A PROJECT REPORT

ON

SPEED CONTROL OF DC MOTOR IN FOUR QUADRANTS WITHOUT MICROCONTROLLER

Submitted in the partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

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CERTIFICATE

This is to certify that the Project report on **"SPEED CONTROL OF DC MOTOR IN FOUR QUADRANTS WITHOUT MICROCONTROLLER"** is a bonafide record work carried out by **K.LAXMI MAANASA (12361A0210),** in partial fulfillment for the requirement for the award of degree of **BACHELOR OF TECHNOLOGY** in **"ELECTRICAL AND ELECTRONICS ENGINEERING"** from JNTU Hyderabad, during the year 2015-2016.

Signature of the

Internal Guide   Head of the Department

External Examiner

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ABSTRACT

The main intention of this project is to control the speed of a DC motor in alternative directions using speed control unit and to operate the motor in four quadrants: ie, clockwise, counter clock-wise, forward brake and reverse brake.

This system uses an H-bridge motor drive IC for controlling the DC motor from corresponding switches used by the user for pressing. The four switches are connected to the circuit for controlling the movement of the motor. One slide switch interfaced to the circuit is for controlling the alternative direction of the DC motor. A 555 timers is used in the project to develop the required PWM pulses for speed control. The relays are used for changing the polarities of the motor as well as to apply brake to the motor. In the regenerative mode, the current is applied to the circuit in such a way that a revere torque is produced to stop the motor instantaneously.

The four-quadrant control of the DC motor is archived by the varying duty cycles from a 555 timer and their changing polarity with the H-bridge IC by appropriate switch pressing. The alternative speed control feature is achieved by a slide switch operation.

This project in future can be improved by using higher-power electronic devices to operate high- capacity DC motors. Regenerative braking for optimizing the power consumption can also be incorporated.

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The speed of a DC motor in alternative directions and its operation in four quadrants: i.e., clockwise, counter clock-wise, forward braking and reverse braking is done by using speed control unit.

This system uses an H-bridge motor drive IC for controlling the DC motor from corresponding switches used by the user for pressing. The four switches are connected to the circuit for controlling the movement of the motor. One slide switch interfaced to the circuit is for controlling the alternative direction of the DC motor. 555 timers are used in the project to develop the required PWM pulses for speed control. The relays are used for changing the polarities of the motor as well as to apply brake to the motor. In the regenerative mode, the current is applied to the circuit in such a way that a revere torque is produced to stop the motor instantaneously.

The four-quadrant control of the DC motor is archived by the varying duty cycles from a 555 timer and their changing polarity with the H-bridge IC by appropriate switch pressing. The alternative speed control feature is achieved by a slide switch operation.

2. BLOCK DIAGRAM

2.1 Block Diagram

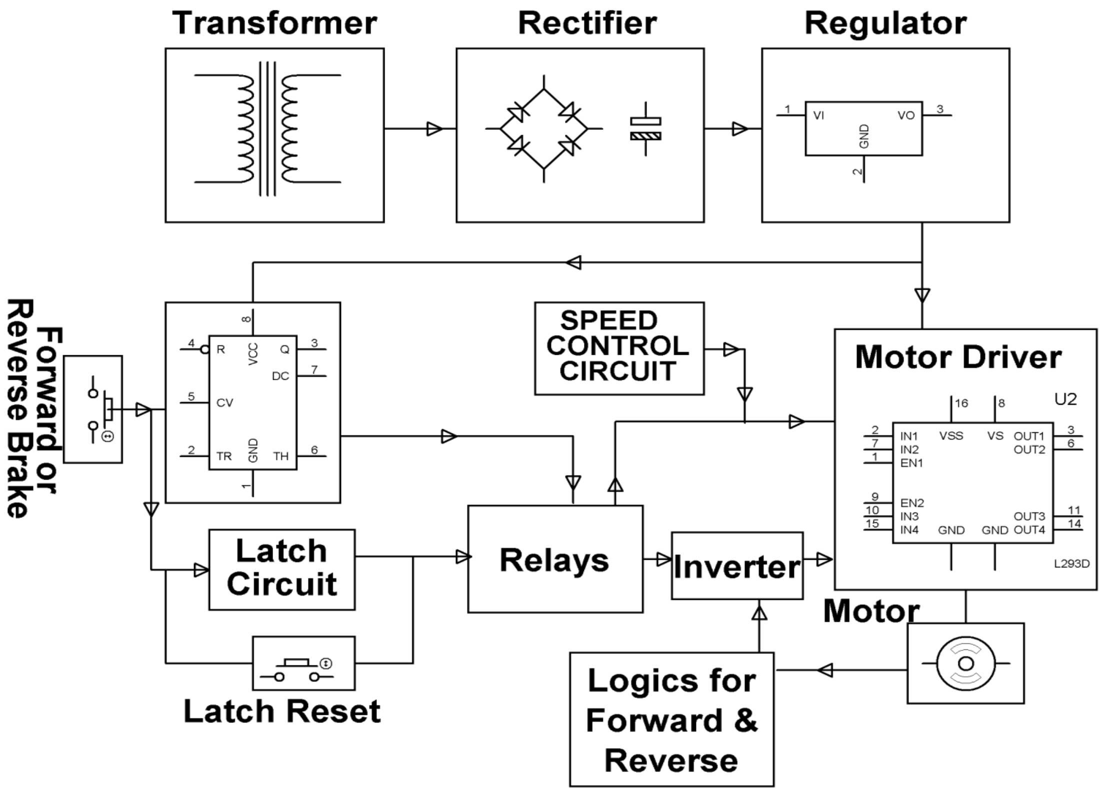


Fig: 2.1.1 Block diagram

3. CIRCUIT DIAGRAM AND COMPONENTS DESCRIPTION

3.1 Circuit Diagram

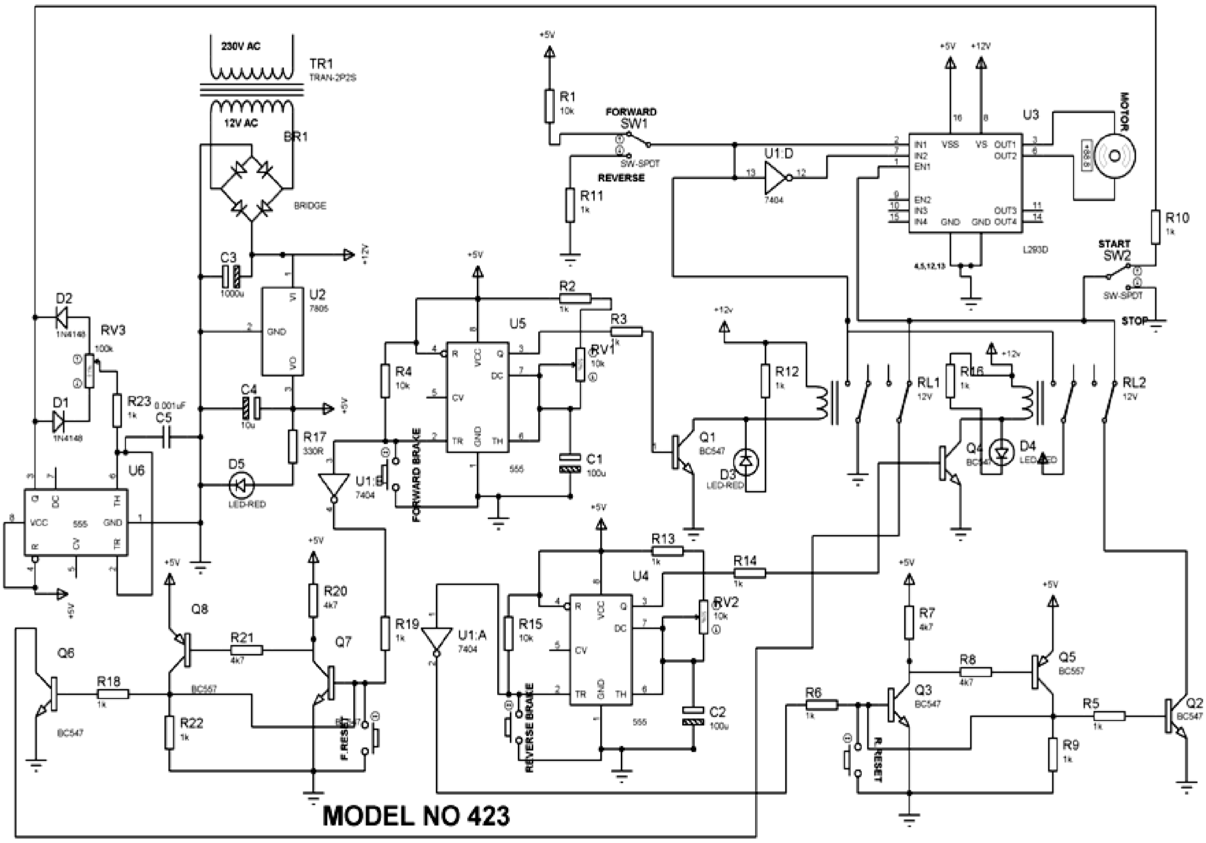


Fig: 3.1.1 Circuit diagram

3.2Component List

1) Transformer
2) Voltage regulator
3) Rectifier 7805
4) Filter
5) 555 Timer
6) Motor driver L293D
7) IC 7404
8) LED
9) Push buttons
10) Resistors
11) Capacitors
12) Diode IN4007
13) Transistors

3.2.1 Transformer

Transformers convert AC electricity from one voltage to another with a little loss of power. Step-up transformers increase voltage, step-down transformers reduce voltage. Most power supplies use a step-down transformer to reduce the dangerously high voltage to a safer low voltage.

Fig: 3.2.1.1A typical transformer

The input coil is called the primary and the output coil is called the secondary. There is no electrical connection between the two coils; instead they are linked by an alternating magnetic field created in the soft-iron core of the transformer. The two lines in the middle of the circuit symbol represent the core. Transformers waste very little power so the power out is (almost) equal to the power in. Note that as voltage is stepped down and current is stepped up.

The ratio of the number of turns on each coil, called the turn's ratio, determines the ratio of the voltages. A step-down transformer has a large number of turns on its primary (input) coil which is connected to the high voltage mains supply, and a small number of turns on its secondary (output) coil to give a low output voltage.

Turns ratio = (V_p / V_s) = (N_p / N_s)

Where,

V_p = primary (input) voltage.

V_s = secondary (output) voltage

N_p = number of turns on primary coil

N_s = number of turns on secondary coil

I_p = primary (input) current

I_s = secondary (output) current.

3.2.1.1 Ideal Power Equation

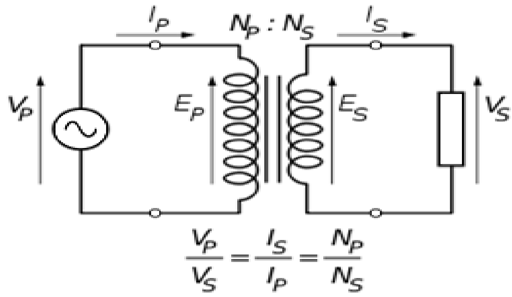


Fig: 3.2.1.1.1 Circuit of ideal transformer

If the secondary coil is attached to a load that allows current to flow, electrical power is transmitted from the primary circuit to the secondary circuit. Ideally, the transformer is perfectly efficient; all the incoming energy is transformed from the primary circuit to the magnetic field and into the secondary circuit. If this condition is met, the incoming electric power must equal the outgoing power:

Giving the ideal transformer equation

$$\frac{Vs}{Vp} = \frac{Ns}{Np} = \frac{Ip}{Is}$$

Transformers normally have high efficiency, so this formula is a reasonable approximation.If the voltage is increased, then the current is decreased by the same factor. The impedance in one circuit is transformed by the square of the turn's ratio.For example, if impedanceZs is attached across the terminals of the secondary coil, it appears to the primary circuit to have an impedance of $(N_p/N_s)^2 Z_s$. This relationship is reciprocal, so that the impedance Z_p of the primary circuit appears to the secondary to be $(N_s/N_p)^2 Z_p$.

3.2.2 Voltage Regulator 7805

3.2.2.1 Features

• Output Current up to 1A.

• Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V.

• Thermal Overload Protection.

• Short Circuit Protection.

• Output Transistor Safe Operating Area Protection.

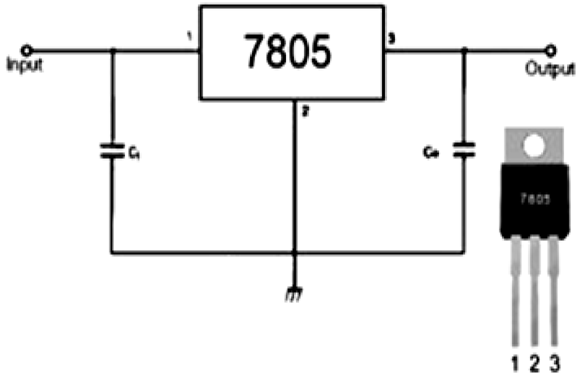


Fig: 3.2.2.1.1A typical diagram of voltage regulator7805

3.2.2.2 Description

The LM78XX/LM78XXA series of three-terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a Wide range of applications. Each type employs internal current limiting, thermal shutdown and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output Current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.

