Design and Implementation of Automated Thunderbolt Protector Using Light Sensor

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Submitted in partial fulfillment of the requirements for the degree of
Bachelor of Science in Computer Science and Engineering

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
SONARGAON UNIVERSITY (SU)
January 2023

APPROVAL

The project titled "**Design and Implementation of Automated Thunderbolt Protector Using Light Sensor**" submitted by Moriumnasa Mim (CSE1901016138), Tasnimul Hasan (CSE1901016145), Naima Akter Moon (CSE1901016143), Md.Emamul Haque Munna (CSE1901016080) and Md.Zihad Hossain (CSE1901016016) to the Department of Computer Science and Engineering, Sonargaon University (SU), has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science and Engineering and approved as to its style and contents.

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DECLARATION

We, hereby, declare that the work presented in this report is the outcome of the investigation performed by us under the supervision of **Salma Tabashum, Lecturer,** Department of Computer Science and Engineering, Sonargaon University, Dhaka, Bangladesh. We reaffirm that no part of this Project has been or is being submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

Lightning of thunderbolt is a normal occurrence during the rainy season. For this reason we have to face many problems like as people die due to thunder bolt. Even different electronic devices in houses, offices, shops are destroyed due to the thunder bolt. And we will try to solve this problem. That's why we have tried to create a smart multiplug that will solve our thunder bolt related issue. When rain, we forget to unplug our electronic devices, so the device is destroyed by the thunder bolt. Ours smart multiplug will turn off plugged in devices by thunder bolt light. As we know, light travels faster than sound. During lightning, the light is seen first and the sound heard later. Smart multiplug will turn off the devices after the light is reflected. Basically, it was our effort not to destroy the electronic devices.

ACKNOWLEDGEMENT

At the very beginning, we would like to express my deepest gratitude to the Almighty Allah for giving us the ability and the strength to finish the task successfully within the schedule time.

We are auspicious that we had the kind association as well as supervision of **Salma Tabashum**, Lecturer, Department of Computer Science and Engineering, Sonargaon University whose hearted and valuable support with best concern and direction acted as necessary recourse to carry out our project.

We would like to convey our gratitude to **Prof. Dr Md Alamgir Hossain**, Dean, Faculty of Science & Engineering and special gratitude our honorable departmental head **Bulbul Ahamed**, Associate Professor & Head, Department of Computer Science and Engineering for their kind concern, discretion, friendly behavior and precious suggestions.

We are also thankful to all our teachers during our whole education, for exposing us to the beauty of learning.

Finally, our deepest gratitude and love to my parents for their support, encouragement, and endless love.

LIST OF ABBREVIATION

AAA	Authentication, Authorization and Accounting
AC	Alternating Current
ADC	Analog-to-digital Conversion
AI	Artificial Intelligence
AM	Ante-Meridiem
BC	Bayonet Cap
CD	Compact Disk
COM	Common Contacts
DC	Direct Current
DIL	Dual Inline
EMF	Electromagnetic Field
IC	Integrated Circuit
LDR	Light-Dependent Resistors
LED	Light Emitting Diode
LSB	Least-significant Bit
NC	Normally Closed
NO	Normally Open
NPN	Negative-Positive-Negative
PCB	Printed Circuit Board
PM	Post Meridiem
PNP	Positive-Negative- Positive
PPM	Parts Per Million
RAM	Random Access Memory
RMS	Root Mean Square
ROM	Read Only Memory
SIL	Single Inline
TCR	T-cell Receptor
UFD	Unique Factorization Domain
VCC	Voltage Common Collect

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CHAPTER 1

AN INTRODUCTION TO MACHINE LEARNING

1.1 Introduction

Machine learning is a subfield of artificial intelligence (AI). The goal of Machine learning generally is to understand the structure of data and fit that data into models that can be understood and utilized by people [1].

Although machine learning is a field within computer science, it differs from traditional computational approaches. In traditional computing, algorithms are sets of explicitly programmed instructions used by computers to calculate or problem solve. Machine learning algorithms instead allow for computers to train on data inputs and use statistical analysis in order to output values that fall within a specific range. Because of this, machine learning facilitates computers in building models from sample data in order to automate decision-making processes based on data inputs [2].

1.2 Data, Models, and Learning

It is worth at this point, to pause and consider the problem that a machine learning algorithm is designed to solve. As discussed in Chapter 1(1.1), there are three major components of a machine learning system: data, models, and learning. The main question of machine learning is "What do we mean by good models?" The word model has many subtleties, and we model will revisit it multiple times in this chapter. It is also not entirely obvious how to objectively define the word "good". One of the guiding principles of machine learning is that good models should perform well on unseen data. This requires us to define some performance metrics, such as accuracy or distance from ground truth, as well as figuring out ways to do well under these performance metrics. This chapter covers a few necessary bits and pieces of mathematical and statistical language that are commonly used to talk about machine learning models. By doing so, we briefly outline the current best practices for training a model such that the resulting predictor does well on data that we have not yet seen. As mentioned in Chapter 1, there are two different senses in which we use the phrase "machine learning algorithm": training and prediction. We will describe these ideas in this chapter, as well as the idea of selecting among different models [3].

Fig.1.1: Machine Learning

CHAPTER 2

BASIC CONCEPT OF THUNDERBOLT

2.1 Introduction

Thunderbolt is a flash of light in the sky. During this time we hear loud noises due to expansion and contraction of air. The emission of such electrical charges may occur within a cloud or between a cloud and the ground.

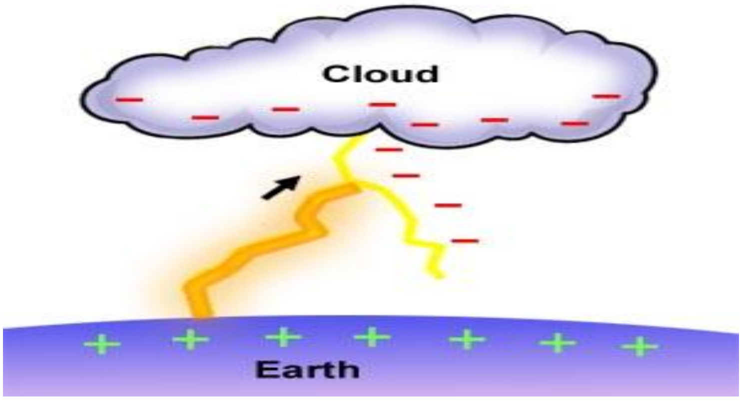

Fig.2.1: Thunderbolt

2.2 How many degrees is the temperature of Thunderbolt usually?

The temperature of lightning can be up to 30 thousand degrees Celsius. A little after the thunder can be heard! The reason for this is that when the current flows from top to bottom, the air moves away and creates a hollow tunnel-like region from top to bottom.

2.3 Speed of lightning

We know that during lightning the light is seen first and the sound heard later. The main reason for this is the difference in speed of light and sound. The speed of light is much faster than the speed of sound. The speed of light is 300000 kilometers per second (3 × 10^8 meters per second). On the other hand, the speed of sound at 0 degree Celsius is 332 meters per second. Because of this difference in speed, the sound of thunder is heard shortly after the lightning strikes.

CHAPTER 3

HARDWARE

3.1 IC (Integrated Circuit)

Before the discovery of ICs, the basic method of making circuits was to select the components like diodes, transistors, resistors, inductors and capacitors and connect them by shouldering. But due to size and power consumption issues, it was necessary to develop a small size circuit with less power consumption, reliability and shockproof. After the invention of the semiconductors and transistors, things were quite simplified to a particular extent, but the development of integrated circuits changed electronics technology's face. Jack Kilby from Texas Instruments and Bob Noyce from Intel are the official creators of integrated circuits, and they did it independently [4].

