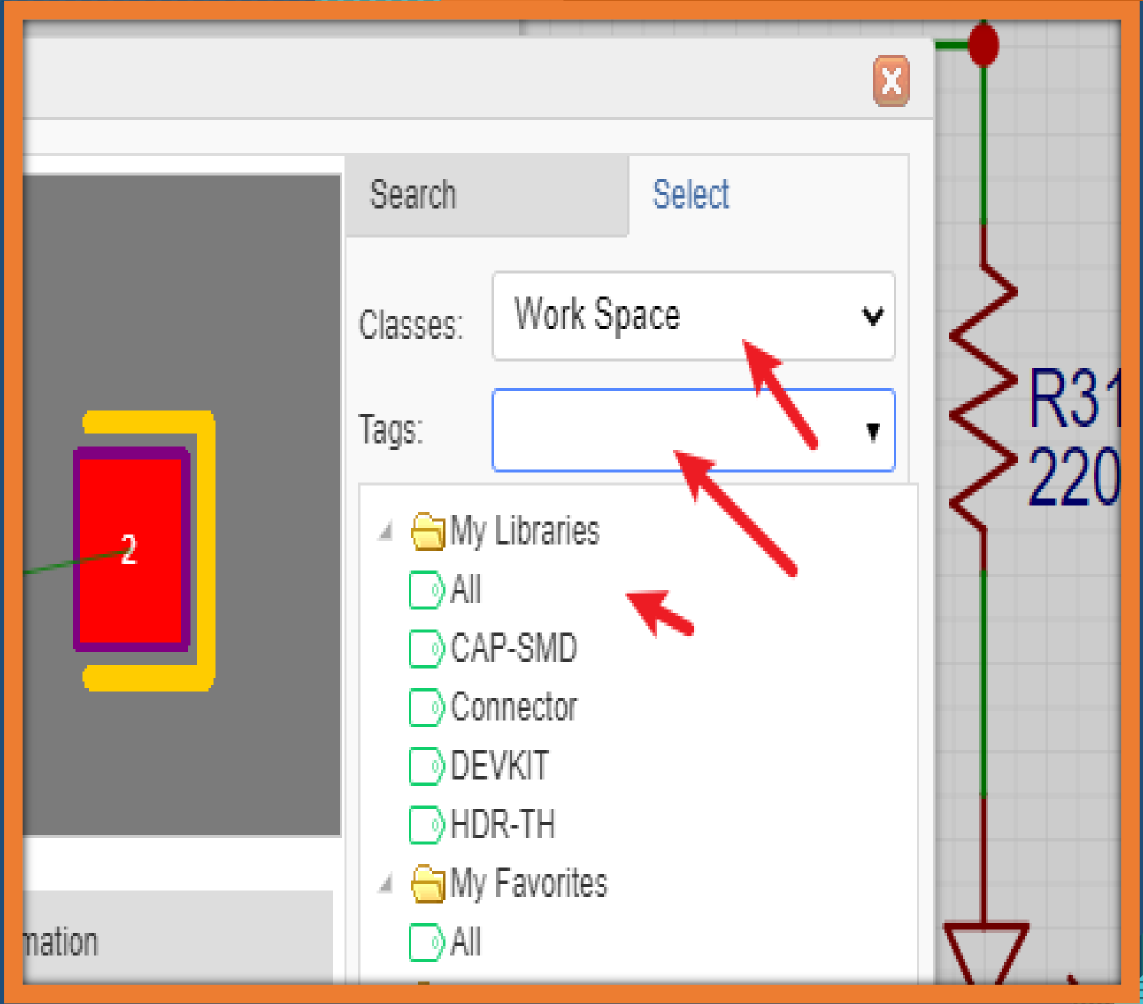
Note:

To ensure that you use a footprint type that is already in the EasyEDA library, it is recommended that you use this technique to change component footprints rather than just typing a footprint name directly into the footprint text input box.because of the footprint manager will add the footprint's global unique ID into the schematic when the footprint updating.

Update in Batch
If you want to batch modify components' footprints,

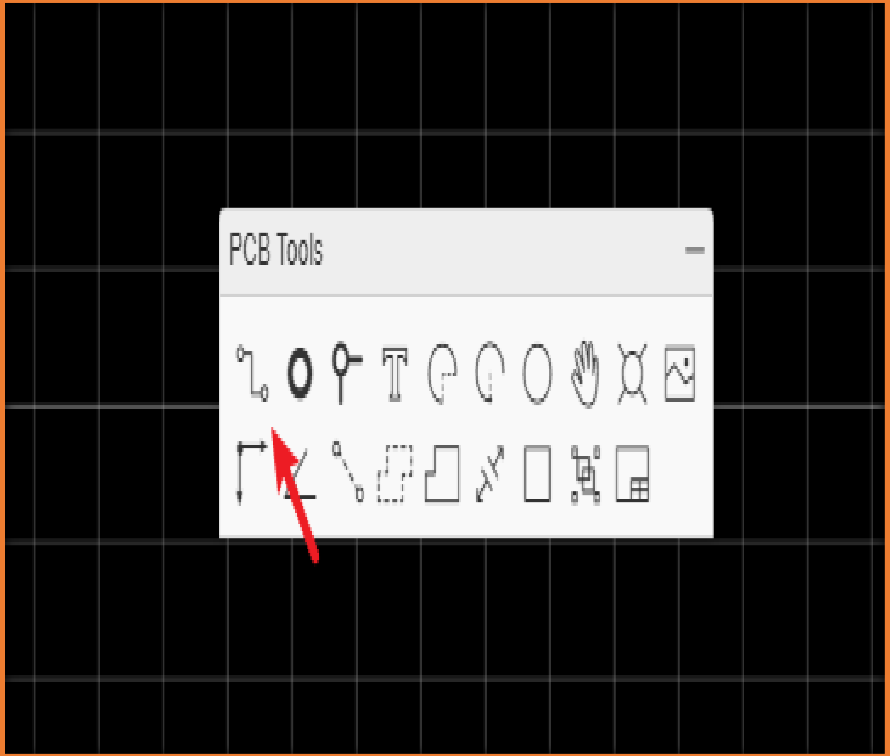
In the footprint manager dialog, you can press CTRL + click or SHIFT + select to select the components, and then select the footprint to update.
In schematic canvas, you can frame select the components as you want, and then click the "footprint" attribute input box at the right-hand property panel.