3.2.2.3 Internal Block Diagram

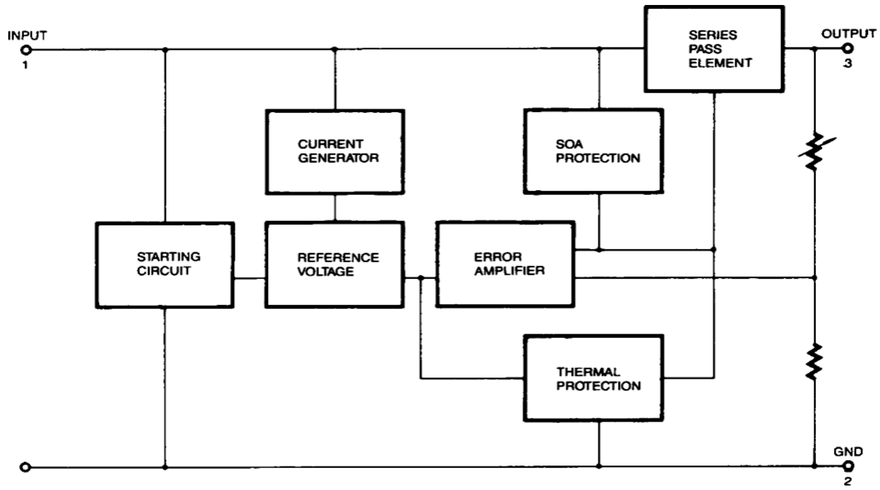


Fig: 3.2.2.3.1 Block diagram of voltage regulator7805

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input voltage (for VO=5v-18v) (for V)=24)	VI VI	35 40	V V
Thermal Resistance Junction-Cases(TO-220)	RJC	5	C/W
Thermal resistance Junction-Air (TO-220)	RJA	65	C/W
Operating Temperature Range (KA78XX/A/R)	TOPR	0 - +125	C
Storage Temperature Range	TSTG	-65 - +150	C

Table: 3.2.2.3.1 Ratings of voltage regulator7805

3.2.3 Rectifier

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), current that flows in only one direction, a process known as rectification. Rectifiers have many uses including as components of power supplies and as detectors of radio signals. Rectifiers may be made of solid statediodes, vacuum tube diodes, mercury arc valves, and other components. The output from the transformer is fed to the rectifier. It converts A.C. into pulsating D.C. The rectifier may be a half wave or a full wave rectifier. In this project, a bridge rectifier is used because of its merits like good stability and full wave rectification. In positive half cycleonly two diodes (1 set of parallel diodes) will conduct, in negative half cycle remaining two diodes will conduct and they will conduct only in forward bias only.

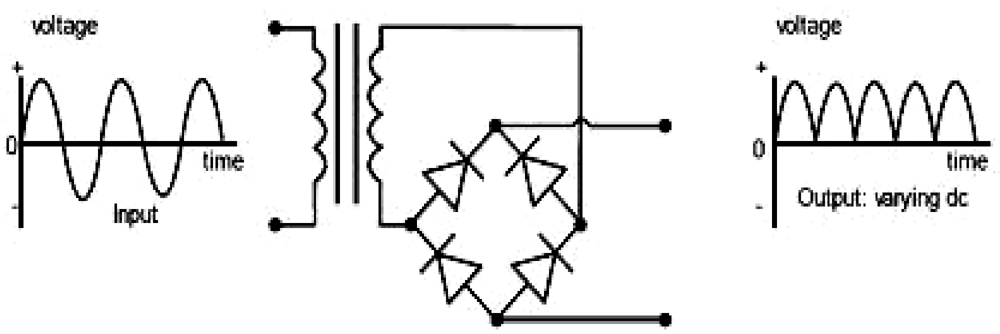


Fig 3.2.3.1 output waveform of rectifier

3.2.4 Filter

Capacitive filter is used in this project. It removes the ripples from the output of rectifier and smoothens the D.C. Output received from this filter is constant until the mains voltage and load is maintained constant. However, if either of the two is varied, D.C. voltage received at this point changes. Therefore a regulator is applied at the output stage.

The simple capacitor filter is the most basic type of power supply filter. The use of this filter is very limited. It is sometimes used on extremely high-voltage, low-current power supplies for cathode-ray and similar electron tubes that require very little load current from the supply. This filter is also used in circuits where the power-supply ripple frequency is not critical and can be relatively high.Below figure can show how the capacitor charges and discharges.

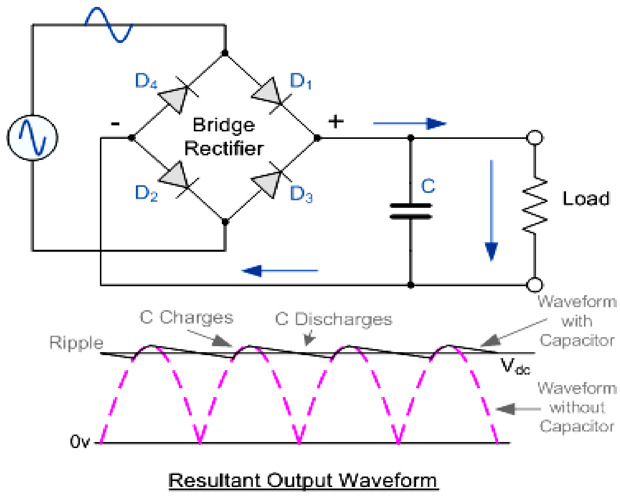


Fig: 3.2.4.1 Output of a capacitive filter

3.2.5 555 Timer

The 555 Timer IC is an integrated circuit (chip) implementing a variety of timer and multivibrator applications. The IC was designed by Hans R. Camenzind in 1970 and brought to market in 1971 by Signetics (later acquired by Philips). The original name was the SE555 (metal can)/NE555 (plastic DIP) and the part was described as "The IC Time Machine". It has been claimed that the 555 gets its name from the three 5 kΩ resistors used in typical early implementations,[2] but Hans Camenzind has stated that the number was arbitrary. The part is still in wide use, thanks to its ease of use, low price and good stability. As of 2003, it is estimated that 1 billion units are manufactured every year.

Fig: 3.2.5.1 555 timer IC

Depending on the manufacturer, the standard 555 package includes over 20 transistors, 2 diodes and 15 resistors on a silicon chip installed in an 8-pin mini dual-in-line package (DIP-8). Variants available include the 556 (a 14-pin DIP combining two 555s on one chip), and the 558 (a 16-pin DIP combining four slightly modified 555s with DIS & THR connected internally, and TR falling edge sensitive instead of level sensitive).

Ultra-low power versions of the 555 are also available, such as the 7555 and TLC555. The 7555 is designed to cause less supply glitching than the classic 555 and the manufacturer claims that it usually does not require a "control" capacitor and in many cases does not require a power supply bypass capacitor.

3.2.5.1 Operating Modes Of 555 Timer

Pin	Name	Purpose
1	GND	Ground, low level (0 V)
2	TRIG	OUT rises, and interval starts, when this input falls below 1/3 V_{CC}.
3	DIS	Open collector output; may discharge a capacitor between intervals.
4	OUT	This output is driven to $+V_{CC}$ or GND.
5	RESET	A timing interval may be interrupted by driving this input to GND.
6	CTRL	"Control" access to the internal voltage divider (by default, 2/3 V_{CC}).
7	DIS THR	The interval ends when the voltage at THR is greater than at CTRL.
8	$V+$, V_{CC}	Positive supply voltage is usually between 3 and 15 V.

Table: 3.2.5.1.1 Pins description of 555 timer

- Monostable mode: In this mode, the 555 functions as a "one-shot". Applications include timers, missing pulse detection, bounce free switches, touch switches, frequency divider, capacitance measurement, pulse-width modulation (PWM) etc.
- Astable - free running mode: the 555 can operate as an oscillator. Uses include LED and lamp flashers, pulse generation, logic clocks, tone generation, security alarms, pulse position modulation, etc.
- Bistable mode or Schmitt trigger: the 555 can operate as a flip-flop, if the DIS pin is not connected and no capacitor is used. Uses include bouncefree latched switches, etc

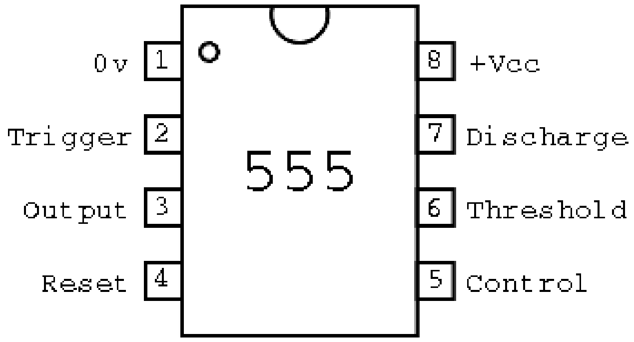


Fig: 3.2.5.1.1 555 timer pin diagram

The 555 timer IC is a simple 8 pin DIL package IC. It can:

- be used as a monostable
- be used as an astable
- source or sink 100mA
- Use supply voltages of 5v to 15v disrupt the power supply - use a decoupling capacitor!

3.2.5.2 555 As a Buffer

A buffer circuit allows an input circuit to be connected to an output circuit, it is like an interface between one circuit and another. The buffer circuit requires very little input current but should be able to supply adequate output current. The 555 can supply in excess of 100mA of current and so can be used as a convenient buffer for logic gates which cannot supply much current. The 555 can also 'sink' a similar amount of current.

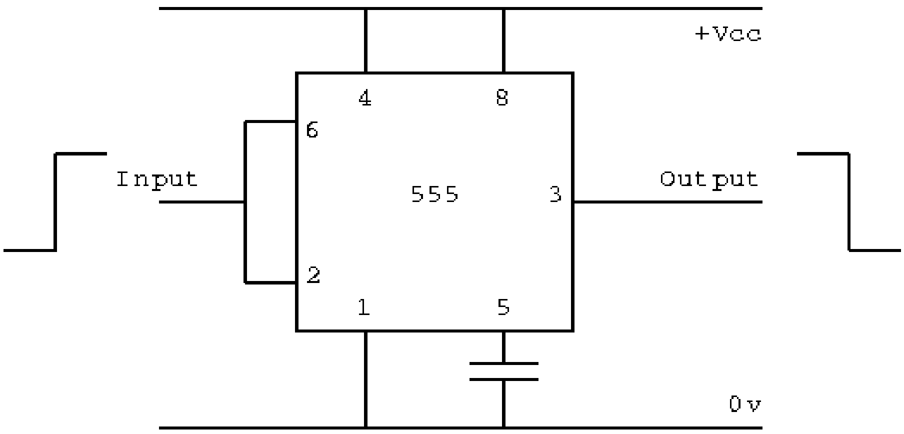


Fig: 3.2.5.2.1 555 timer as a buffer

The circuit acts like an inverter or NOT gate. When the input is held low, the output is high and will provide (source) current. When the input is held high, the output is low and will sink current. Remember, for a buffer for even higher power devices that require even larger currents, the 555 buffer can be used to drive a relay or a transistor circuit.

3.2.5.3 555 As a Monostable

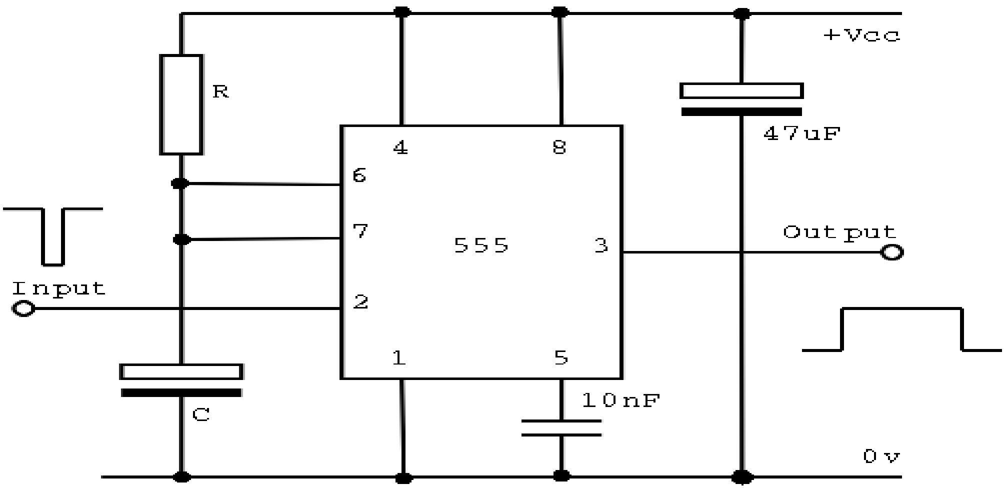


Fig: 3.2.5.3.1 555 timer as a monostable

- The output is normally low but will go high for a short length of time depending on the values of the other components.
- R and C determine the time period of the output pulse.
- The input is normally high and goes low to trigger the output (falling edge triggered).
- The length of the input pulse must be less than the length of the output pulse.