Fig.3.1: IC

3.1.1 Definition of IC

Integrated circuits are made up of several components such as R, C, L, diodes and transistors. They are built on a small single block or chip of a semiconductor known as an integrated circuit (IC). All of them work together to perform a particular task. The IC is easily breakable, so to be attached to a circuit board, it is often housed in a plastic package with metal pins.

Integrated Circuits Design

An integrated circuit is created using certain logic methods and circuit layouts. The two categories of IC design are as follows:

1. Analog Design
2. Digital Design
3. Mixed Design

Analog Design

IC chip is created by using the analog design process when ICs are utilized as regulators, filters and oscillators. Optimal power dissipation, gain and resistance are required. IC chip is created by using the analog design process when ICs are utilized as regulators, filters and oscillators. Optimal power dissipation, gain and resistance are required.

Digital Design

The digital design approach is used to create integrated circuits (ICs), which are utilized as computer memories (such as RAM and ROM) and microprocessors. With this approach to design, the circuit density and overall efficiency are both maximized. The ICs created with this technique operate with binary input data like 0 and 1. The process for designing digital integrated circuits is depicted in the diagram below.

Mixed Design

The analog and digital design ideas are used in mixed designs. The mixed ICs perform either Analog to Digital or Digital to Analog conversion.

How Do IC Timers Function?

There are several ways in which IC timers function. IC timers or electronic timers work on the principle of elapsed time and real time. Elapsed and real time are used for activating the output signal when the signal achieves the preset time. A MicroPC1555 IC timer requires a supply voltage of 4.5 to 16 volts and an operating current range of 3 mA. This electronic timer also supports temperature stability of 0.005% per degree Celsius for semiconductor timers present in it. A MicroPC617 should have an output current capacity of 200mA. This semiconductor timer should also have rising and falling time of 100 nano seconds and a supply capacitive voltage of 5 volts. IC timers are designed and manufactured to meet most industry specifications.

3.1.2 Integrated Circuits Feature

Constructor and Packing: ICs are built with semiconducting components such as silicon. Because of the small size and delicate nature of IC, a series of tiny gold and aluminum wires are joined together and molded into a flat block of plastic or ceramic. Metal pins on the block’s exterior link to cables inside. The solid block stops the chip from overheating and keeps it cool.

Size of an IC: The size of the integrated chip varies between 1 square mm to more than 200 mm.

Integration of an IC: Because they combine various devices on one chip, integrated chips get their name. A microcontroller is an integrated circuit (IC) that combines a microprocessor, memory, and interface into a single unit.

3.1.3 Commonly Used IC’s

Logic gate IC’s: The combinational circuit generates logical outputs based on a variety of input signals. It may only have two to three inputs but one output.

Timer IC’s: A Timer IC is produced with accurate timing cycles with a 100 % or 50 % duty cycle.

Operational Amplifier: An OpAmp or an Operational Amplifier is a high gain voltage amplifier with a differential input and a single-ended output.

Voltage Regulator: A voltage regulator IC provides a constant DC output irrespective of the changes in DC input.

3.2 What is Transformer

A transformer is defined as a passive electrical device that transfers electrical energy from one circuit to another through the process of electromagnetic induction. It is most commonly used to increase ('step up') or decrease ('step down') voltage levels between circuits[5].

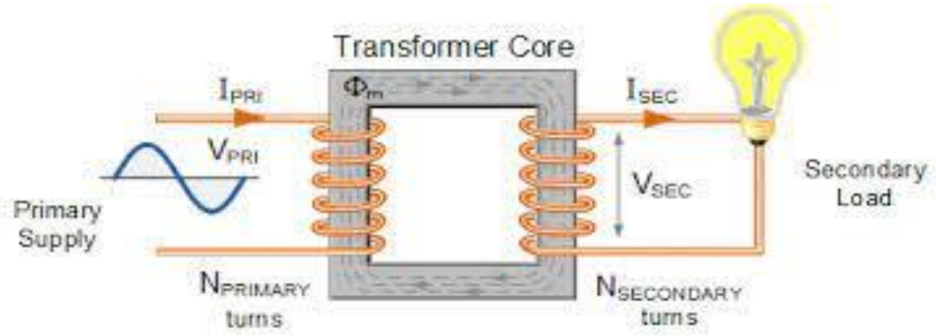

Fig.3.2: Transformer

Working Principle of Transformer

The Working Principle of Transformer is very simple. Mutual induction between two or more windings (also known as coils) allows for electrical energy to be transferred between circuits. This principle is explained in further detail below.

Transformer Theory

Say you have one winding (also known as a coil) which is supplied by an alternating electrical source. The alternating current through the winding produces a continually changing and alternating flux that surrounds the winding. If another winding is brought close to this winding, some portion of this alternating flux will link with the second winding. As this flux is continually changing in its amplitude and direction, there must be a changing flux linkage in the second winding or coil. According to Faraday's law of electromagnetic induction, there will be an EMF induced in the second winding. If the circuit of this secondary winding is closed, then a current will flow through it. This is the basic Working Principle of Transformer Let us use electrical symbols to help visualize this. The winding which receives electrical power from the source is known as the 'primary winding'. In the diagram below this is the 'First Coil'. The winding which gives the desired output voltage due to mutual induction is commonly known as the 'secondary winding'. This is the 'Second Coil' in the diagram above. A transformer that increases voltage between the primary to secondary windings is defined as a step-up transformer. Conversely, a transformer that decreases voltage between the primary to secondary windings is defined as a step-down transformer. Whether the transformer increases or decreases the voltage level depends on the relative number of turns between the primary and secondary side of the transformer. If there are more turns on the primary coil than the secondary coil than the voltage will decrease (step down). If there are less turns on the primary coil than the secondary coil than the voltage will increase (step up). While the diagram of the transformer above is theoretically possible in an ideal transformer – it is not very practical. This is because in the open air only a very tiny portion of the flux produced from the first coil will link with the second coil. So the current that flows through the closed circuit connected to the secondary winding will be extremely small (and difficult to measure). The rate of change of flux linkage depends upon the amount of linked flux with the second winding. So ideally almost all of the flux of primary winding should link to the secondary winding. This is effectively and efficiently done by using a core type transformer. This provides a low reluctance path common to both of the windings. The purpose of the transformer core is to provide a low reluctance path, through which the maximum amount of flux produced by the primary winding is passed through and linked with the secondary winding. The current that initially passes through the transformer when it is switched on is known as the transformer inrush current.

Transformer Parts and Construction

The three main parts of a transformer:

1. Primary Winding of Transformer
2. Magnetic Core of Transformer
3. Secondary Winding of Transformer

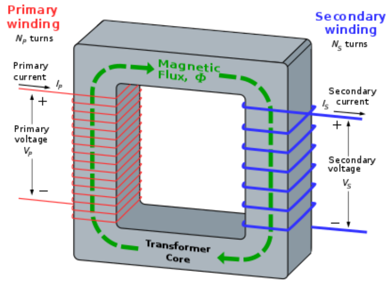

Fig.3.3: Transformer Parts

Primary Winding of Transformer: Primary Winding of Transformer Which produces magnetic flux when it is connected to an electrical source.

Magnetic Core of Transformer: The magnetic flux produced by the primary winding, that will pass through this low reluctance path linked with secondary winding and create a closed magnetic circuit.