To use your own footprints, you can select Work Space under the Select tab.



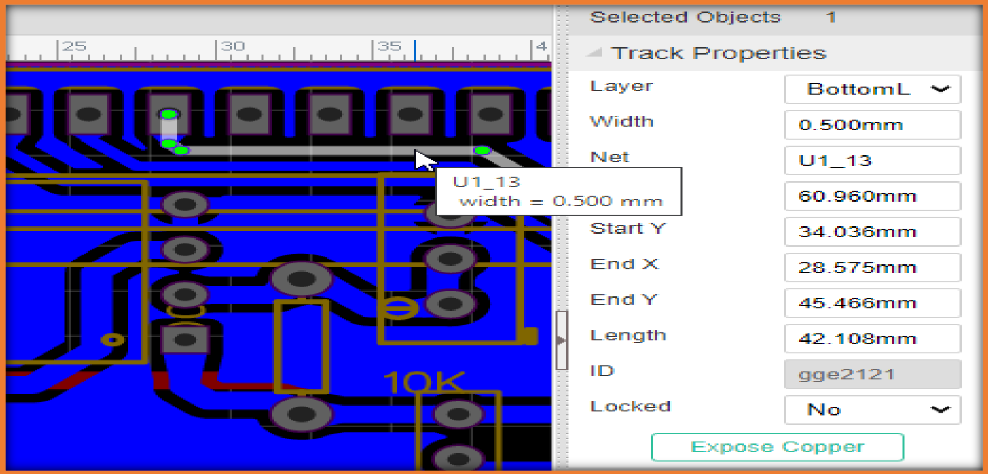
PCB TOOLS

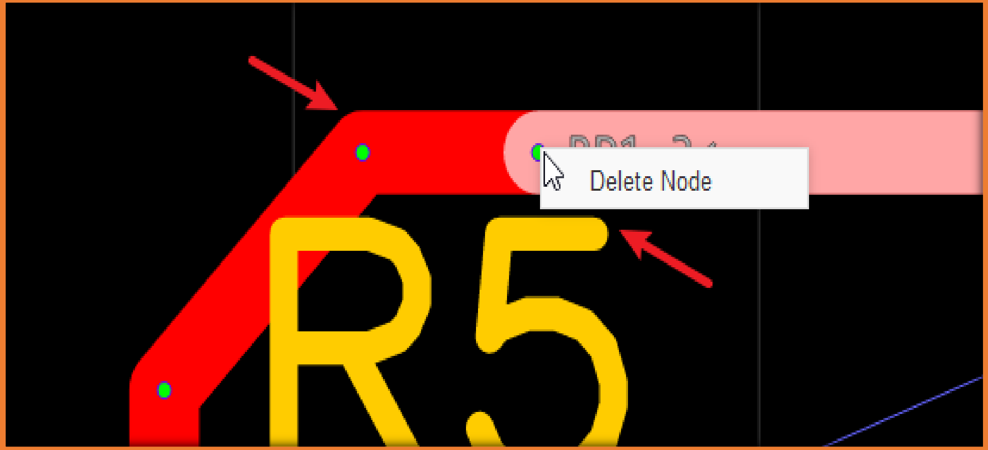
- PCB tools provide many function to fulfill your PCB design requirement.
- Such as: Track, Pad, Via, Text, Arc, Circle, Move, Hole, Image, Canvas Origin, Connect Pad to Pad, Copper Area, Solid Region, Measure/Dimension, Rect, Group/Ungroup. etc. Track
- In the schematic editor, we use Wire or the W Hotkey to connect Pins, in a similar way in the PCB editor, we use Track to connect Pads. Track allows you to draw PCB tracks and can be found on the PCB Tools palette or using the W Hotkey (not T: see above!).



Track

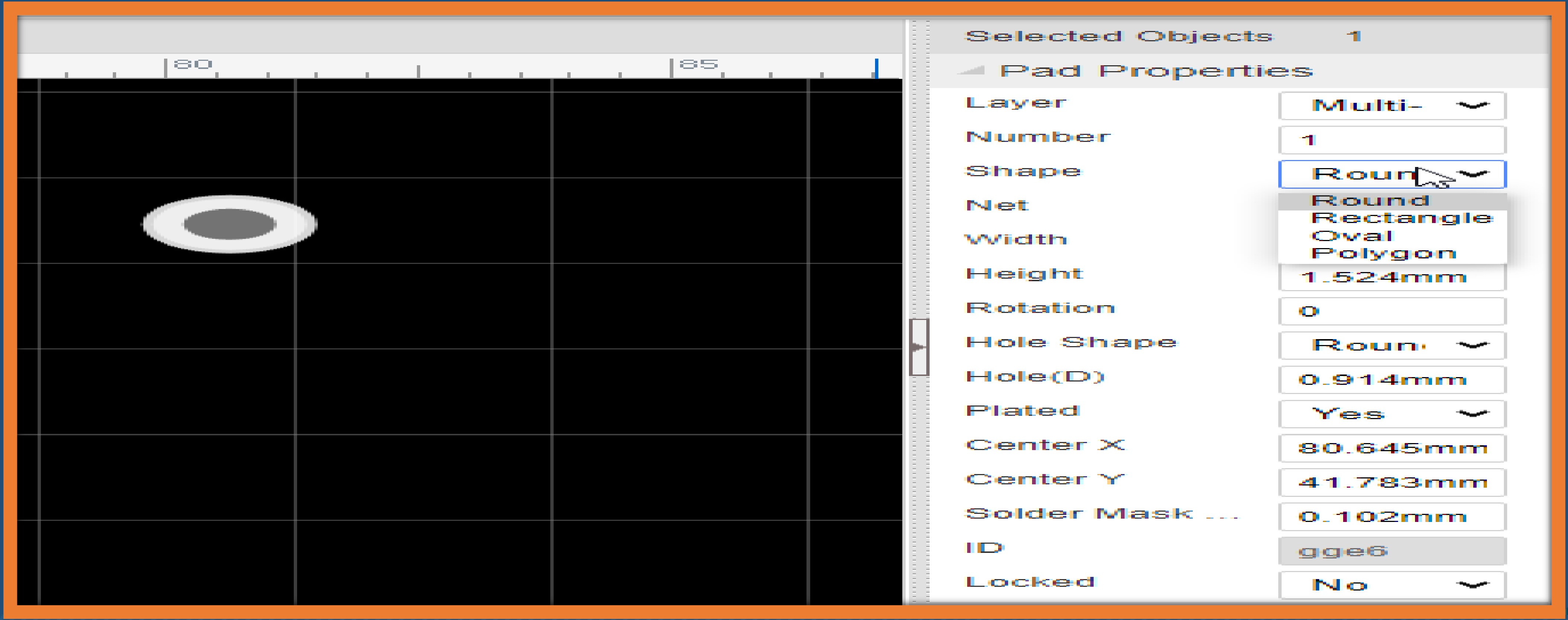
- When a track is selected, you can find its Length attribute in the right panel.
- If you want to create solder mask for the track, you can click the “Expose Copper” button at the right-hand property panel.
- When click the track, you will see the nodes, you can drag it or right-click delete it. when select the point to point separated tracks, you can convert them as Solid Region or continus track at right-click menu.
- The more information of routing, please refer at PCB: Route Tracks



