UNIVERSITY OF NAIROBI

FACULTY OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND INFORMATION ENGINEERING

MAINS VOLTAGE ANALYZER AND POWER CONTROL UNIT

PROJECT INDEX: PRJ 070

BY

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A report submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Science in Electrical and Information Engineering of the University of Nairobi.

Date of submission: 18th May 2011.

DEDICATION

I dedicate this project to my parents for both their moral and financial support they gave me for the entire period I was in the university.

ACKNOWLEDGEMENT

It goes without saying that I am indebted many of my fellow students who have extended their cooperation and help during my research, design and implementation of the project.

I am particularly grateful to Dr. Wekesa, my supervisor, whose assistance and guidance throughout the project helped me a lot. To all my lecturers since 1st year thanks a lot for the knowledge you have equipped me with.

DECLARATION

Except where indicated and acknowledged, I certify that the information presented in this report is my original effort and has not been presented before for a degree award in this or any other university to the best of my knowledge.

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F17/1789/2006

This report has been submitted to the Dept. of Electrical and Information Engineering, University of Nairobi with my approval as supervisor:

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Dr. Cyrus Wekesa

Date: 18^{th} May 2011

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CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

AC voltage transmission is the most common mode of power transmission because of the various advantages it has over DC voltage transmission. Worldwide, many different mains power systems are found for the operation of household and light commercial electrical appliances and lighting. The different systems are primarily characterized by their voltage and frequency. They are also characterized by their earthing system, protection against over current damage, electric shock, and fire hazards and parameter tolerances. All these parameters vary among regions. The voltages are generally in the range 100ï 240 V (root-mean-square voltage). The two commonly used frequencies are 50 Hz and 60 Hz.

However due to various factors it suffers from fluctuations which cause costly damages to electrical machinery. These factors include heavy sags, surges, transient, power back surge, lightening strike, over-voltage and under voltage

1.2 CAUSES OF FLUCTUATION

1.2.1 Over voltage

These are long duration (milliseconds, seconds, minutes, hours or days) rise in voltage above acceptable limits depending on the level of over-voltage the damage can be instantaneous, severe and irreparable. It is mainly caused by on return on mains supply after power cut or accidental connection between two phrases.

1.2.2 Power back surge

These are typically seen when power return after power cut and connected equipment receive a surge of electricity at an over ï voltage level which can be very damaging. It occur when lightening occur on event of mains returns.

1.2.3 Sags

Short duration of under voltage, (micro-mill-seconds 0.15 to few seconds), they may be caused when compressor is switched ON, these cause electric light to dim for a short moment.

1.2.4 Transient

Pulse like energetic disturbance followed occasionally by decaying wave their duration vary from few micro-seconds to few milliseconds. They may have amplitude up to ten thousands volts this occurs when electric motor is switched off and lightening strike supply the lines.

1.2.5 Spike/surge.

Very short (one milliseconds) event of very high surge in voltage to thousands of volts and amps spike are common in all part of the world and repeated exposure to spike will damage electronic equipment and corrupt data. It occurs due to switching on/off of nearby equipment or on event of lightening.

Big industries have been able to protect themselves from damages caused by voltage fluctuation by investing in expensive power protection and power correction equipments hence the need to design a cheap but effective device for use in small industries and also in home appliances.

1.3 OBJECTIVE

The objectives of the project were:

a) To design a Mains voltage analyzer
b) To design the power control unit
c) To implement a model of the Mains voltage analyzer and the power control unit

1.4 JUSTIFICATION

The purpose for designing the Mains voltage analyzer and the power control unit was for analysis of the Mains voltage and control of the power. This was to ensure that only the normal voltage was supplied to the electrical equipments hence protecting them from damages caused by voltage fluctuation. In the market there are various protection devices available which function differently but whose main aim is power protection. However most of these products are very expensive hence the need for designing an affordable mains voltage analyser and power control unit.

1.5 TYPES OF ELECTRICAL PROTECTION DEVICES

1.5.1 Power Switches

Prevent damage to equipment from over or under ï voltage of long duration works by disconnecting power when voltage level exceeds set parameter. Reconnect again when power rates inside parameter for pre-set period fully automate operation, it includes High volt guard, fridge guard, volt guard, lightening guard, Automatic voltage switches Avs 30, and Automatic voltage switches Avs 303.

1.5.2 Power Suppressors

Stops short-term disturbance created by lightning strike, power stations or nearby equipment switching ON and OFF from causing damage that is spike guard, communications guard, Mains filter adapter pure AC and distribution surge protector.