Secondary Winding of Transformer: The flux, produced by primary winding, passes through the core, will link with the secondary winding. This winding also wounds on the same core and gives the desired output of the transformer.

3.3 Resistor

Resistor, electrical component that opposes the flow of either direct or alternating current, employed to protect, operate, or control the circuit. Voltages can be divided with the use of resistors, and in combination with other components resistors can be used to make electrical waves into shapes most suited for the electrical designer's requirements. Resistors can have a fixed value of resistance, or they can be made variable or adjustable within a certain range, in which case they may be called rheostats, or potentiometers.[6]

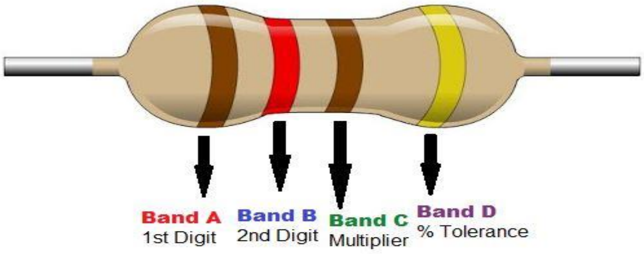

Fig.3.4: Resistor

What Do Resistors Do in a Circuit?

Resistors have many uses in circuits. Below are some of the more common functions; most applications require multiple resistors in serial or parallel configurations [7]. Some of the more common uses of resistors include:

1. Potential dividers. Two or more resistors in series will give a voltage at their junction point proportional to the ratio of their values. This functionality is widely used in circuits for generating intermediate voltages
2. Biasing resistors. Transistors and many other devices need to have their AC and DC operating characteristics and gain values set up for correct operation. This is done with multiple resistors and is often called biasing
3. Op-amp gain and feedback. Most op-amp circuits need to have their gain and feedback functionality set by resistors external to the amplifier chip; resistors are the primary means of doing this
4. Current limiting. Resistors can be used to limit the amount of current that flows in a circuit element. This is a useful safety function in many circuits e.g. limiting the current that can flow into an LED to manage its brightness
5. Impedance matching. To maximise power transmission at high frequencies the impedance of the receive and transmit ends of a circuit need to be the same. Resistors can perform at least part of this requirement
6. Current measuring. Many circuits need to know how much current is flowing, however, it is much easier to measure voltage, so inserting a resistor into the circuit to ‘develop’ a voltage – remember Ohm's law- is a common technique for measuring current
7. Data and address bus pull-ups. This functionality helps to reduce noise issues on high-speed computer busses. When a data bus tri-states or is driven high, it is often necessary to pull it into a known state or to make sure its output high is well above the switching point of other logic elements on the bus, and a pull up helps to do this

Type of Resistor

There are many different types of resistors and they can be made from various materials, all of which have their own unique advantages and disadvantages. Before looking at the materials, it’s worth considering the various available configurations.

Fixed Value Resistors

These are the predominant type of resistor configuration, and as the name suggests, they have a fixed resistance value. It is possible to buy a resistor of any ohmic value that you require, however in the vast majority of cases, it is possible to 'tweak' the circuit to change the value that is required. For this reason, all manufacturers will supply families of resistors, with a given number of resistors to each decade of value. So, for instance, a common family is the E24 family. This has 24 values between 100Ω and 1000Ω or between 10KΩ and 100KΩ. The values in the range are chosen so that when you take the tolerances for each value into account, you have coverage over most possible values. The number of values in a family depends on the accuracy and tolerance required, so the E192 family has far more values to choose from, with tolerances down to 0.1%. This, of course, can increase the cost of the resistors.

Fig.3.5: Fixed value resistor

Variable Resistors

Variable resistors (also known as potentiometers) are resistors that can have their value changed either by turning a shaft or in pre-set pots by a screwdriver. A variable resistor is a three-terminal device. The Centre pin with the arrow is known as the wiper and is where the variable resistance is available. The devices come in the form of a moveable contact running along a resistive track, or in the case of multiturn devices used as panel controls, a tightly wound wire. Although useful for tuning resistance values in a circuit, 'pots' can be prone to movement of the wiper because of vibration and hence can be problematic if wrongly specified.

Fig.3.6: Variable Resistor

Resistor Networks

It is often the case that multiple resistors of the same value are needed, in data bus pull up applications, for example. For these applications, it is possible to purchase resistor packs either as single inline (SIL) or dual inline (DIL) packages. They can come as multiple non-connected resistors, or with one pin of each resistor connected to a single contact on the package. Although this solution can be more expensive on a per resistor basis, the mounting costs are of course lower as only one insertion is required and so a balance is possible. This consideration has led to the availability of dual resistors in a single pack for potential divider applications.

Fig.3.7: Resistor Network

Resistor Color Code

The system is a little simpler for through-hole resistors. A color code has been in place for many years and is still current. This diagram shows the system in use. Each resistor has three or four bands specifying the value, plus a tolerance band. For a 4-band resistor, the first two bands are numerical values and the third band is a multiplier. If, for instance, we had a case where the first two bands were red and the third band was orange, then the resistor value would be 22KΩ. If the fourth band was also red, then the resistor would have a tolerance of 2%. If we take the case of a 5-band resistor with the first three colors as red, and the fourth as brown, we would have a value of 2.22KΩ.

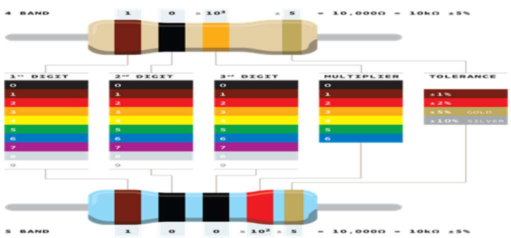

Fig.3.8: Resistor color code

Resistor Value Marking

Most resistors have value marked on them. For surface mount resistors, this can be one of several options. They can be a 3 or 4-digit code representing the value using a value and multiplier system. For example, 102 would represent 10^2or 1kΩ, the 4-digit type could be 1002 which is 100 x 10^2 or 10KΩ. For low values, you may see something like 4R7 which is 4.7Ω. R is used as a decimal point in this instance. Given the minute size of surface resistors, these can be extremely difficult to see, especially now that SMD resistors are available in tighter tolerances, and with more values. For this reason, the EIA96 system is used. This involves a lookup table where a three-digit value is used to point to a value and multiplier, hence specifying the value in a minimum number of digits.

Resistive Materials

Having looked at the basics of resistor design and the configurations that are possible, it is now time to look at the materials that are used in resistors and to highlight their advantages and disadvantages.

Carbon Film Resistors

Carbon film resistors have largely been replaced by metal types for general purpose applications, due to their poorer tolerance and noise characteristics. However, they are still used in some specialist applications. The resistor is constructed by forming a carbon film onto a ceramic substrate. This has multiple advantages. Firstly, the film is largely non-inductive, secondly, the ceramic is an excellent insulator for heat and electricity, and thirdly, the layout has a large cross-section. So, their low inductance makes them useful for high-frequency applications and their larger cross-section lends itself to higher operating voltages and better survivability to transients than many other types. As a result, although less widely used, they are still commonly available.

Fig.3.9: Carbon film resistors

Metal Film Resistors

Metal film resistors are made by placing a layer of metals such as ruthenium onto an insulating substrate. They are available in a large number of types and packages and compared to carbon film resistors, their construction is simpler to mass-produce and smaller physically. Metal film resistors have largely replaced carbon film resistors in most standard applications due to their lower noise, tighter tolerances and generally better temperature coefficients. Although often perceived as a ‘standard’ resistor, they have evolved from a lower performance base to the point where they are offered with quite high precision (0.1%) and low TCRs in the single-digit PPM/C range. It’s worth noting that metal film resistors are offered in both trough hole and surface mount (chip resistor) types.

