ULTRA-FAST ELECTRONIC CIRCUIT BREAKER

Report submitted

in

Partial fulfillment of

requirement for the award of

degree of

Bachelor of Engineering In Electrical Engineering

Submitted by

KHAN MOHAMMED OMAIR MOHIUDDIN

ANSARI MOHAMMED ZEESHAN

MOMIN MOHD HUZAIFA MOHAMMED DAWOOD

AKARSH AKHILESH GEETA

Under The Guidance Of

PROF. TAHOORA QURESHI

Department of Electrical Engineering

Anjuman-I-Islam's Kalsekar Technical Campus, Panvel

Mumbai University, Mumbai

2020-21

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CERTIFICATE

This is to certify that the dissertation titled "**ULTRA-FAST ELECTRONIC CIRCUIT BREAKER**", which is being submitted herewith for the award of the, **'Bachlor of Engineering'** in **Electrical Engineering** of Anjuman-I-Islam's Kalsekar Technical Campus, New Panvel (M.S., India). This is the result of the original research work and contribution by

Mr. KHAN MOHAMMED OMAIR MOHIUDDIN
Mr. ANSARI MOHAMMED ZEESHAN
Mr.MOMIN MOHD HUZAIFA
Mr.AKARSH AKHILESH GEETA

under my supervision and guidance. The work embodied in this dissertation has not formed earlier for the basis of award of any degree or compatible certificate or similar title of this for any other diploma/examining body or university to the best of knowledge and belief.

Place: Panvel
Date:18/06/2021

PROF.TAHOORA QURESHI
Guide

PROF. KALEEM SYED
H.O.D.

Mr.ABDUR RAZZAK HONNUTAGI
(DIRECTOR)

DECLARATION

I hereby declare that I have formed, completed and written the dissertation entitled "**ULTRA-FAST ELECTRONIC CIRCUIT BREAKER**". It has not previously submitted for the basis of the award of any degree or diploma or either similar title of this for any other diploma/examining body/university.

PLACE: PANVEL
DATE: 18/06/2021

KHAN MOHAMMED OMAIR MOHIUDDIN
MOMIN MOHD HUZAIFA MOHAMMED DAWOOD
AKARSH AKHILESH GEETA
ANSARI MOHAMMED ZEESHAN

PREFACE

We take an opportunity to present this project report on "ultra-fast Electronic Circuit Breaker" and put before readers some useful information regarding our project.

We have made sincere attempts and taken every care to present this matter in precise and compact form, the language being as simple as possible.

We are sure that the information contained in this volume would certainly prove useful for the better insight in the scope and dimension of this project in its true perspective.

The task of completion of the project though being difficult was quite simple, interesting and successful due to deep involvement of our group members.

ACKNOWLEGEMENT

It is indeed a matter of great pleasure and proud privilege to be able to present this project on “Ultra-fast Electronic Circuit Breaker”.

The completion of the project work is a millstone in student life and its execution is inevitable in the hands of guide. We are highly indebted the project guide.

Ms. TAHOORA QURESHI for her invaluable guidance and appreciation for giving form and substance to this report. It is due to her enduring efforts; patience and enthusiasm, which has given a sense of direction and purpose fullness to this project and ultimately made it a success.

ANJUMAN ISLAM KALSHEKAR TECHNICAL CAMPUS, PANVEL-8

ELECTRICAL ENGINEERING (2020-21)

Report on:

ULTRA FAST Electronic Circuit Breaker

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1. ABSTRACT

The outline of the project is to shut down the power supply when it is overloaded. Conventional circuit breaker is based on thermal bimetal lever trip mechanism, which is very slow and the trip time is dependent upon the percentage of overload.

Electronic circuit breaker is based on the voltage drop across a series element typically a low value resistor or a CT (current Transformer). The voltage sensed is compared against the preset voltage proportional to the current by a level comparator to generate an output for the Relay or contactor to trip the load. The unit is extremely fast and overcomes the drawback of the thermal type.

2. INTRODUCTION

In this project electrical system can be protected from the over load condition. Industrial instruments or home appliances failures have many causes and one of the main causes is over load. The primary of the distribution transformer or any other transformer is designed to operate at certain specific current, if that current flowing through that instrument is more than the rated current, then immediately the System may burn because of over load, through this project we are going to protect the system from over load condition.

In this project work for generating high current or over load current more loads are applied to the circuit; so that the current will be increased. Whenever the over current is drawn by load the circuit willbe tripped. To trip the circuit we are using one relay which will be controlled through IC LM324.

When overload occurred the relay will trip the total circuit. For protection from over current condition first we have to measure the total load current. Here we are using CT for measuring the load current and the output of CT is given to transistor. When current increases behind certain limit then we are going to trip the load by using relay. In this project we are using 12v DC bulbs as a load. We are going to increase the load by increasing the number of bulbs ON. When we ON more bulbs it causes over load condition and microcontroller will detect that and it will trip the total load by using relay through TRANSISTOR which acts as switching circuit.

3. LITERATURE REVIEW

The history of power electronics is very much connected to the development of switching devices and it emerged as a separate discipline when high-power and MOSFET devices were introduced in the 1960s and 1970s. Since then, the introduction of new devices has been accompanied by dramatic improvement in power rating and switching performance. Because of their functional importance, drive complexity, fragility, and cost, the power electronic design engineer must be equipped with a thorough understanding of the device operation, limitation, drawbacks, and related reliability and efficiency issues. In the 1980s, the development of power semiconductor devices took an important turn when new process technology was developed that allowed integration of MOS and bipolar junction transistor (BJT) technologies on the same chip. Thus far, devices using this new technology have been introduced: insulated bipolar transition (IGBT) and MOS controlled thyristor (MCT). Many integrated circuit(IC) processing methods as well as equipment have been adapted for the development of power devices. However, unlike microelectronic ICs, which process information, power device ICs process power and so their packaging and processing techniques are quite different. Power semiconductor devices represent the heart of modern power electronics, with two major desirable characteristics of power semiconductor devices guiding their development:

1. Switching speed (turn-on and turn-off times)

2. Power handling capabilities (voltage blocking & current carrying capabilities)

Improvements in both semiconductor processing technology and manufacturing and packaging techniques have allowed power semiconductor development for high-voltage and high current ratings and fast turn-on and turn-off characteristics. Today switching devices are manufactured with amazing power handling capabilities and switching speeds as will be shown later. The availability of different

devices with different switching speeds, power handling capabilities, size, cost etc., makes it possible to cover many power electronics applications. As a result, trade-offs are made when it comes to selecting power devices.

