Embedded System Interfacing

Lecture 5
Electronic Switches

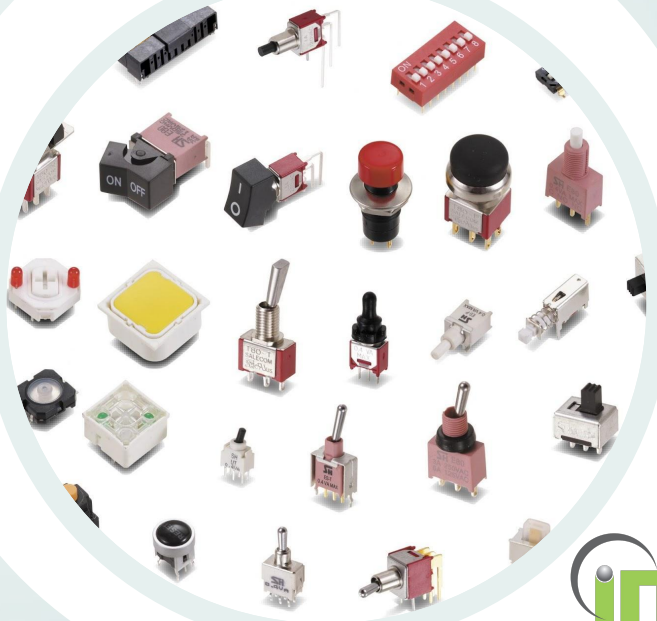
Introduction to Switches

Introduction to switches

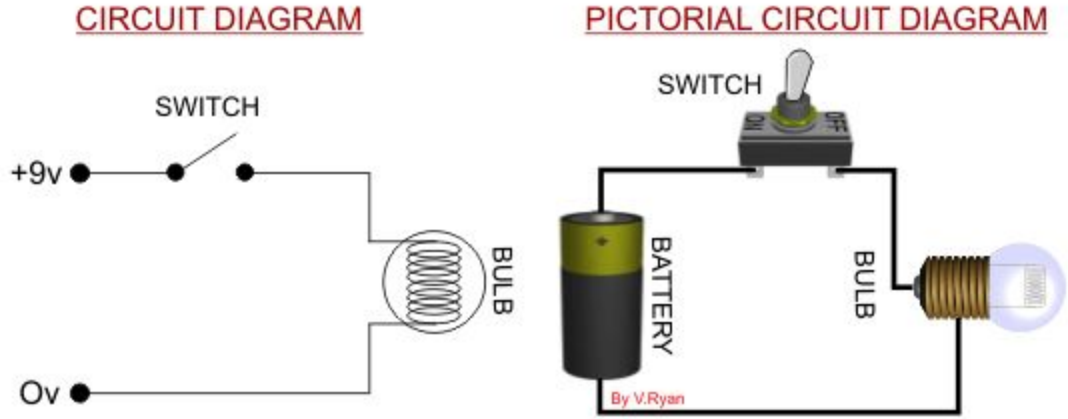
A Switch is a device which is designed to interrupt the current flow in a circuit. In simple words, a Switch can make or break an electrical circuit. Every electrical and electronics application uses at least one switch to perform ON and OFF operation of the device.

Why Electronic switches?

- ✔Allow the Microcontroller to control the electrical circuits without human interaction
- ✔Help in switching the power circuit on and off, the microcontroller plays the switching element not the driving element
- ✔The Isolation between the control circuit and the power circuit.



How Electronic Switch works



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Switches Types

02

Switches Types

Mechanical Switches

Mechanical Switches are physical switches, which must be activated physically, by moving, pressing, releasing, or touching its contacts.

Electrical Switches

Electronic Switches, on the other hand, do not require any physical contact in order to control a circuit. These are activated by semiconductor action.

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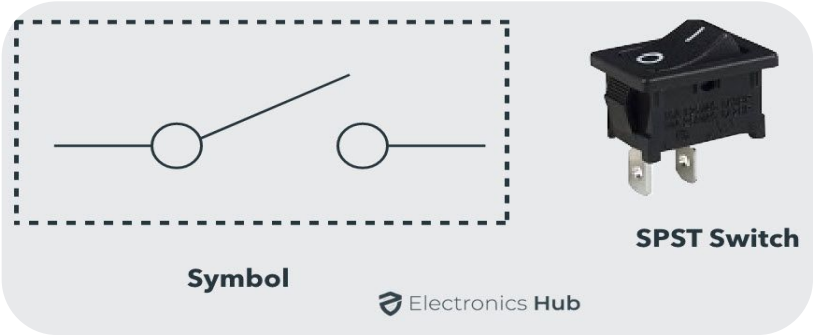
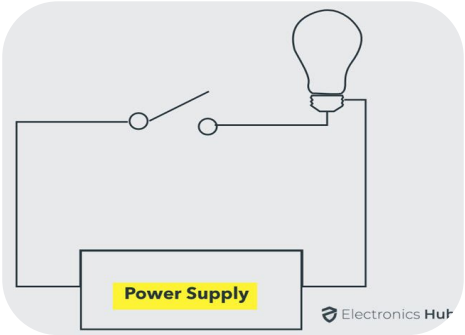
Mechanical Switches Types

03

Single Pole Single Throw Switch (SPST)

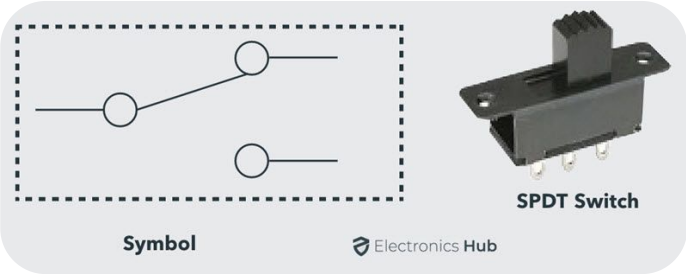
- This is the basic ON and OFF switch consisting of one input contact and one output contact.
- It switches a single circuit and it can either make (ON) or break (OFF) the load.
- The contacts of SPST can be either normally open or normally closed configurations .

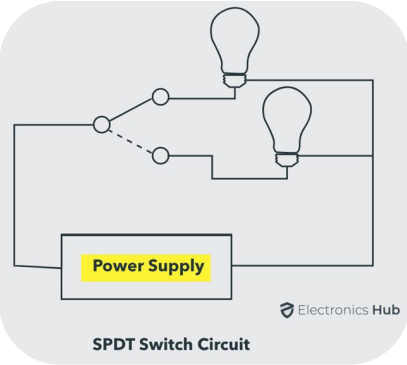




Single Pole Double Throw Switch (SPDT)

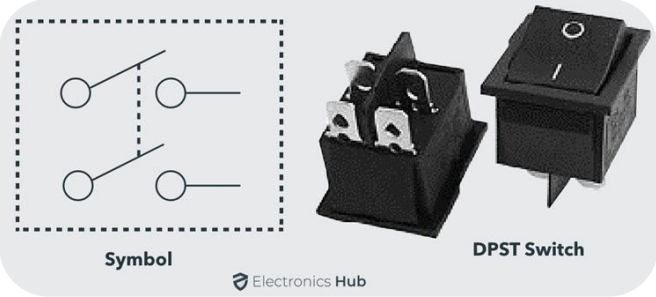
- This switch has three terminals: one is input contact and remaining two are output contacts.
- This means it consist two ON positions and one OFF position.
- In most of the circuits, these switches are used as changeover to connect the input between two choices of outputs.
- The contact which is connected to the input by default is referred as normally closed contact and contact which will be connected during ON operation is a normally open contact.

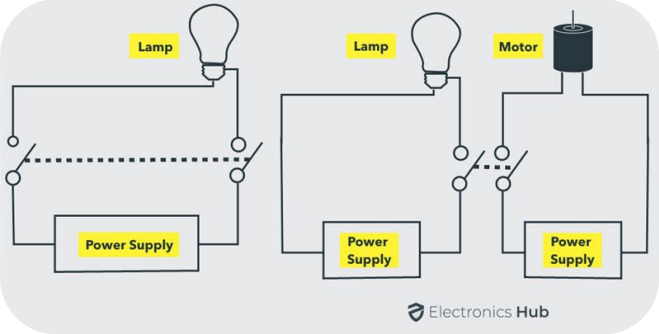




Double Pole Single Throw Switch (DPST)

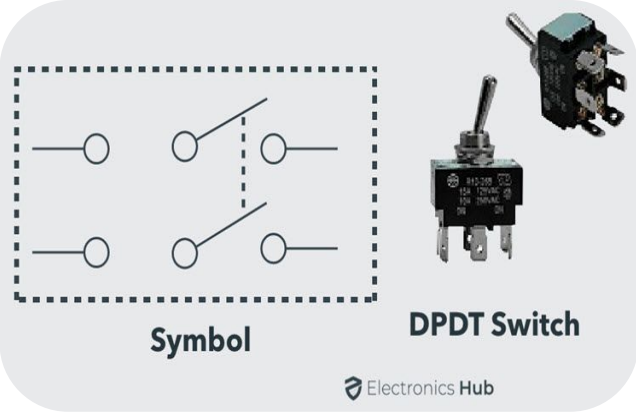
- This switch consists of four terminals: two input contacts and two output contacts.
- It behaves like a two separate SPST configurations, operating at the same time.
- It has only one ON position, but it can actuate the two contacts simultaneously, such that each input contact will be connected to its corresponding output contact.
- In OFF position both switches are at open state.
- This type of switches is used for controlling two different circuits at a time.
- Also, the contacts of this switch may be either normally open or normally closed configurations.