1.5.3 Uninterruptable Power Supply (UPS)

These systems can work as a power source whenever the main power is cut off. These UPS systems are designed to give the user around 5 to 30 minutes of power before it shuts off. This gives you time to turn off your electronic equipment and prevent them from experiencing any surges. These systems are also very different from standby generators because a standby generator will have 10 to 15 seconds of fluctuating power levels. These 10 to 15 seconds can damage electrical devices like a home theatre system.

1.5.4 Regulator/Stabilizer

Ensure equipment can still operate although the voltage level is outside the (normal range) by automatic corrections within set levels e.g. sollatak voltage stabilizer, voltage regulator, switching regulator, SCR regulator, combinational regulator and shunt regulator. Electronic researchers have come up with this type of protective devices to safeguard machines/equipment and minimize losses that are incurred by industries and hospitals in repair and maintenance of the equipment.

Mains voltage analyzer and power control unit is meant to safeguard machine from under voltage and over voltage by this is done by switching off the mains supply automatically in case of AC voltage fluctuations.

CHAPTER TWO: LITERATURE REVIEW

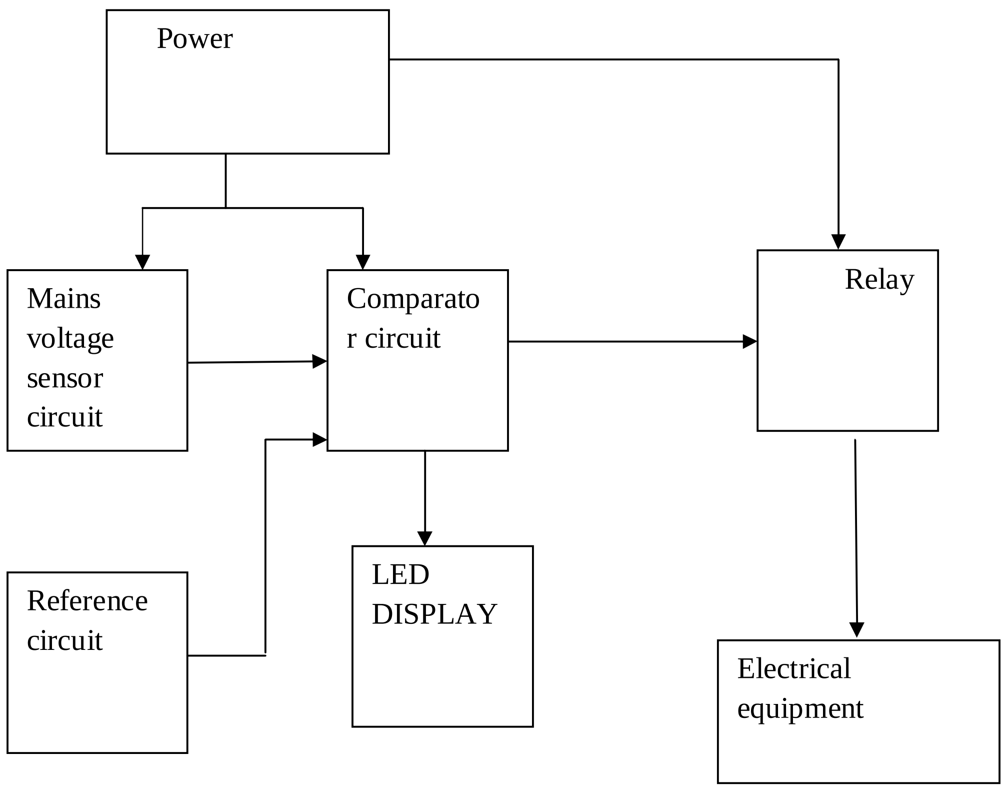
2.1 Introduction

The project was divided into two main areas;

a) Mains voltage analyser

b) Power control unit

2.1.1 BLOCK DIAGRAM REPRESENTATION OF THE MAINS VOLTAGE ANALYSER AND POWER CONTROL UNIT



2.1.2 MAINS VOLTAGE ANALYSER

The mains voltage analyser was made up of;