4. BLOCK DIAGRAM:

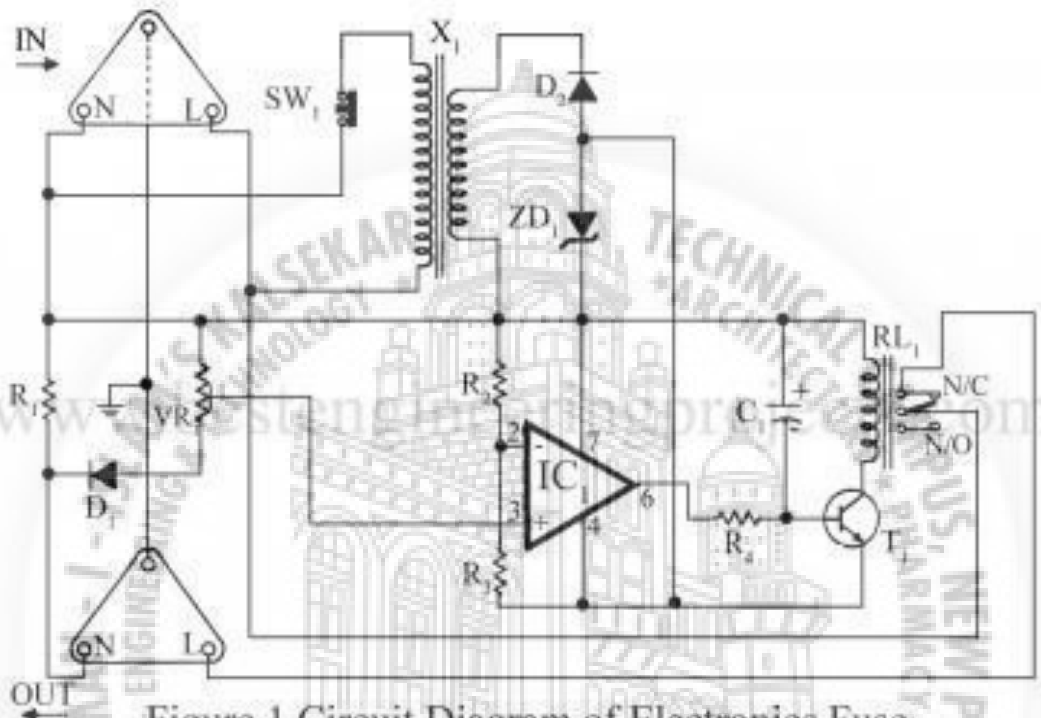


Figure 1 Circuit Diagram of Electronics Fuse

5. HARDWARE REQUIREMENTS

HARDWARE COMPONENTS:

5.1 TRANSFORMER (230 – 12 V AC)

5.2 VOLTAGE REGULATOR (LM 7812)

5.3 RECTIFIER

5.4 FILTER

5.5 RELAY

5.6 LM324

5.7 POT

5.8 LED

5.9 CAPACITORS

5.10 1N4007

5.11 RESISTORS

5.1 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 4.1: A 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 = (Vp / Vs) = (Np / Ns)

Where,

Vp = primary (input)
voltage. Vs = secondary
(output) voltage
Np = number of turns on primary
coil Ns = number of turns on
secondary coil Ip = primary
(input) current
Is = secondary (output) current.

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:

$$P_{\mathrm{incoming}} = I_{\mathrm{p}} V_{\mathrm{p}} = P_{\mathrm{outgoing}} = I_{\mathrm{s}} V_{\mathrm{s}},$$

Giving the ideal transformer equation

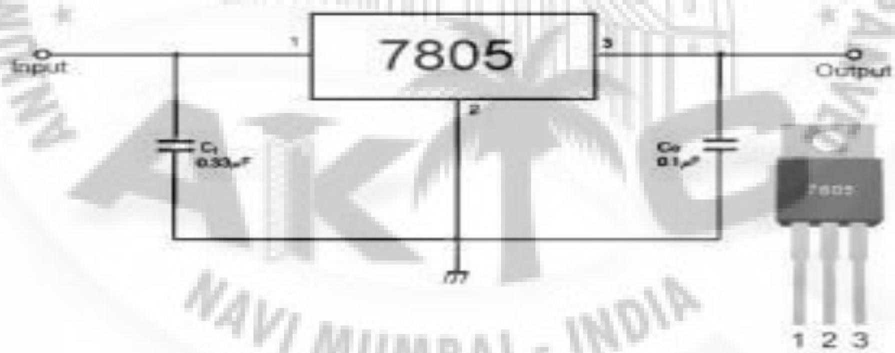
$$\frac{V_{\mathrm{s}}}{V_{\mathrm{p}}} = \frac{N_{\mathrm{s}}}{N_{\mathrm{p}}} = \frac{I_{\mathrm{p}}}{I_{\mathrm{s}}}.$$

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 an impedance Z_s 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 $(N_s/N_p)^2 Z_p$.

5.2 VOLTAGE REGULATOR 7812

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.



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

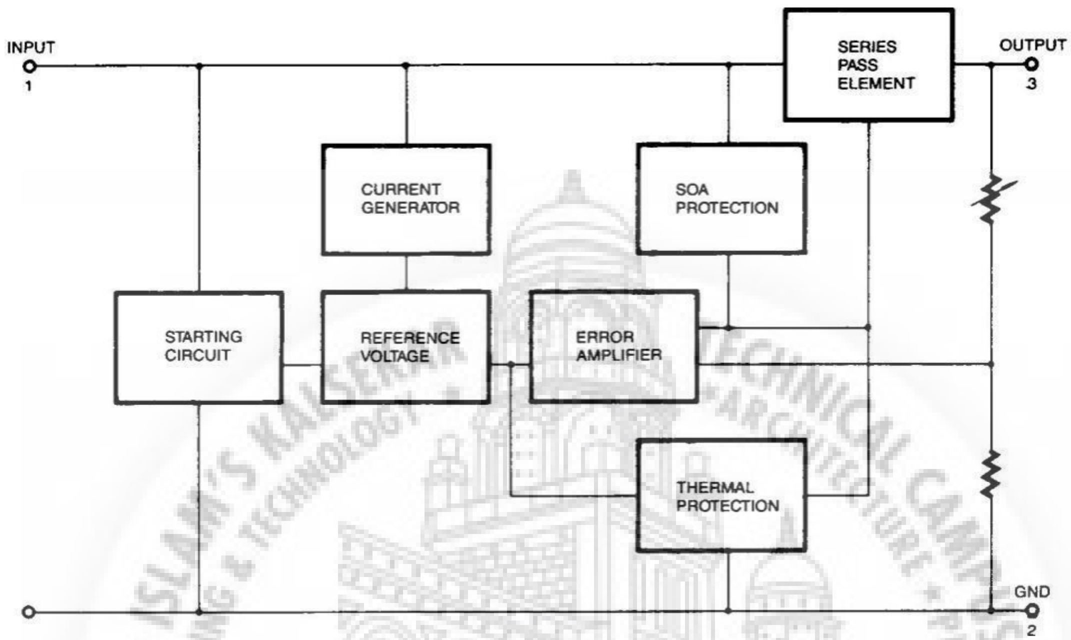


FIG 4.2(a): BLOCK DIAGRAM OF VOLTAGE REGULATOR

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.