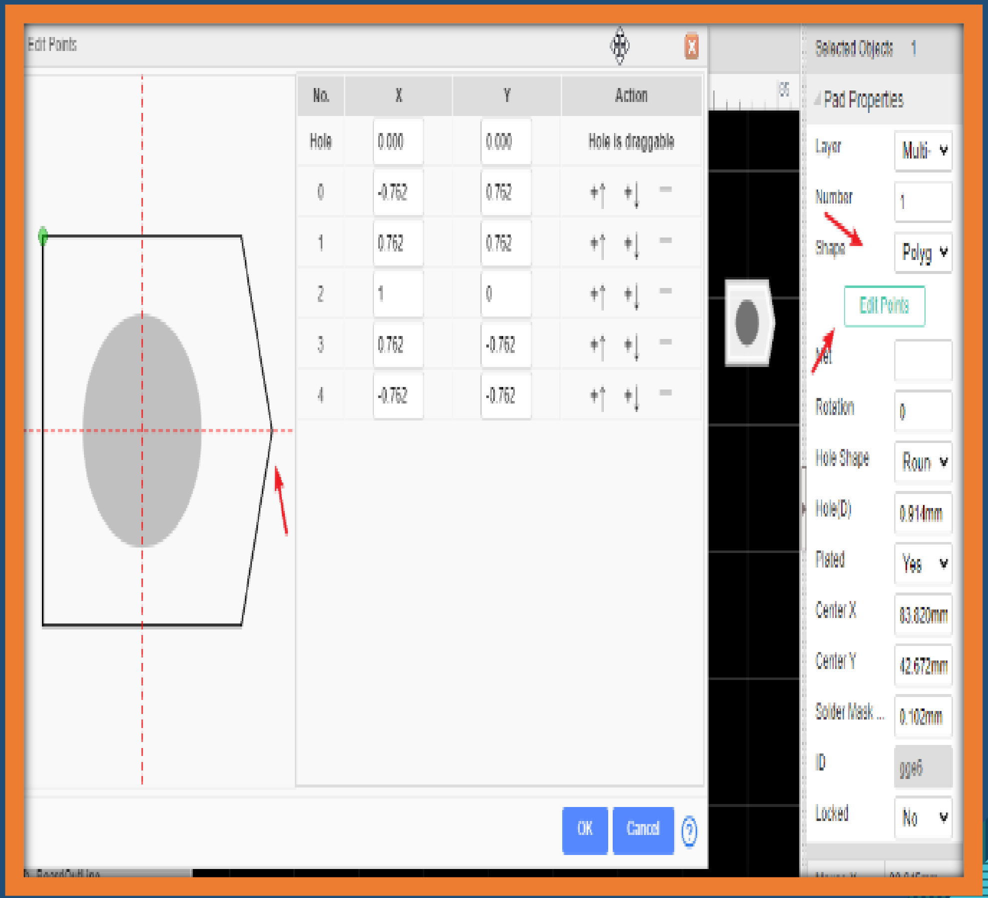


PAD

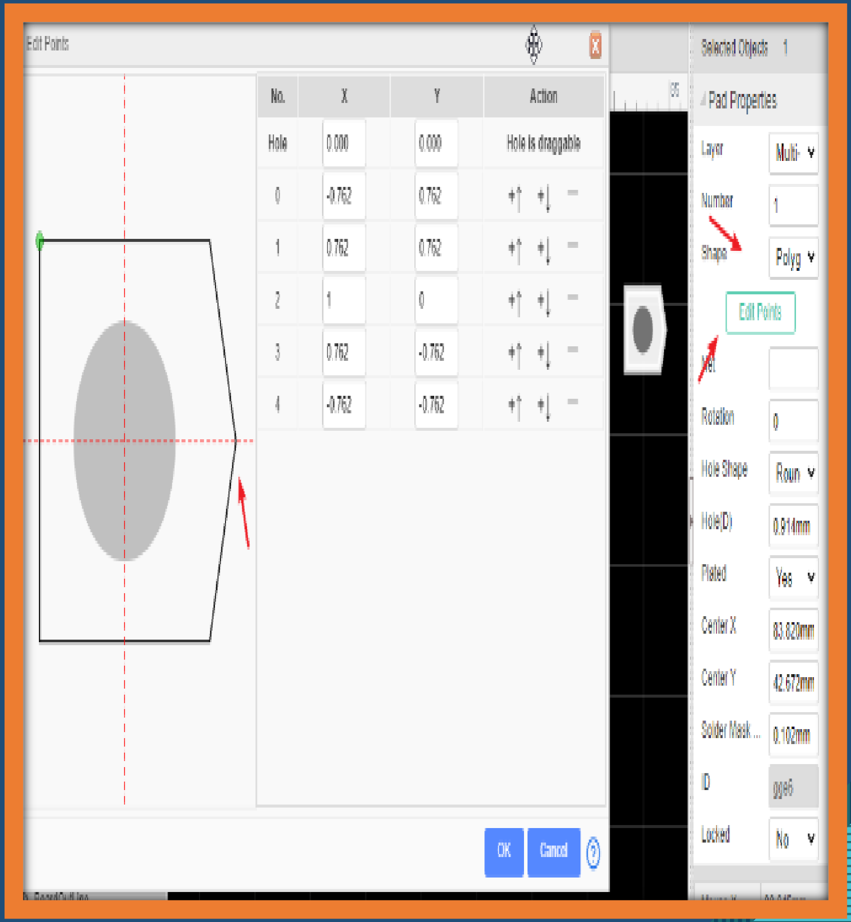
- You can add pads using the Pads button from the Footprint Tools palette or using the P hotkey.
- After selecting one of the pads, you can view and adjust its attributes in the right hand Properties panel.