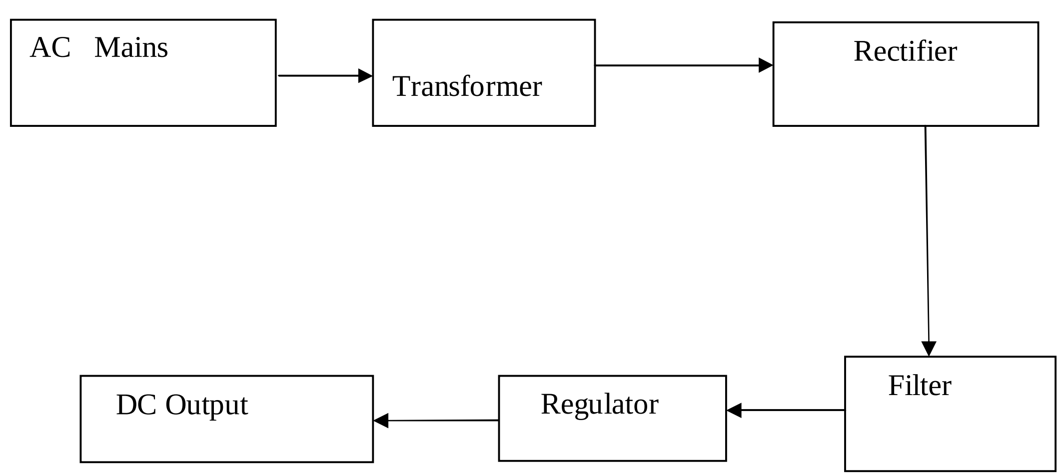
a) Power supply
b) Voltage sensor circuits
c) Comparators circuits
d) Reference circuit
e) Display circuit

2.2 Power supplies

Most electronic equipment needs direct current (dc) to work. Batteries produce dc, but there is a limit to how much energy and how much voltage a battery can provide. The same is true of solar panels.

The electricity from the utility company is alternating current (ac) with a frequency of 50 Hz. In house, most wall outlets carry an effective voltage of 240 V. The energy from a wall outlet is practically unlimited, but it must be converted from ac to dc, and tailored to just the right voltage, to be suitable for electronic equipment.

2.2.1 BLOCK DIAGRAM REPRESENTATION OF A DC POWER SUPPLY



First, the ac encounters a transformer that steps the voltage either down or up, depending on the exact needs of the electronic circuits. Second, the ac is rectified, so that it becomes pulsating dc with a frequency of 50 Hz. This is almost always done by one or more semiconductor diodes.

Third, the pulsating dc is filtered, or smoothed out, so that it becomes a continuous voltage having either positive or negative polarity with respect to ground. Finally, the dc voltage might need to be regulated. Some equipment is finicky, insisting on just the right amount of voltage all the time. Other devices can put up with some voltage changes.

Power supplies that provide more than a few volts must have features that protect the user from receiving a dangerous electrical shock. All power supplies need fuses and/or circuit breakers to minimize the fire hazard in case the equipment shorts out.

2.2 Parts of a power supply

A power supply provides the proper voltage and current for electronic apparatus.

Most power supplies consist of several stages, always in the same order

2.3 The power transformer

Power transformers can be categorized as step-down or step-up. The output, or secondary, voltage of a step-down unit is lower than the input, or primary, voltage. The reverse is true for a step-up transformer.

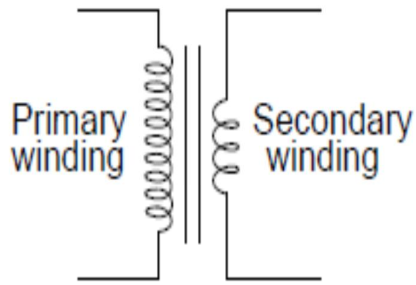


Figure 2.1: Schematic representation of a transformer

2.3.1 Step-down

Most solid-state electronic devices, such as radios, need only a few volts. The power supplies for such equipment use step-down power transformers. The physical size of the transformer depends on the current.

Some devices need only a small current and a low voltage. The transformer in a radio receiver, for example, can be quite small physically. A ham radio transmitter or hi-fi amplifier needs much more current. This means that the secondary winding of the transformer must be of heavy-gauge wire, and the core must be bulky to contain the magnetic flux. Such a transformer is massive.

2.3.2 Step-up

Some circuits need high voltage. The picture tube in a TV set needs several hundred volts. Some ham radio power amplifiers use vacuum tubes working at kilovolts dc. The transformers in these appliances are step-up types. They are moderate to large in size because of the number of turns in the secondary, and also because high voltages can spark, or arc, between wire turns if the windings are too tight.