Absolute Maximum Ratings:

Parameter	Symbol	Value	Unit
Input Voltage (for V_O = 5V to 18V) (for V_O = 24V)	V_I V_I	35 40	V V
Thermal Resistance Junction-Cases (TO-220)	$R_{\theta JC}$	5	°C/W
Thermal Resistance Junction-Air (TO-220)	$R_{\theta JA}$	65	°C/W
Operating Temperature Range (KA78XX/A/R)	T_{OPR}	0 ~ +125	°C
Storage Temperature Range	T_{STG}	-65 ~ +150	°C

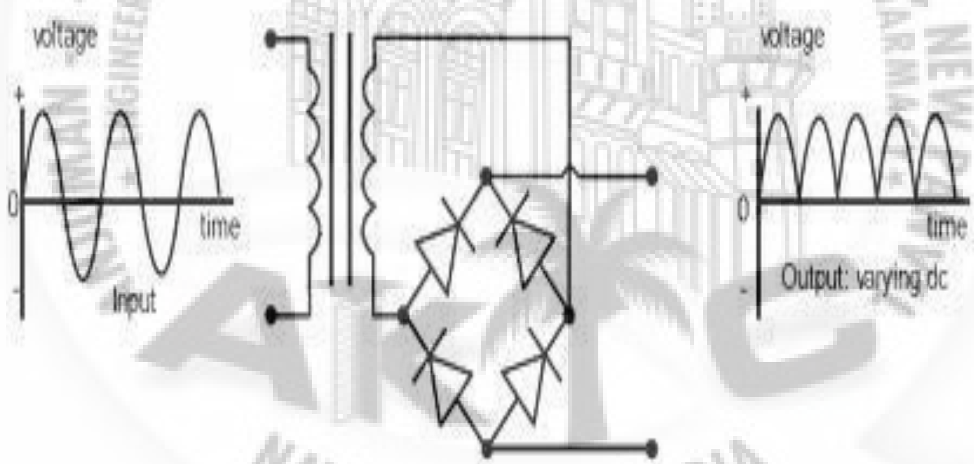
TABLE 4.2(b): RATINGS OF THE VOLTAGE REGULATOR

TABLE 2: TRIP CURRENT SETTING

Voltage across CT In volts	Filtered DC trip current In amps	Full wave DC & AC trip current In amps
2.85	14.25	10.08
2.70	13.50	9.55
2.55	12.75	9.02
2.40	12.00	8.49
2.25	11.25	7.96
2.00	10.00	7.07
1.95	9.75	6.90
1.80	9.00	6.36
1.65	8.25	5.83
1.50	7.50	5.30
1.35	6.75	4.77
1.20	6.00	4.24
1.05	5.25	3.71
0.90	4.50	3.18
0.75	3.75	2.65
0.60	3.00	1.59
0.45	2.25	1.06
0.30	1.50	1.06
0.15	0.75	0.53
0.10	0.50	0.3

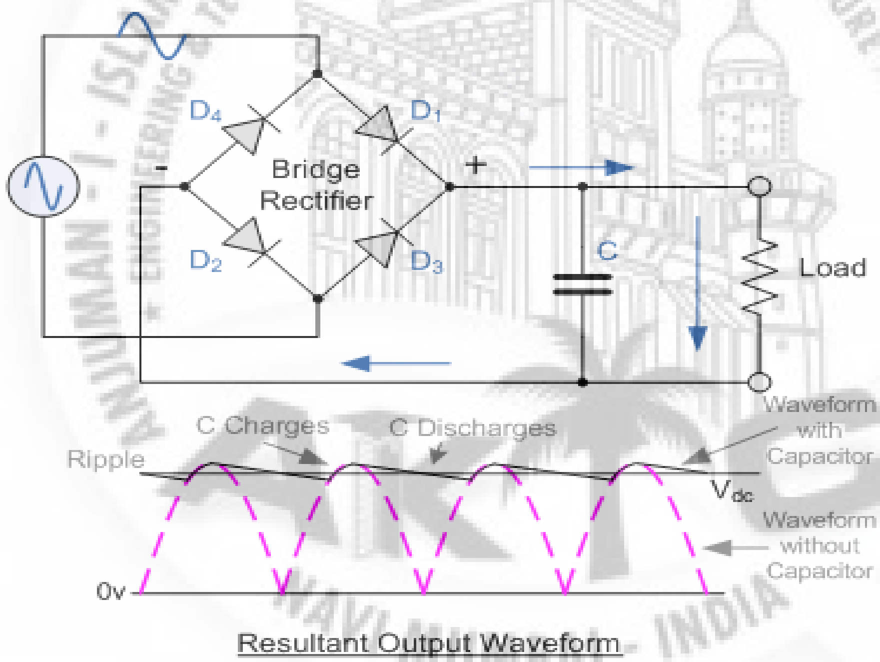
5.3 RECTIFIER

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 state diodes, 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 cycle only 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.



5.4 FILTER

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



5.5 RELAY

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal.



A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and most have double throw (changeover) switch contacts as shown in the diagram.

Relay showing coil and switch contacts

Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits; the link is magnetic and mechanical.

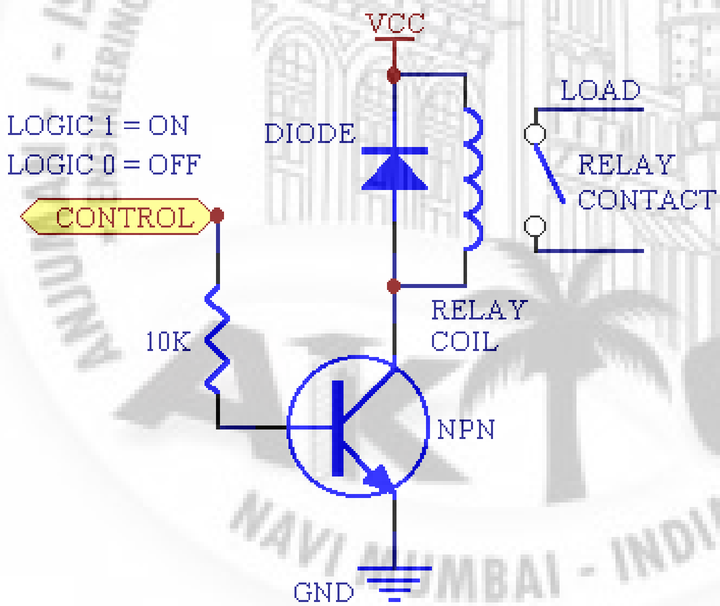
The coil of a relay passes a relatively large current, typically 30mA for a 12V relay, but it can be as much as 100mA for relays designed to operate from lower voltages. Most ICs (chips) cannot provide this current and a transistor is usually used to amplify the small IC current to the larger value required for the relay coil. The maximum output current for the popular 555 timer IC is 200mA so these devices can supply relay coils directly without amplification.

Relays are usually SPDT or DPDT but they can have many more sets of switch contacts, for example relays with 4 sets of changeover contacts are readily available. For further information about switch contacts and the terms used to describe them please see the page on switches.

Most relays are designed for PCB mounting but you can solder wires directly to the pins providing you take care to avoid melting the plastic case of the relay.

The supplier's catalogue should show you the relay's connections. The coil will be obvious and it may be connected either way round. Relay coils produce brief high voltage 'spikes' when they are switched off and this can destroy transistors and ICs in the circuit. To prevent damage you must connect a protection diode across the relay coil.

The figure shows a relay with its coil and switch contacts. You can see a lever on the left being attracted by magnetism when the coil is switched on. This lever moves the switch contacts.



There is one set of contacts (SPDT) in the foreground and another behind them, making the relay DPDT.

The relay's switch connections are usually labelled COM, NC and NO:

APPLICATIONS OF RELAYS

Relays are used to and for:

- Control a high-voltage circuit with a low-voltage signal, as in some types of modems or audio amplifiers.
- Control a high-current circuit with a low-current signal, as in the starter solenoid of an automobile.
- Detect and isolate faults on transmission and distribution lines by opening and closing circuit breakers.
- Time delay functions. Relays can be modified to delay opening or delay closing a set of contacts. A very short delay (a fraction of a second) would use a copper disk between the armature and moving blade assembly.
- Current flowing in the disk maintains magnetic field for a short time, lengthening release time. For a slightly longer (up to a minute) delay, a dashpot is used. A dashpot is a piston filled with fluid that is allowed to escape slowly.
- The time period can be varied by increasing or decreasing the flow rate. For longer time periods, a mechanical clockwork timer is installed.