Fig.3.10: Metal film resistors

Wire Wound Resistors

Wire wound resistors have some characteristics that are attractive in specialist applications, such as high precision instrumentation where tolerances much better than 0.01% and very low-temperature coefficients (TCR) are required. They are also often the resistor type of choice for high power applications (examples rated up to 100s of watts are available). However, it’s worth noting that as they consist of wire wound around an insulated core, which is an inductor by definition, these resistors are not recommended for high-frequency applications, and are generally not available in surface mount form.

Fig.3.11: Wire Wound resistors

Metal Oxide Resistors

These items are similar to metal film resistors, save that the resistive element is an oxide (often tin). Their performance is subtly different from metal film in that they typically are better for higher voltage and higher power applications than metal film parts. However, they are typically offered in smaller ranges and may offer reduced tolerances and TCRs. Again, they are offered in both surface mount and through-hole types.

Fig.3.12: Metal oxide resistors

Metal Strip Resistors

These are specialist resistors generally used for current measuring applications in power supplies. They are characterized by often very low ohmic values, so they are offered with relatively low-temperature coefficients and medium power dissipation to minimally affect the overall circuit operation. As the name suggests, they are effectively a laser-trimmed strip of metal. Another key characteristic for these devices is a low thermal resistance as they are potentially carrying high currents which may lead to the need to dissipate heat generated in operation.

Fig.3.13: Metal strip resistors

Resistor Specification

What are the key characteristics and specifications that affect the choice of resistor? Factors that should be taken into consideration include initial tolerance and value selection. However, the tolerance or variation of the value of a resistor is affected by multiple parameters, as explained below.

Temperature Coefficient

This is a measure of the variation of the nominal value as a result of temperature changes. Generally quoted as a single value in parts per million per degree centigrade (or Kelvin), it can be positive or negative. The equation for calculating the resistance at a given temperature is:

$$R_t=R_0\ [1+\alpha\ (T-T_0)]$$

Where Ro is nominal value for room temperature resistance, to be the temperature at which the nominal resistance is given, T is operating temperature and α is the TCR. Put simply, a 1 MΩ resistor with a TCR of 50ppm/K will change by 50Ω per 1 degree of temperature rise or fall. This may not sound like much but consider if you were using this resistor as the gain resistor in a x10 non-inverting amplifier circuit with 0.3v on the + input. The worst-case change in output could be as much as 7.5mv which is equivalent to about 5LSBs in a 5v 12-bit ADC circuit. This kind of change can be quite noticeable in precision design. Remember also that the TCR is quoted as ±x ppm/C so it is feasible, although unlikely, that the second resistor in the circuit could change in the opposite direction hence double the possible error. Finally, it's worth noting that some precision resistors quote variable TCRs over the temperature range the circuit is operating in, and this can complicate the design process significantly.

Resistor Ageing or Stability

Ageing and stability are a complex amalgam of multiple changes to the value of a resistance value over time and are the result of temperature cycling, high-temperature operation, humidity ingress and so on. Typically, the value will lead to an increase in resistance over time as conduction atoms migrate within the device.

Thermal Resistance

The thermal resistance is a measure of how well the resistor can dissipate power into the environment. In practice, engineers use thermal resistance to model the heat dissipation for a system – it is thought of as a set of series 'thermal resistors', each representing one element of the heat dissipation of the system. This is mainly important if the design means the resistor is running at or near its maximum value and can significantly affect the long-term reliability of the system. An example of where this parameter could be used is to calculate the size of a PCB pad or ground plane requirement that would be used to keep the resistor's value and operating temperature within acceptable limits.

Thermal and Power Rating

All resistors come with a maximum power rating, specified in watts. This can be anything from 1/8th watt right up to 10s of watts for power resistors. In a first pass analysis, the engineer would check that the resistor is operating within its rated value. The equation for calculating this is $P=I^2 R$, where p is the power dissipated in the resistor, i is the current flowing and R is the resistance. Sadly, things can be more complicated than this; for exact work, the engineer needs to take account of the thermal derating curve for the resistor. This specifies the amount by which the designer needs to de-rate the maximum power dissipation above a given temperature. This might seem theoretical as often the de-rating kicks in at quite high temperatures, but a power circuit in an enclosed housing in a hot region can often exceed the cut in point and the maximum power dissipation will need to be reduced appropriately. It's also worth noting that the maximum operating voltage of a resistor is de-rated with power dissipation.

Resistor Noise

Any electronic component that has flowing electrons is going to be a source of noise, and resistors are no different in this respect. In high gain amplifier systems or when dealing with very low voltage signals, it needs to be considered. The major contributor to noise in a resistor is thermal noise caused by the random fluctuation of electrons in the resistive material. It is generally modeled as white noise (i.e. a constant RMS voltage over the frequency range) and is given by the equation $E=\sqrt{4RkT\Delta F}$ where E is the RMS noise voltage, R is the resistance value, k is Boltzmann's constant, T is the temperature and Δf is the bandwidth of the system. It is possible to lessen system noise by reducing the resistance, the operating temperature or the system's bandwidth. Additionally, there is another type of resistor noise called current noise which is a result of the electron flow in devices. It is rarely specified but can be compared if the standard numbers using IEC60195 are available from the manufacturer.

High-Frequency Behavior

The final challenge to consider is the high-frequency performance of the particular resistor. In simple terms, you can model a resistor as a series inductor, feeding the resistor which has a parasitic capacitor in parallel with it. At frequencies as low as 100 Mhz (even for surface mount resistors which have lower parasitic values than through-hole parts) the parallel capacitance can start to dominate, and the impedance will drop below nominal. At a higher frequency still, the inductance may predominate, and the impedance will start to increase from its minima and may well end up above the nominal value.

3.4 Timer IC

IC timers are programmable semiconductor circuits that generate or set timing for electronic circuits. These chips function as single or multi-function units. An IC timer working is based on an external capacitor for determining on and off intervals in the output pulse. Timer chips differ in function based on their counting sequence. In an up direction function of an IC timer, the counter can advance forward in the counting sequence. In a down counter function, the counter can advance backward. In the bi-direction function, the chip can set the counter for either forward or backward counting sequence. There are many different types of IC timers. Examples include a microPC1555 and a microPC617. A MicroPC1555 timer chip is used as a timing signal generator and can act as a stable and constable generators. A MicroPC617 timer chip is used for driving lamps and relays and can act as a timing signal generator for this purpose. Other IC timers are commonly available [8].

Fig.3.14: Timer IC

How Do IC Timers Function?

There are several ways in which IC timers function. IC timers or electronic timers work on the principle of elapsed time and real time. Elapsed and real times are used for activating the output signal when the signal achieves the preset time. A MicroPC1555 IC timer requires a supply voltage of 4.5 to 16 volts and an operating current range of 3 mA. This electronic timer also supports temperature stability of 0.005% per degree Celsius for semiconductor timers present in it. A MicroPC617 should have an output current capacity of 200mA. This semiconductor timer should also have rising and falling time of 100 nano seconds and a supply capacitive voltage of 5 volts. IC timers are designed and manufactured to meet most industry specifications [8].