If a step-up transformer needs to supply only a small amount of current, it need not be big. But for ham radio transmitters and radio/TV broadcast amplifiers, the transformers are large and heavyð and expensive.

2.3.3 Transformer ratings

Transformers are rated according to output voltage and current. For a given unit, the volt-ampere *(VA)* capacity is often specified. This is the product of the voltage and current.

A transformer with a 12-V output, capable of delivering 10 A, would have 12 V *10 A = 120 VA of capacity. The nature of power-supply filtering makes it necessary for the power-transformer VA rating to be greater than just the wattage needed by the load.

A high-quality, rugged power transformer, capable of providing the necessary currents and or voltages, is crucial in any power supply.

2.4 Rectifier

Rectifier diodes are available in various sizes, intended for different purposes. Most rectifier diodes are made of silicon and are therefore known as silicon rectifiers. A few are fabricated from selenium, and are called selenium rectifiers.

Two important features of a power-supply diode are the average forward current (I_o) rating and the peak inverse voltage *(PIV)* rating. There are also other specifications that engineers need to know when designing a specialized power supply.

2.4.0.1 Average forward current

Electric current produces heat. If the current through a diode is too great, the heat will destroy the P-N junction. During designing of a power supply, diodes with an I_o rating of at least 1.5 times the expected average dc forward current should be used.

2.4.0.2 Peak inverse voltage

The PIV rating of a diode is the instantaneous inverse, or reverse-bias, voltage that it can withstand without avalanche taking place. A good power supply has diodes whose
PIV ratings are significantly greater than the peak voltage of the A.C at the input.

If the PIV rating is not great enough, the diode or diodes in a supply will conduct for part of the reverse cycle. This will degrade the efficiency of the supply; the reverse current will ñbuckò the forward current.

Diodes can be connected in series to get a higher PIV capacity than a single diode alone. This scheme is sometimes seen in high-voltage supplies, such as those needed for tube-type ham radio power amplifiers. High-value resistors, of about 500 ɋ for each peak-inverse volt, are placed across each diode in the set to distribute the reverse bias equally among the diodes. Also, each diode is shunted by a capacitor of 0.05 F or 0.1 εF

2.4.1 The half-wave rectifier

In half wave rectification, the rectifier conducts current only during the positive half cycles of input A.C supply. The negative half-cycle of A.C supply are suppressed that is during negative half-cycle, no current is conducted and hence no voltage appears across the load. Therefore, current always flows in one direction (D.C) through the load though after every half-cycle.

The simplest rectifier circuit uses just one diode (or a series or parallel combination) to ñchop offò half of the ac input cycle.

In a half-wave circuit, the average output voltage is approximately 45 percent of the rms ac input voltage. But the PIV across the diode can be as much as 2.8 times the rms ac input voltage. Itôs a good idea to use diodes whose PIV ratings are at least 1.5 times the maximum expected PIV; therefore, with a half-wave supply, the diodes should be rated for at least 4.2 times the rms ac input voltage.

Half-wave rectification has some shortcomings.

a) The output is hard to smooth out, because the waveform is so irregular.
b) The voltage output tends to drop when the supply is connected to a load. This can be overcome to some extent by means of a good voltage regulator.
c) Half-wave rectification puts a disproportionate strain on the power transformer and the diodes.

Half-wave rectification is useful in supplies that do not have to deliver much current, or that do not need to be especially well regulated. The main advantage of using a half-wave circuit in these situations is that it costs a little less than full-wave or bridge circuits.