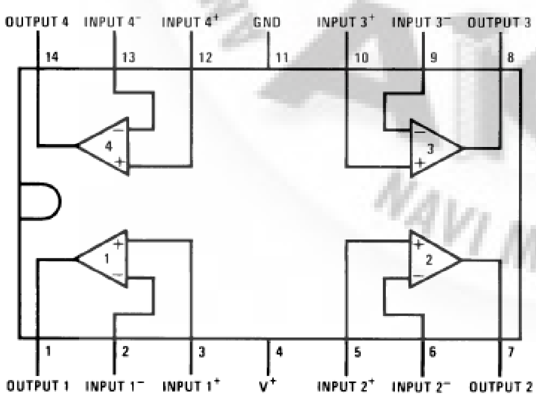
5.6 LM 324

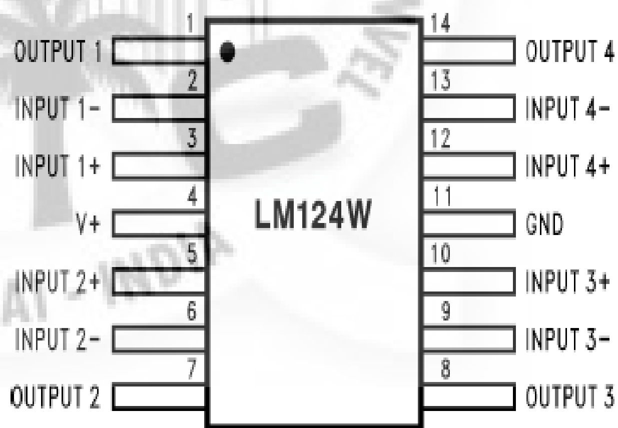
The LM324 series consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, DC gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM324 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

Connection Diagrams:

Dual-In-Line Package





- **Unique Characteristics**

5.6.1 In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage

5.6.2 The unity gain cross frequency is temperature compensated

5.6.3 The input bias current is also temperature compensated

- **Advantages**

5.6.4 Eliminates need for dual supplies

5.6.5 Four internally compensated op amps in a single package

5.6.6 Allows directly sensing near GND and VOUT also goes to GND

5.6.7 Compatible with all forms of logic

5.6.8 Power drain suitable for battery operation

- **Features**

5.6.9 Internally frequency compensated for unity gain

5.6.10 Large DC voltage gain 100 dB

5.6.11 Wide bandwidth (unity gain) 1 MHz (temperature compensated)

5.6.12 Wide power supply range: Single supply 3V to 32V or dual supplies ±1.5V to ±16V

5.6.13 Very low supply current drain (700 μA)—essentially independent of supply voltage

5.6.14 Low input biasing current 45 nA (temperature compensated)

5.6.15 Low input offset voltage 2 mV and offset current: 5 Na

5.6.16 Input common-mode voltage range includes ground

5.6.17 Differential input voltage range equal to the power supply voltage

5.6.18 Large output voltage swing 0V to V+ − 1.5V

5.7 1N4007

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

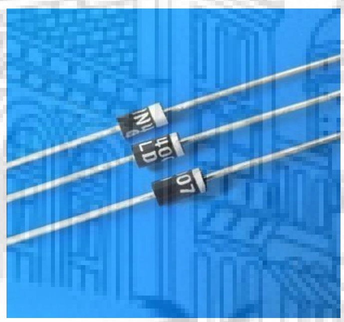


Fig: 1N4007 diodes

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

5.7.1.1 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.

5.7.1.2 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 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.

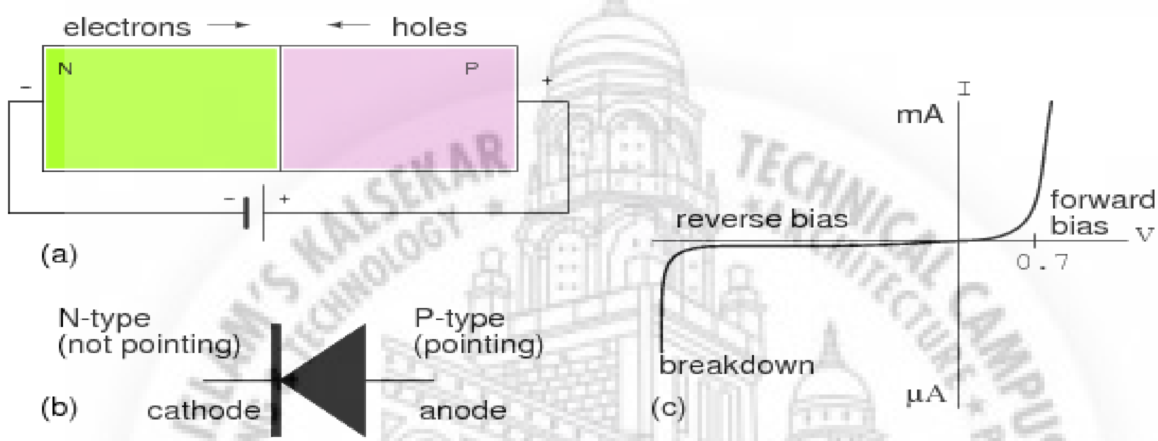


Fig:PN Junction diode

- **PN JUNCTION OPERATION**

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

- **<u>Current Flow in the N-Type Material</u>**

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 would flow in a copper wire. This is shown in figure 1-15. The positive potential of the battery will attract the free electrons in the crystal. These electrons will leave the crystal and flow into the positive terminal of the battery. As an electron leaves the crystal, an electron from the negative terminal of the battery will enter the crystal, thus completing the current path. Therefore, the majority current carriers in the N-type material (electrons) are repelled by the negative side of the battery and move through the crystal toward the positive side of the battery.

- **<u>Current Flow in the P-Type Material</u>**

Current flow through the P-type material is illustrated. Conduction in the P material is by positive holes, instead of negative electrons. A hole moves from the positive terminal of the P material to the negative terminal. Electrons from the external circuit enter the negative terminal of the material and fill holes in the vicinity of this terminal. At the positive terminal, electrons are removed from the covalent bonds, thus creating new holes. This process continues as the steady stream of holes (hole current) moves toward the negative terminal

5.8 LEDS

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.

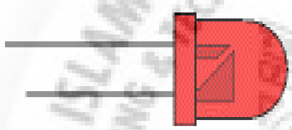


Fig 4.14(a): Typical LED

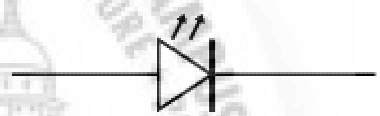


Fig 4.14(b): symbol

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.

- **Types of LED**

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.