- The 47uF capacitor 'decouples' the supply to avoid affecting other parts of the circuit.
- It is standard to add a 10nF capacitor from pin-5 to gnd.

$$T = 1.1\ R\ C$$

T - Seconds, R - ohms, C - Farads

The minimum value of R should be about 1k to avoid too much current flowing into the555. The maximum value of R should be about 1M so that enough current can flow into the input of the 555 and there is also current to allow for the electrolytic capacitors leakage current The minimum value of C = 100pF to avoid the timing equation being too far off. The maximum value of C should be about 1000µF as any bigger capacitors will discharge too much current through the chip. These maximum and minimum values give a minimum period of 0.1 µs and a maximum period of 1000s.

3.2.5.4 555 As an Astable

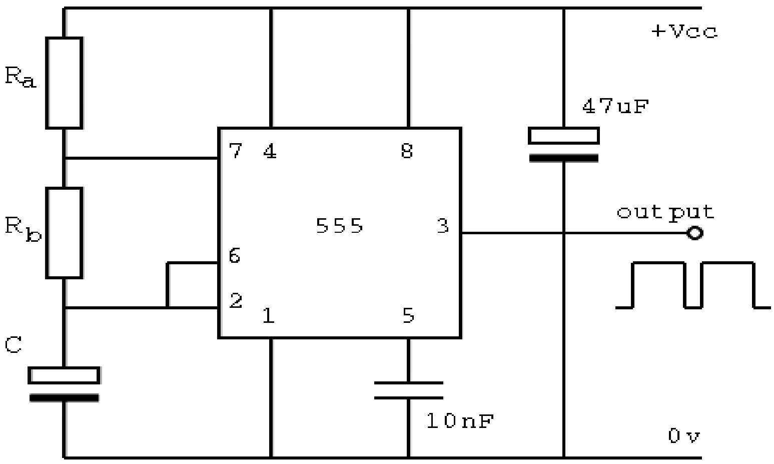


Fig: 3.2.5.4.1 555 timer as aastable

- The output will oscillate between high and low continuously - the circuit is not stable in any state
- R_a, R_b and C determine the time period of the output
- The reset, pin 4, must be held high for the circuit to oscillate. If pin 4 is held low then the output remains low. Pin 4 can be used to turn the astable 'on' and 'off' in effect
- The 47uF capacitor 'decouples' the supply to avoid affecting other parts of the circuit
- It is standard to add a 10nF capacitor from pin5 to gnd.

$$T = 0.7\ (Ra + 2R_b)\ C$$

T - Seconds, R - ohms, C - Farads

As with the monostable the minimum value of Ra should be about 1k to avoid too much current flowing into the 555.The maximum value of Ra or Rb should be about 1M so that enough current can flow into the input of the 555 and there is also current to allow for the electrolytic capacitors leakage current. The minimum value of C = 100pF to avoid the timing equation being too far off. The maximum value of C should be about 1000µF as any bigger capacitors will discharge too much current through the chip. These maximum and minimum values give a minimum frequency of 0.001 Hz and a maximum frequency of 4.8 MHz (in reality it would not be able to attain these frequencies).

Considering the oscillations in more detail:

- The output is controlled by the charging and discharging of the capacitor.
- The capacitor charges through Ra and Rb.
- But discharges through the discharge pin (pin 7) and thus only through Rb.
- The time that the capacitor takes to charge or discharge is given as

  T = 0.7 RC.
- Thus the charge time is 0.7 (Ra + Rb) C.
- The discharge time is 0.7 Rb C.
- Giving a total time of (0.7 (Ra + Rb) C) + (0.7 Rb C) = 0.7 (Ra + 2Rb) C.
- The time the output is high (mark) is thus always longer than the time the output is low (space).
- The 555 astable cannot produce a square wave!

3.2.5.5Operation Of The 555

It is not necessary to know how the 555 works. In fact a systems approach to electronics would never consider how any such sub-block works. However, a knowledge of how the 555 functions is useful. A much simplified block diagram of the 555 timer is shown:

- The resistors are arranged across the power supply to form a potential divider. The voltages at the junctions of the potential divider are 2/3 Vcc and 1/3 Vcc. They are connected to the inputs to a pair of comparators.

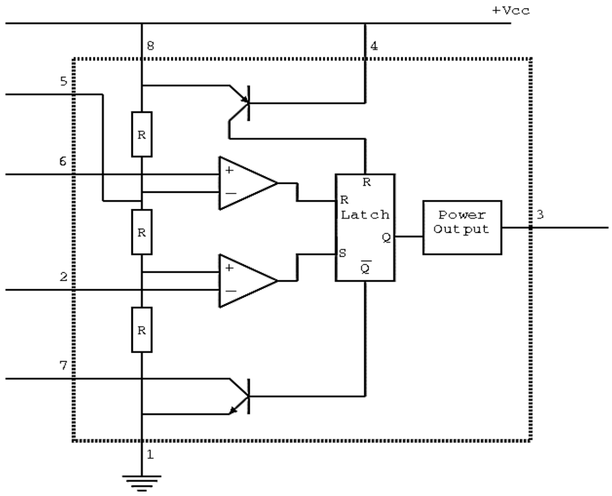


Fig: 3.2.5.5.1 Operation of a 555 timer

- One comparator, switching at 2/3 Vcc is controlled via the thresholdinput.
- The voltage at which the threshold comparator switches can be changed from 2/3 Vcc by applying a voltage to the controlpin. This pin is usually decoupled to ground via a 10nF capacitor and, in this case, the comparator switches at 2/3 Vcc as expected.
- One comparator, switching at 1/3 Vcc is controlled via thetriggerinput.
- The outputs from the two comparators control a set-reset flip flop (bistable).
- The resetpin of the 555 (not of the bistable) is usually held high. Taking this pin momentarily low applies a voltage to the reset pin of the flip flop and the output falls to zero.
- The output of the flip flop is connected to the output pin via a power amplifier circuit which includes short circuit protection etc.
- The output goes high when the trigger input is less than 1/3 Vcc.
- The output then remains high until the threshold input rises above 2/3 Vcc.
- When the output is low, the discharg**e** pin is connected to ground via a transistor. The capacitor can be organized to discharge through this pin but the value of the capacitor should be less than 1000µF to avoid damaging the transistor.

3.2.6 Motor Driver L293D

3.2.6.1 Features

- Wide supply-voltage range: 4.5V to 36V
- Separate input- logic supply

- Internal ESD protection
- Thermal shutdown
- High-Noise-Immunity input
- Functional Replacements for SGS L293 and SGS L293D
- Output current 1A per channel (600 mA for L293D)
- Peak output current 2 A per channel (1.2 A for L293D)
- Output clamp diodes for Inductive Transient Suppression(L293D)

Fig: 3.2.6.1.1 Motor driver L293D

L293D is a dual H-bridge motor driver integrated circuit (IC). Motor drivers act as current amplifiers since they take a low-current control signal and provide a higher-current signal. This higher current signal is used to drive the motors.

L293D contains two inbuilt H-bridge driver circuits. In its common mode of operation, two DC motors can be driven simultaneously, both in forward and reverse direction. The motor operations of two motors can be controlled by input logic at pins 2 & 7 and 10 & 15. Input logic 00 or 11 will stop the corresponding motor. Logic 01 and 10 will rotate it in clockwise and anticlockwise directions, respectively.

Enable pins 1 and 9 (corresponding to the two motors) must be high for motors to start operating. When an enable input is high, the associated driver gets enabled. As a result, the outputs become active and work in phase with their inputs. Similarly, when the enable input is low, that driver is disabled, and their outputs are off and in the high-impedance state.

- L293D is a typical Motor driver or Motor Driver IC which allows DC motor to drive on either direction. L293D is a 16-pin IC which can control a set of two DC motors simultaneously in any direction.

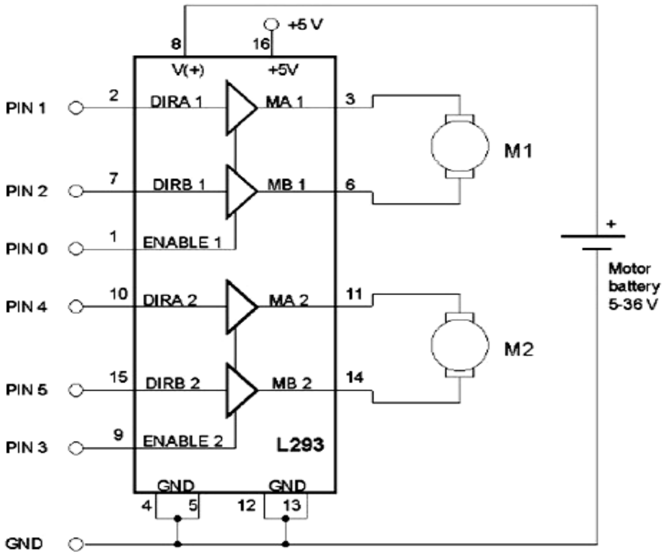


Fig: 3.2.6.1.2 Block diagram of L293D

- It works on the concept of H-bridge. H-bridge is a circuit which allows the voltage to be flown in either direction.
- Turning these switches ON and OFF can drive a motor in different ways.

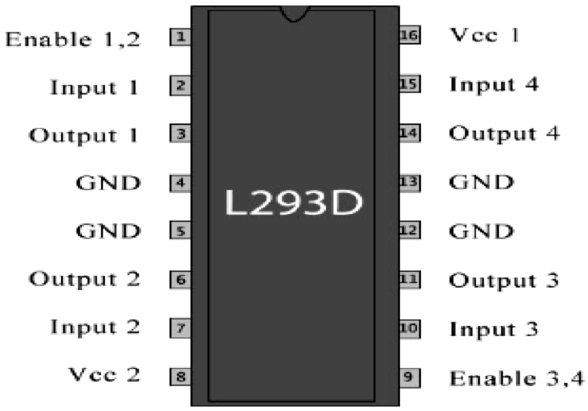


Fig: 3.2.6.1.3 Pin diagram of L293D

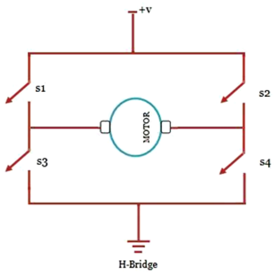


Fig: 3.2.6.1.3H-bridge

- Turning on Switches **S1** and **S4** makes the motor rotate clockwise
- Turning on Switches **S2** and **S3** makes the motor rotate anti-clockwise

- Turning on Switches **S1** and **S2** will stop the motor (Brakes)
- Lastly turning on **S1** & **S3** at the same time or **S2** & **S4** at the same time shorts your entire circuit.

S_1	S_2	S_3	S_4	OPERATION
1	0	0	1	Motor moves right
0	1	1	0	Motor moves left
0	0	0	0	Motor free runs
1	1	0	0	Motor brakes
0	0	1	1	Motor brakes
1	1	1	1	Short power supply
1	0	1	0	Short power supply
0	1	0	1	Short power supply

Table: 3.2.6.1.2 Operation of motordriverL293D

3.2.7 DC Motor

A DC motor is an electric motor that runs on direct current (DC) electricity. In any electric motor, operation is based on simple electromagnetism. A current-carrying conductor generates a magnetic field; when this is then placed in an external magnetic field, it will experience a force proportional to the current in the conductor, and to the strength of the external magnetic field. As you are well aware of from playing with magnets as a kid, opposite (North and South) polarities attract, while like polarities (North and North, South and South) repel. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current-carrying conductor and an external magnetic field to generate rotational motion.

Let's start by looking at a simple 2-pole DC electric motor (here red represents a magnet or winding with a "North" polarization, while green represents a magnet or winding with a "South" polarization).

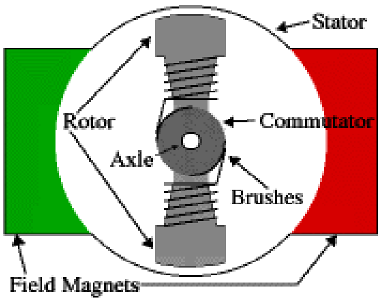


Fig: 3.2.7.1 DC Motor

Every DC motor has six basic parts -- axle, rotor (a.k.a., armature), stator, commutator, field magnet(s), and brushes. In most common DC motors, the external magnetic field is produced by high-strength permanent magnets[1]. The stator is the stationary part of the motor -- this includes the motor casing, as well as two or more permanent magnet pole pieces. The rotor rotates with respect to the stator. The rotor consists of windings (generally on a core), the windings being electrically connected to the commutator. The above diagram shows a common motor layout -- with the rotor inside the stator (field) magnets.