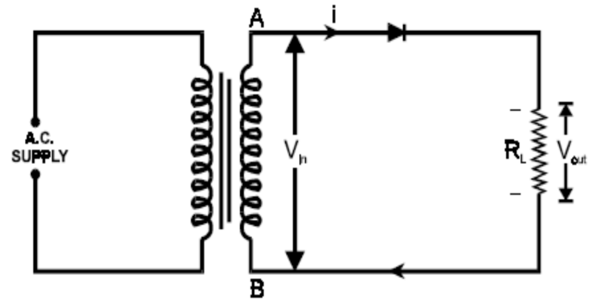


Figure 2. 2: Half wave rectification

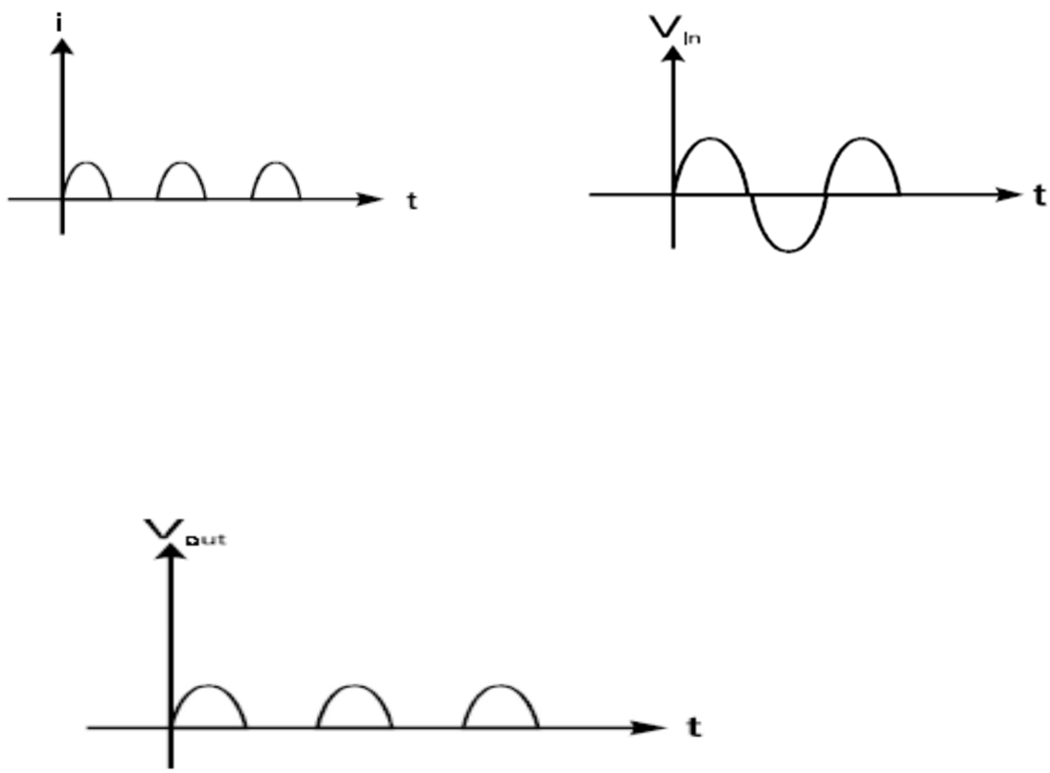


Figure 2.3: Half wave rectification waveforms

2.4.2 The full –wave rectifier

In full wave rectification, current flows through the load in the same direction for both half cycles of input a.c voltage. This can be achieved with two diodes working alternatively. For the positive half cycle of input voltage, one diode supplies current to the load and for the negative half cycle, the other diode does, current being always in the in the same direction through the load.

Two commonly used methods are:

a. Center tap full wave rectifier
b. Full wave bridge rectifier

In the center tap, a wire coming out of the exact middle of the secondary winding, is connected to common ground. This produces out-of-phase waves at the ends of the winding. These two waves can be individually half-wave rectified, cutting off the negative half of the cycle. Because the waves are 180 degrees (half a cycle) out of phase, the output of the circuit has positive pulses for both halves of the cycle

In this rectifier, the average dc output voltage is about 90 percent of the rms ac input voltage. The PIV across the diodes can be as much as 2.8 times the rms input voltage. Therefore, the diodes should have a PIV rating of at least 4.2 times the rms ac input.

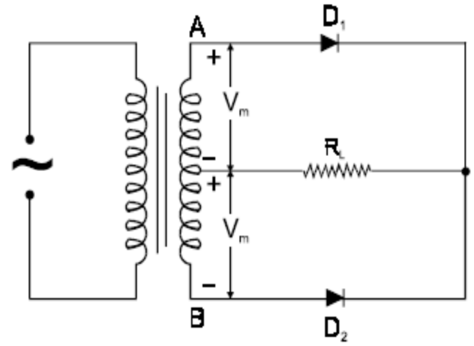


Figure 2.4: full wave rectifier

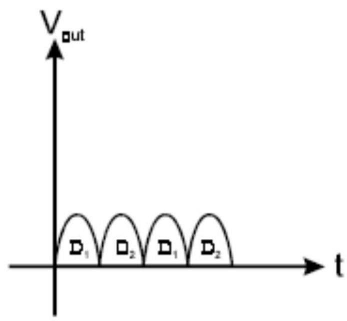


Figure 2.5: full wave rectification waveform

2.4.3 The bridge rectifier

Another way to get full-wave rectification is the bridge rectifier. The output waveform is just like that of the full-wave, center-tap circuit. The average dc output voltage in the bridge circuit is 90 percent of the rms ac input voltage, just as is the case with center-tap rectification. The PIV across the diodes is 1.4 times the rms ac input voltage. Therefore, each diode needs to have a PIV rating of at least 2.1 times the rms ac input voltage.