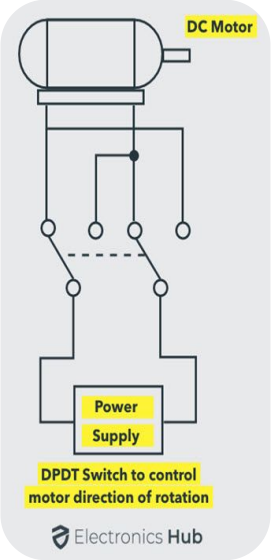




Double Pole Double Throw Switch (DPDT)

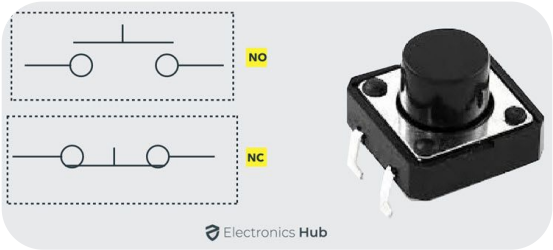
- This is a dual ON/OFF switch consisting of two ON positions.
- It has six terminals, two are input contacts and remaining four are the output contacts.
- It behaves like a two separate SPDT configuration, operating at the same time.
- Two input contacts are connected to the one set of output contacts in one position and in another position, input contacts are connected to the other set of output contacts.





Push Button Switch

- It is a momentary contact switch that makes or breaks connection as long as pressure is applied (or when the button is pushed).
- Generally, this pressure is supplied by a button pressed by someone's finger.
- This button returns its normal position, once the pressure is removed.
- The internal spring mechanism operates these two states (pressed and released) of a push button.
- It consists of stationary and movable contacts, of which stationary contacts are connected in series with the circuit to be switched while movable contacts are attached with a push button.
- Push buttons are majorly classified into normally open, normally closed and double acting push buttons as shown in the above figure.
- Double acting push buttons are generally used for controlling two electrical circuits.

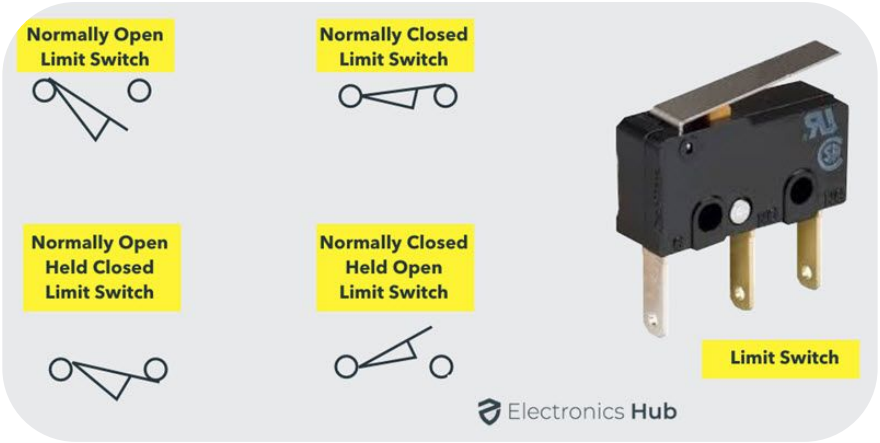


Toggle Switch

- A toggle switch is manually actuated (or pushed up or down) by a mechanical handle, lever or rocking mechanism. These are commonly used as light control switches.
- Most of these switches come with two or more lever positions which are in the versions of SPDT, SPST, DPST and DPDT switch. These are used for switching high currents (as high as 10 A) and can also be used for switching small currents.
- These are available in different ratings, sizes and styles and are used for different type of applications. The ON condition can be any of their level positions, however, by convention the downward is the closed or ON position.

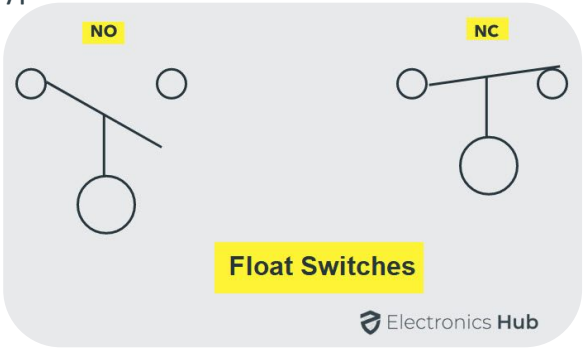
Limit Switch

- The control schemes of a limit switch are shown in above figure , in which four varieties of limit switches are presented.
- Some switches are operated by the presence of an object or by the absence of objects or by the motion of machine instead of human hand operation. These switches are called as limit switches.
- These switches consist of a bumper type of arm actuated by an object. When this bumper arm is actuated, it causes the switch contacts to change position.



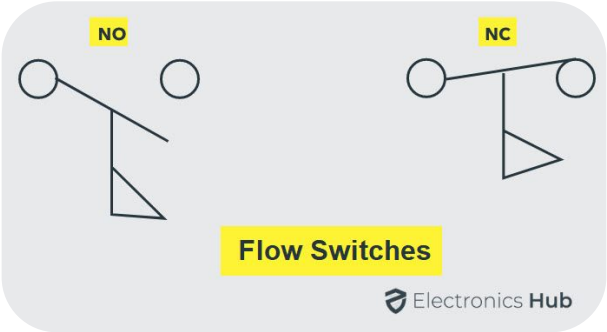
Float Switch

- Float switches are mainly used for controlling DC and AC motor pumps according to the liquid or water in a tank or sump.
- This switch is operated when the float (or floating object) moves downward or upward based on water level in a tank.
- This float movement of rod or chain assembly and counterweight causes to open or close electrical contacts. Another form of float switch is the mercury bulb type switch that does not consist of any float rod or chain arrangement.
- This bulb consist of mercury contacts such that when the liquid level rises or falls, the state of contacts also changes.
- The ball float switch symbol is shown in the above figure. These float switches can be normally open or normally closed type.



Flow Switch

- These are mainly used to detect the movement of liquid or air flow through a pipe or duct. The air flow switch (or a micro switch) is constructed by a snap-action.
- This micro switch is attached to a metal arm .To this metal arm, a thin plastic or metal piece is connected.
- When a large amount of air passes through the metal or plastic piece, it causes the movement of metal arm and thus operates the contacts of the switch.
- Liquid flow switches are designed with a paddle that inserted across the flow of liquid in a pipe. When liquid flows through the pipe, force exerted against the paddle changes the position of the contacts.
- The above figure shows the switch symbol used for both air flow and liquid flow. The flag symbol on the switch indicates the paddle which senses the flow or movement of liquid.
- These switches again normally open or normally closed type configurations.



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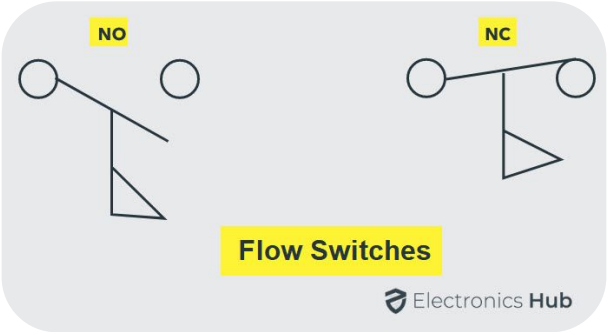
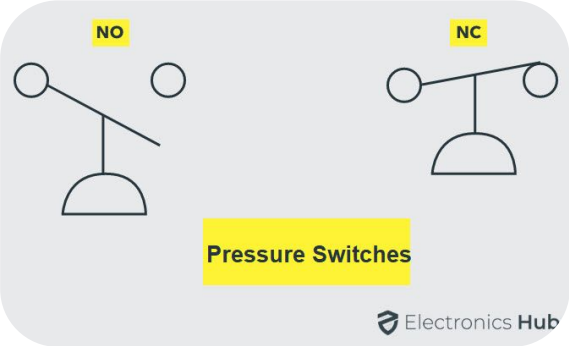


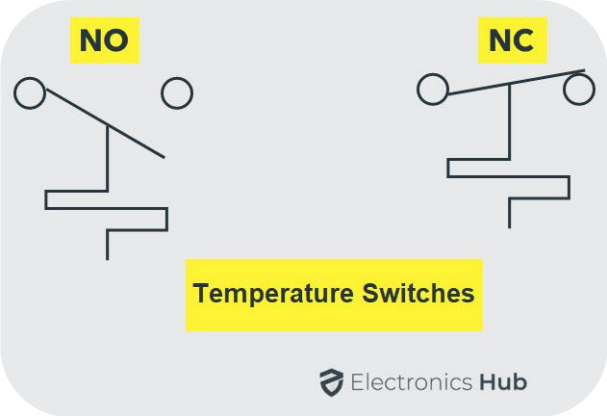
Pressure Switch

- These switches are commonly used in industrial applications in order to sense the pressure of hydraulic systems and pneumatic devices.
- Depends on the range of pressure to be measured, these pressure switches are classified into diaphragm operated pressure switch, metal bellow type pressure switch and piston type pressure switch.
- In all these types, pressure detection element operates a set of contacts (which can be either double pole or single pole contacts).
- This switch symbol consist a half-circle connected to a line in which flat part indicates a diaphragm. These switches may be either normally open or normally closed type configurations.



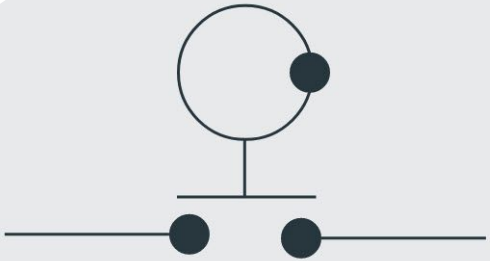
Temperature Switch

- The most common heat sensing element is the bimetallic strip that operates on the principle of thermal expansion.
- The bimetallic strips are made with two dissimilar metals (that are having different thermal expansion rates) and are bonded with each other.
- The switch contacts are operated when the temperature causes the strip to bend or wrap. Another method of operating the temperature switch is to use mercury glass tube.
- When the bulb is heated, mercury in the tube will expand and then generates pressure to operate the contacts.