The geometry of the brushes, commutator contacts, and rotor windings are such that when power is applied, the polarities of the energized winding and the stator magnet(s) are misaligned, and the rotor will rotate until it is almost aligned with the stator's field magnets. As the rotor reaches alignment, the brushes move to the next commutator contacts, and energize the next winding. Given our example two-pole motor, the rotation reverses the direction of current through the rotor winding, leading to a "flip" of the rotor's magnetic field, driving it to continue rotating.

In real life, though, DC motors will always have more than two poles (three is a very common number). In particular, this avoids "dead spots" in the commutator. You can imagine how with our example two-pole motor, if the rotor is exactly at the middle of its rotation (perfectly aligned with the field magnets), it will get "stuck" there. Meanwhile, with a two-pole motor, there is a moment where the commutator shorts out the power supply (i.e., both brushes touch both commutator contacts simultaneously). This would be bad for the power supply, waste energy, and damage motor components as well. Yet another disadvantage of such a simple motor is that it would exhibit a high amount of torque "ripple".

So since most small DC motors are of a three-pole design, let's tinker with the workings of one via an interactive animation (JavaScript required):

You'll notice a few things from this -- namely, one pole is fully energized at a time (but two others are "partially" energized). As each brush transitions from one commutator contact to the next, one coil's field will rapidly collapse, as the next coil's field will rapidly charge up (this occurs within a few microsecond). We'll see more about the effects of this later, but in the meantime you can see that this is a direct result of the coil windings' series wiring.

3.2.8 Inverter 7404

Outputs of one gate can be connected to inputs of another within the same chip or to another chip as long as they share the same ground. The figure to the left illustrates a basic circuit showing how to wire inputs and using LEDs to display outputs.

The 7404 is an inverting buffer, especially useful when the output of one circuit cannot sink much current. A computer's parallel port is a notorious example and can easily be damaged by excessive current draw. Each of the parallel ports outputs can be connected to one of the six inputs on the 7404 hex inverter chip.

NOT GATE Logic rules: The output is the inverse of the input, in other words if the input is HIGH then the output is LOW and if the input is LOW the output is HIGH.

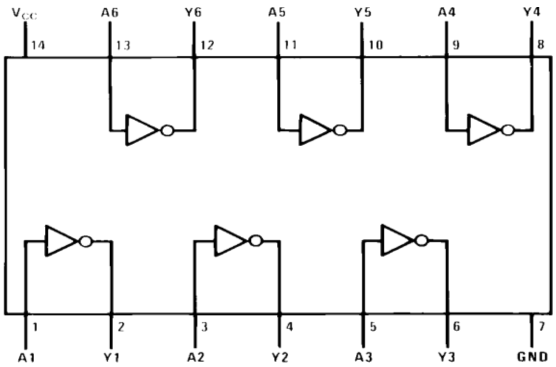


Fig: 3.2.8.1 Inverter 7404 IC

3.2.8.1 Features

- Output Drive Capability - 10 LSTTL Loads
- Outputs Directly Interface to CMOS, NMOS and TTL
- Large Operating Voltage Range
- Low Input Current and high Noise Immunity

Absolute Maximum Ratings

Sl.No.	Items	Values
1	Supply voltage	7V
2	Input Voltage	5.5V
3	Opertaing free air temperature	0C to +70C
4	Storage Temperature range	-65C to +150C

Table: 3.2.8.1.1 Maximum ratings of IC 7404

3.2.8.2 Pin Description

Pin number	Description
1	A Input gate 1
2	Y Output gate 1
3	A Input gate 2
4	Y output gate 2
5	A Input gate 3
6	Y Output gate 3
7	Ground
8	Y output gate 4
9	A Input gate 4
10	Y output gate 5
11	A Input gate 5
12	Y output gate 6
13	A Input gate 6
14	Positive supply

Table 3.2.8.2.1 Pin description of IC

3.2.8.3 Applications

- Logical inversion
- pulse shaping
- Oscillators

3.2.9 LED

Light Emitting Diodes (LED) have recently become available that are white and bright, so bright that they seriously compete with incandescent lamps in lighting applications. They are still pretty expensive as compared to a GOW lamp but draw much less current and project a fairly well focused beam.

The diode in the photo came with a neat little reflector that tends to sharpen the beam a little but doesn't seem to add much to the overall intensity.

When run within their ratings, they are more reliable than lamps as well. Red LEDs are now being used in automotive and truck tail lights and in red traffic signal lights. You will be able to detect them because they look like an array of point sources and they go on and off instantly as compared to conventional incandescent lamps.

LEDs are monochromatic (one color) devices. The color is determined by the band gap of the semiconductor used to make them. Red, green, yellow and blue LEDs are fairly common. White light contains all colors and cannot be directly created by asingle LED. The most common form of "white" LED really isn't white. It is a Gallium Nitride blue LED coated with a phosphor that, when excited by the blue LED light, emits a broad range spectrum that in addition to the blue emission, makes a fairly white light.

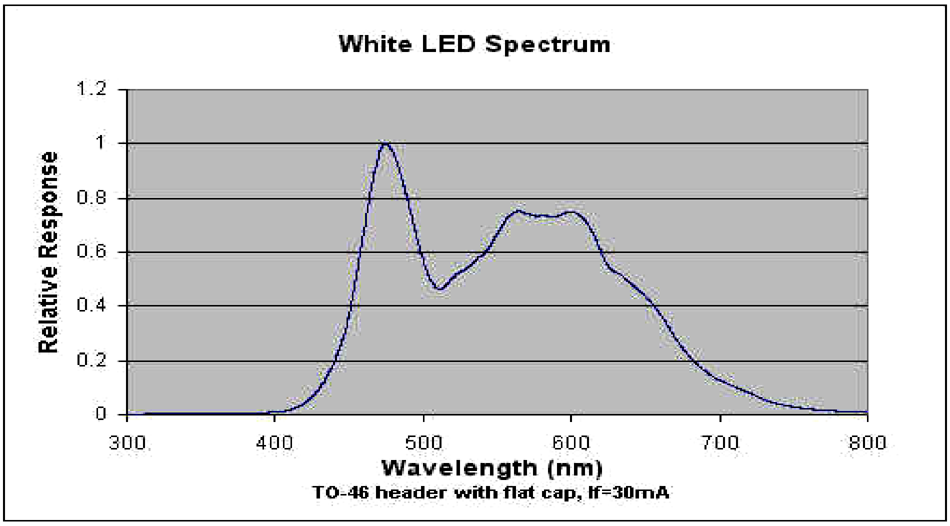


Fig: 3.2.9.1 Spectrum of white LED

There is a claim that these white LED's have a limited life. After 1000 hours or so of operation, they tend to yellow and dim to some extent. Running the LEDs at more than their rated current will certainly accelerate this process.

There are two primary ways of producing high intensity white-light using LED'S. One is to use individual LED'S that emit three primary colours—red, green, and blue—and then mix all the colours to form white light. The other is to use a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light, much in the same way a fluorescent light bulb works. Due to metamerism, it is possible to have quite different spectra that appear white.

LEDs are semiconductor devices. Like transistors, and other diodes, LEDs are made out of silicon. What makes an LED give off light are the small amounts of chemical impurities that are added to the silicon, such as gallium, arsenide, indium, and nitride. When current passes through the LED, it emits photons as a byproduct. Normal light bulbs produce light by heating a metal filament until it is white hot.

LEDs produce photons directly and not via heat, they are far more efficient than incandescent bulbs.

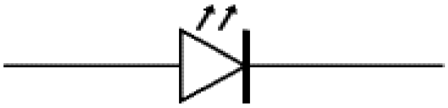


Fig: 3.2.9.2 circuit symbol

Not long ago LEDs were only bright enough to be used as indicators on dashboards or electronic equipment. But recent advances have made LEDs bright enough to rival traditional lighting technologies. Modern LEDs can replace incandescent bulbs in almost any application.

LEDs are produced in an array of shapes and sizes. The 5 mm cylindrical package is the most common, estimated at 80% of world production. The color of the plastic lens is often the same as the actual color of light emitted, but not always. For instance, purple plastic is often used for infrared LEDs, and most blue devices have clear housings. There are also LEDs in extremely tiny packages, such as those found on blinkers and on cell phone keypads. The main types of LEDs are miniature, high power devices and custom designs such as alphanumeric or multi-color.

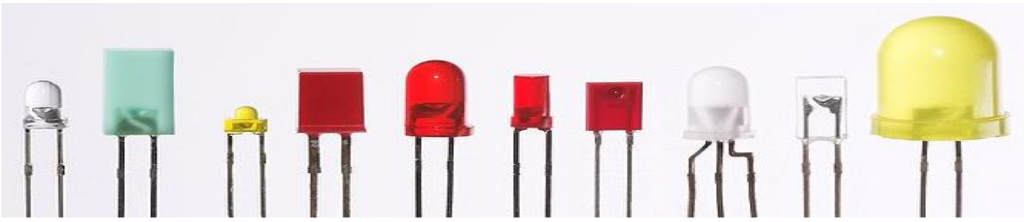


Fig: 3.2.9.3 Models of LED

3.2.9.1 Advantages Of Using LEDs

- Efficiency: LEDs produce more light per watt than incandescent bulbs; this is useful in battery powered or energy-saving devices.
- Size: LEDs can be very small (smaller than 2 mm^2) and are easily populated onto printed circuit boards.
- On/Off time: LEDs light up very quickly. A typical red indicator LED will achieve full brightness in microseconds. LEDs used in communications devices can have even faster response times.

- Cycling:LEDs are ideal for use in applications that are subject to frequent on-off cycling, unlike fluorescent lamps that burn out more quickly when cycled frequently, or HID lamps that require a long time before restarting.
- Cool light:In contrast to most light sources, LEDs radiate very little heat in the form of IR that can cause damage to sensitive objects or fabrics. Wasted energy is dispersed as heat through the base of the LED.
- Lifetime: LEDs can have a relatively long useful life. One report estimates 35,000 to 50,000 hours of useful life, though time to complete failure may be longer.
- No Toxicity:LEDs do not contain mercury, unlike fluorescent lamps.

3.2.9.2 Disadvantages Of Using LED's

- High price: LEDs are currently more expensive, price per lumen, on an initial capital cost basis, than most conventional lighting technologies.
- Temperature dependence: LED performance largely depends on the ambient temperature of the operating environment. Over-driving the LED in high ambient temperatures may result in overheating of the LED package, eventually leading to device failure.
- Voltage sensitivity:LEDs must be supplied with the voltage above the threshold and a current below the rating. This can involve series resistors or current-regulated power supplies.
- Area light source: LEDs do not approximate a "point source" of light, but rather a lambertian distribution. So LEDs are difficult to use in applications requiring a spherical light field. LEDs are not capable of providing divergence below a few degrees. This is contrasted with lasers, which can produce beams with divergences of 0.2 degrees or less.
- Blue Hazard: There is increasing concern that blue LEDs and cool-white LEDs are now capable of exceeding safe limits of the so-called blue-light hazard as defined in eye safety.

3.2.10 Push Buttons

A push-button (also spelled pushbutton) or simply button is a simple switch mechanism for controlling some aspect of a machine or a process. Buttons are typically made out of hard material, usually plastic or metal. The surface is usually flat or shaped to accommodate the human finger or hand, so as to be easily depressed

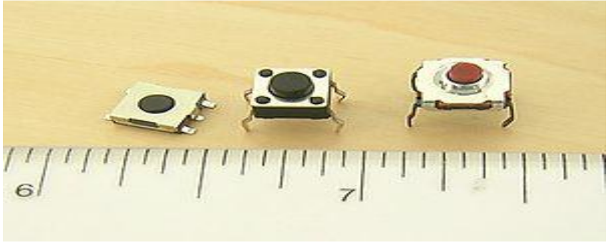


Fig: 3.2.10.1 Types of push buttons

or pushed. Buttons are most often biased switches, though even many un-biased buttons (due to their physical nature) require a spring to return to their un-pushed state. Different people use different terms for the "pushing" of the button, such as press, depress, mash, and punch.

Uses:

In industrial and commercial applications push buttons can be linked together by a mechanical linkage so that the act of pushing one button causes the other button to be released. In this way, a stop button can "force" a start button to be released. This method of linkage is used in simple manual operations in which the machine or process have no electrical circuits for control.

Pushbuttons are often color-coded to associate them with their function so that the operator will not push the wrong button in error. Commonly used colors are red for stopping the machine or process and green for starting the machine or process.