- Number: Remembering the pin numbers you set in the schematic symbol in your Schematic Lib: to connect those schematic symbol pins to the pads in your PCB footprint, the pad numbers you set here in the Footprint footprint must be the same.
- Shape: Round , Rectangular , Oval and Polygon.
- EasyEDA supports four shapes: Round , Rectangular , OVAL and POLYGON.
- OVAL PAD will give your more space.
- POLYGON PAD will let you to create some strange pad.
- Like in the image below, you can edit the PADs points when you select a POLYGON PAD

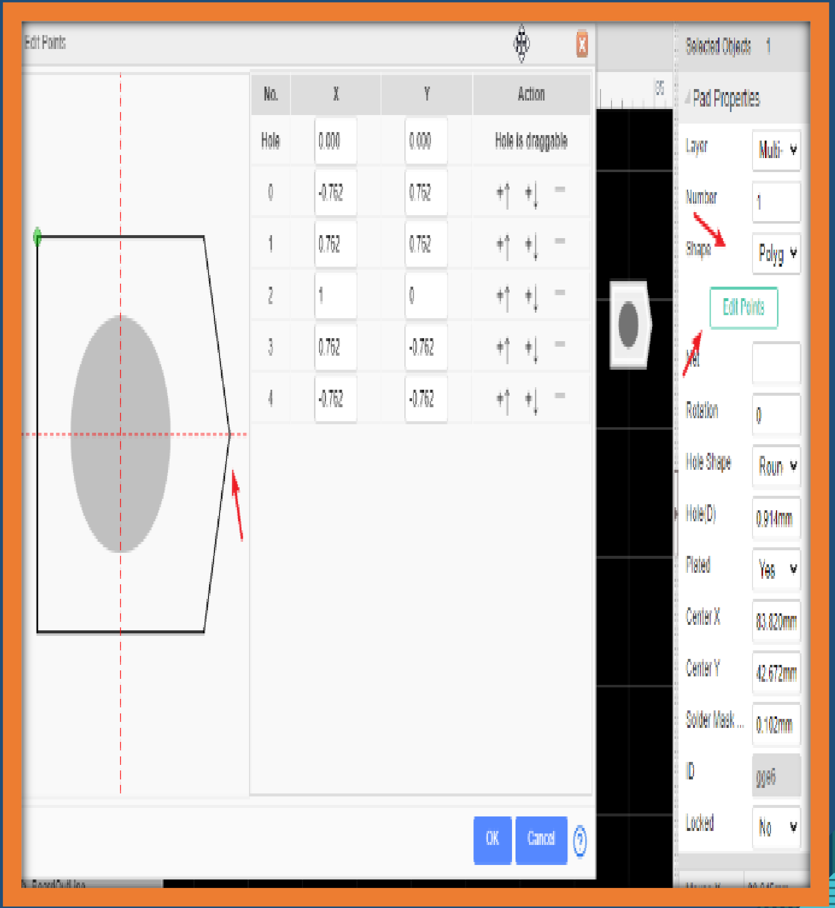


- **Layer**: For SMD footprints, set the layer to Top or Bottom. For through-hole components, set it to Multi-Layer to connect with all copper layers.
- **Net**: No need to enter anything if the footprint isn't connected in the circuit.
- **Width and Height**: If the shape is Round, width equals height.
- **Rotation**: Set the pad's rotation as needed.
- **Hole (D)**: For through-hole pads, specify the drill hole diameter. For SMD pads, set layer to Top or Bottom.
- **Hole Shape**: Choose between Round and Slot. Avoid setting as Slot for round holes to prevent overlapping errors during DFM detection in production