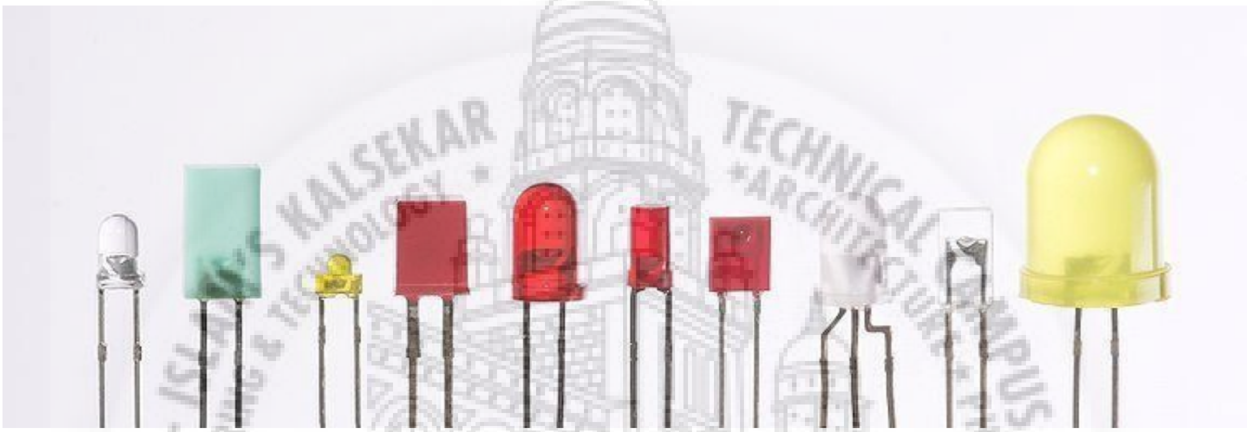
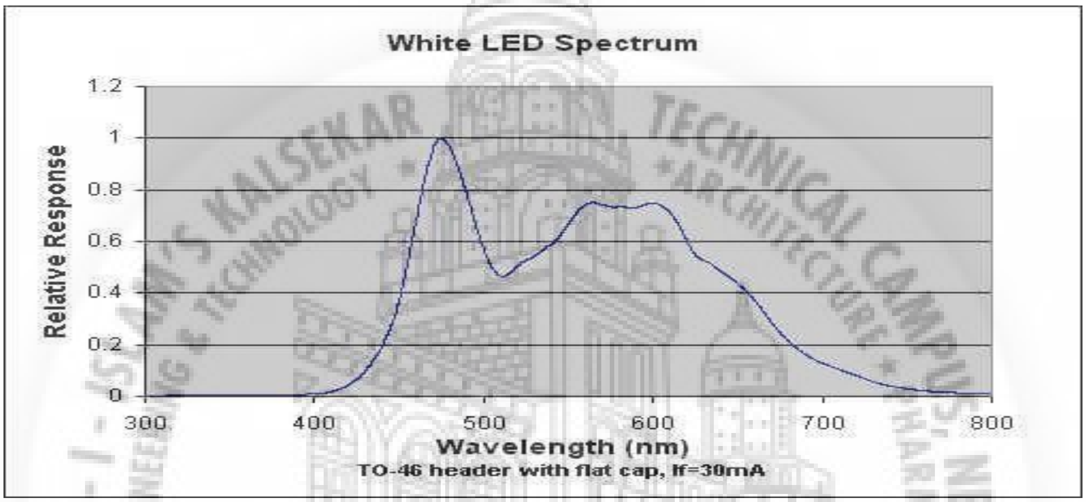


Fig 4.14(c) Different types of LED'S

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 a single 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.

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.

5.9 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).

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 equipment designers; resistors must be physically large enough not to overheat when dissipating their power.

A resistor is a two-terminal passive electronic 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:

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

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 analogue 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 behavior 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.

Units

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.

- **VARIABLE RESISTORS**

Adjustable resistors

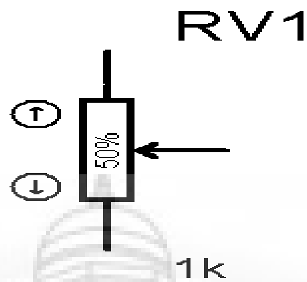
A resistor may have one or more fixed tapping points so that the resistance can be changed by moving the connecting wires to different terminals. Some wire wound power resistors have a tapping point that can slide along the resistance element, allowing a larger or smaller part of the resistance to be used.

Where continuous adjustment of the resistance value during operation of equipment is required, the sliding resistance tap can be connected to a knob accessible to an operator. Such a device is called a rheostat and has two terminals.

- **Potentiometer**

A potentiometer is a manually adjustable resistor. The way this device works is relatively simple. One terminal of the potentiometer is connected to a power source. Another is hooked up to ground (a point with no voltage or resistance and which serves as a neutral reference point), while the third terminal runs across a strip of resistive material. This resistive strip generally has a low resistance at one end; its resistance gradually increases to a maximum resistance at the other end. The third terminal serves as the connection between the power source and ground, and is usually interfaced to the user by means of a knob or lever. The user can adjust the position of the third terminal along the resistive strip in order to manually increase or decrease resistance. By controlling resistance, a potentiometer can determine how much current flow through a circuit. When used to regulate current, the potentiometer is limited by the maximum resistivity of the strip.

The power of this simple device is not to be underestimated. In most analog devices, a potentiometer is what establishes the levels of output. In a loud speaker, for example, a potentiometer directly adjusts volume; in a television monitor, it controls brightness.



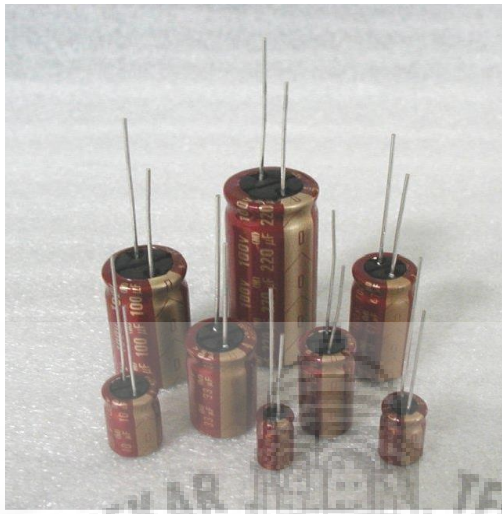
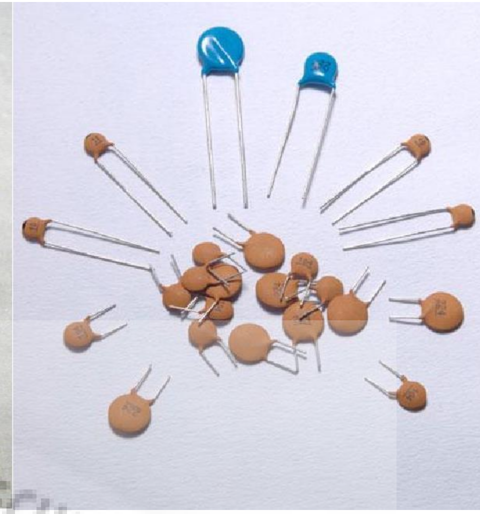
A potentiometer can also be used to control the potential difference, or voltage, across a circuit. The setup involved in utilizing a potentiometer for this purpose is a little bit more complicated. It involves two circuits: the first circuit consists of a cell and a resistor. At one end, the cell is connected in series to the second circuit, and at the other end it is connected to a potentiometer in parallel with the second circuit. The potentiometer in this arrangement drops the voltage by an amount equal to the ratio between the resistance allowed by the position of the third terminal and the highest possible resistivity of the strip. In other words, if the knob controlling the resistance is positioned at the exact halfway point on the resistive strip, then the output voltage will drop by exactly fifty percent, no matter how high the potentiometer's input voltage. Unlike with current regulation, voltage regulation is not limited by the maximum resistivity of the strip

5.10 CAPACITOR

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.