Red pushbuttons can also have large heads (mushroom shaped) for easy operation and to facilitate the stopping of a machine. These pushbuttons are called emergency stop buttons and are mandated by the electrical code in many jurisdictions for increased safety. This large mushroom shape can also be found in buttons for use with operators who need to wear gloves for their work and could not actuate a regular flush-mounted push button. As an aid for operators and users in industrial or commercial applications, a pilot light is commonly added to draw the attention of the user and to provide feedback if the button is pushed. Typically this light is included into the center of the pushbutton and a lens replaces the pushbutton hard center disk.

The source of the energy to illuminate the light is not directly tied to the contacts on the back of the pushbutton but to the action the pushbutton controls. In this way a start button when pushed will cause the process or machine operation to be started and a secondary contact designed into the operation or process will close to turn on the pilot light and signify the action of pushing the button caused the resultant process or action to start.

In popular culture, the phrase "the button" refers to a (usually fictional) button that a military or government leader could press to launch nuclear weapons.

Push to ON button:

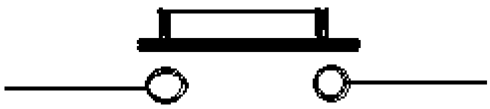


Fig: 3.2.10.2push on button

Initially the two contacts of the button are open. When the button is pressed they become connected. This makes the switching operation using the push button.

3.2.11 Resistors

A resistor is a two-terminal electronic component designed to oppose an electric current by producing a voltage drop between its terminals in proportion to the current, that is, in accordance with Ohm's law:V = IR

Resistors are used as part of electrical networks and electronic circuits. They are extremely commonplace in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel/chrome).

Fig: 3.2.11.1 Types of Resistors

The primary characteristics of resistors are their resistance and the power they can dissipate. Other characteristics include temperature coefficient, noise, and inductance. Less well-known is critical resistance, the value below which power dissipation limits the maximum permitted current flow, and above which the limit is applied voltage. Critical resistance depends upon the materials constituting the resistor as well as its physical dimensions; it's determined by design.

Resistors can be integrated into hybrid and printed circuits, as well as integrated circuits. Size, and position of leads (or terminals) are relevant to equipmentdesigners; resistors must be physically large enough not to overheat when dissipating their power.

A resistor is a two-terminal lpassiveelectronic component which implements electrical resistance as a circuit element. When a voltage V is applied across the terminals of a resistor, a current I will flow through the resistor in direct proportion to that voltage. The reciprocal of the constant of proportionality is known as the resistance R, since, with a given voltage V, a larger value of R further "resists" the flow of current I as given by Ohm's law.

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel-chrome). Resistors are also implemented within integrated circuits, particularly analog devices, and can also be integrated into hybrid and printed circuits.

The electrical functionality of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than 9 orders of magnitude. When specifying that resistance in an electronic design, the required precision of the resistance may require attention to the manufacturing tolerance of the chosen resistor, according to its specific application. The temperature coefficient of the resistance may also be of concern in some precision applications. Practical resistors are also specified as having a maximum power rating which must exceed the anticipated power dissipation of that resistor in a particular circuit: this is mainly of concern in power electronics applications. Resistors with higher power ratings are physically larger and may require heat sinking. In a high voltage circuit, attention must sometimes be paid to the rated maximum working voltage of the resistor.

The series inductance of a practical resistor causes its behaviour to depart from ohms law; this specification can be important in some high-frequency applications for smaller values of resistance. In a low-noise amplifier or pre-amp the noise characteristics of a resistor may be an issue. The unwanted inductance, excess noise, and temperature coefficient are mainly dependent on the technology used in manufacturing the resistor. They are not normally specified individually for a particular family of resistors manufactured using a particular technology. A family of discrete resistors is also characterized according to its form factor, that is, the size of the device and position of its leads (or terminals) which is relevant in the practical manufacturing of circuits using them.

The ohm (symbol: Ω) is the SI unit of electrical resistance, named after Georg Simon Ohm. An ohm is equivalent to a volt per ampere. Since resistors are specified and manufactured over a very large range of values, the derived units of milliohm (1 mΩ = 10^{-3} Ω), kilohm (1 kΩ = 10^3 Ω), and megohm (1 MΩ = 10^6 Ω) are also in common usage.

The reciprocal of resistance R is called conductance G = 1/R and is measured in Siemens (SI unit), sometimes referred to as a mho. Thus a Siemens is the reciprocal of an ohm: $S = \Omega^{-1}$. Although the concept of conductance is often used in circuit analysis, practical resistors are always specified in terms of their resistance (ohms) rather than conductance.

3.2.11.1 Theory of Operation

Ohm's law: The behavior of an ideal resistor is dictated by the relationship specified by

$$\boldsymbol{V = I.R}$$

Ohm's law states that the voltage (V) across a resistor is proportional to the current (I) passing through it, where the constant of proportionality is the resistance (R).

Equivalently, Ohm's law can be stated:

$$I = \frac{V}{R}$$

This formulation of Ohm's law states that, when a voltage (V) is present across a resistance (R), a current (I) will flow through the resistance. This is directly used in practical computations. For example, if a 300 ohm resistor is attached across the terminals of a 12 volt battery, then a current of 12 / 300 = 0.04 amperes (or 40 mill amperes) will flow through that resistor.

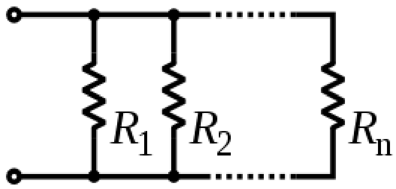
Series and parallel resistors:

In a series configuration, the current through all of the resistors is the same, but the voltage across each resistor will be in proportion to its resistance. The potential difference (voltage) seen across the network is the sum of those voltages, thus the total resistance can be found as the sum of those resistances:

$$Req = R1 + R2 + \cdots + Rn$$

As a special case, the resistance of N resistors connected in series, each of the same resistance R is given by NR.

Resistors in a parallel configuration are each subject to the same potential difference (voltage), however the currents through them add. The conductances of the resistors then add to determine the conductance of the network. Thus the equivalent resistance (R_{eq}) of the network can be computed:



$$\frac{1}{Req} = \frac{1}{R1} + \frac{1}{R2} + \cdots + \frac{1}{Rn}$$

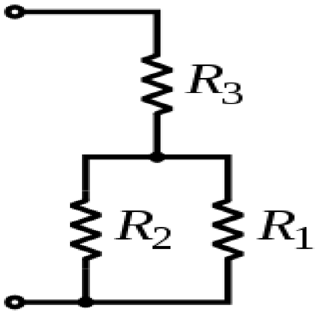
The parallel equivalent resistance can be represented in equations by two vertical lines "||" (as in geometry) as a simplified notation. For the case of two resistors in parallel, this can be calculated using:

$$Req = \frac{R1R2}{R1 + R2}$$

As a special case, the resistance of N resistors connected in parallel, each of the same resistance R, is given by R/N.

A resistor network that is a combination of parallel and series connections can be broken up into smaller parts that are either one or the other. For instance,

However, some complex networks of resistors cannot be resolved in this manner, requiring more sophisticated circuit analysis. For instance, consider a cube, each edge of which has been replaced by a resistor. What then is the resistance that would be measured between two opposite vertices? In the case of 12 equivalent resistors, it can be shown that the corner-to-corner resistance is $^5\!/_6$ of theindividual resistance. More generally, the Y-Δ transform, or matrix methods can be used to solve such a problem.



$$Req = \frac{R1R2}{R1 + R2} + R3$$

One practical application of these relationships is that a non-standard value of resistance can generally be synthesized by connecting a number of standard values in series and/or parallel. This can also be used to obtain a resistance with a higher power rating than that of the individual resistors used. In the special case of N identical resistors all connected in series or all connected in parallel, the power rating of the individual resistors is thereby multiplied by N.

Power dissipation:

The power P dissipated by a resistor (or the equivalent resistance of a resistor network) is calculated as: $P = I^2R = IV = \frac{V^2}{R}$

The first form is a restatement of Joule's first law. Using Ohm's law, the two other forms can be derived.

The total amount of heat energy released over a period of time can be determined from the integral of the power over that period of time:

$$W = \int_{t1}^{t2} v(t)\, i(t) dt$$

Practical resistors are rated according to their maximum power dissipation. The vast majority of resistors used in electronic circuits absorb much less than a watt of electrical power and require no attention to their power rating. Such resistors in their discrete form, including most of the packages detailed below, are typically rated as 1/10, 1/8, or 1/4 watt.

Resistors required to dissipate substantial amounts of power, particularly used in power supplies, power conversion circuits, and power amplifiers, are generally referred to as power resistors; this designation is loosely applied to resistors with power ratings of 1 watt or greater. Power resistors are physically larger and tend not to use the preferred values, colour codes, and external packages described below.

If the average power dissipated by a resistor is more than its power rating, damage to the resistor may occur, permanently altering its resistance; this is distinct from the reversible change in resistance due to its temperature coefficient when it warms. Excessive power dissipation may raise the temperature of the resistor to a point where it can burn the circuit board or adjacent components, or even cause a fire. There are flameproof resistors that fail (open circuit) before they overheat dangerously.

Note that the nominal power rating of a resistor is not the same as the power that it can safely dissipate in practical use. Air circulation and proximity to a circuit board, ambient temperature, and other factors can reduce acceptable dissipation significantly. Rated power dissipation may be given for an ambient temperature of 25 °C in free air. Inside an equipment case at 60 °C, rated dissipation will be significantly less; a resistor dissipating a bit less than the maximum figure given by the manufacturer may still be outside the safe operating area and may prematurely fail.

3.2.11.2 Electronic Colour Code

Most axial resistors use a pattern of coloured stripes to indicate resistance. Surface-mount resistors are marked numerically, if they are big enough to permit marking; more-recent small sizes are impractical to mark. Cases are usually tan, brown, blue, or green, though other colours are occasionally found such as dark red or dark gray.

Early 20th century resistors, essentially uninsulated, were dipped in paint to cover their entire body for colour coding. A second colour of paint was applied to one end of the element, and a colour dot (or band) in the middle provided the third digit. The rule was "body, tip, dot", providing two significant digits for value and the decimal multiplier, in that sequence. Default tolerance was ±20%. Closer-tolerance resistors had silver (±10%) or gold-coloured (±5%) paint on the other end.

<u>Four-band resistors:</u>

Four-band identification is the most commonly used colour-coding scheme on resistors. It consists of four coloured bands that are painted around the body of the resistor. The first two bands encode the first two significant digits of the resistance value, the third is a power-of-ten multiplier or number-of-zeroes, and the fourth is the tolerance accuracy, or acceptable error, of the value. The first three bands are equally spaced along the resistor; the spacing to the fourth band is wider. Sometimes a fifth band identifies the thermal coefficient, but this must be distinguished from the true 5-color system, with 3 significant digits.

For example, green-blue-yellow-red is $56 \times 10^4\ \Omega = 560\ \mathrm{k}\Omega \pm 2\%$. An easier description can be as followed: the first band, green, has a value of 5 and the second band, blue, has a value of 6, and is counted as 56. The third band, yellow, has a value of 10^4, which adds four 0's to the end, creating 560,000 Ω at ±2% tolerance accuracy. 560,000 Ω changes to 560 kΩ ±2% (as a kilo- is 10^3).

Early resistors were made in more or less arbitrary round numbers; a series might have 100, 125, 150, 200, 300, etc. Resistors as manufactured are subject to a certain percentage tolerance, and it makes sense to manufacture values that correlate with the tolerance, so that the actual value of a resistor overlaps slightly with its neighbours. Wider spacing leaves gaps; narrower spacing increases manufacturing and inventory costs to provide resistors that are more or less interchangeable.

A logical scheme is to produce resistors in a range of values which increase in a geometrical progression, so that each value is greater than its predecessor by a fixed multiplier or percentage, chosen to match the tolerance of the range. For example, for a tolerance of ±20% it makes sense to have each resistor about 1.5 times its predecessor, covering a decade in 6 values. In practice the factor used is 1.4678, giving values of 1.47, 2.15, 3.16, 4.64, 6.81, 10 for the 1-10 decade (a decade is a range increasing by a factor of 10; 0.1-1 and 10-100 are other examples); these are rounded in practice to 1.5, 2.2, 3.3, 4.7, 6.8, 10; followed, of course by 15, 22, 33, … and preceded by … 0.47, 0.68, 1. This scheme has been adopted as the E6 range of the IEC 60063 preferred numberseries.There are also E12, E24, E48, E96 and E192 ranges for components of ever tighter tolerance, with 12, 24, 96, and 192 different values within each decade. The actual values used are in the IEC 60063 lists of preferred numbers.