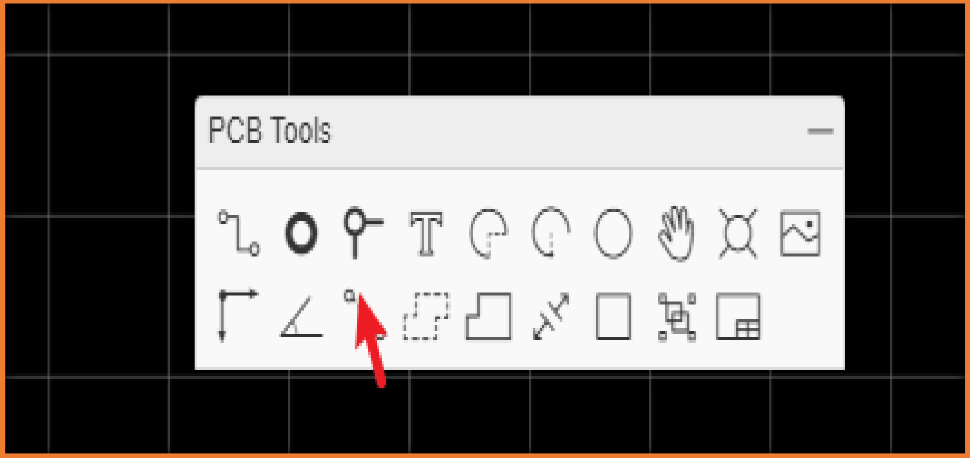


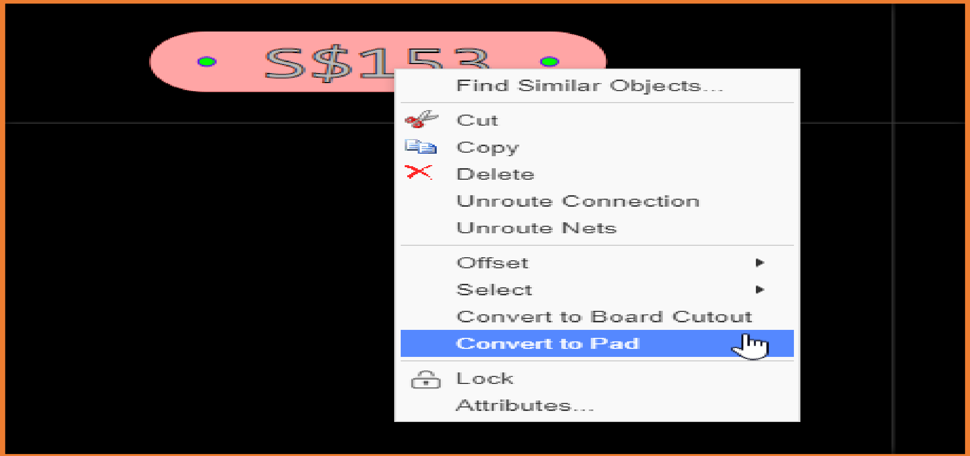
Easyeda Layers

- **Center-X and Center-Y**: using these two attributes, you can set the pad's position with more precision, compared to using the mouse.
- **Plated** : Yes or No. When you set it as No, this pad Inner wall do not metallization.
- **Paste Mask Expansion**: For single layer pad. This property affects the size of the tin area on the plate of the steel mesh. If you want to set a pad that is not open in the steel mesh, you can set the value to be negative, which is usually larger than the diagonal of the pad.
- **Solder Mask Expansion** : This property affects the size of the green oil area cover on the pad. If you want to set a pad not open covered with green oil, you can set the value to be negative, the value is usually set larger than the diagonal of the pad.

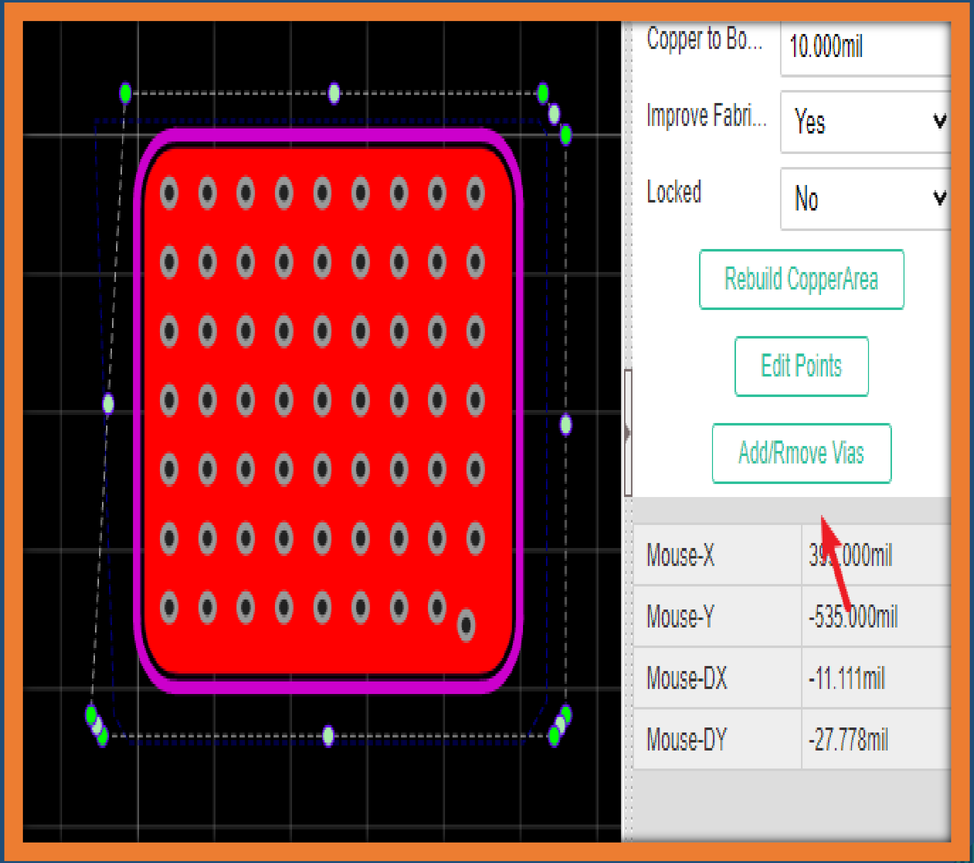


- And you can select a track/Solid Region, right-click it and convert to a pad.
- Via
- When you want to lay a multilayer PCB, you need to add Vias for nets getting through layer and layer.
- Place a Via on a Track
- When placing a via on a track, the track will be cut to two segments, and the via net will follow track's net. Placing two vias on a tracks, you will get three segments, then you can change one segment to other layer id, or remove one of them.





- Place Multiple Vias
- Click the copper area outline, click the “Add/Remove Vias” button. this feature needs the same net copper areas on two and more layers in the same time, the cross area will add the vias.



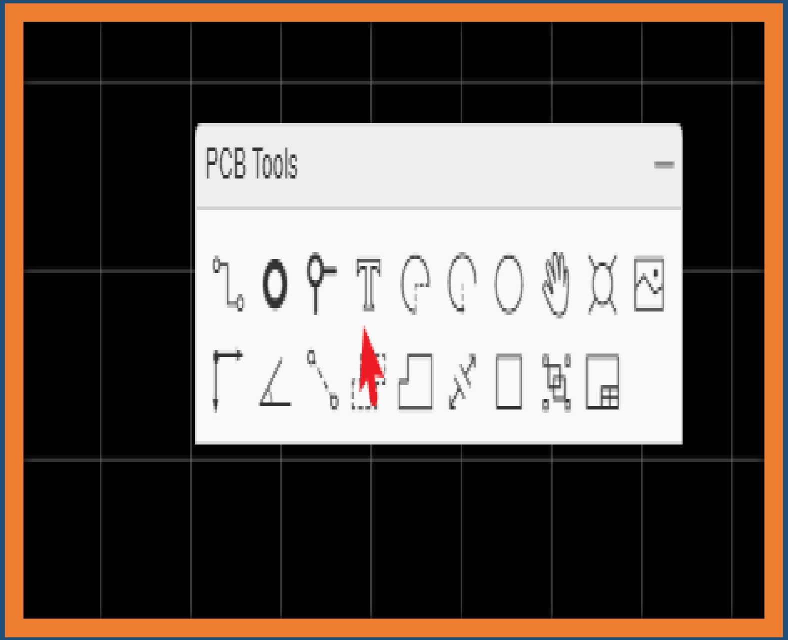
Notice:

EasyEDA only support the through via for all layers, doesn’t support the buried/blind via.