The bridge circuit does not need a center-tapped transformer secondary. This is its main practical advantage. Electrically, the bridge circuit uses the entire secondary on both halves of the wave cycle; the center-tap circuit uses one side of the secondary for one half of the cycle, and the other side for the other half of the cycle. For this reason, the bridge circuit makes more efficient use of the transformer.

The main disadvantage of the bridge circuit is that it needs four diodes rather than two. This doesnøt always amount to much in terms of cost, but it can be important when a power supply must deliver a high current. Then, the extra diodesð two for each half of the cycle, rather than oneð dissipate more overall heat energy. When current is used up as heat, it canøt go to the load. Therefore, center-tap circuits are preferable in high-current applications.

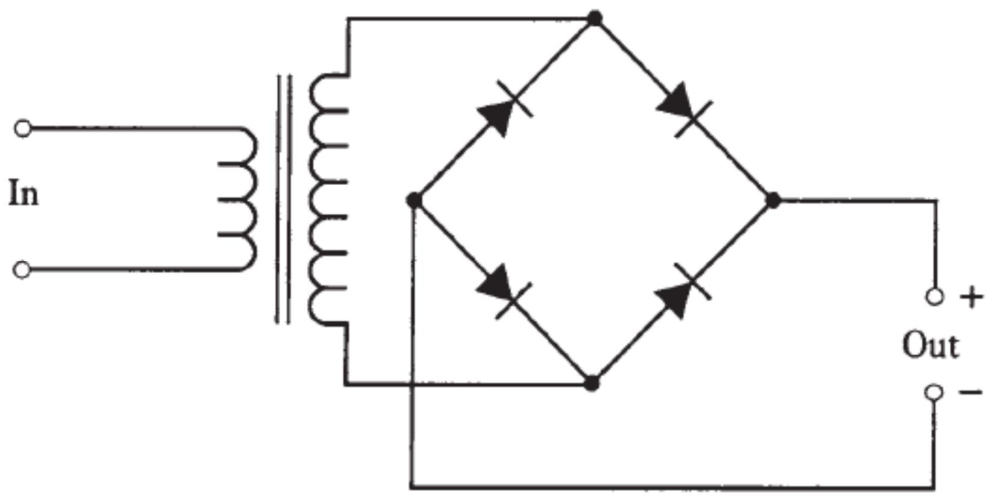


Figure 2.6: full wave bridge rectifier

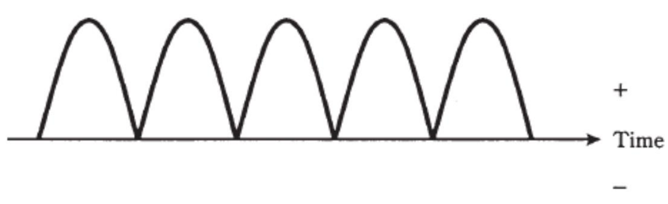


Figure 2. 7: Bridge rectification waveforms

2.5 The filter

Electronic equipment does not like the pulsating dc that comes straight from a rectifier.
The ripple in the waveform must be smoothed out, so that pure, battery-like dc is supplied.
The filter does this.

2.5.1 Capacitors alone

The simplest filter is one or more large-value capacitors, connected in parallel with the rectifier output. Electrolytic capacitors are almost always used. They are polarized; they must be hooked up in the right direction. Typical values range in the hundreds or thousands of microfarads.

The more current drawn, the more capacitance is needed for good filtering. This is because the load resistance decreases as the current increases. The lower the load resistance, the faster the filter capacitors will discharge. Larger capacitances hold charge for a longer time with a given load.

Filter capacitors work by ñtryingò to keep the dc voltage at its peak level. The remaining waveform bumps are the ripple. With a half-wave rectifier, this ripple has the same frequency as the ac, or 50 Hz. With a full-wave supply, the ripple is 100 Hz. The capacitor gets recharged twice as often with a full-wave rectifier, as compared with a half-wave rectifier. This is why the ripple is less severe, for a given capacitance, with full-wave circuits.