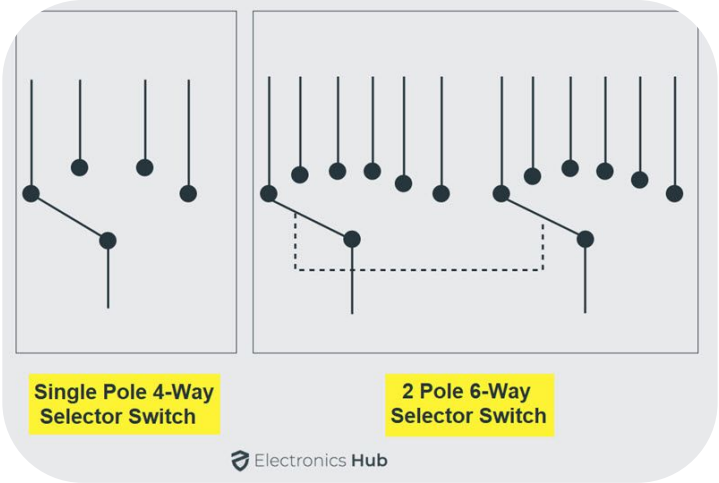
Joystick Switch

- Joystick switches are manually actuated control devices used mainly in portable control equipment.
- It consists of a lever which moves freely in more than one axis of motion.
- Depending on the movement of the lever pushed, one or more switch contacts are actuated.
- These are ideally suited for lowering, raising and triggering movements to the left and right.
- These are used for building machinery, cable controls and cranes. The symbol for the joystick is shown below.



Rotary Switch

- These are used for connecting one line to one of many lines.
- Examples of these switches are range selectors in electrical metering equipment, channel selectors in communication devices and band selectors in multi-band radios.
- It consists of one or more moving contacts (knob) and more than one stationary contact.
- These switches are come with different arrangement of contacts such as single pole 12-way, 3-pole 4-way, 2-pole 6-way and 4-pole 3-way.



04

Electronic Switches

Electronic Switches

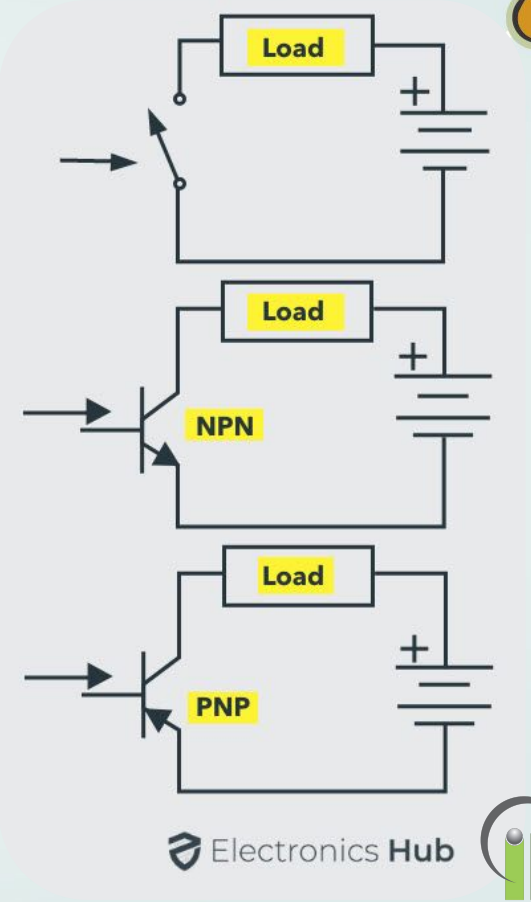
- The electronic switches are generally called as Solid State switches because there are no physical moving parts and hence no physical contacts. Most of the appliances are controlled by semiconductor switches such as motor drives and HVAC equipment.
- There are different types of solid state switches are available in todays consumer, industrial and automotive market with different sizes and ratings. Some of these solid state switches include transistors, SCRs, MOSFETs, TRIACs and IGBTs.

Bipolar Transistor

A transistor either allows the current to pass or it blocks the current as similar to working of normal switch.In switching circuits, transistor operates in cut-off mode for OFF or current blocking condition and in saturation mode for ON condition. The active region of the transistor is not used for switching applications.

Both NPN and PNP transistors are operated or switched ON when a sufficient base current is supplied to it. When a small current flows though the base terminal supplied by a driving circuit (connected between the base and emitter), it causes the transistor to turn ON the collector-emitter path.

And it is turned OFF when the base current is removed and base voltage is reduced to a slight negative value. Even though it utilizes small base current, it is capable of carrying much higher currents through the collector- emitter path.



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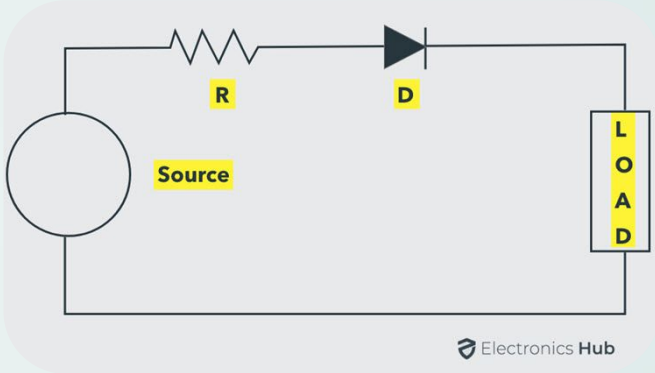
Power Diode

A diode can perform switching operations between its high and low state impedance states. Semiconductor materials like Silicon and Germanium are used for constructing the diodes.

Usually, Power Diodes are constructed using Silicon in order to operate the device at higher currents and higher junction temperatures. These are constructed by joining p and n type semiconductor materials together to form PN junction. It has two terminals namely anode and cathode.

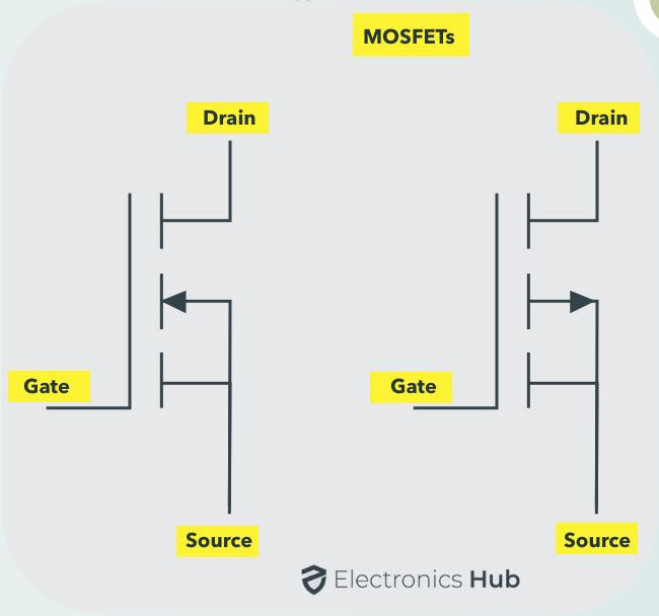
When the anode is made positive with respect to cathode and by the application of voltage greater than the threshold level, PN junction is forward biased and starts conducting (like ON switch). When the cathode terminal is made positive with respect to anode, PN junction reverse biased and its blocks the current flow (like OFF switch).



Mosfet

Perhaps the most popular and most commonly used Semiconductor Switching Device is the MOSFET. Metal Oxide Semiconductor Field Effect Transistor (MOSFET) is a unipolar and high frequency switching device. It is most commonly used switching device is power electronic applications. It has three terminals namely drain (output), source (common) and gate (input).

It is a voltage controlled device i.e., by controlling the input (gate to source) voltage, resistance between the drain and source is controlled, which further determines the ON and OFF state of the device. MOSFETs can be a P-Channel or N-Channel devices. The N-Channel MOSFET is tuned ON by applying a positive VGS with respect to the source (provided that VGS should be greater than threshold voltage).P-channel MOSFET operates in a similar manner of N-channel MOSFET but it uses reverse polarity of voltages. Both VGS and VDD are negative with respect to the source to switch ON the P-channel MOSFET.

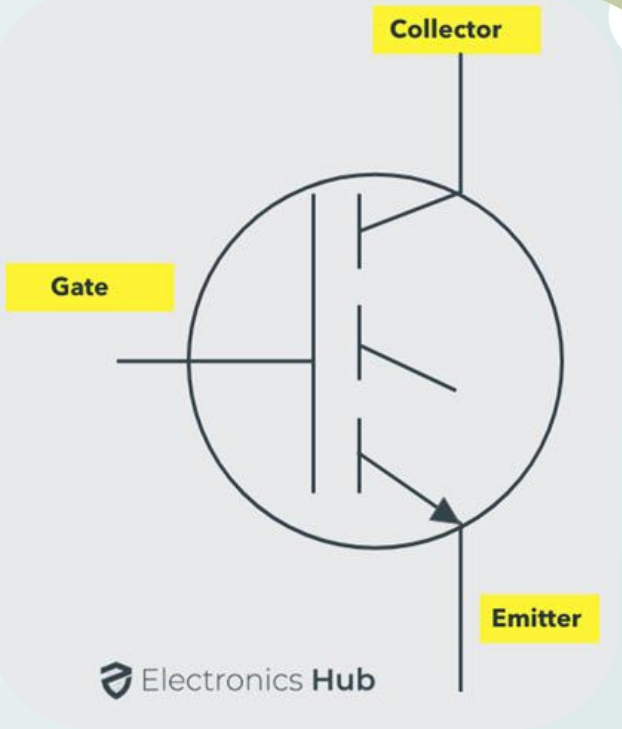


IGBT

IGBT (Insulated Gate Bipolar Transistor) combines the several advantages of bipolar junction power transistor and power MOSFET. Like a MOSFET, it is a voltage controlled device and has lower ON state voltage drop (less than that of MOSFET and closer to power transistor).

It is a three terminal semiconductor high speed switching device. These terminals are emitter, collector and gate.