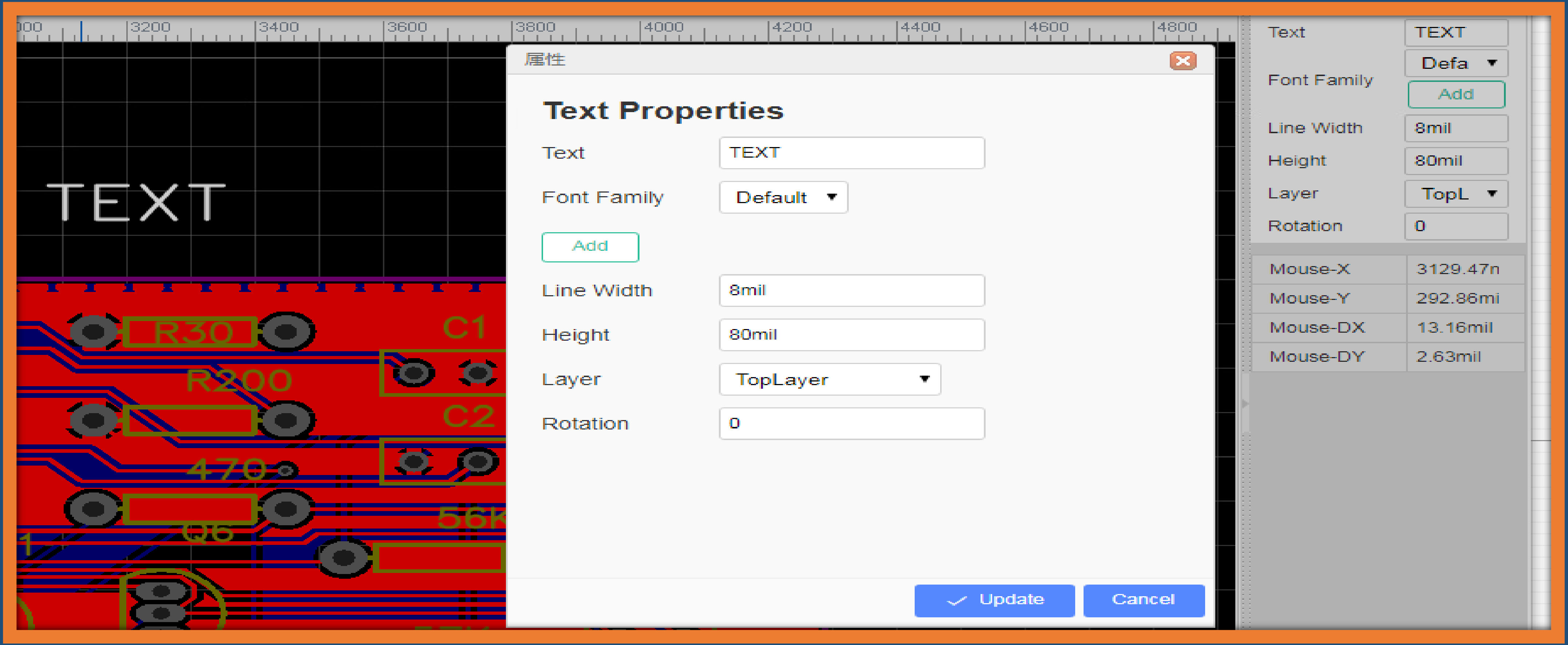
- **Text**

- You can add more fonts from your computer or download free fonts: http://www.fontspace.com/.
- if you need Japanese or Korean you can use Google Noto fonts

The editor including fonts are:
(NotoSansCJKsc-DemiLight)[https://github.com/googlefonts/noto-cjk/blob/main/Sans/OTF/SimplifiedChinese/NotoSansCJKsc-DemiLight.otf]
(NotoSerifCJKsc-Medium)[https://github.com/googlefonts/noto-cjk/blob/main/Serif/OTF/SimplifiedChinese/NotoSerifCJKsc-Medium.otf].



Select the text, then you can find a Font-family attribute on the right panel like in the image below.



Click the add button, then choose the font, the font file must be ttf or otf.

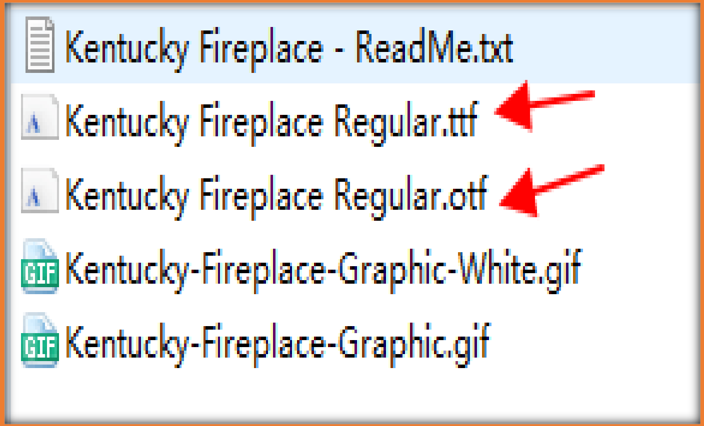
So you can add any fonts by yourself. EasyEDA doesn't cache the font on our server, so if you close the editor, you need to add the font again by yourself.

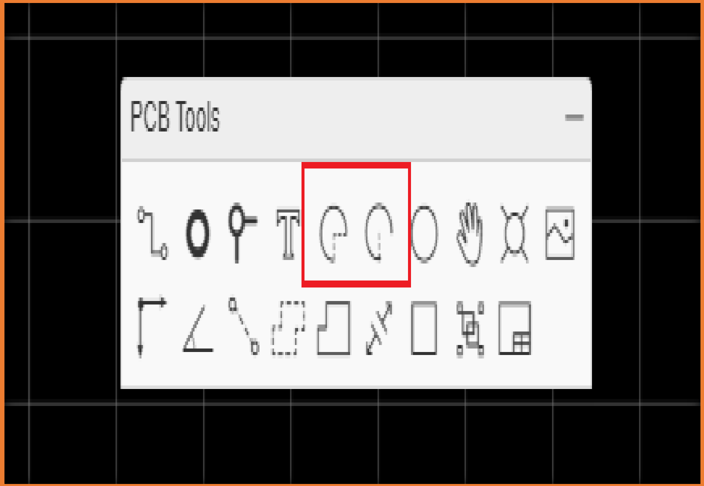
- **Note:**

  If you use the other font, the LineWidth attribute is useless, because it will be automatically set by changing the Height.