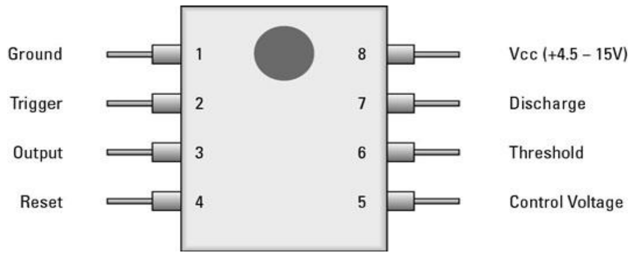

Fig.3.15: 8 pins of IC

Here are the functions of each of the eight pins:

1. **Ground**: Pin 1 is connected to ground.
2. **VCC**: Pin 8 is connected to the positive supply voltage. This voltage must be at least 4.5 V and no greater than 15 V. It's common to run 555 circuits using four AA or AAA batteries, providing 6 V, or a single 9 V battery.
3. **Output**: Pin 3 is the output pin. The output is either low, which is very close to 0 V, or high, which is close to the supply voltage that's placed on pin 8. The exact shape of the output — that is, how long it's high and how long it's low, depends on the connections to the remaining five pins.
4. **Trigger**: Pin 2 is the trigger, which works like a starter's pistol to start the 555 timer running. The trigger is an active low trigger, which means that the timer starts when voltage on pin 2 drops to below one-third of the supply voltage. When the 555 is triggered via pin 2, the output on pin 3 goes high.
5. **Discharge**: Pin 7 is called the discharge. This pin is used to discharge an external capacitor that works in conjunction with a resistor to control the timing interval. In most circuits, pin 7 is connected to the supply voltage through a resistor and to ground through a capacitor.
6. **Threshold**: Pin 6 is called the threshold. The purpose of this pin is to monitor the voltage across the capacitor that's discharged by pin 7. When this voltage reaches two thirds of the supply voltage (Vcc), the timing cycle ends, and the output on pin 3 goes low.
7. **Control**: Pin 5 is the control pin. In most 555 circuits, this pin is simply connected to ground, usually through a small 0.01 μF capacitor. (The purpose of the capacitor is to level out any fluctuations in the supply voltage that might affect the operation of the timer.)
8. **Reset**: Pin 4 is the reset pin, which can be used to restart the 555's timing operation. Like the trigger input, reset is an active low input. Thus, pin 4 must be connected to the supply voltage for the 555 timer to operate. If pin 4 is momentarily grounded, the 555 timer's operation is interrupted and won't start again until it's triggered again via pin 2.

3.5 Transistor

The transistor is a semiconductor device which transfers a weak signal from low resistance circuit to high resistance circuit. The words "trans" mean transfer property and “istor” mean resistance property offered to the junctions. In other words, it is a switching device which regulates and amplifies the electrical signal likes voltage or current [9].

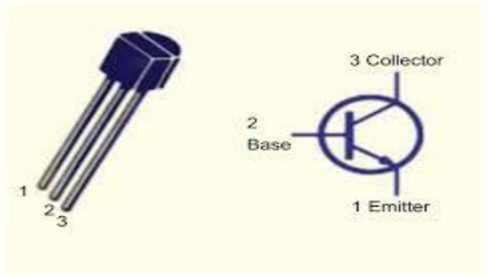

Fig.3.16: Transistor

Transistor Symbols

There are two types of transistor, namely NPN transistor and PNP transistor. The transistor which has two blocks of n-type semiconductor material and one block of P-type semiconductor material is known as NPN transistor. Similarly, if the material has one layer of N-type material and two layers of P-type material then it is called PNP transistor. The arrow in the symbol indicates the direction of flow of conventional current in the emitter with forward biasing applied to the emitter-base junction. The only difference between the NPN and PNP transistor is in the direction of the current. The symbol of NPN and PNP is shown in the figure below.

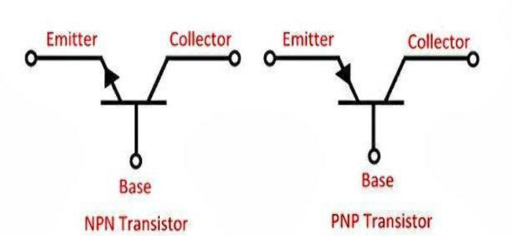

Fig.3.17: Two Types of Transistor

Transistor Terminals

The transistor has three terminals namely, emitter, collector and base. The terminals of the diode are explained below in details.

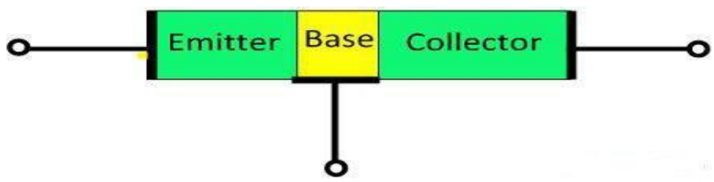

Fig3.18: Terminal of Transistor

Emitter – The section that supplies the large section of majority charge carrier is called emitter. The emitter is always connected to the forward biased with respect to the base so that it supplies the majority charge carrier to the base. The emitter-base junction injects a large amount of majority charge carrier into the base because it is heavily doped and moderate in size.

Collector – The section which collects the major portion of the majority charge carrier supplied by the emitter is called a collector. The collector-base junction is always in reverse bias. Its main function is to remove the majority charges from its junction with the base. The collector section of the transistor is moderately doped, but larger in size so that it can collect most of the charge carrier supplied by the emitter.

Base – The middle section of the transistor is known as the base. The base forms two circuits, the input circuit with the emitter and the output circuit with the collector. The emitter-base circuit is in forward biased and offered the low resistance to the circuit. The collector-base junction is in reverse bias and offers the higher resistance to the circuit. The base of the transistor is lightly doped and very thin due to which it offers the majority charge carrier to the base.

Working of Transistor

Usually, silicon is used for making the transistor because of their high voltage rating, greater current and less temperature sensitivity. The emitter-base section kept in forward biased constitutes the base current which flows through the base region. The magnitude of the base current is very small. The base current causes the electrons to move into the collector region or create a hole in the base region. The base of the transistor is very thin and lightly doped because of which it has less number of electrons as compared to the emitter. The few electrons of the emitter are combined with the hole of the base region and the remaining electrons are moved towards the collector region and constitute the collector current. Thus we can say that the large collector current is obtained by varying the base region.

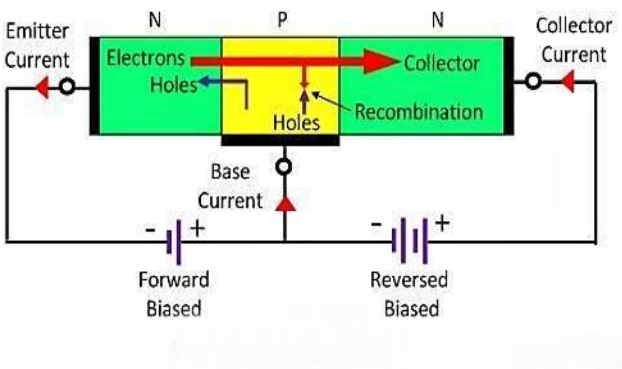

Fig.3.19: Working of Transistor

Collector Base Transistor

The middle section of the transistor is known as the base. The base forms two circuits, the input circuit with the emitter and the output circuit with the collector. The emitter-base circuit is in forward biased and offered the low resistance to the circuit. The collector-base junction is in reverse bias and offers the higher resistance to the circuit. The base of the transistor is lightly doped and very thin due to which it offers the majority charge carrier to the base.