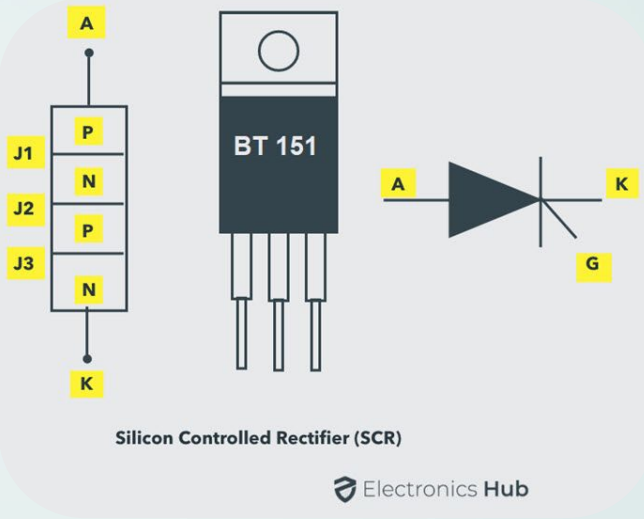
Similar to the MOSFET, IGBT can be turned ON by applying a positive voltage (greater than the threshold voltage) between the gate and emitter. IGBT can be turned OFF by reducing the voltage across the gate-emitter to zero. In most of the cases, it needs a negative voltage to reduce the turn OFF losses and safely turn OFF the IGBT.



SCR

A Silicon Controlled Rectifier (SCR) is one of the most widely used high speed switching device for power control applications. It is a unidirectional device as a diode, consisting of three terminals, namely anode, cathode and gate.

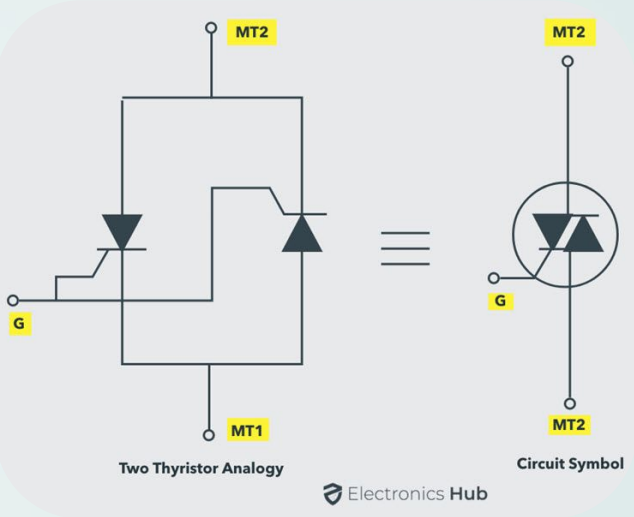
An SCR is turned ON and OFF by controlling its gate input and biasing conditions of the anode and cathode terminals. SCR consists of four layers of alternate P and N layers such that boundaries of each layer forms junctions J1, J2 and J3.



TRIAC

Triac (or TRIode AC) switch is a bidirectional switching device, which is an equivalent circuit of two back to back SCRs connection with one gate terminal.

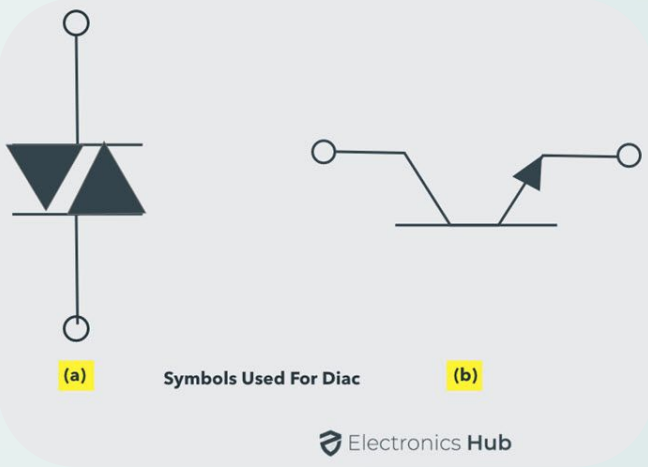
Its capability to control AC power in both positive and negative peaks of the voltage waveform often makes these devices to be used in motor speed controllers, light dimmers, pressure control systems, motor drives and other AC control equipment.



DIAC

A DIAC (or DIode AC Switch) is bidirectional switching device and it consists of two terminals, which are not named as anode and cathode as it is a bidirectional device i.e., a DIAC can be operated in either direction regardless of the terminal identification. This indicates that the DIAC can be used in either direction.

When a voltage is applied across a DIAC, it either operates in forward blocking or reverse blocking mode unless the applied voltage is less than the breakover voltage. Once the voltage is increased more than breakover voltage, avalanche breakover occurs and device starts conducting.

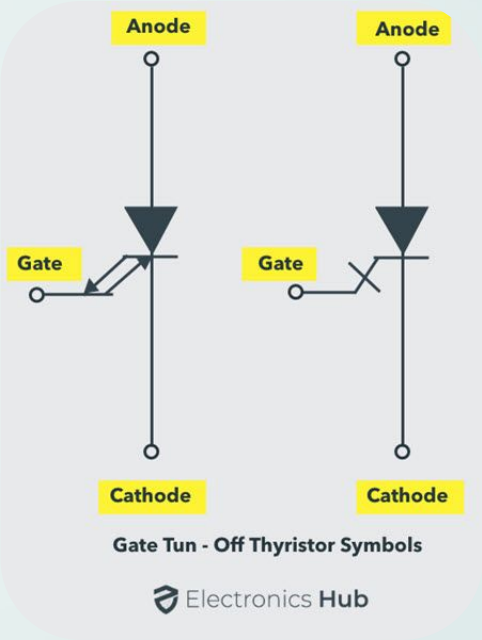


Symbols Used For Diac

Gate Turn-off Thyristor

A GTO (Gate Turn off Thyristor) is a bipolar semiconductor switching device. It has three terminals: an anode, a cathode and a gate. As the name implies, this switching device is capable to turn OFF through gate terminal.

A GTO is turned ON by applying a small positive gate current, which triggers the conduction mode. It can be turned OFF by a negative pulse to the gate. GTO symbol consists of double arrows on the gate terminal, which represents the bidirectional flow of current through gate terminal.



Our Scope

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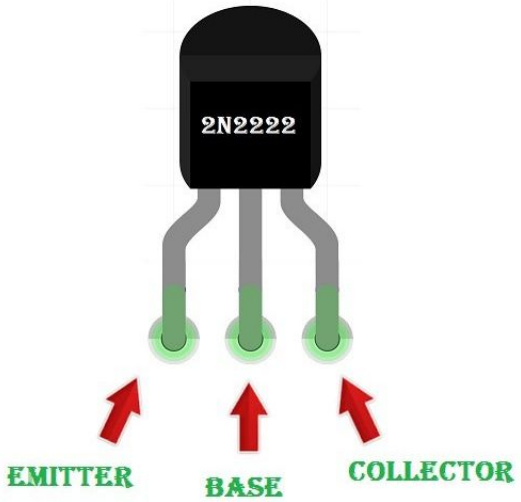
Transistor

A transistor is **a semiconductor device used to amplify or switch electronic signals and electrical power**. Transistors are one of the basic building blocks of modern electronics. It is composed of semiconductor material usually with at least three terminals for connection to an external circuit.

The transistor's ability to change between these two states enables it to have two basic functions: "***Switching***" (digital electronics) or "***Amplification***" (analogue electronics).

There are two basic types of bipolar transistor construction, NPN and PNP

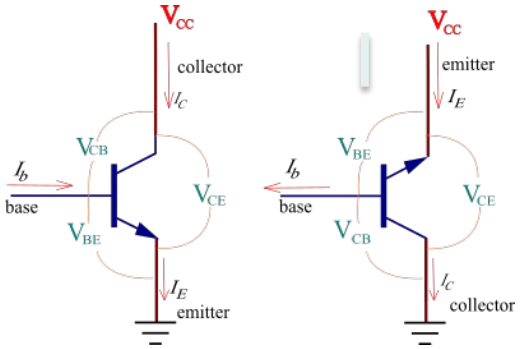


Transistor Regions

- **1. Active Region –**

Condition: **V**be = 0.7 v and **V**c > **V**b

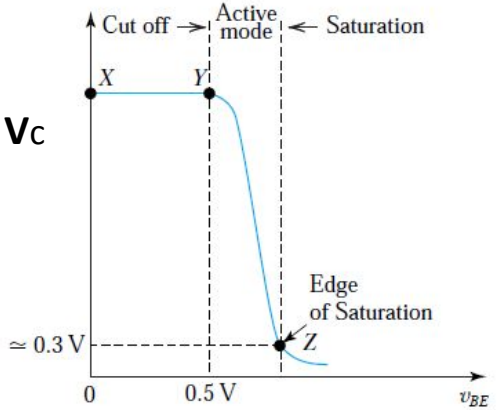
Action: works as amplifier, **I**c = β **I**b , where β is the amplification factor



- **2. Saturation**

Condition: **V**be = 0.7 v and **V**c < **V**b

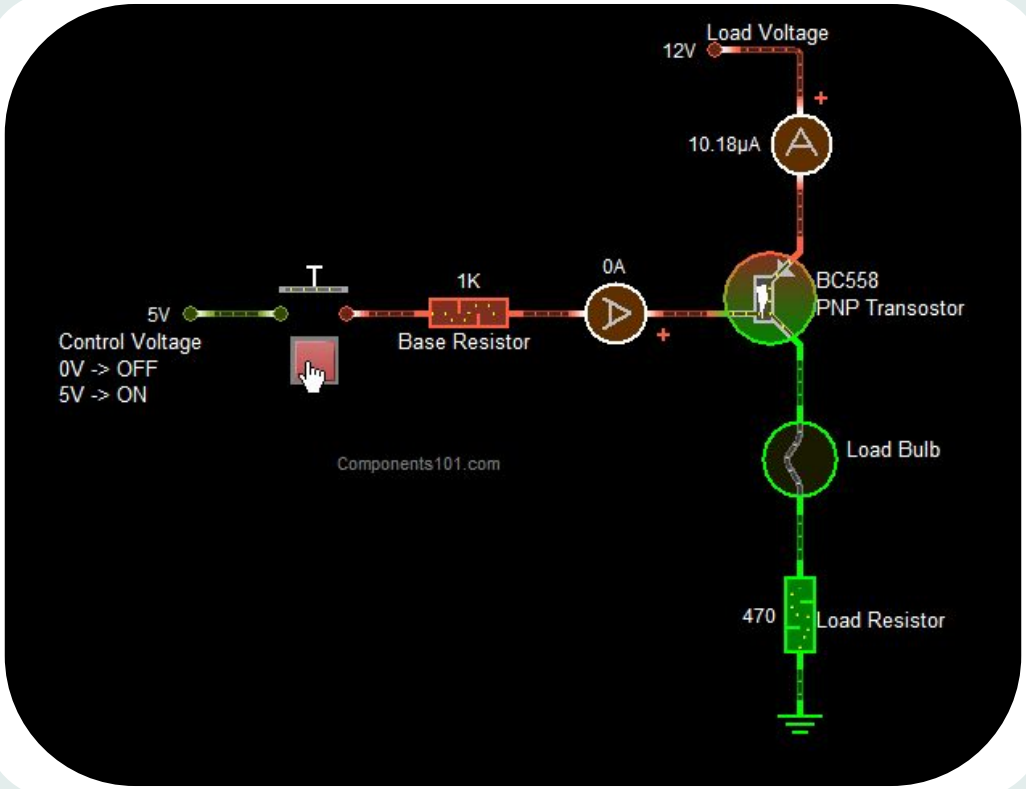
Action: - the transistor is "fully-ON" operating as a switch and **V**c approximately equals to **V**e