- **Arc**

  You can draw many Arcs with different sizes, it's easy to create a pretty cool PCB as you like.





➢ Circle

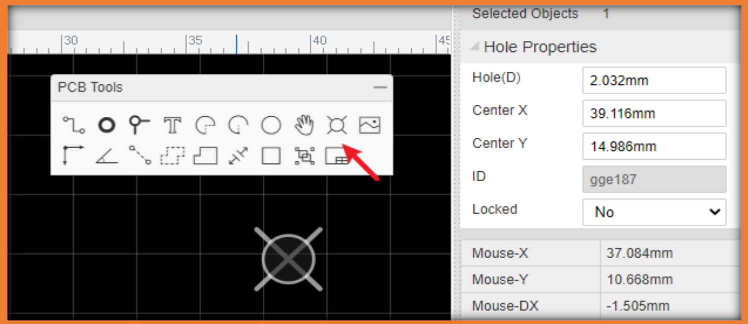
You can draw a circle in PCB. If you want to draw a circle at Top Layer or Bottom Layer, please use Arc.

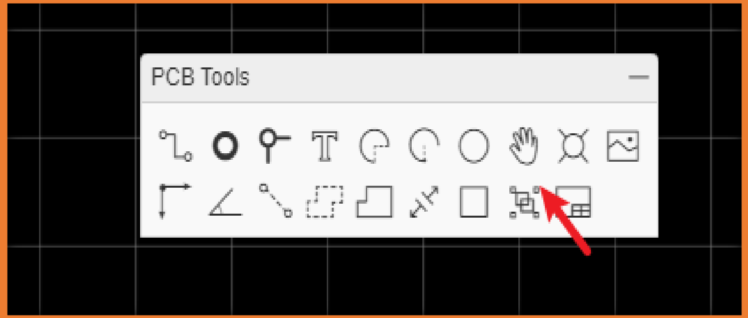
➢ Move

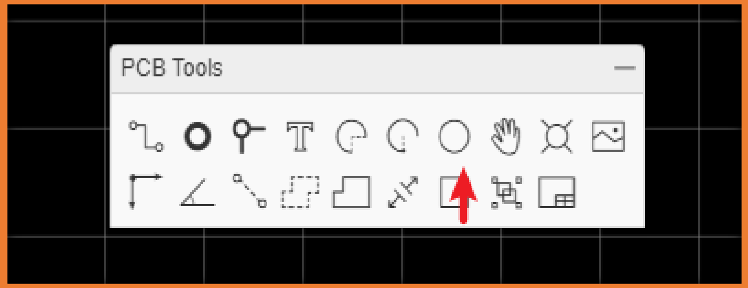
This option is same as schematic's drag.

➢ Hole

There were lots of users that didn't know how to use PAD or VIA as a HOLE, they asked EasyEDA for help, so EasyEDA added a HOLE TOOL in the PCB toolbar.