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 (formerly known as condenser) is a device for storing electric charge. The forms of practical capacitors vary widely, but all contain at least two conductors separated by a non-conductor. Capacitors used as parts of electrical systems, for example, consist of metal foils separated by a layer of insulating film.

Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass, in filter networks, for smoothing the output of power supplies, in the resonant circuits that tune radios to particular frequencies and for many other purposes.

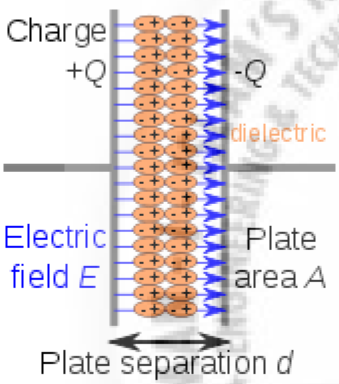
A capacitor is a passive electronic component consisting of a pair of conductors separated by a dielectric (insulator). When there is a potential difference (voltage) across the conductors, a static electric field develops in the dielectric that stores energy and produces a mechanical force between the 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.

Theory of operation

Main article: Capacitance



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

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 semiconductor depletion 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:

$$C = \frac{\mathrm{d}q}{\mathrm{d}v}$$

- **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:[11]

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

- **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 antiderivative, a constant of integration is added to represent the initial voltage v (t_0). This is the integral form of the capacitor equation,

.

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

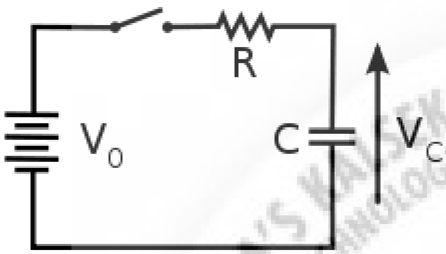
$$i(t) = \frac{\mathrm{d}q(t)}{\mathrm{d}t} = C\frac{\mathrm{d}v(t)}{\mathrm{d}t}$$

$$v(t) = \frac{q(t)}{C} = \frac{1}{C}\int_{t_0}^{t} i(\tau)\mathrm{d}\tau + v(t_0)$$

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.

- **DC circuits**

See also: RC circuit



A simple resistor-capacitor circuit demonstrates charging of a capacitor. A series circuit containing only a resistor, a capacitor, a switch and a constant DC source of voltage V_0 is known as a charging circuit.[14] If the capacitor is initially uncharged while the switch is open, and the switch is closed at t = 0, it follows from Kirchhoff's voltage law that

$$V_0 = v_{\text{resistor}}(t) + v_{\text{capacitor}}(t) = i(t)R + \frac{1}{C}\int_0^t i(\tau)\,\mathrm{d}\tau.$$

Taking the derivative and multiplying by C, gives a first-order differential equation,

$$RC\frac{\mathrm{d}i(t)}{\mathrm{d}t} + i(t) = 0.$$

At t = 0, the voltage across the capacitor is zero and the voltage across the resistor is V_0. The initial current is then i (0) =V_0 /R. With this assumption, the differential equation yields

$$i(t) = \frac{V_0}{R} e^{-t/\tau_0}$$

$$v(t) = V_0 \left(1 - e^{-t/\tau_0}\right),$$

Where τ_0 = RC is the time constant of the system.

As the capacitor reaches equilibrium with the source voltage, the voltage across the resistor and the current through the entire circuit decay exponentially. The case of discharging a charged capacitor likewise demonstrates exponential decay, but with the initial capacitor voltage replacing V_0 and the final voltage being zero.

- **AC circuits**

See also: reactance (electronics) and electrical impedance deriving the device specific impedances

Impedance, the vector sum of reactance and resistance, describes the phase difference and the ratio of amplitudes between sinusoidally varying voltage and sinusoidally varying current at a given frequency. Fourier analysis allows any signal to be constructed from a spectrum of frequencies, whence the circuit's reaction to the various frequencies may be found. The reactance and impedance of a capacitor are respectively

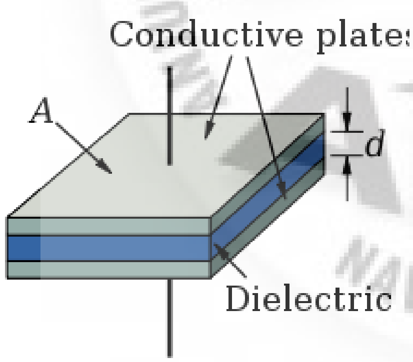
$$X = -\frac{1}{\omega C} = -\frac{1}{2\pi f C}$$

$$Z = \frac{1}{j\omega C} = -\frac{j}{\omega C} = -\frac{j}{2\pi f C}$$

Where j is the imaginary unit and ω is the angular velocity of the sinusoidal signal. The - j phase indicates that the AC voltage V = Z I lags the AC current by 90°: the positive current phase corresponds to increasing voltage as the capacitor charges; zero current corresponds to instantaneous constant voltage, etc.

Note that impedance decreases with increasing capacitance and increasing frequency. This implies that a higher-frequency signal or a larger capacitor results in a lower voltage amplitude per current amplitude—an AC "short circuit" or AC coupling. Conversely, for very low frequencies, the reactance will be high, so that a capacitor is nearly an open circuit in AC analysis; those frequencies have been "filtered out". Capacitors are different from resistors and inductors in that the impedance is inversely proportional to the defining characteristic, i.e. capacitance.

- **Parallel plate model**



Dielectric is placed between two conducting plates, each of area A and with a separation of d.

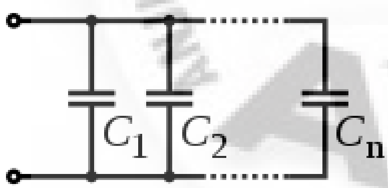
The simplest capacitor consists of two parallel conductive plates separated by a dielectric with permittivity ε (such as air). The model may also be used to make qualitative predictions for other device geometries. The plates are considered to extend uniformly over an area A and a charge density ±ρ = ±Q/A exists on their surface. Assuming that the width of the plates is much greater than their separation d, the electric field near the centre of the device will be uniform with the magnitude E = ρ/ε. The voltage is defined as the line integral of the electric field between the plates

$$V = \int_0^d E\,\mathrm{d}z = \int_0^d \frac{\rho}{\varepsilon}\mathrm{d}z = \frac{\rho d}{\varepsilon} = \frac{Qd}{\varepsilon A}.$$

Solving this for C = Q/V reveals that capacitance increases with area and decreases with separation

$$C = \frac{\varepsilon A}{d} .$$

The capacitance is therefore greatest in devices made from materials with a high permittivity.



Several capacitors are in parallel.

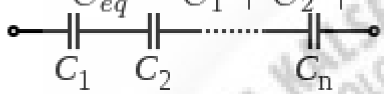
- **Networks**

For capacitors in parallel

Capacitors in a parallel configuration each have the same applied voltage. Their capacitances add up. Charge is apportioned among them by size. Using the schematic diagram to visualize parallel plates, it is apparent that each capacitor contributes to the total surface area.