Collector Base Working of Transistor

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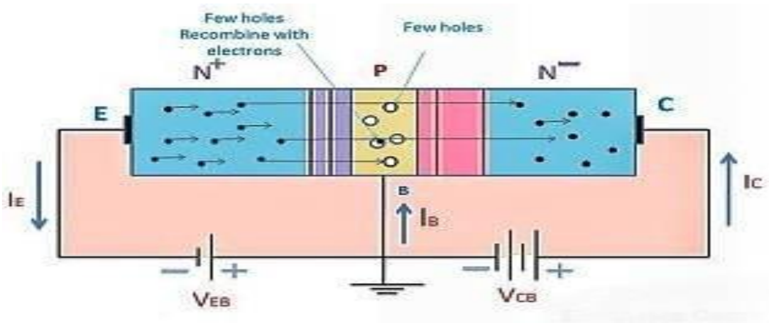

Fig.3.20: Collector Base Working of Transistor

3.6 What is Capacitor

Capacitor, device for storing electrical energy, consisting of two conductors in close proximity and insulated from each other. A simple example of such a storage device is the parallel-plate capacitor. If positive charges with total charge +Q are deposited on one of the conductors and an equal amount of negative charge −Q is deposited on the second conductor, the capacitor is said to have a charge Q. (See also electricity: Principle of the capacitor [10].

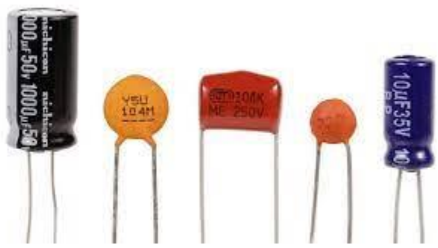

Fig.3.21: Capacitor

Capacitor Design Formula

The governing equation for capacitor design is: C = ε.A/d, In this equation, C is capacitance; ε is permittivity, a term for how well dielectric material stores an electric field; A is the parallel plate area; and d is the distance between the two conductive plates [10].

Types of Capacitor

Capacitors are mainly divided into two mechanical groups:

1. Fixed capacitors.
2. Variable capacitors.

3.6.1 How cloud capacitors cause lightning

When clouds drift through the sky, ice particles inside them rub against the air and gain static electrical charges—in just the same way that a balloon gets charged up when you rub it on your jumper. The top of a cloud becomes positively charged when smaller ice particles swirl upward (1); the bottom of a cloud becomes negatively charged when the heavier ice particles gather lower down (2). The separation of positive and negative charges in a cloud makes a kind of moving capacitor! As a cloud floats along, the electric charge it contains affects things on the ground beneath it. The huge negative charge at the bottom of the cloud repels negative charge away from it, so the ground effectively becomes positively charged (3). The separation of charge between the bottom of the cloud and the ground beneath means that this area of the atmosphere is also, effectively, a capacitor. Over time, enormous electrical charges can build up inside clouds. If the charge is really big, the cloud contains an enormous amount of electrical potential energy (it has a really high voltage). When the voltage reaches a certain level (sometimes several hundred million volts), the air is transformed from being an insulator into a conductor, and electricity will flow through it as though it were a metal wire, creating a giant spark better known as a bolt of lightning (4). The cloud behaves like a flash gun in a camera: the huge electrical energy stored in its "capacitor" is discharged in an instant and converted into a flash of light **[**11**].**

Capacitor Usage

Capacitors have many important applications. They are used, for example, in digital circuits so that information stored in large computer memories is not lost during a momentary electric power failure; the electric energy stored in such capacitors maintains the information during the temporary loss of power. Capacitors play an even more important role as filters to divert spurious electric signals and thereby prevent damage to sensitive components and circuits caused by electric surges.

Advantages and Disadvantages of Capacitor

In deciding the appropriateness of using capacitors as an energy storage medium, it is worth looking at some of the advantages and advantages:

Advantages

1. Can charge and accumulate energy quickly.
2. Can deliver the stored energy quickly.
3. Losses are small compared to other storage medium.
4. Long service life and low (or no) maintenance.
5. Can deliver the stored energy quickly.
6. Losses are small compared to other storage medium. Long service life and low (or no) maintenance

Disadvantages

1. Low energy capacity compared to batteries.
2. Limited energy storage per dollar cost.
3. Stored energy will eventually deplete due to internal losses.
4. Low energy capacity compared to batteries. Limited energy storage per dollar cost. Stored energy will eventually deplete due to internal losses.

3.7 Relay

A Relay is a simple electromechanical switch. While we use normal switches to close or open a circuit manually, a Relay is also a switch that connects or disconnects two circuits. But instead of a manual operation, a relay uses an electrical signal to control an electromagnet, which in turn connects or disconnects another circuit [12]. Relays can be of different types like electromechanical, solid state. Electromechanical relays are frequently used. Let us see the internal parts of this relay before' knowing about it working. Although many different types of relay were present, their working is same. Every electromechanical relay consists of an

1. Electromagnet
2. Mechanically movable contact
3. Switching points and
4. Spring

Electromagnet is constructed by wounding a copper coil on a metal core. The two ends of the coil are connected to two pins of the relay as shown. These two are used as DC supply pins. Generally two more contacts will be present, called as switching points to connect high ampere load. Another contact called common contact is present in order to connect the switching points. These contacts are named as normally open (NO), normally closed (NC) and common (COM) contacts.

How to Relay Work?

Relay works on the principle of electromagnetic induction.

1. When the electromagnet is applied with some current, it induces a magnetic field around it.
2. Above image shows working of the relay. A switch is used to apply DC current to the load.
3. In the relay, Copper coil and the iron core acts as electromagnet.
4. When the coil is applied with DC current, it starts attracting the contact as shown. This is called energizing of relay.
5. When the supply is removed it retrieves back to the original position. This is called De energizing of relay.

Types of Relays

We listed out some of the common types of relays here.

1. Electromagnetic
2. Latching

3. Electronic
4. Non-Latching
5. Reed
6. High-Voltage
7. Small Signal
8. Time Delay
9. Multi-Dimensional
10. Thermal
11. Differential
12. Distance
13. Automotive
14. Frequency
15. Polarized
16. Rotary
17. Sequence
18. Moving Coil
19. Safety
20. Supervision
21. Ground Fault

How to Test a Relay?

Since they are electromechanical devices, relays can wear out eventually and stop working overtime. But there are few techniques to test if a relay is working or not. These techniques include:

1. Testing a Relay with a Multimeter
2. Build a simple circuit to test the Relay
3. Use a DC Power Supply to see whether a relay is functioning properly

Relay Switch Circuit

A Relay is a simple electromechanical switch. While we use normal switches to close or open a circuit manually, a Relay is also a switch that connects or disconnects two circuits. But instead of a manual operation, a relay uses an electrical signal to control an electromagnet, which in turn connects or disconnects another circuit. Relays can be of different types like electromechanical, solid state. Electromechanical relays are frequently used. Let us see the internal parts of this relay before' knowing about it working. Although many different types of relay were present, their working is same.

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CHAPTER 4

PRINCIPLE OF LIGHT

4.1 Introduction

The use of a light meter and gray card will facilitate your measurement of the amount of light illuminating your subject. However, the quality of light as determined by the angle, direction, and contrast can only be determined through observation and experience. Look before you shoot. To use the reflected light meter point the meter at the subject. Keep the meter parallel to the camera lens plane. You may choose to move in closer to meter off a gray card; be careful not to cast your shadow onto the card.[13]

4.2 Ambient Light

Avoid shooting in the middle of the day when sunlight is most contrast. When using natural light, try shooting before 10:00 AM or after 2:00 PM to take advantage of the softer light present at those times of day. To fill in shadows with contrast, ambient light, try using a large white card, reflecting light back into the shadows--as in portraiture or landscape. Take advantage of shaded areas with lots of reflected light or areas partially covered by trees for uneven dappled light patterns. Artificial Light: When working with artificial light, you may need higher wattage...as in tungsten lights or the total-lights...that are rated over 300 watts.