A resistor of 100 ohms ±20% would be expected to have a value between 80 and 120 ohms; its E6 neighbours are 68 (54-82) and 150 (120-180) ohms. A sensible spacing, E6 is used for ±20% components; E12 for ±10%; E24 for ±5%; E48 for ±2%, E96 for ±1%; E192 for ±0.5% or better. Resistors are manufactured in values from a few milliohms to about a gigaohm in IEC60063 ranges appropriate for their tolerance.

Each colour corresponds to a certain digit, progressing from darker to lighter colours, as shown in the chart below.

Color	**1st band**	**2nd band**	**3rd band (multiplier)**	**4th band (tolerance)**	**Temp. Coefficient**
Black	0	0	$\times 10^0$		
Brown	1	1	$\times 10^1$	±1% (F)	100 ppm
Red	2	2	$\times 10^2$	±2% (G)	50 ppm
Orange	3	3	$\times 10^3$		15 ppm
Yellow	4	4	$\times 10^4$		25 ppm
Green	5	5	$\times 10^5$	±0.5% (D)	
Blue	6	6	$\times 10^6$	±0.25% (C)	
Violet	7	7	$\times 10^7$	±0.1% (B)	
Gray	8	8	$\times 10^8$	±0.05% (A)	
White	9	9	$\times 10^9$		
Gold			$\times 10^{-1}$	±5% (J)	
Silver			$\times 10^{-2}$	±10% (K)	
None				±20% (M)	

Table: 3.2.11.2.1 Preferred values of resistor

Earlier power wire-wound resistors, such as brown vitreous-enamelled types, however, were made with a different system of preferred values, such as some of those mentioned in the first sentence of this section.

<u>5-band axial resistors:</u>

5-band identification is used for higher precision (lower tolerance) resistors (1%, 0.5%, 0.25%, 0.1%), to specify a third significant digit. The first three bands represent the significant digits, the fourth is the multiplier, and the fifth is the tolerance. Five-band resistors with a gold or silver 4th band are sometimes encountered, generally on older or specialized resistors. The 4th band is the tolerance and the 5th the temperature coefficient.

3.2.12 Capacitors

A capacitor or condenser is a passive electronic component consisting of a pair of conductors separated by a dielectric. When a voltage potential difference exists between the conductors, an electric field is present in the dielectric. This field stores energy and produces a mechanical force between the plates. The effect is greatest between wide, flat, parallel, narrowly separated conductors.

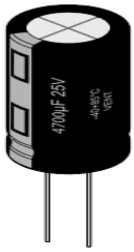


Fig: 3.2.12.1 Capacitor

An ideal capacitor is characterized by a single constant value, capacitance, which is measured in farads. This is the ratio of the electric charge on each conductor to the potential difference between them. In practice, the dielectric between the plates passes a small amount of leakage current. The conductors and leads introduce an equivalent series resistance and the dielectric has an electric field strength limit resulting in a breakdown voltage.

The properties of capacitors in a circuit may determine the resonant frequency and quality factor of a resonant circuit, power dissipation and operating frequency in a digital logic circuit, energy capacity in a high-power system, and many other important aspects.

A capacitor is a passiveelectronic component consisting of a pair of conductors separated by a dielectric (insulator). When there is a potential difference (voltage) across the conductors, a static electric field develops in the dielectric that stores energy and produces a mechanical force between the conductors. An ideal capacitor is characterized by a single constant value, capacitance, measured in farads. This is the ratio of the electric charge on each conductor to the potential difference between them.

The capacitance is greatest when there is a narrow separation between large areas of conductor; hence capacitor conductors are often called "plates", referring to an early means of construction. In practice the dielectric between the plates passes a small amount of leakage current and also has an electric field strength limit, resulting in a breakdown voltage, while the conductors and leads introduce an undesired inductance and resistance.

In October 1745, Ewald Georg von Kleist of Pomerania in Germany found that charge could be stored by connecting a high voltage electrostatic generator by a wire to a volume of water in a hand-held glass jar. Von Kleist's hand and the water acted as conductors and the jar as a dielectric (although details of the mechanism were incorrectly identified at the time). Von Kleist found, after removing the generator that touching the wire resulted in a painful spark. In a letter describing the experiment, he said "I would not take a second shock for the kingdom of France." The following year, the Dutch physicist Pieter van Musschenbroek invented a similar capacitor, which was named the Leyden jar, after the University of Leiden where he worked.

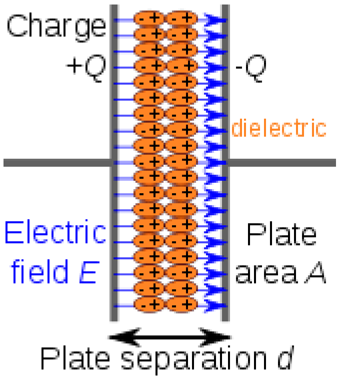
Daniel Gralath was the first to combine several jars in parallel into a "battery" to increase the charge storage capacity. Benjamin Franklin investigated the Leyden jar and "proved" that the charge was stored on the glass, not in the water as others had assumed. He also adopted the term "battery", (denoting the increasing of power with a row of similar units as in a battery of cannon), subsequently applied to clusters of electrochemical cells. Leyden jars were later made by coating the inside and outside of jars with metal foil, leaving a space at the mouth to prevent arcing between the foils.[citation needed] The earliest unit of capacitance was the 'jar', equivalent to about 1 nanofarad.[citation needed]

Leyden jars or more powerful devices employing flat glass plates alternating with foil conductors were used exclusively up until about 1900, when the invention of wireless (radio) created a demand for standard capacitors, and the steady move to higher frequencies required capacitors with lower inductance. A more compact construction began to be used of a flexible dielectric sheet such as oiled paper sandwiched between sheets of metal foil, rolled or folded into a small package.

Early capacitors were also known as condensers, a term that is still occasionally used today. The term was first used for this purpose by Alessandro Volta in 1782, with reference to the device's ability to store a higher density of electric charge than a normal isolated conductor.[7]

3.2.12.1 Theory of Operation

CapacitanceCharge separation in a parallel-plate capacitor causes an internal electric field. A dielectric (orange) educes the field and increases the capacitance.



3.2.12.1.1 Capacitor showing with charges

A capacitor consists of two conductors separated by a non-conductive region. The non-conductive region is called the dielectric or sometimes the dielectric medium. In simpler terms, the dielectric is just an electrical insulator. Examples of dielectric mediums are glass, air, paper, vacuum, and even a semiconductordepletion region chemically identical to the conductors. A capacitor is assumed to be self-contained and isolated, with no net electric charge and no influence from any external electric field. The conductors thus hold equal and opposite charges on their facing surfaces, and the dielectric develops an electric field. In SI units, a capacitance of one farad means that one coulomb of charge on each conductor causes a voltage of one volt across the device.

The capacitor is a reasonably general model for electric fields within electric circuits. An ideal capacitor is wholly characterized by a constant capacitance C, defined as the ratio of charge ±Q on each conductor to the voltage V between them:

$$C = \frac{Q}{V}$$

Sometimes charge build-up affects the capacitor mechanically, causing its capacitance to vary. In this case, capacitance is defined in terms of incremental changes: $C = \frac{dq}{dv}$

3.2.12.2 Energy Storage

Work must be done by an external influence to "move" charge between the conductors in a capacitor. When the external influence is removed the charge separation persists in the electric field and energy is stored to be released when the charge is allowed to return to its equilibrium position. The work done in establishing the electric field, and hence the amount of energy stored, is given by:

$$W = \int_{q=0}^{Q} V dq = \int_{q=0}^{Q} \frac{q}{C} dq = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}VQ$$

Current-voltage relation:

The current i(t) through any component in an electric circuit is defined as the rate of flow of a charge q(t) passing through it, but actual charges, electrons, cannot pass through the dielectric layer of a capacitor, rather an electron accumulates on the negative plate for each one that leaves the positive plate, resulting in an electron depletion and consequent positive charge on one electrode that is equal and opposite to the accumulated negative charge on the other. Thus the charge on the electrodes is equal to the integral of the current as well as proportional to the voltage as discussed above. As with any anti-derivative, a constant of integration is added to represent the initial voltage v (t_0). This is the integral form of the capacitor equation,

$$v(t) = \frac{q(t)}{C} = \frac{1}{C}\int_{t0}^{t} i(T)dT + v(t0)$$

Taking the derivative of this, and multiplying by C, yields the derivative form,

$$i(t) = \frac{dq(t)}{dt} = C\frac{dv(t)}{dt}$$

The dual of the capacitor is the inductor, which stores energy in the magnetic field rather than the electric field. Its current-voltage relation is obtained by exchanging current and voltage in the capacitor equations and replacing C with the inductance L.

3.2.13 Diode IN4007

Diodes are used to convert AC into DC these are used as half wave rectifier or full wave rectifier. Three points must he kept in mind while using any type of diode.

1. Maximum forward current capacity
2. Maximum reverse voltage capacity
3. Maximum forward voltage capacity

The number and voltage capacity of some of the important diodes available in the market are as follows:

- Diodes of number IN4001, IN4002, IN4003, IN4004, IN4005, IN4006 and IN4007 have maximum reverse bias voltage capacity of 50V and maximum forward current capacity of 1 Amp.

- Diode of same capacities can be used in place of one another. Besides this diode of more capacity can be used in place of diode of low capacity but diode of low capacity cannot be used in place of diode of high capacity. For example, in place of IN4002; IN4001 or IN4007 can be used but IN4001 or IN4002 cannot be used in place of IN4007.The diode BY125made by company BEL is equivalent of diode from IN4001 to IN4003. BY 126 is equivalent to diodes IN4004 to 4006 and BY 127 is equivalent to diode IN4007.

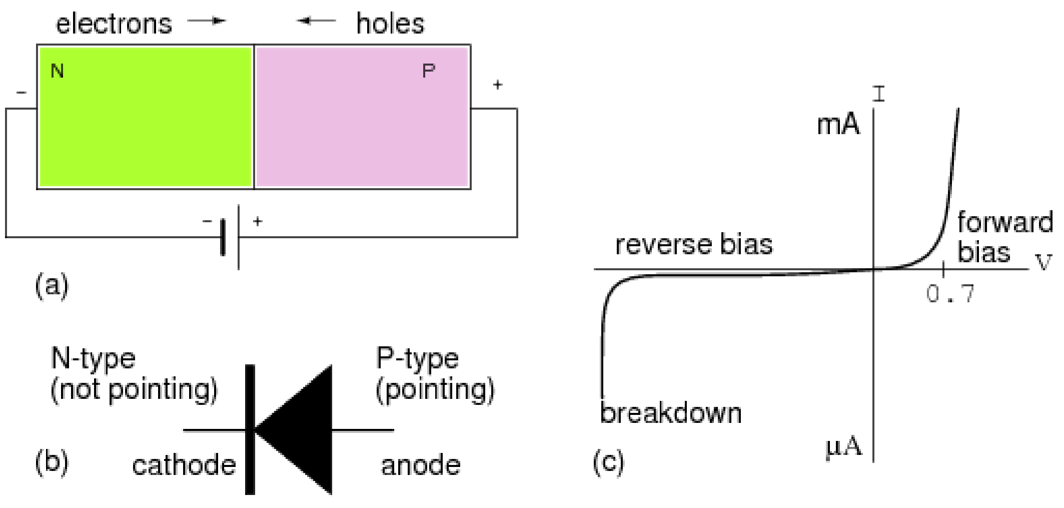


Fig: 3.2.13.1PN Junction diode

Fig: 3.2.13.2 Diodes

3.2.13.1 PN Junction Operation

Now that you are familiar with P- and N-type materials, how these materials are joined together toform a diode, and the function of the diode, let us continue our discussion with the operation of the PNjunction. But before we can understand how the PN junction works, we must first consider current flow inthe materials that make up the junction and what happens initially within the junction when these twomaterials are joined together.

Current Flow in the N-Type Material:

Conduction in the N-type semiconductor, or crystal, is similar to conduction in a copper wire. That is, with voltage applied across the material, electrons will move through the crystal just as current wouldflow in a copper wire. This is shown in figure 1-15. The positive potential of the battery will attract thefree electrons in the crystal. These electrons will leave the crystal and flow into the positive terminal ofthe battery. As an electron leaves the crystal, an electron from the negative terminal of the battery willenter the crystal, thus completing the current path. Therefore, the majority current carriers in the N-typematerial (electrons) are repelled by the negative side of the battery and move through the crystal towardthe positive side of the battery.

Current Flow in the P-Type Material:

Current flow through the P-type material is illustrated. Conduction in the P material isby positive holes, instead of negative electrons. A hole moves from the positive terminal of the P materialto the negative terminal. Electrons from the external circuit enter the negative terminal of the material andfill holes in the vicinity of this terminal. At the positive terminal, electrons are removed from the covalentbonds, thus creating new holes. This process continues as the steady stream of holes (hole current) movestoward the negative terminal.