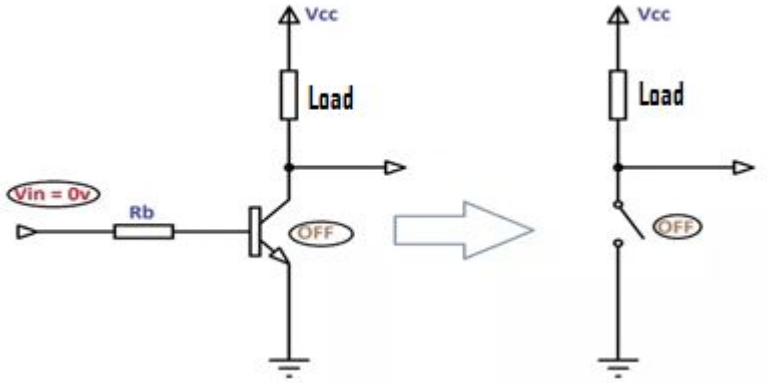
- **3. Cut-off**

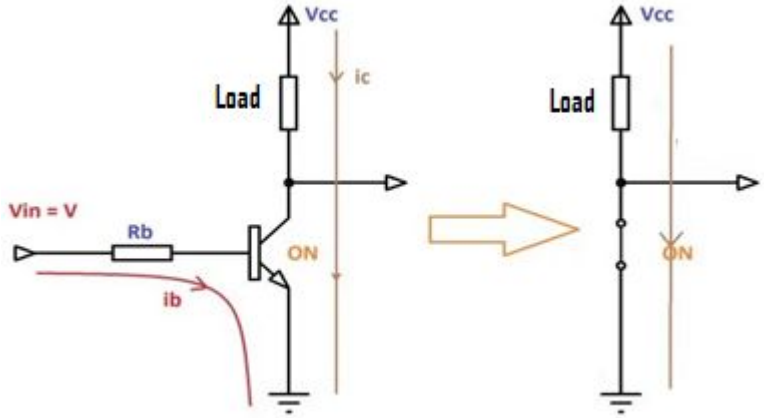
Condition: - the transistor is "fully-OFF" operating as a switch and Ic = 0

Transistor as Switch



Transistor as Switch

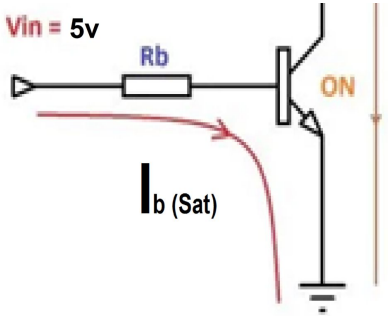




Rb is called a limiting resistor, which is used in order to keep the **Vbe** not exceeding 0.7 v.

Transistor as Switch

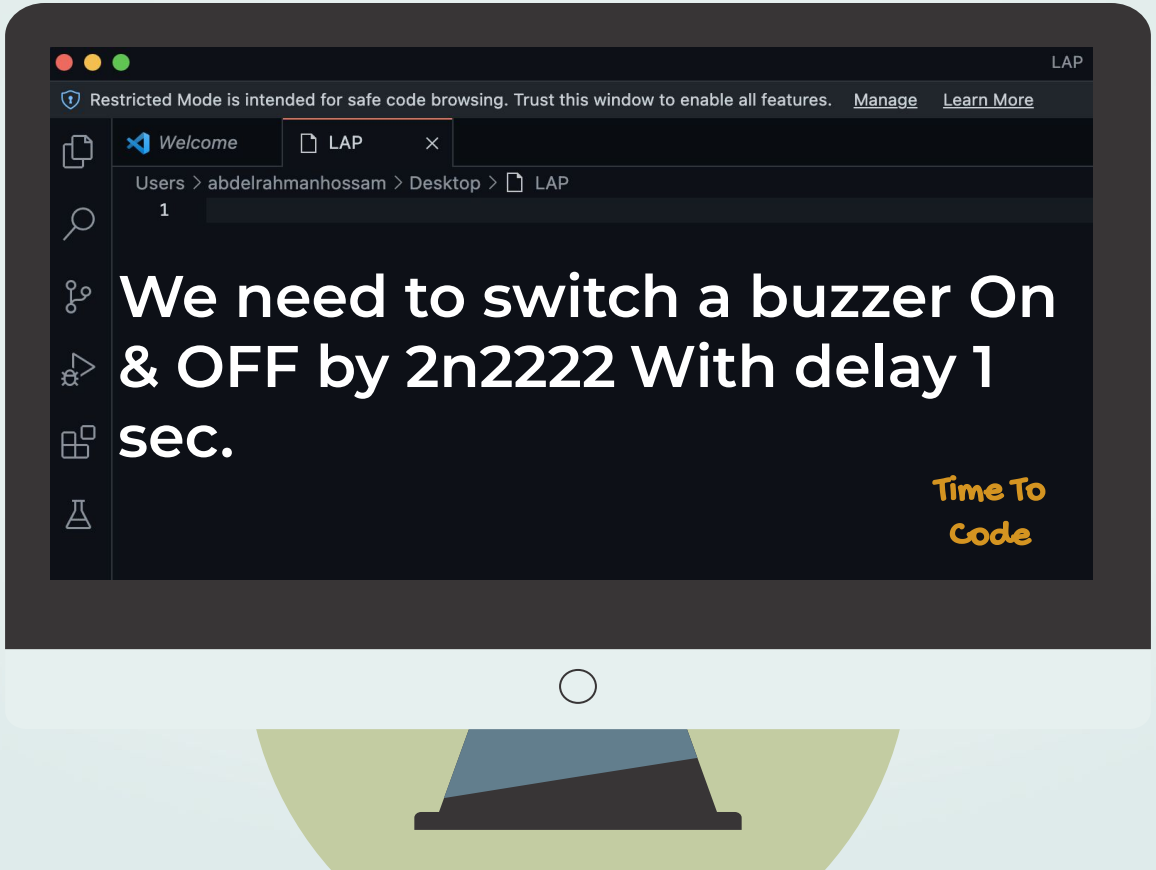
We need to calculate the value of **R**b which achieve the ***saturation*** state when applying 5v on the base.



From the datasheet of the used transistor ***2n222***, the value of the saturation current at base is 15 mA.

By applying Ohm's law: $R = \frac{V}{I} = \frac{5v - 0.7v}{15\ mA} = 286\ ohm$

LAb 1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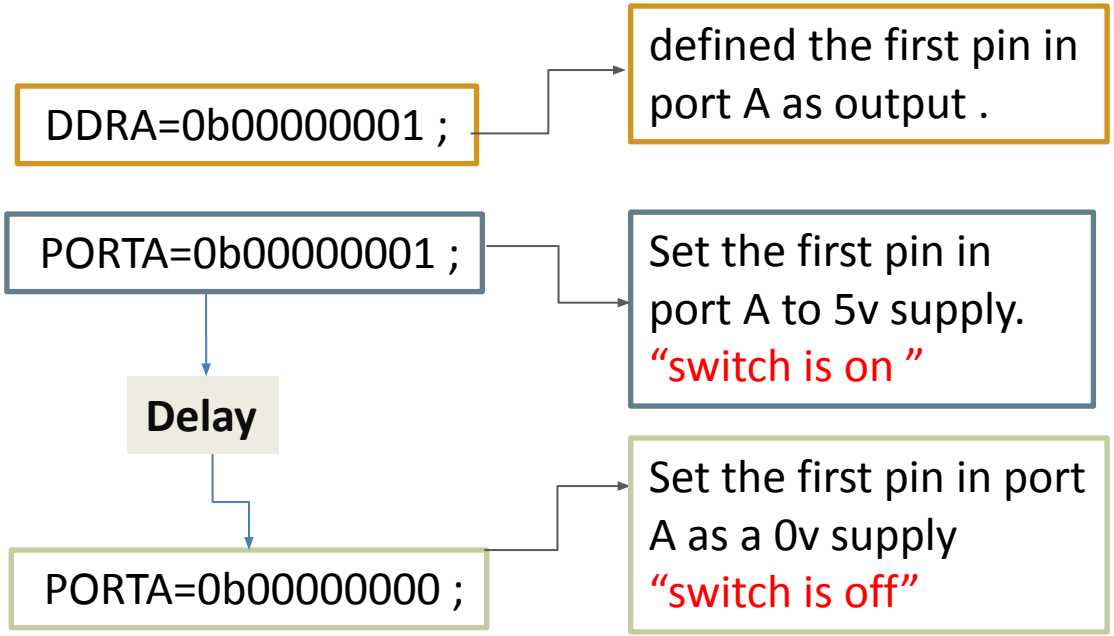
1
We need to switch a buzzer On & OFF by 2n2222 With delay 1 sec.
Time To Code

Interfacing Algorithm



LAb 2

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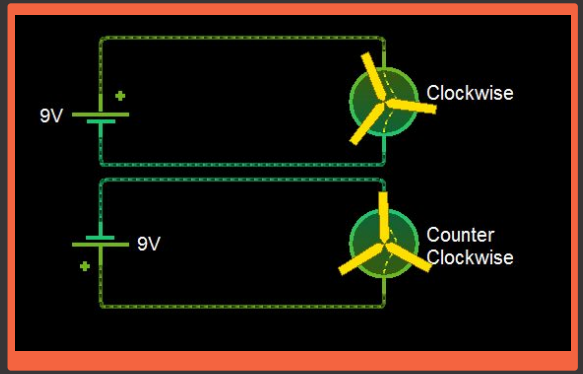
1

Write a C code to control a DC motor in one direction using a tactile switch. The switch shall act as a breaking the system, the motor shall rotate as long as the switch is not pressed.