4.3 Light Angle and Direction

The angle of incidence equals the angle of reflection. The angle of the light can affect the mood of the photograph, especially by altering the shape of shadows. Light travels in straight lines. Directions of light: front, side, back, top, bottom common positioning of light: top light, side light. The direction of illumination affects perception of volume, contrast, texture and space. The direction of illumination defines the direction, size and placement of shadows in the photograph.

4.4 Measuring Light Intensity

Inverse-Square Law: Light from a source changes in intensity proportional to the inverse of the square of the relative distance from the source.

Intensity = _____1_____

Square of distance between object and light source

Doubling the distance will cut the level of illumination by a factor of four Tripling the distance will cut the level of illumination by nine. Cutting the distance in half will increase the level of illumination by four times

4.5 Categories of Light

Direct light is light traveling unimpeded from the light source to the subject, not filtered

Principles of Light: diffused, reflected or altered. Direct light is like full sun on a clear day.

Reflected: Reflected light is light proceeding from a light source and bouncing off a remote surface and reflecting onto an object. Light reflected into an umbrella with a black backing is an example of reflected light. Light can also be reflected off a white wall or a silver or white card and directed toward a subject. Reflected light is less directional than an unimpeded source light.

Diffused: Diffused light passes through a remote diffusion device or material prior to reaching the subject. Diffuse light is created by clouds or haze in the sky. This light becomes less directional and less contrast. An example of diffused light is created through the use of a shoot through umbrella. The umbrella acts as a diffuser. Other types of diffusers include translucent white panels.

Radiant: A radiant light is a light source that is directly entering a lens such as flare, or a silhouette created by a backlight.

4.6 Light Sensors

A light sensor is a photoelectric device that converts light energy (photons) detected to electrical energy (electrons). Seems simple? There is more to a light sensor than just its definition. It comes in different types and is used in various applications

What are the Types of Light Sensors?

Different types of light sensors are available, mainly Photo resistors, Photodiodes, and Phototransistors. Sounds technical? I'll break it down with the explanations below!

4.7 Photoresistors

The most common light sensor types used in a light sensor circuit are photo resistors, also known as Light-Dependent Resistors (LDR). Photo resistors detect whether a light is on or off and compare the relative light levels throughout the day.

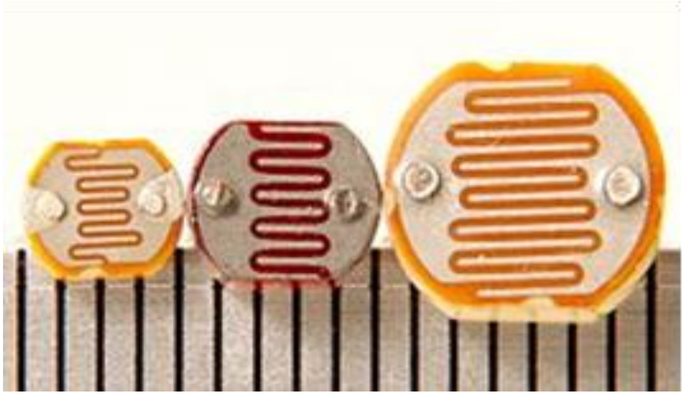

Fig.4.1: Photoresistor

What is Photo Resistors Made of?

Photo resistors are made of highly-resistance semiconductor material called cadmium sulfide cell, which is highly sensitive to visible and near-infrared light. The resistance of a photoresistor decreases with increase in incident light intensity; in other words, it exhibits photoconductivity. A photoresistor can be applied in light-sensitive detector circuits and light-activated and dark-activated switching circuits acting as a resistance semiconductor.

How do Photo Resistors Work?

As its name suggests, photo resistors work similarly to your regular resistors, but the resistance change depends on the amount of light it is exposed to. High light intensity will cause a lower resistance between the cadmium sulfide cells, while low light intensity results in a higher resistance between the cadmium sulfide cells. This working principle can be seen in applications such as street lamps, wherein during the day, the high light intensity results in lower resistance, and thus they are not lit up when the sun is still shining brightly

4.8 Photodiodes

Photodiodes are another type of light sensor. But instead of using the change in resistance like LDR, it’s more complex to light, easily changing light into a flow of electric currents. It is also commonly known as a photo detector or photo sensor.

Fig.4.2: Photodiodes

What are Photodiodes Made Of?

Photodiodes are mainly made from silicon and germanium materials and comprise optical filters, built-in lenses, and surface areas.

How do Photodiodes Work?

Photodiodes work on the working principle called the inner photoelectric effect. When a beam of light hits, electrons are loosened, causing electron holes that result in the electrical current flowing through. The brighter the light, the stronger the electrical current will be.

Photodiode Light Sensor Applications

Since the current generated by photodiodes is directly proportional to light intensity, it makes it favorable for light sensing that requires fast light response changes. Also, they are very responsive to infrared light, thus more projects can be done in that field.

Here are some of the applications of photodiode:

1. Compact disc players
2. Smoke detectors
3. Remote control devices
4. Solar panels
5. Medical applications

4.9 Phototransistor

The last light sensor type we'll be exploring today is the phototransistor. The phototransistor light sensor can be described as a photodiode + amplifier. With the added amplification, light sensitivity is far better on the phototransistors. However, it does not fair better in low-light detection than in photodiodes.

Fig.4.3: Phototransistor

CHAPTER 5

SMART MULTIPLUG AND THUNDERBOLT PROTECTOR

5.1 Introduction

Our Smart Multiplug is intended to protect electronic devices from being damaged by lightning. After light is reflected by the thunderbolt, it automatically turns off the plug and save our important devices. That means our main goal is to protect our devices from thunderbolt.

5.2 Description

Our smart multiplug will turn on after 3 minutes when the torch light falls on the Indoor Sensor of the multiplug for the first time. And then a second lightning strike on the outdoor sensor will turn off the multiplug. This is how our smart multiplug saves our important devices.

5.3 Equipment

1. PCB Board
2. Box (1 piece)
3. 8 Pin Socket (1 piece)
4. 12v Adapter (2 piece)
5. 12v Rile (1 piece)
6. 555 Timer IC (1 piece)
7. BC 547 Transistor (1 piece)
8. LDR (2 piece)
9. 1k Resistor (02 piece)
10. AC Plug (1 piece)
11. 100 UFD 25v Capacitor (1 piece)
12. 1000 UFD 25v Capacitor (1 piece)
13. CD 4017 IC (1 piece)
14. 104 Variable (1 piece)

5.4 Methodology

Our smart multiplug will protect any electronic device from over voltage and lightning. Our Smart Multiplug has 2 sensors.

1. Indicator sensor
2. Outdoor sensor

Indicator Sensor: This sensor will be in our house which will help us launch the Smart Multiplug. Some home sensors can be compared to the key to start a car.

Outdoor Sensor: This sensor will be outside the house (on the roof or balcony or next to the window). It will work only when there is lightning.