For capacitors in series

$$C_{eq} = C_1 + C_2 + \cdots + C_n$$



Several capacitors are in series.

Connected in series, the schematic diagram reveals that the separation distance, not the plate area, adds up. The capacitors each store instantaneous charge build-up equal to that of every other capacitor in the series. The total voltage difference from end to end is apportioned to each capacitor according to the inverse of its capacitance. The entire series acts as a capacitor smaller than any of its components.

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$$

Capacitors are combined in series to achieve a higher working voltage, for example for smoothing a high voltage power supply. The voltage ratings, which are based on plate separation, add up. In such an application, several series connections may in turn be connected in parallel, forming a matrix. The goal is to maximize the energy storage utility of each capacitor without overloading it.

Series connection is also used to adapt electrolytic capacitors for AC use.

- **Non-ideal behavior**

Capacitors deviate from the ideal capacitor equation in a number of ways. Some of these, such as leakage current and parasitic effects are linear, or can be assumed to be linear, and can be dealt with by adding virtual components to the equivalent circuit of the capacitor. The usual methods of network analysis can then be applied. In other cases, such as with breakdown voltage, the effect is non-linear and normal (i.e., linear) network analysis cannot be used, the effect must be dealt with separately. There is yet another group, which may be linear but invalidate the assumption in the analysis that capacitance is a constant. Such an example is temperature dependence.

- **Breakdown voltage**

Main article: Breakdown voltage

Above a particular electric field, known as the dielectric strength E_{ds}, the dielectric in a capacitor becomes conductive. The voltage at which this occurs is called the breakdown voltage of the device, and is given by the product of the dielectric strength and the separation between the conductors,[15]

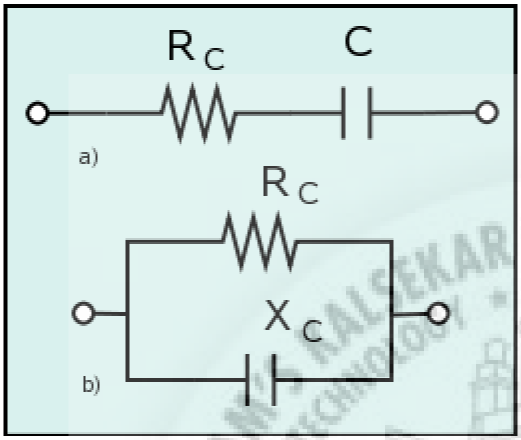
$V_{bd} = E_{ds} d$

The maximum energy that can be stored safely in a capacitor is limited by the breakdown voltage. Due to the scaling of capacitance and breakdown voltage with dielectric thickness, all capacitors made with a particular dielectric have approximately equal maximum energy density, to the extent that the dielectric dominates their volume.

For air dielectric capacitors the breakdown field strength is of the order 2-5 MV/m; for mica the breakdown is 100-300 MV/m, for oil 15- 25 MV/m, and can be much less when other materials are used for the dielectric. The dielectric is used in very thin layers and so absolute breakdown voltage of capacitors is limited. Typical ratings for capacitors used for general electronics applications range from a few volts to 100V or so. As the voltage increases, the dielectric must be thicker, making high-voltage capacitors larger than those rated for lower voltages. The breakdown voltage is critically affected by factors such as the geometry of the capacitor conductive parts; sharp edges or points increase the electric field strength at that point and can lead to a local breakdown. Once this starts to happen, the breakdown will quickly "track" through the dielectric till it reaches the opposite plate and cause a short circuit.

The usual breakdown route is that the field strength becomes large enough to pull electrons in the dielectric from their atoms thus causing conduction. Other scenarios are possible, such as impurities in the dielectric, and, if the dielectric is of a crystalline nature, imperfections in the crystal structure can result in an avalanche breakdown as seen in semi-conductor devices. Breakdown voltage is also affected by pressure, humidity and temperature.

- **Equivalent circuit**



Two different circuit models of a real capacitor

An ideal capacitor is only store and release electrical energy, without dissipating any energy. In reality, all capacitors have imperfections within the capacitor's material that create resistance. This is specified as the equivalent series resistance or **ESR** of a component. This adds a real component to the impedance:

$$R_C = Z + R_{ESR} = \frac{1}{j\omega C} + R_{ESR}$$

As frequency approaches infinity, the capacitive impedance (or reactance) approaches zero and the ESR becomes significant. As the reactance becomes negligible, power dissipation approaches $P_{RMS} = V_{RMS}^2 / R_{ESR}$.

Similarly to ESR, the capacitor's leads add equivalent series inductance or **ESL** to the component. This is usually significant only at relatively high frequencies. As inductive reactance is positive and increases with frequency, above a certain frequency capacitance will be cancelled by inductance. High-frequency engineering involves accounting for the inductance of all connections and components.

If the conductors are separated by a material with a small conductivity rather than a perfect dielectric, then a small leakage current flows directly between them. The capacitor therefore has a finite parallel resistance,[10] and slowly discharges over time (time may vary greatly depending on the capacitor material and quality).

- **Ripple current**

Ripple current is the AC component of an applied source (often a switched-mode power supply) whose frequency may be constant or varying. Certain types of capacitors, such as electrolytic tantalum capacitors, usually have a rating for maximum ripple current (both in frequency and magnitude). This ripple current can cause damaging heat to be generated within the capacitor due to the current flow across resistive imperfections in the materials used within the capacitor, more commonly referred to as equivalent series resistance (ESR). For example electrolytic tantalum capacitors are limited by ripple current and generally have the highest ESR ratings in the capacitor family, while ceramic capacitors generally have no ripple current limitation and have some of the lowest ESR ratings.

- **Capacitance instability**

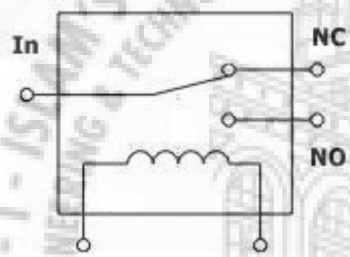
The capacitance of certain capacitors decreases as the component ages. In ceramic capacitors, this is caused by degradation of the dielectric. The type of dielectric and the ambient operating and storage temperatures are the most significant aging factors, while the operating voltage has a smaller effect. The aging process may be reversed by heating the component above the Curie point. Aging is fastest near the beginning of life of the component, and the device stabilizes over time. Electrolytic capacitors age as the electrolyte evaporates. In contrast with ceramic capacitors, this occurs towards the end of life of the component.

Temperature dependence of capacitance is usually expressed in parts per million (ppm) per °C. It can usually be taken as a broadly linear function but can be noticeably non-linear at the temperature extremes. The temperature coefficient can be either positive or negative, sometimes even amongst different samples of the same type. In other words, the spread in the range of temperature coefficients can encompass zero. See the data sheet in the leakage current section above for an example.

Capacitors, especially ceramic capacitors, and older designs such as paper capacitors, can absorb sound waves resulting in a microphonic effect. Vibration moves the plates, causing the capacitance to vary, in turn inducing AC current. Some dielectrics also generate piezoelectricity. The resulting interference is especially problematic in audio applications, potentially causing feedback or unintended recording. In the reverse microphonic effect, the varying electric field between the capacitor plates exerts a physical force, moving them as a speaker. This can generate audible sound, but drains energy and stresses the dielectric and the electrolyte, if any.