Time To Code



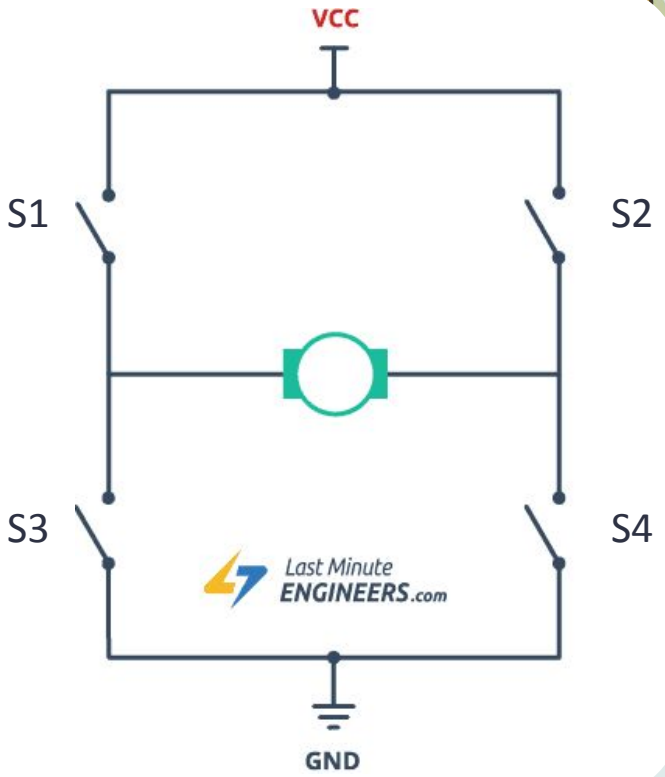
IMT SCHOOL

H-bridge

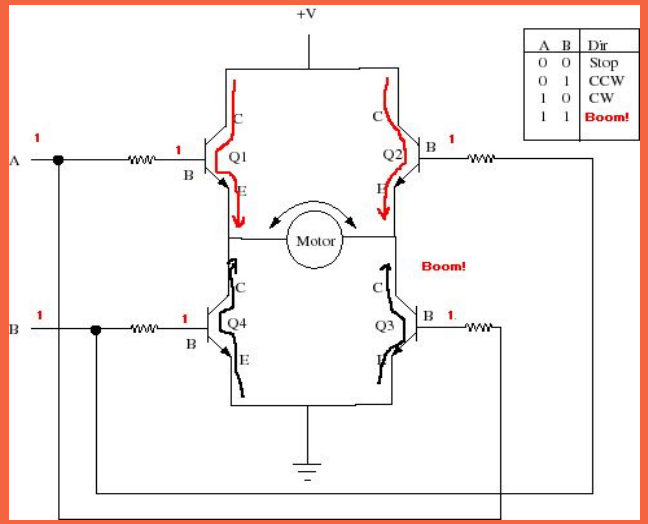
An H-bridge is a simple circuit that lets you control a DC motor to go backward or forward.

You normally use it with a microcontroller, such as an Atmega32, to control motors.

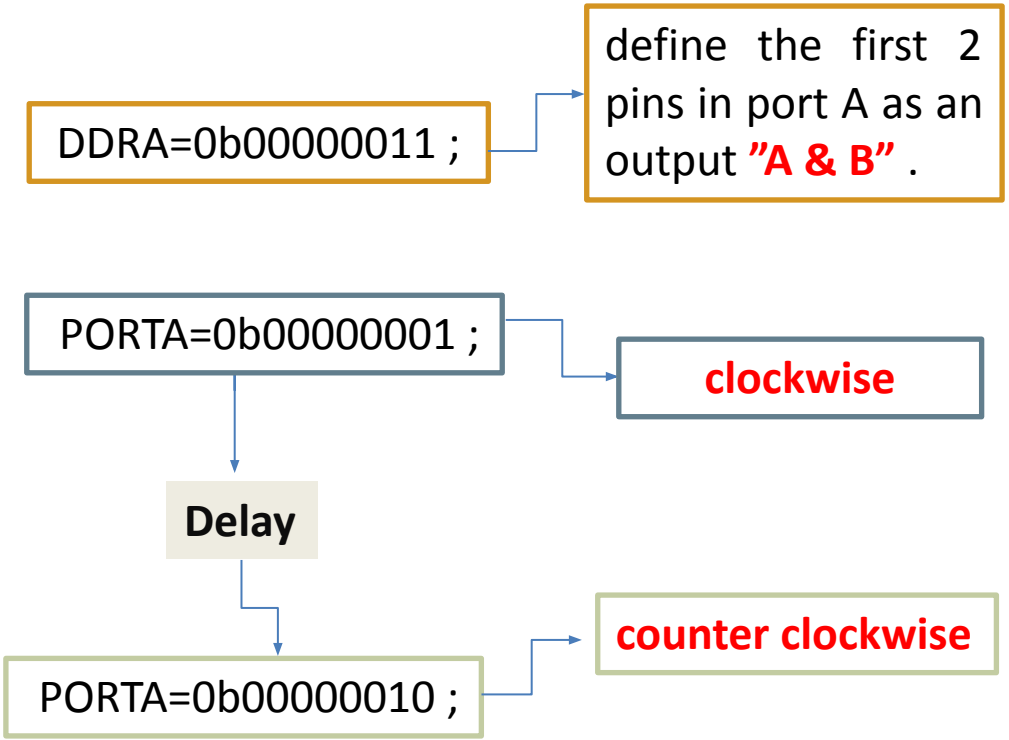
What will happen if we close (S1 & S3) at the same time…?



LAb 3

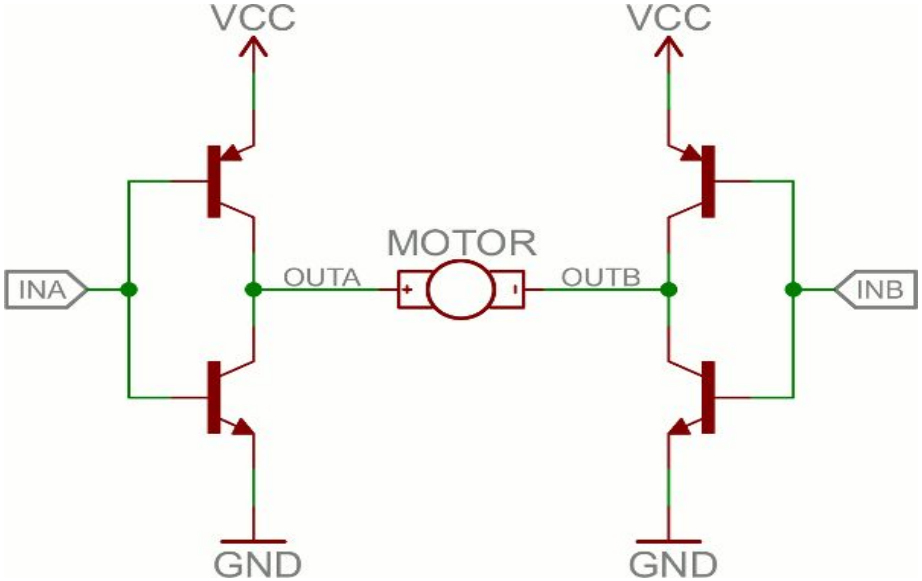

+V
A
B
Q1
Q2
Q3
Q4
C
B
E
Motor
Boom!
1
A B Dir
0 0 Stop
0 1 CCW
1 0 CW
1 1 Boom!

Interfacing Algorithm



H-Bridge

We can prevent the danger of **S.C** of the H-bridge by using two NPN and 2 PNP transistors .



H-Bridge

❑ Advantages :

- Low cost electronic switch
- Small base current controls larger collector current.
- High switching speed.

❑ Disadvantages :

- can’t use in switching for loads which need very high Power .
- No isolation between power circuit and control unit

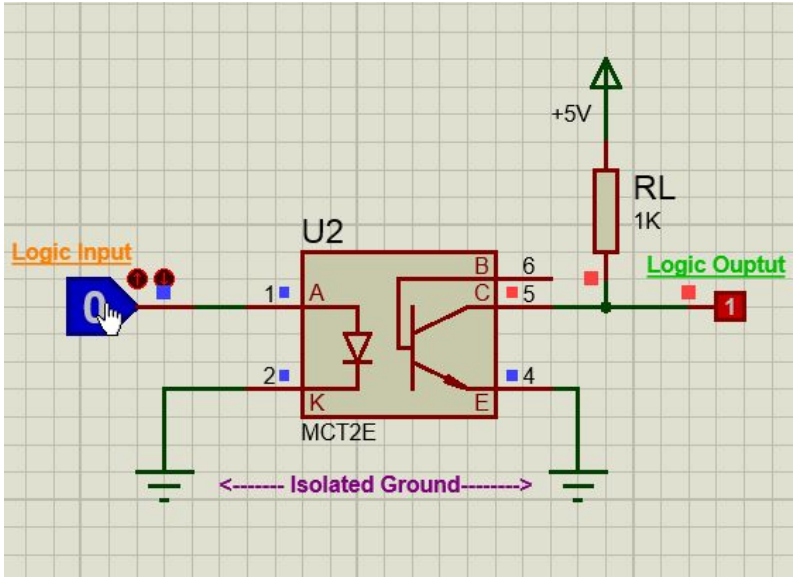
Optocouplers

An ***Optocoupler*** (or an optoelectronic coupler) is basically an interface between two circuits which operate at (usually) different voltage levels.

the only contact between the input and the output is a ***beam of light***.