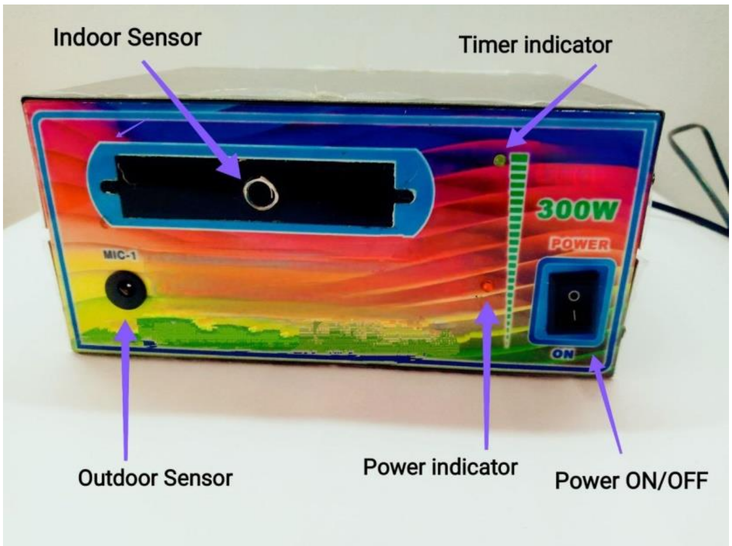

Fig.5.1: Home Sensor & Outdoor Sensor

Let’s talk about how our Smart Multiplug works. Our smart multiplug will work on 3 sections.

1. Input Section
2. Output Section
3. Thunderbolt Protection method

Input Section: As soon as the cable of the Smart Multiplug is connected to the supply current, the output section will not turn on. Then only the supply current will reach the input section.

Fig.5.2: Power Indicator

Output Section: To turn on the output section of the device, shine the torch light on the indoor sensor. Next the Smart Multiplug's timer sensor will turn on for three minutes. After three minutes the output section of our Smart Multiplug will be activated. Then any device connected to the Smart Multiplug will start running.

Fig.5.3: Power Indicator and Timer Indicator.

Thunderbolt Protection Method: Our smart multiplug turns of automatically when the lightening of the thunderbolt strikes the outdoor sensor of our smart multiplug. Again to turn on our smart multiplug, we need to shine the torch light on the indoor sensor. Then the Smart Multiplug's timer sensor will turn on for three minutes. After these three minutes our Smart Multiplug will be activated. In short, it repeats the on-off processing continuously like a loop.

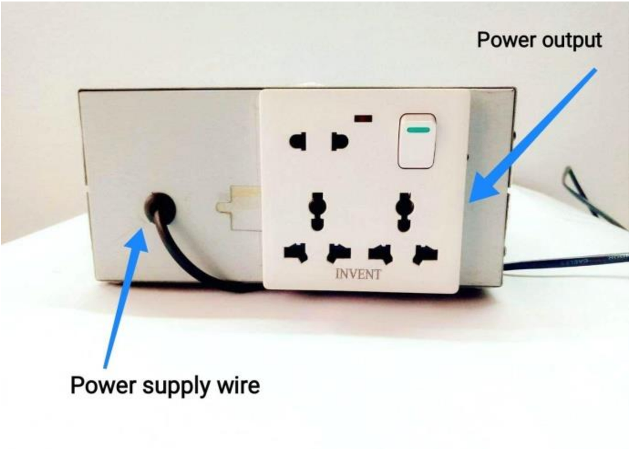

Fig.5.4: Output Section

5.5 Design of Smart Multiplug

The following structure is followed to build our device. We first enter 220 Voltage electricity circuit devices through power supply wire and convert it to 12 volt through adapter. The current will activate the timer IC. Electrons from the IC will enter the capacitor and activate the relay. Then the same electricity will apply 220 Voltage to our main output device.

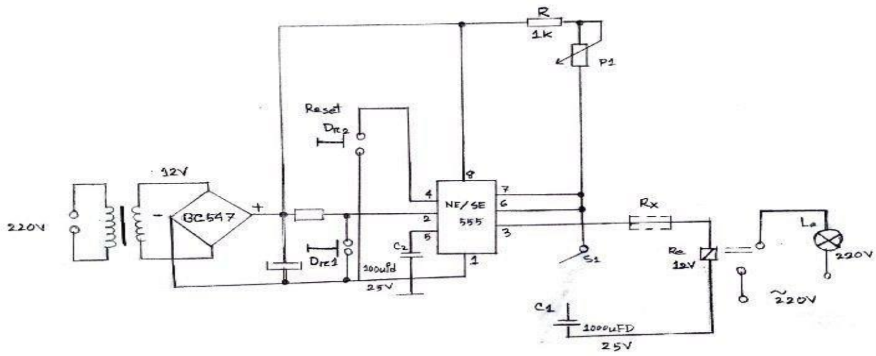

Fig.5.5: Output Section Design

5.6 Limitation

1. Will not react to any light except white light
2. The torch light has to be used repeatedly to turn the device on and off
3. If the device is turned off after the thunderbolt lighting, the device will not restart automatically.

5.7 Output and Final Result

Our Smart Multiplug's outdoor sensor will automatically turn off plugged device when it detects lightning of thunder bolt. As a result it will protect our important electronics devices from over voltage caused by thunderbolt.

CHAPTER 6

CONCLUSION AND FUTURE WORKS

6.1 Conclusion

In conclusion, we can say that we invent various devices to make human life easier, in this device we have tried to do something like that. In the device we have worked on how to protect the electronic devices we need from thunderbolt.

6.2 Future Works

1. We will improve our device outlook.
2. We will try to add thunder bolt sound recognition system.
3. Also try to add only thunder bolt lightning colour detection system.

REFERENCES

[1] Valeriu Manuel Ionescu, Florentina-Magda Enescu, "The implementation of a software system for detecting a pattern in an ambient light sensor data stream", 2018 10th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), pp.1-4, 2018.

[2] H. Seo, J. Choi, H. Kim, T. Park and H. Kim, "Short paper: Surveillance system with light sensor," 2014 IEEE World Forum on Internet of Things (WF-IOT), Seoul, Korea (South), 2014, pp. 165-166, doi: 10.1109/WF-IoT.2014.6803141

[3] M. Buck, "Considerations for light sources: For semiconductor light sensor test," 2015 IEEE 20th International Mixed-Signals Testing Workshop (IMSTW), Paris, France, 2015, pp. 1-6, doi: 10.1109/IMS3TW.2015.7177862

[4] W. J. Sarjeant, "Capacitor fundamentals," Proceedings of the 19th Electrical Electronics Insulation Conference,, Chicago, IL, USA, 1989, pp. 1-51, doi: 10.1109/EEIC.1989.208190.

[5] M. Brotherton, "Paper Capacitors under Direct Voltages," in Proceedings of the IRE, vol. 32, no. 3, pp. 139-143, March 1944, doi: 10.1109/JRPROC.1944.230036.

[6] Setia Veenu, “Resistor”, July 17, 2008, [Online]. Available: https://www.britannica.com/technology/resistor

[7] https://uk.rs-online.com/web/generalDisplay.html?id=ideas-and-advice/resistors-guide

[8] Jefferson “How do IC Timer Function”, May 01, 2008, [Online]. Available: https://www.globalspec.com/learnmore/semiconductors/timing_circuits/ic_timers

[9] Circuit Globe “Transistor Symbol and Terminals”, [online]. Available: https://circuitglobe.com/transistor.html

[10] Gregersen Erik, “Capacitor”, December 23, 2022, [Online]. Available: https://www.britannica.com/technology/capacitor

[11] Woodford Chris, “How cloud capacitors cause lightning”, October 12, 2021, [Online]. Available: https://www.explainthatstuff.com/capacitors.html

[12] Leela Prasad, “What is Relay”, February 28, 2022, [Online]. Available: https://www.electronicshub.org/what-is-relay-and-how-it-works