6. BRIEF DESCRIPTION OF WORKING OF RELAY

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and most have double throw (changeover) switch contacts. Relays allow one circuit to switch a second circuit which can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits; the link is magnetic and mechanical.

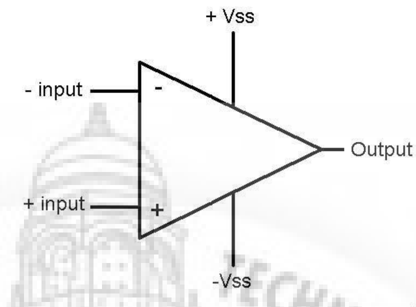


COMPARATOR

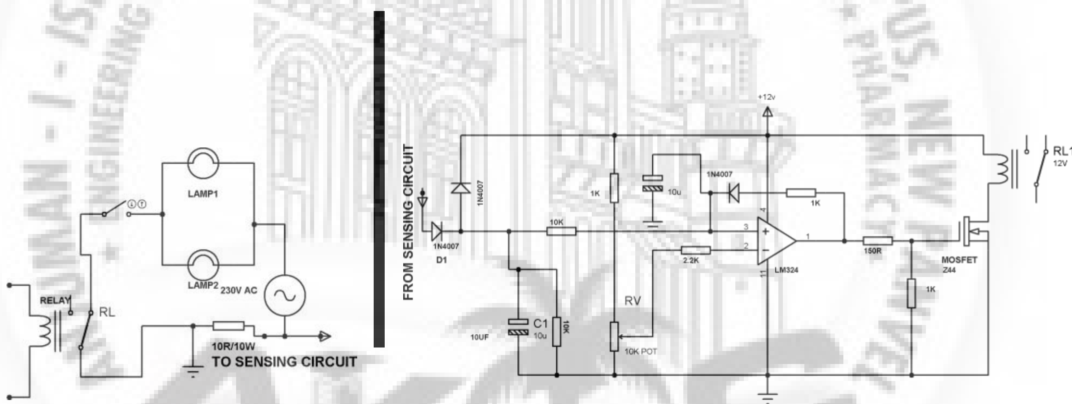
How an op-amp can be used as a comparator?

Potential dividers are connected to the inverting and non inverting inputs of the op-amp to give some voltage at these terminals. Supply voltage is given to +Vss and –Vss is connected to ground. The output of this comparator will be logic high (i.e., supply voltage) if the non-inverting terminal input is greater than the inverting terminal input of the comparator.

i.e., Non inverting input (+) > inverting input (-) = output is logic high If the inverting terminal input is greater than the non-inverting terminal input then the output of the comparator will be logic low (i.e., ground) i.e., inverting input (-) > Non inverting input (+) = output is logic low



- **working:-**



Current Sensing circuit

The project uses a current sensing 5k variable resistor in series with the load. The AC voltage drop across the same is rectified by IN4007 in the sensing circuit and further filtered by C1, a 10mf capacitor before being fed to the non inverting input of an op-amp

LM324 pin no 3 used as comparator. The inverting input terminal is provided with a fixed voltage adjustable to desired value by RV, via 5k potentiometer. The potentiometer is so set that in the event of normal load the rectified voltage so derived from the current sensing resistor, is less than the fixed, voltage given to inverting input terminal pin no. 2 from the potential divider 5k pot. This result in output pin going logic low. No drive gate voltage. While extra load is connected the voltage drop at the series resistor 10Ω, 10 watt goes up to drive the non- inverting input higher than the inverting input resulting in drive voltage availability to the transistor. Thus a switch on a relay, the contacts of relay disconnects the load which is in series with the sensing resistor. The comparator is wired with a positive feedback i.e. from pin–1 to pin - 3 in a combination of a 1k resistor. To restart it has to be switched off and switch on again without excessive load

7. BILL OF MATERIAL

Sr.no	COMPONENTS	QUANTITY	PRICE(Rs.)
01	Bread board	02 Nos	300
02	12v relay	02 Nos	750
03	Fixed 2k2 resistor	02 Nos	40
04	1k resistor	01 Nos	30
05	4 k resistor	02 Nos	75
06	IC LM324	02 Nos	400
07	2k2 variable resistor	01 Nos	50
08	3V LED	04 Nos	20
09	230/12v transformer	01 Nos	700
10	1000 mF capacitor	02 Nos	100
11	0.1 mF capacitor	02 Nos	60
12	Rectifier diode	10 Nos	100
13	IC 7812	02 Nos	500
14	D.C. bulbs	02 Nos	300
15	Bulb holders	02 Nos	120
16	Electronic connecting wire	03 metre	60
21	Main wire	02 metre	70
18	Wooden plate	1 ½ * 1 ½	400
19	Wooden cutting		200

20	**Acrylic plastic**		**400**
21	**Acrylic cutting**		**200**
22	**P.C.B**		**200**
23	**P.C.B designing**		**1000**
24	**Miscellaneous**		**500**
25	**Manufacturer person cost**		**1500**
26	**Total**		**8075/-**

8. HARDWARE TESTING

8.1 CONTINUITY TEST:

In electronics, a continuity test is the checking of an electric circuit to see if current flows (that it is complete circuit). A continuity test is performed by placing a small voltage (with multimeter) 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 multimeter 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.

8.2 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 multimeter & put it in voltage mode. Firstly, we check the output of the transformer, whether we get the required 12 v AC voltage.

Then we apply this voltage to the power supply circuit. Note that we do this test without microcontroller because if there is any excessive voltage, this may lead to damaging the controller. We check for the input to the voltage regulator i.e., are we getting an output of 12v. 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.

9. RESULTS

The main power supply is given directly to load through CT and step down transformer 230 v to 12v, and supplied to regulate supply unit which consist of bridge rectifier to convert ac to dc and passed through 7812 regulator to get 12v supply for working of IC LM324, capacitor filters are used to remove the ripples to get pure constant dc voltage. The current passing to load is sensed by the current transformer and output of CT.

The current sensed is compared with the inbuilt comparator of which as pre-set reference value. If the current sensed is less than the pre-set value than TRANSISTOR will be in OFF state and relay will not trip the supply to load. As we increase the load current drawn is more so if the current is increase than the pre-set value than TRANSISTOR will turn ON and energizes the relay. Thus LED used as an Indicator is properly biased, and it glows. The relay coil gets energized, causing the armature to shift its position to the normal open point from the normal closed point. The AC supply to the load is thus cut off from the load within 15micre sec to 30microsec and the load is tripped. Once the circuit is tripped it must be reset for further use using reset button. In case of normal operation microcontroller will pin will receive 12v dc from regulator.

10. CONCLUSION

Now A days the protection and control of equipment plays a very important role. To avoid electrical failure we use fast responding circuit breakers because of its considerable accuracy in fault detection and cut off- time, and also its smooth operation compared to conventional type. Comprehensive experiments conducted by constructing the necessary circuit yielded successful results. It was proved that electronic circuit breaker is very useful circuit for sensitive loads. The main advantage of this circuit is that over all tripping time is less as compare to conventional circuit breaker. The experiment is successful and energy saving. Further research on improving the load capacity and tripping time is being undertaken.

FUTURE SCOPE

The operating time of electromagnetic relay can be improved by using sophisticated electronic components.

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