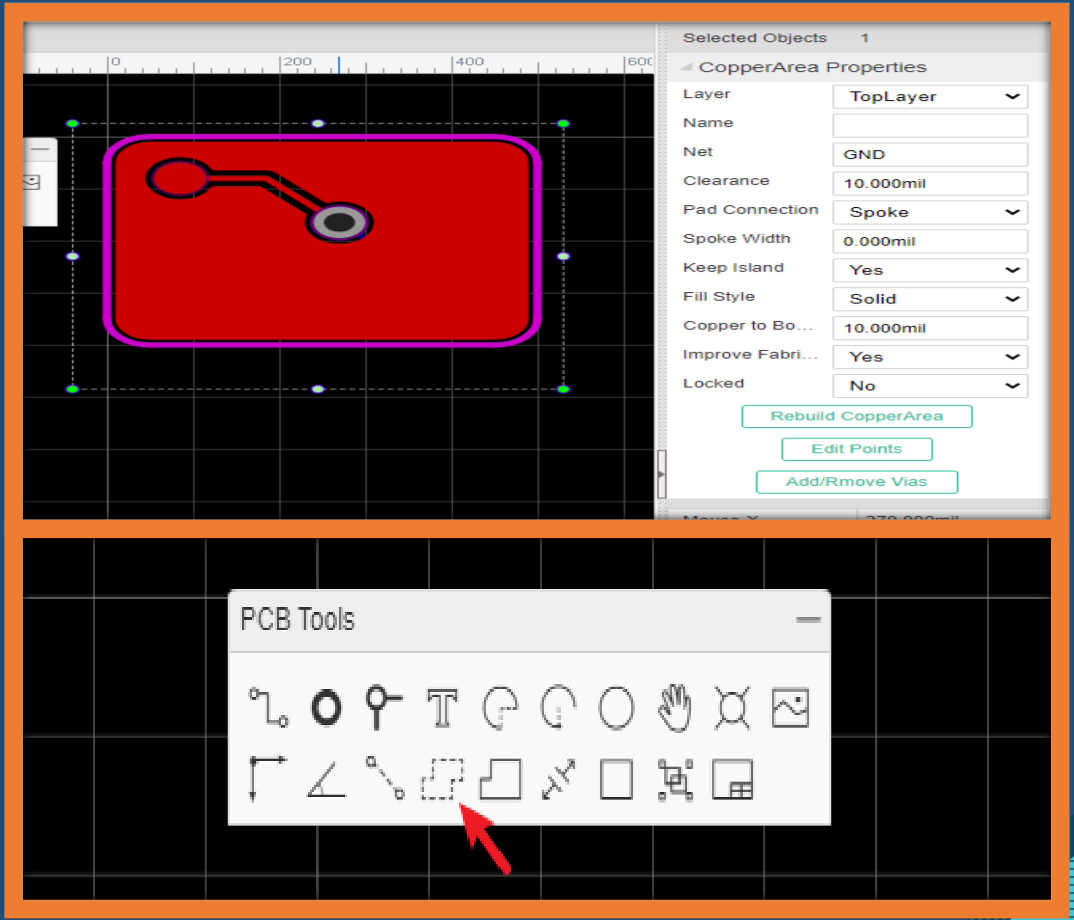




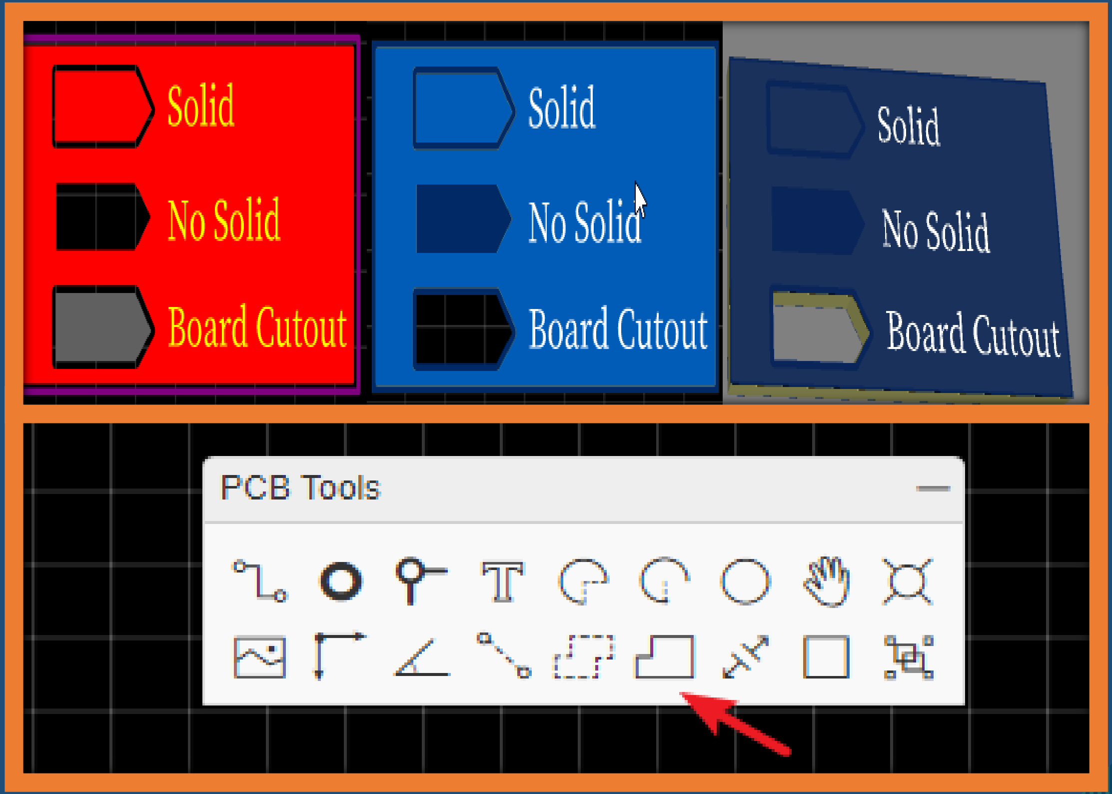


Copper Area

- Sometimes you will want to fill in or flood an area with copper. Usually this copper area will be connected to a net such as GND or a supply rail. You can draw the outline of a flood using the Copper Area button from the PCB Tools palette.
- When selecting a copper area, you can find its attributes from the right hand **Properties** panels.

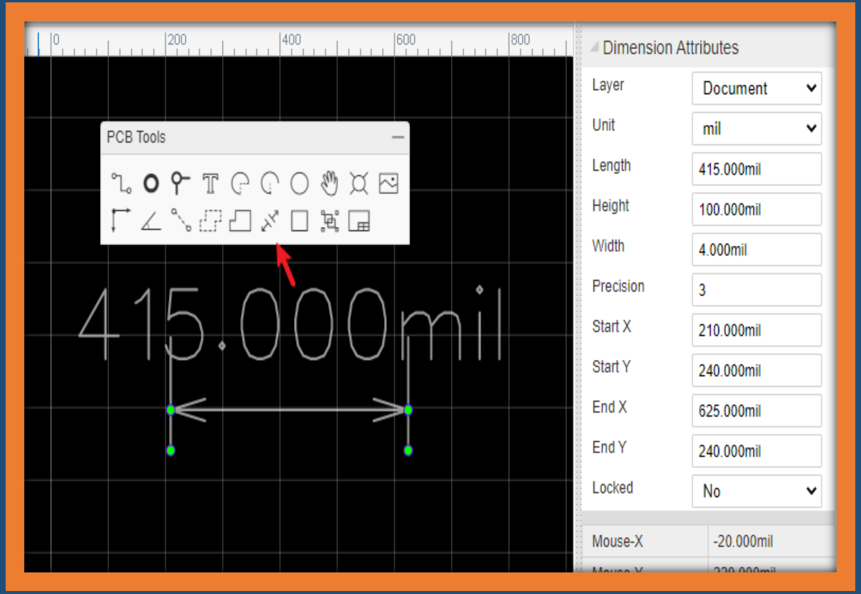


- Solid Region
- EasyEDA has added a new tool Solid Region for PCB design
- This is a very useful, quick way to connect Pads. You can draw a Solid Region to include all of these pads with same net name, then set the region to the same net name as the pads. It is like Copper Area but easier to use for small areas. To use Solid Region like this, set the Type attribute (in the right hand Properties panel) to Solid.



Measure/Dimension

- Making and adding measurements is useful in PCB design. EasyEDA provides two methods to do this.
- Dimension tool in the PCB Tools palette:
  This tool can show three units on the canvas, milliliter, inch and millimeter.
- When you click one side of the dimension on the PCB, you can drag it for any directions or change its length.
- Measure a distance using Hotkey **M**, Or Via: **Top Menu > Edit > Measure Distance**, then click the two points which you would like to measure.



- **Tips**:
- *It's unit follows canvas's units.*
- *You can disable the snap option to measure at the canvas property panel.*