3.2.14 Transistor

Fig: 3.2.14.1Transistor

A transistor is a semiconductor device commonly used to amplify or switch electronic signals. A transistor is made of a solid piece of a semiconductor material, with at least three terminals for connection to an external circuit. A voltage or current applied to onepair of the transistor's terminals changes the current flowing through another pair of terminals. Because the controlled (output) power can be much more than the controlling (input) power, the transistor provides amplification of a signal. Some transistors are packaged individually but most are found in integrated circuits.

3.2.14.1 Usage

The bipolar junction transistor, or BJT, was the most commonly used transistor in the 1960s and 70s. Even after MOSFETs became widely available, the BJT remained the transistor of choice for many analog circuits such as simple amplifiers because of their greater linearity and ease of manufacture. Desirable properties of MOSFETs, such as their utility in low-power devices, usually in the CMOS configuration, allowed them to capture nearly all market share for digital circuits; more recently MOSFETs have captured most analog and power applications aswell, including modern clocked analog circuits, voltage regulators, amplifiers, power transmitters, motor drivers, etc

3.2.14.2Advantages

The key advantages that have allowed transistors to replace their vacuum tube predecessors in most applications are

- Small size and minimal weight, allowing the development of miniaturized electronic devices.
- Highly automated manufacturing processes, resulting in low per-unit cost.
- Lower possible operating voltages, making transistors suitable for small, battery-powered applications.
- No warm-up period for cathode heaters required after power application.
- Lower power dissipation and generally greater energy efficiency.
- Higher reliability and greater physical ruggedness.
- Extremely long life. Some transistorized devices have been in service for more than 30 years.
- Complementary devices available, facilitating the design of complementary-symmetry circuits, something not possible with vacuum tubes.
- Insensitivity to mechanical shock and vibration, thus avoiding the problem of micro phonics in audio applications.

3.2.14.3 Limitations

- Silicon transistors do not operate at voltages higher than about 1,000 volts (SiC devices can beoperated as high as 3,000 volts). In contrast, electron tubes have been developed that can be operated at tens of thousands of volts.
- High power, high frequency operation, such as used in over-the-air television broadcasting, is better achieved in electron tubes due to improved electron mobility in a vacuum.
- On average, a higher degree of amplificationlinearity can be achieved in electron tubes as compared to equivalent solid state devices, a characteristic that may be important in high fidelityaudio reproduction.
- Silicon transistors are much more sensitive than electron tubes to an electromagnetic pulse, such as generated by an atmospheric nuclear explosion.

3.2.14.4Bipolar Junction Transistor

The bipolar junction transistor (BJT) was the first type of transistor to be mass-produced. Bipolar transistors are so named because they conduct by using both majority and minority carriers. The three terminals of the BJT are named emitter, base, and collector. The BJT consists of two p-n junctions: the base–emitter junction and the base–collector junction, separated by a thin region of semiconductor known as the base region (two junction diodes wired together without sharing an intervening semiconducting region will not make a transistor). "The [BJT] is useful in amplifiers because the currents at the emitter and collector are controllable by the relatively small base current. In an NPN transistor operating in the active region, the emitter-base junction is forward biased (electrons and holes recombine at the junction), and electrons are injected into the base region. Because the base is narrow, most of these electrons will diffuse into the reverse-biased (electrons and holes are formed at, and move away from the junction) base-collector junction and be swept into the collector; perhaps one-hundredth of the electrons will recombine in the base, which is the dominant mechanism in the base current. By controlling the number of electrons that can leave the base, the number of electrons entering the collector can be controlled. Collector current is approximately β (common-emitter current gain) times the base current. It is typically greater than 100 for small-signal transistors but can be smaller in transistors designed for high-power applications.

Unlike the FET, the BJT is a low–input-impedance device. Also, as the base–emitter voltage (V_{be}) isincreased the base–emitter current and hence the collector–emitter current (I_{ce}) increase exponentiallyaccording to the Shockley diode model and the Ebers-Moll model. Because of this exponentialrelationship, the BJT has a higher trans conductance than the FET.

Bipolar transistors can be made to conduct by exposure to light, since absorption of photons in the base region generates a photocurrent that acts as a base current; the collector current is approximately β times the photocurrent. Devices designed for this purpose have a transparent window in the package and are called phototransistors.

4. WORKING AND ITS OPERATION

4.1 Power Supply

The circuit uses standard power supply comprising of a step-down transformer from 230Vto 12V and 4 diodes forming a Bridge Rectifier that delivers pulsating dc which is then filtered by an electrolytic capacitor of about 470µF to 1000µF. The filtered dc being unregulated, IC LM7805 is used to get 5V DC constant at its pin no 3 irrespective of input DC varying from 9V to 14V. The input dc shall be varying in the event of input ac at 230volts section varies in the ratio of V1/V2=N1/N2.

The regulated 5V DC is further filtered by a small electrolytic capacitor of 10µF for any noise so generated by the circuit. One LED is connected of this 5V point in series with a resistor of 330Ω to the ground i.e., negative voltage to indicate 5V power supply availability. The 12V point is used for other applications as on when required.

4.2 Motor Driver IC L293D

L293D has 2 set of arrangements where one set has input 1, input 2, output1 and output 2 and other set has input 3, input 4, output 3 and output 4, according to block diagram if pin no 2 & 7 are high then pin no 3 & 6 are also high. In this project only one set is been used.

If enable 1 and pin number 2 are high leaving pin number 7 as low then the motor rotates in forward direction.

If enable 1 and pin number 7 are high leaving pin number 2 as low then the motor rotates in reverse direction.

U4 & U5 are two 555 timers used in monostable mode i.e., pins 6 & 7 of timer are shorted. Pin-22 of timers are connected to switches for triggering. Pin 3 of U4 and U5 are connected to base of transistor Q4 & Q1 to drive the relays RL2 & RL1 respectively. Pin 5 of U4 & U5 is connected to +5V. L293D IC in1 is connected to a slide switch and in2 is connected to a NOT gate output. En pin is controlled by one of the contacts of RL1 relay. Pin-16 & pin-8 of L293D is connected to +12V and +5V resp. Op1 and Op2 of L293D is connected to a DC motor.

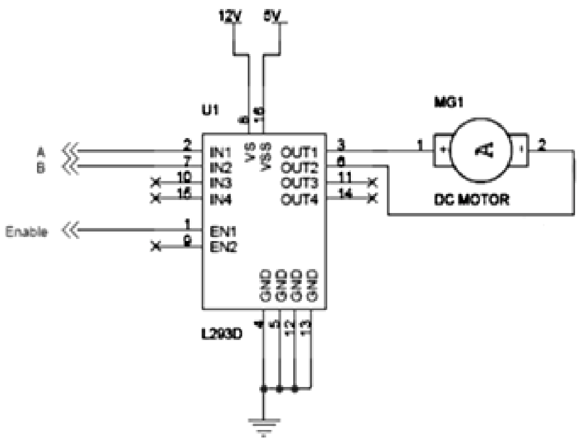


Fig: 4.2.1 Driver L293D circuit

4.3Operation of DC Motor In Four Quadrants

Firstly, the steady-state speed is determined by the applied voltage, so we can make the motorrun at the any desired speed in either direction simply by applying the appropriate magnitude and polarity of the armature voltage. Secondly, the torque is directly proportional to the armature current, which in turn depends on the difference between the applied voltage V and the back e.m.f.E.We can therefore make the machine develop positive (motoring) or negative (generating) torque simply by controlling the extent to which the applied voltage is greater or less than the back e.m.f. An armature voltage controlled d.c. machine is therefore inherently capable of what is known as ‘four-quadrant’ operation, with reference to the numbered quadrants of the torque speed plane. Figure looks straightforward but experience shows that to draw the diagram correctly calls for a clear head, so it is worth spelling out the key points in detail. A proper understanding of this diagram is invaluable as an aid to seeing how controlled-speed drives operate. Firstly, one of the motor terminals is shown with a dot, and in all four quadrants the dot is uppermost. The purpose of this convention is to indicate the sign of the torque: if current flows into the dot, the machine produces positive torque, and if current flows out of the dot, the torque is negative. .Secondly, the supply voltage is shown by the old-fashioned battery symbol, as use of the more modern circle symbol for a voltage source would make it more difficult to differentiate between the source and the circle representing the machine armature. The relative magnitudes of applied voltage and motional e.m.f. are emphasised by the use of two battery cells when $V > E$ and one when $V < E$.

We have seen that in a d.c. machine speed is determined by applied voltage and torque is determined by current. Hence on the right-hand side of the diagram the supply voltage is positive (upwards), while on the left-hand side the supply voltage is negative (downwards). And in the upper half of the diagram current is positive (into the dot),

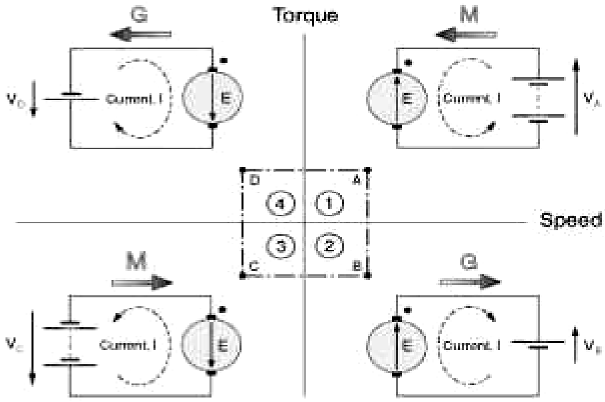


Fig: 4.3.1Four quadrants of motor

while in the lower half it is negative (out of the dot). For the sake of convenience, each of the four operating conditions (A, B, C, D) has the same magnitude of speed and the same magnitude of torque: these translate to equal magnitudes of motional e.m.f. and current for each condition. When the machine is operating as a motor and running in the forward direction, it is operating in quadrant 1. The applied voltage VA is positive and greater than the back e.m.f. E, and positive current therefore flows into the motor: in Figure 3.16, the arrow representing VA has accordingly been drawn larger than E. The power drawn from the supply (VAI) is positive in this quadrant, as shown by the shaded arrow labelled M to represent motoring. The power converted to mechanical form is given by EI, and an amount I2R is lost as heat in the armature. If E is much greater than IR (which is true in all but small motors), most of the input power is converted to mechanical power is efficient.If, with the motor running at position A, we suddenly reduce the supply voltage to a value VB which is less than the back e.m.f., the current (and hence torque) will reverse direction, shifting the operating point to B in Figure 3.16. There can be no sudden change in speed, so the e.m.f. will remain the same. If the new voltage is chosen so that E — VB = VA — E, the new current will have the same amplitude as at position A, so the new (negative) torque will be the same as the original positive torque, as shown in Figure 3.16. But now power is supplied from the machine to the supply, i.e. the machine is acting as a generator as shown in the shaded region. We should be quite clear that all that was necessary to accomplish this remarkable reversal of power flow was a modest reduction of the voltage applied to the machine. At position A, the applied voltage was E + IR, while at position B it is E-IR. Since IR will be small compared with E, the change (2IR) is also small. Needless to say the motor will not remain at point B if left to its own devices. The combined effect of the load torque and the negative machine torque will cause the speed to fall, so that the back e.m.f. again falls below the applied voltage VB, the current and torque become positive again, and the motor settles back into quadrant 1, at a lower speed corresponding to the new (lower) supply voltage. During the deceleration phase, kinetic energy from the motor and load inertia is returned to the supply. This is therefore an example of regenerative braking, and it occurs naturally every time we reduce the voltage in order to lower the speed. If we want to operate continuously at position B, the machine will have to be driven by a mechanical source. We have seen above that the natural tendency of the machine is to run at a lower speed than that corresponding to point B, so we must force it to run faster, and create an e.m.f greater than VB, if we wish it to generatecontinuously.It should be obvious that similar arguments to those set out above apply when the motor is running in reverse (i.e. V is negative). Motoring then takes place in quadrant 3 (point C), with brief excursions into quadrant 4 (point D, accompanied by regenerative braking), whenever the voltage is reduced in order to lower the speed.

4.4 Working

The circuit uses an H-Bridge motor driver IC L293D to drive a small DC motor of 12V from its output. The input control is provided by low high logic in combination with an inverter from 7404 U1: D as per the forward and reverse movement selected by the switch sw1. The enable pin of the input 1 & 2 of L293D is controlled with low/high logic while in forward direction and reverse direction by one of the 2 of contacts of each relay-1 & relay-2 being driven by Q1 & Q4 being fed from two independent timers comprising of 555 IC in monostable mode the time period of which are independently adjusted by RV1 and RV2. The other 1 contact of 2 relays of each contacts are used for latching enable pin to ground through Q2 after a while as decided by the monostable while operation like forward brake or reverse brake switches are pressed. The latching circuit comprises of Q3 & Q5 while logic high is placed upon R6. The push button used for forward bake and reverse brake triggers the monostable to develop a logic high to drive the relays as explained before. Simultaneously two inverters used from IC 7404 U1: A & U1: B develop logic high which are ANDed by D1 & D2 to drive the latching circuit. Thus, while in running condition the motor in one direction gets a reverse supply for a brief period so decided by the monostable timer while any of the brake switches is pressed. This reverse voltage brings the rotating motor to an instantaneous stop.