The value of the capacitor used in a circuit is calculated from the formula

$$C = \frac{[illegible]}{[illegible]\,\frac{[illegible]}{\sqrt{[illegible]}}\,[illegible]}$$

Where C is the value of the capacitor, f is the frequency and R is the value of the load.

2.5.2 Capacitors and chokes

Another way to smooth out the dc from a rectifier is to use an extremely large inductance in series with the output. This is always done in conjunction with parallel capacitance.

The inductance, called a filter choke, is on the order of several henrys. If the coil must carry a lot of current, it will be physically bulky.

2.6 Voltage regulation

A full-wave rectifier, followed by a choke-input filter, offers fairly stable voltage under varying load conditions. But voltage regulator circuitry is needed for electronic devices that are finicky about the voltage they get. There are mainly two types used that is the zener diodes and IC voltage regulators.

2.6.1 Zener diodes

To make a DC voltage regulator, the zener diode is connected in reverse bias. Its anode is connected to circuit common and its cathode is connected through a series resistance to the positive terminal of the power source. The resistance of the zener diode will vary during circuit operation. It attempts to maintain a constant voltage across its terminal under varying current conditions in the circuit. Hence acts as a voltage regulator

The voltage fed into the regulator should be that is higher than the planned output voltage even at the worst combination of circumstances ï low mains voltage and maximum load current. The regulator then controls the voltage difference between input and output so that the output voltage is steady.

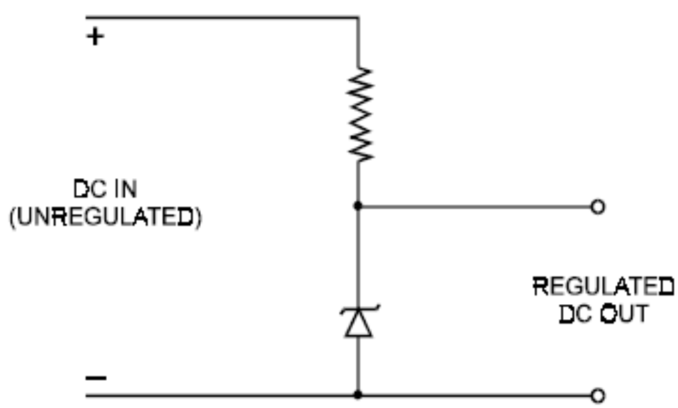


Figure 2.8: Zener regulator circuit

2.6.2 Zener/transistor regulation

A Zener-diode voltage regulator is not very efficient if the load is heavy. When a supply must deliver high current, a power transistor is used along with the Zener diode to obtain regulation. This greatly reduces the strain on the Zener diode, so that a lower-power and therefore less costly diode can be used.

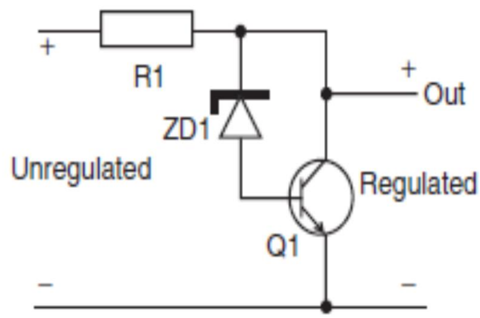


Figure 2.9: Zener/transistor regulator circuit

2.6.3 Integrated circuits regulator

Voltage regulators can be of the fixed type, giving an output voltage fixed by the internal circuitry, or the variable type whose output voltage can be altered by connecting external resistors. Modern linear regulators fall into three categories, referred to as Standard or NPN Darlington, low dropout (LDO), and Quasi-LDO. The feature that distinguishes these types is the dropout voltage, which is the minimum difference between input voltage and output voltage needed to maintain voltage regulation. A regulator which features low dropout voltage will dissipate less power than one with a higher dropout, and is therefore more efficient, with a lower earth current.

The NPN type makes use of a power NPN transistor structure that is driven by a PNP-NPN Darlington circuit. This requires a minimum of dropout of about 1.5 V to 2.5 V to operate. The LDO type of structure uses a power PNP transistor, ensuring a dropout of less than 500 mV (as low as 10 mV on low loads); the Quasi-LDO provides a dropout voltage whose value lies between the other two.