Optocouplers

When applying a voltage difference between the LED terminal, a beam of light is generated towards the light sensor installed on the base of a transistor. The light sensor then generates an amount of current causes the transistor to enter a saturation mode. The optocoupler now is in the on state. If no voltage on the LED, then the transistor is on off state and the optocoupler too.



LAb 4

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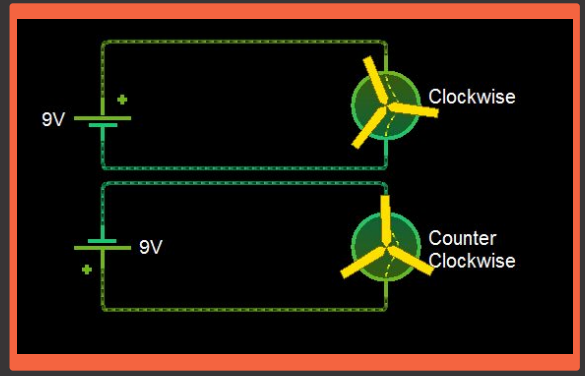
1

Using Optocoupler, write a C code to control a DC motor in one direction using a tactile switch. The switch shall act as a breaking the system, the motor shall rotate as long as the switch is not pressed.

Time To Code



IMT SCHOOL

Optocouplers

❑ Advantages :

- ❑ It is small size & light weight.
- ❑ Low power operation.
- ❑ well protected due to electrical isolation. (High isolation impedance).
- ❑ High switching speed.

❑ Disdvantages :

- can’t use in switching for loads which need high Power.
- High cost comparing to transistor

Relays

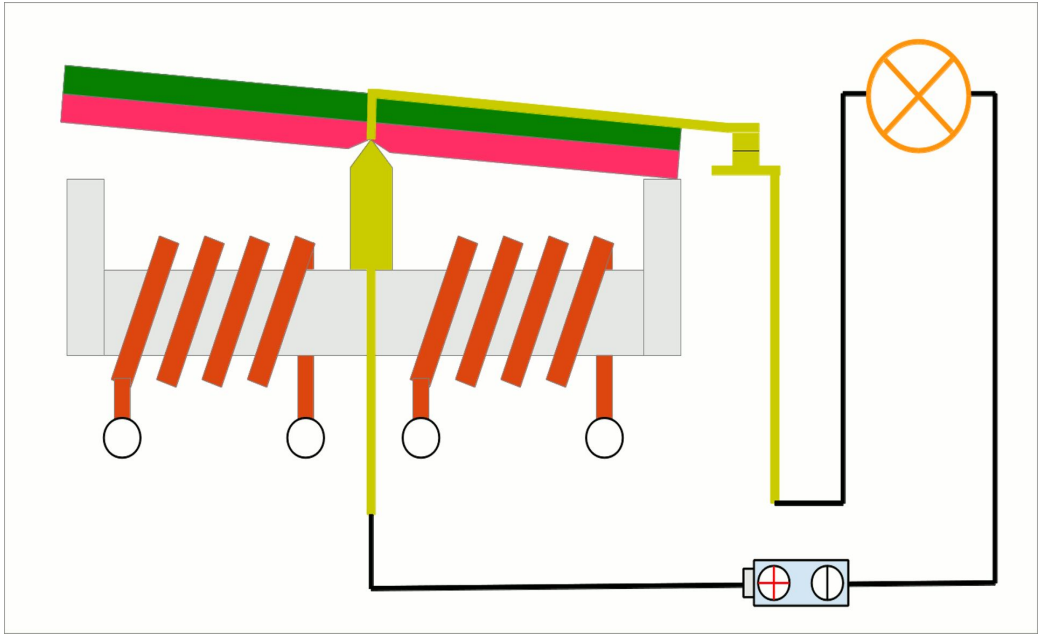
An ***Optocoupler*** (or an optoelectronic coupler) is basically an interface between two circuits which operate at (usually) different voltage levels.

the only contact between the input and the output is a ***beam of light***.

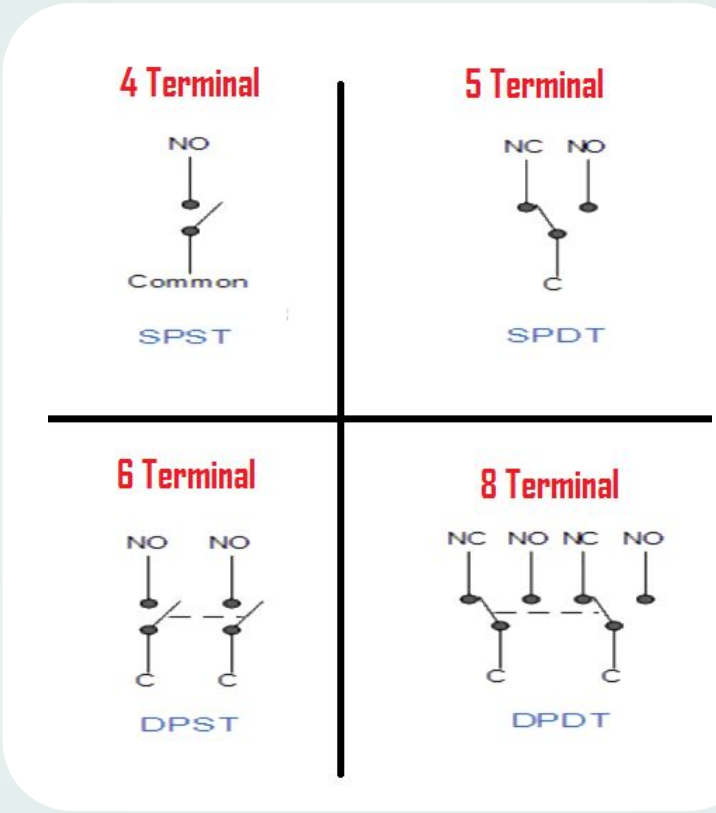
Relays

Relays are electromechanical devices that use an electromagnet to operate a pair of movable contacts from an open position to a closed position.

Low Control Voltage is used to switch contacts of relays which are comparatively at high potential.



Relays


4 Terminal
NO
Common
SPST
5 Terminal
NC NO
C
SPDT
6 Terminal
NO NO
C C
DPST
8 Terminal
NC NO NC NO
C C
DPDT

LAb 5

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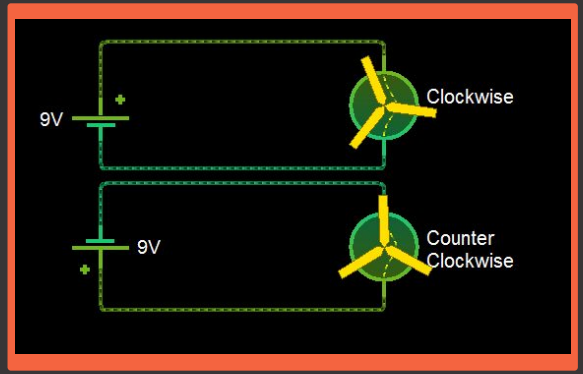
1

Develop a H-bridge circuit using 2 SPDT relays. Rotate the dc motor in clockwise direction for 5 seconds and anticlockwise direction for another 5 seconds.

Time To Code



IMT SCHOOL

Optocouplers

❑ ***Advantages :***

- Simple construction.
- Well protected due to electrical isolation.
- Can be used in switching for loads needs high Power.
- The ability of controlling a AC circuit using a DC control circuit

❑ ***Disdvantages :***

- High cost.
- High power consumption
- Limited speed of operation.
- Suffer from the effects of age.
- Produce magnetic interference.

06

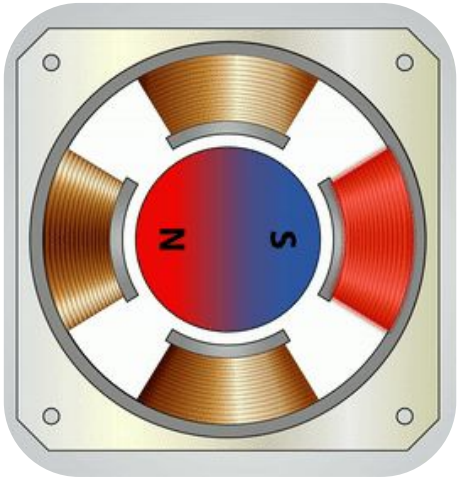
IMT SCHOOL

Stepper Motor

Stepper motor

A stepper motor is a DC motor that divides a full rotation into a number of steps. It is mainly consists of a rotational part (Rotor) which a permanent magnet and a static part (Stator) which is a set of coils. These coils are called phases, by energizing each phase in sequence, the motor will rotate, one step at a time.

Using stepper motor, we can control the rotation direction and rotation speed simply without using and additional electrical components, such as an encoder within the other motors. For this reason, stepper motors are very robust and have high reliability with very few failures.



How It Works ?

When current flows through coil “1" the magnet is attracted and moves one step forward. Then, coil “1" is turned off and coil “2" is turned on. Now, the magnet takes another step, and so on. For a stepper motor to move, these coils should be activated in a correct sequence.

In this simple orientation of coils, we assume that the step is 90 degree. For that the motor makes a full rotation in 4 steps only. But in reality, the motor may have more coils to achieve smaller step.