5. HARDWARE TESTING

5.1 Continuity Test

In electronics, a continuity test is the checking of an electric circuit to see if current flows (that it is in fact a complete circuit). A continuity test is performed by placing a small voltage (wired in series with an LED or noise-producing component such as a piezoelectric speaker) across the chosen path. If electron flow is inhibited by broken conductors, damaged components, or excessive resistance, the circuit is "open".

Devices that can be used to perform continuity tests include multi meters which measure current and specialized continuity testers which are cheaper, more basic devices, generally with a simple light bulb that lights up when current flows.

An important application is the continuity test of a bundle of wires so as to find the two ends belonging to a particular one of these wires; there will be a negligible resistance between the "right" ends, and only between the "right" ends.

This test is the performed just after the hardware soldering and configuration has been completed. This test aims at finding any electrical open paths in the circuit after the soldering. Many a times, the electrical continuity in the circuit is lost due to improper soldering, wrong and rough handling of the PCB, improper usage of the soldering iron, component failures and presence of bugs in the circuit diagram. We use a multi meter to perform this test. We keep the multi meter in buzzer mode and connect the ground terminal of the multi meter to the ground. We connect both the terminals across the path that needs to be checked. If there is continuation then you will hear the beep sound.

5.2 Power On Test

This test is performed to check whether the voltage at different terminals is according to the requirement or not. We take a multi meter and put it in voltage mode. Remember that this test is performed without ICs. Firstly, if we are using a transformer we check the output of the transformer; whether we get the required 12V AC voltage (depends on the transformer used in for the circuit). If we use a battery then we check if the battery is fully charged or not according to the specified voltage of the battery by using multimeter.

Then we apply this voltage to the power supply circuit. Note that we do this test without ICs because if there is any excessive voltage, this may lead to damaging the ICs. If a circuit consists of voltage regulator then we check for the input to the voltage regulator (like 7805, 7809, 7815, 7812, 7915 etc) i.e., are we getting an input of 12V and a required output depending on the regulator used in the circuit.

EX: if we are using 7805 we get output of 5V and if using 7809 we get 9V at output pin and so on.

This output from the voltage regulator is given to the power supply pin of specific ICs. Hence we check for the voltage level at those pins whether we are getting required voltage. Similarly, we check for the other terminals for the required voltage. In this way we can assure that the voltage at all the terminals is as per the requirement.

6. LAYOUT DIAGRAM

6.1 Layout Diagram

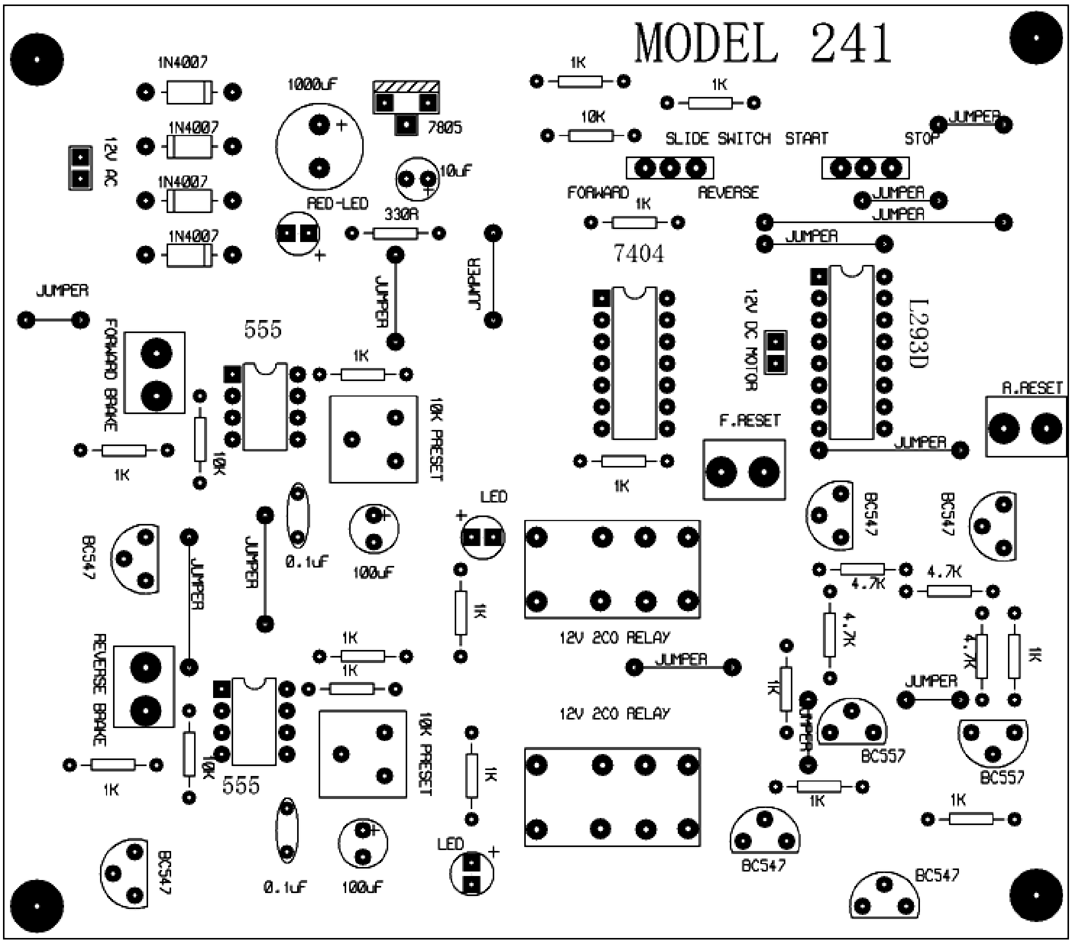


Fig: 6.1.1 Layout diagram

7. RESULTS AND ITS DISCUSSION

When the supply is given to the kit the motor runs in the direction based on the input given to it. And the input is given through the switch.

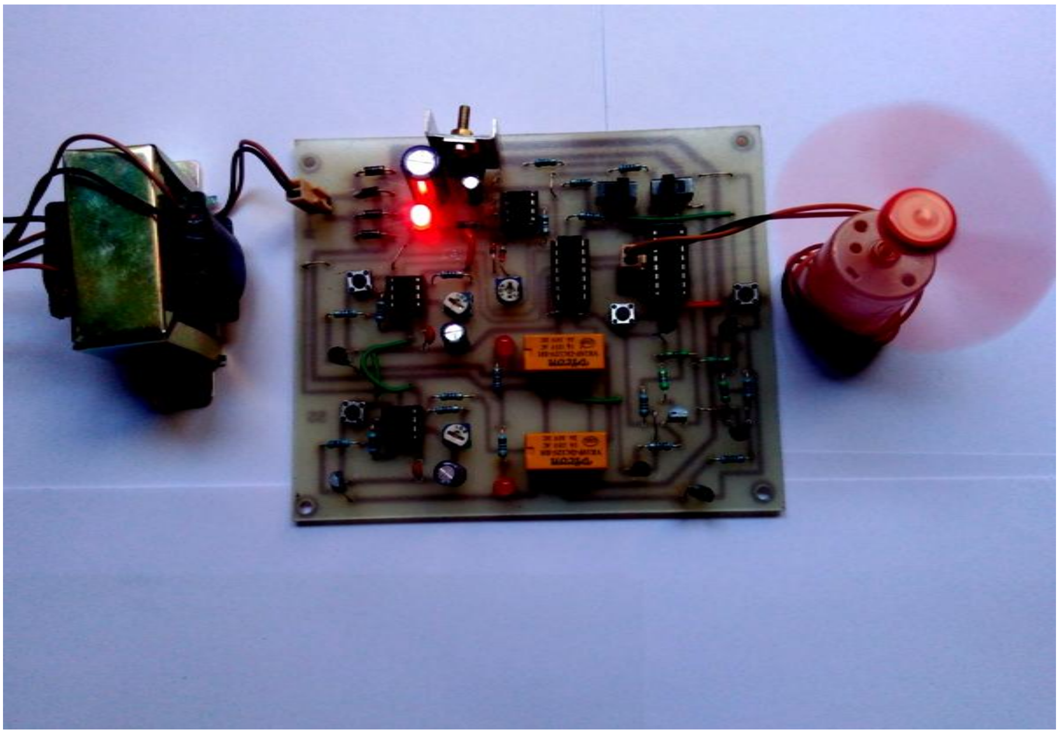


Fig: 7.1 Output of the circuit

Let us say, the motor is running in the forward direction and forward break is applied to it. The motor stops running and the LED glows as shown in the figure.

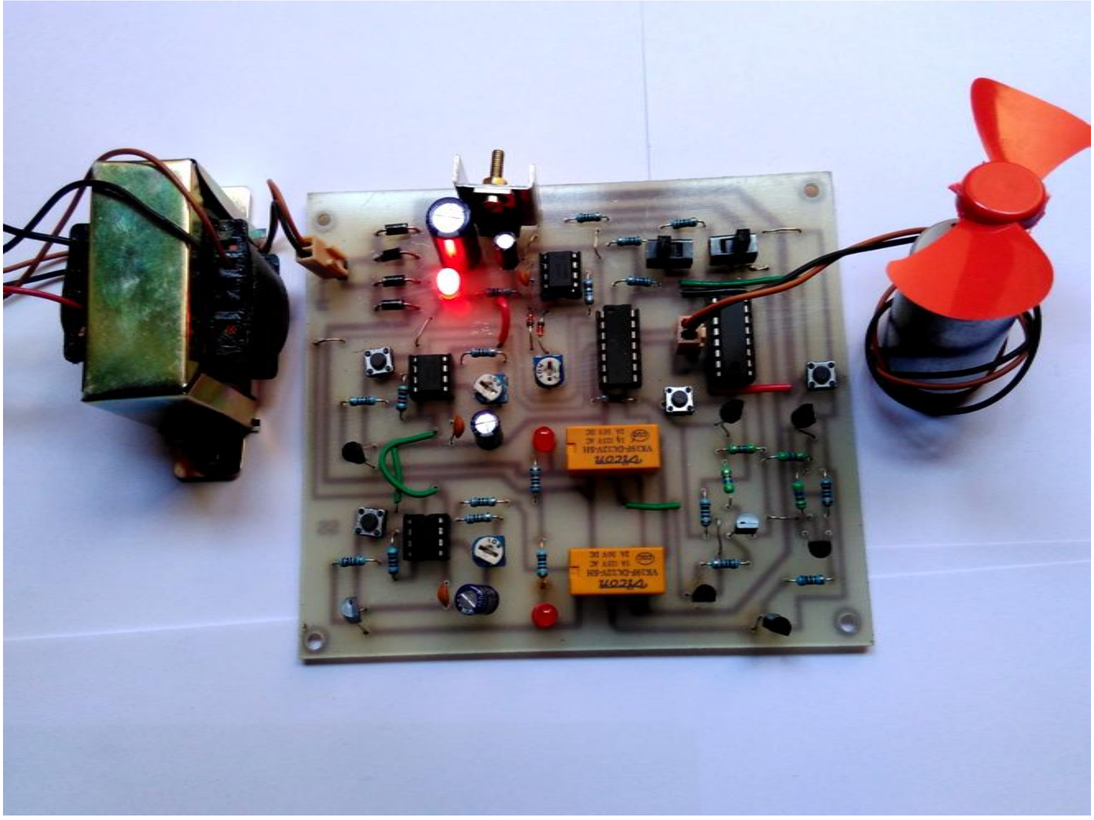


Fig: 7.2 Output of a motor when brake is applied

And again if the preset button is pressed it starts running in its forward direction.Similarly, if the motor is said to run in the backward direction, and if the break is applied to it motor stops running instantaneously and LED glows. And if the preset button is pressed, the motor is said to run in its backward position.

8. CONCLUSION AND FUTURE SCOPE

8.1 Conclusion

This project controls the speed of a DC motor in alternative directions using speed control unit and to operate the motor in four quadrants: i.e., clockwise, counter clock-wise, forward brake and reverse brake.

The four-quadrant control of the DC motor is archived by the varying duty cycles from a 555 timer and their changing polarity with the H-bridge IC by appropriate switch pressing. The alternative speed control feature is achieved by a slide switch operation.

8.2 Future Scope

This project infuture can be improved by using higher-power electronic devices to operate high- capacity DC motors. Regenerative braking for optimizing the power consumption can also be incorporated.

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