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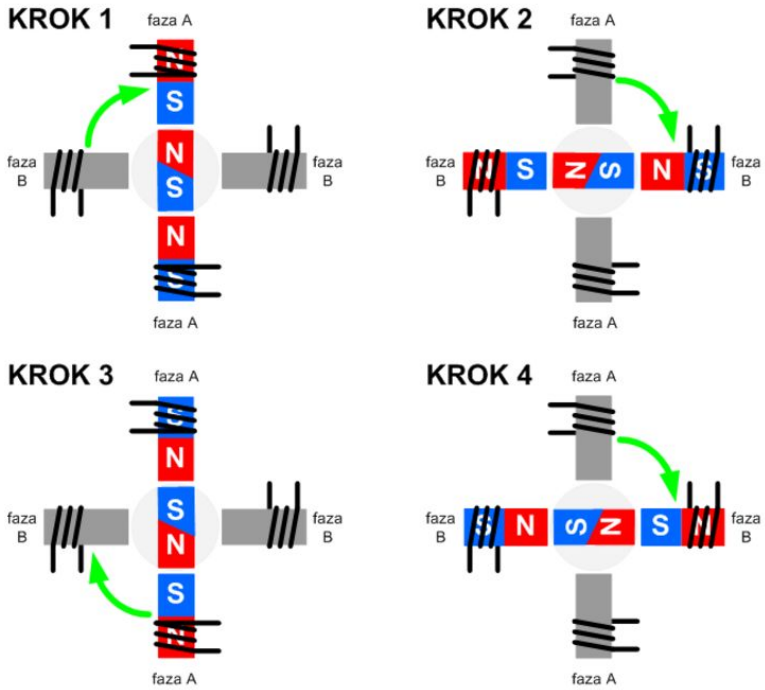
Stepper motor



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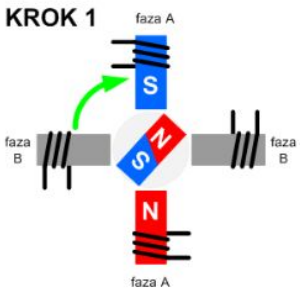
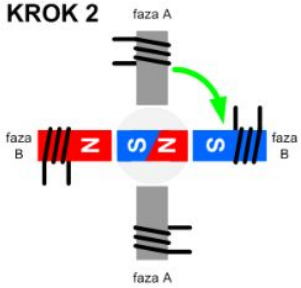
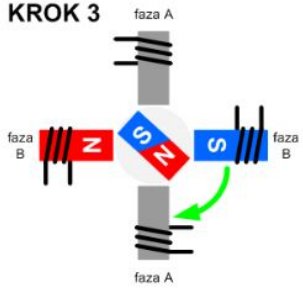
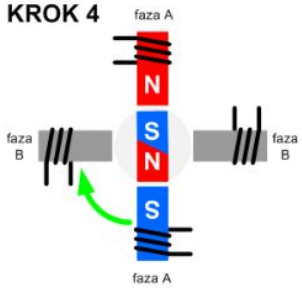
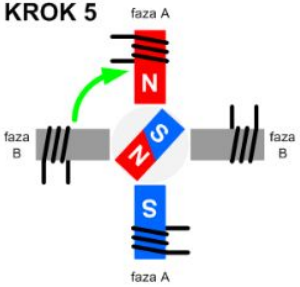
Stepper motor

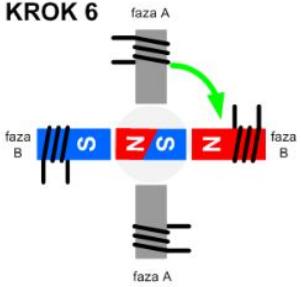


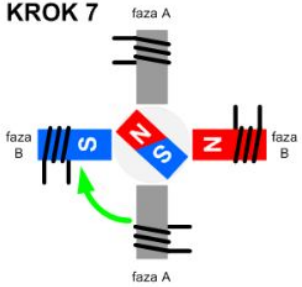


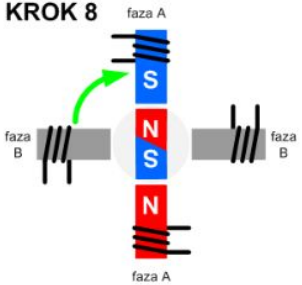






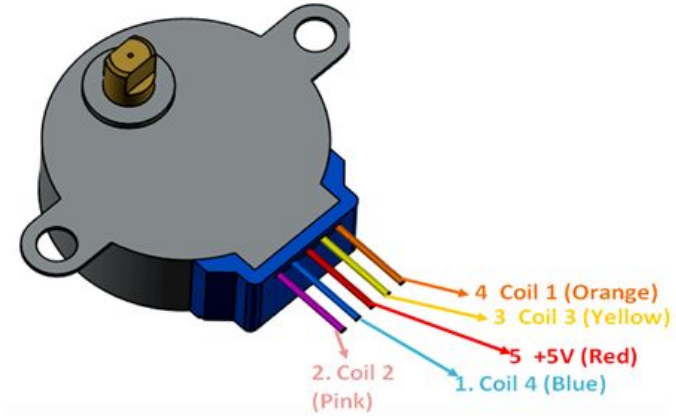






28byj48 Stepper motor

Rated voltage :	5VDC
Number of Phase	4
Stride Angle	5.625°/64
Frequency	100Hz
In-traction Torque	>34.3mN.m(120Hz)
Self-positioning Torque	>34.3mN.m
Friction torque	600-1200 gf.cm
Pull in torque	300 gf.cm



28byj48 Stepper motor

Full Step Mode Clockwise			
4 Orange	3 Yellow	2 Pink	1 Blue
0	0	0	1
0	0	1	0
0	1	0	0
1	0	0	0

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Half Step Mode Clockwise

4 Orange	3 Yellow	2 Pink	1 Blue
1	0	0	1
0	0	0	1
0	0	1	1
0	0	1	0
0	1	1	0
0	1	0	0
1	1	0	0
1	0	0	0

Speed and Direction

After applying any pattern to the motor to move it one step, and before applying the next pattern to move it another step, we have make some delay according to the motor maximum working frequency.

In our case, the motor 28byj48 the maximum frequency is 100 Hz, which means the time between any 2 steps shall not be lower than 10 mille seconds. and this is the maximum speed. Be increasing the time between the step and the next step, the motor speed decreases.

Controlling the direction is simply done by reversing the energizing order of the coils.

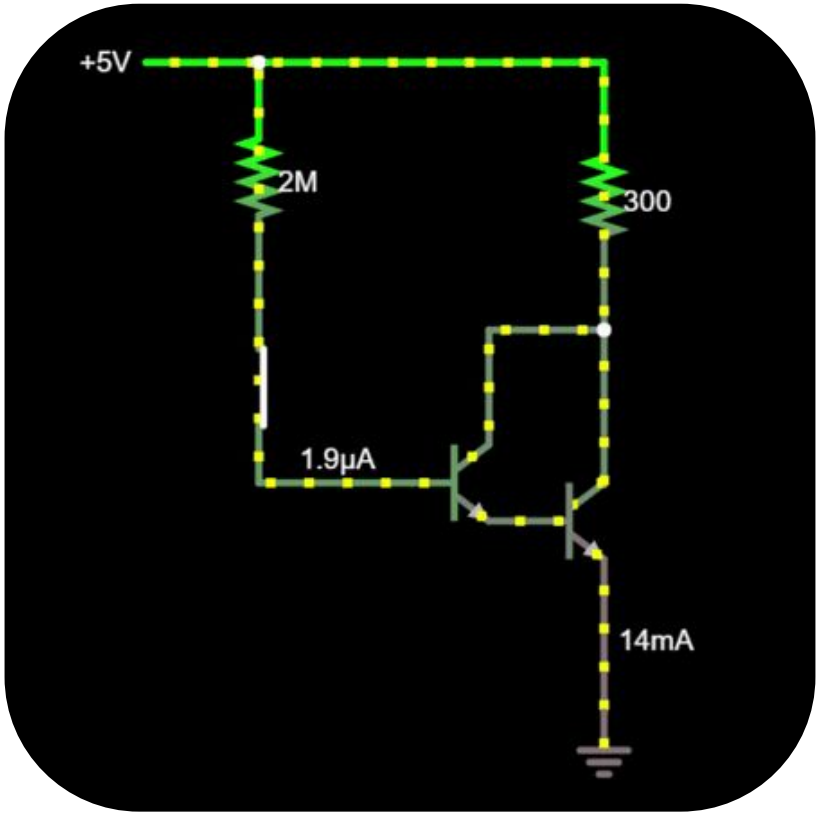
The Darlington Pair

The stepper motor needs high current to work, the current of a digital input output pin in the microcontroller can not drive it. So, we need an electronic switch to that we be controlled by the microcontroller and supply a current to the motor from the power supply.

Transistor can do that as discussed in previous lecture, but what if we have 2 serial transistors. This is called the Darlington pair.

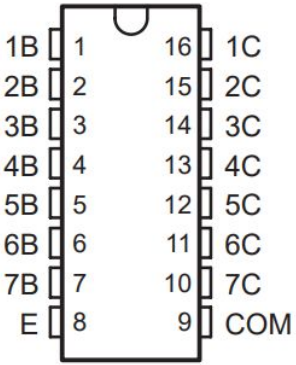
The Darlington transistor (commonly called a Darlington pair) is a compound structure of a particular design made by two bipolar transistors connected in such a way that the current amplified by the first transistor is amplified further by the second one.

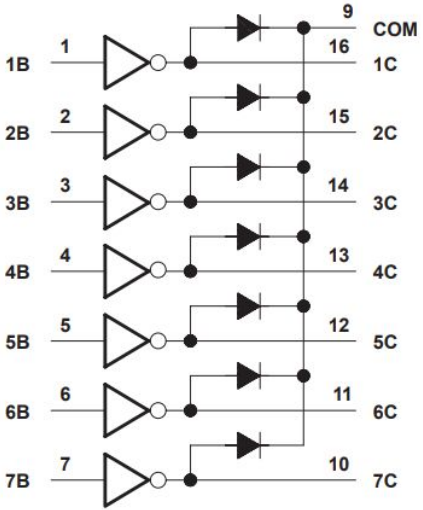
The Darlington Pair



ULN2003 IC

This IC combines 7 Darlington pairs, each one has input for the base and output for its collector.
If the input is 0, the output is GND
if the input is 1, the output is floating pin





Stepper Motor Interface

The End

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07

Assignments

Talk is cheap
show me the Code

- Linus Torvalds

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Assignment 1

Using two tactile switches, control DC motor direction. One switch for rotating the motor clockwise and the other one for counter clockwise. The direction of the rotation shall be written on LCD.

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