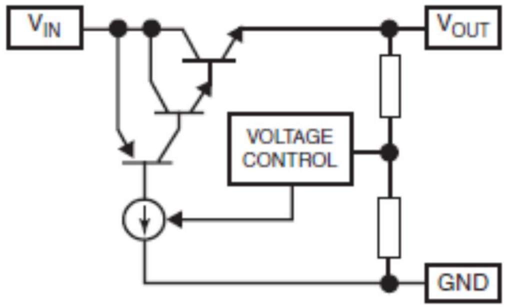


Figure 2.10: NPN voltage regulator

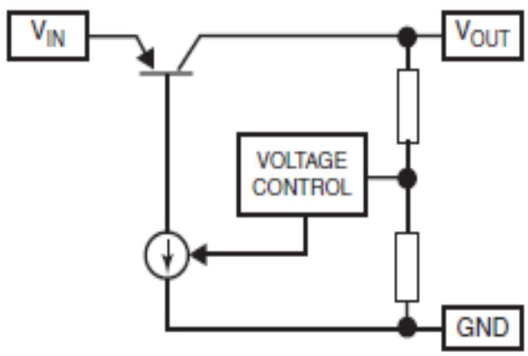


Figure 2.11: PNP voltage regulator

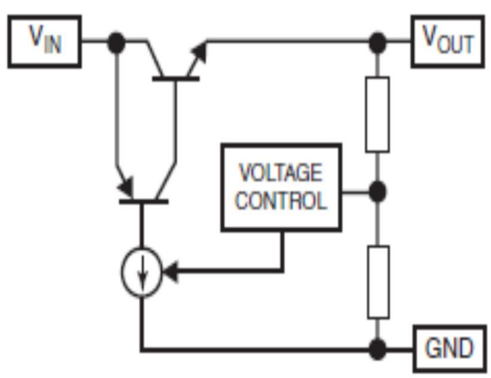


Figure 2.12: Quasi-LDO voltage regulator

Advantages of IC voltage regulators

a) Greatly simplifies power supply design.
b) Easy to use.
c) Due to mass production, low in cost.
d) IC voltage regulators are versatile.
e) Conveniently used for local regulation.
f) They have in built features like thermal protection and programmable output.

2.7 Fuses

A fuse is a piece of soft wire that melts, breaking a circuit if the current exceeds a certain level. Fuses are placed in series with the transformer primary.

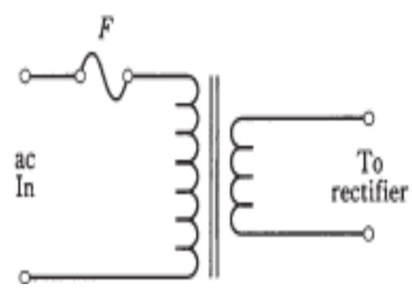


Figure 2.13: Fuse protection circuit

Any component failure, short circuit, or overload that might cause catastrophic damage will burn the fuse out.

Fuses are available in two types: quick-break and slow-blow. A slow-blow fuse is recognized by the spring inside. A quick-break fuse has only a wire or foil strip.

2.8 LEDs

Light-emitting diodes (LEDs) use compound semiconductor materials such as gallium arsenide or indium phosphide. When forward current passes, light is emitted from the junction. The colour of the light depends on the semiconductor material used for the diode and the brightness is approximately proportional to the size of forward current. LEDs have higher forward voltages when conducting; around 1.6 V to 2.2 V as compared to the 0.5 V to 0.8 V of a silicon junction. The maximum permitted reverse voltages are very low, typically only 3 V, so a silicon diode must be connected across the LED if there is any likelihood of reverse voltage (or an AC signal) being applied to the diode. A series resistor must always be used to limit the forward current unless pulsed operation is used.

Advantages of LEDs

a) They are small in size hence can be regarded as point sources of light.
b) They are fast operating devices.
c) They are light in weight.
d) LEDs are available in various colours.
e) LEDS have a long life.
f) They are cheap and reliable.
g) LEDs can be interfaced with various electrical circuits.
h) They are useful for applications which are subjected to frequent on and off cycling.
i) They are shock resistant and difficult to damage due to external shock.

Disadvantages

a) Their characteristics are affected by temperature.
b) LEDs need large power for operation compared to normal pn junction diode.
c) Luminance efficiency of LEDs is low which is about 1.5 lumen/watt.
d) It draws considerable large amount of current.

2.9 Potential divider

A potential divider also known as a voltage divider is a simple linear circuit that produces an output voltage (V_{out}) that is a fraction of its input voltage (V_{in}). Voltage division refers to the partitioning of a voltage among the components of the divider.

A simple example of a voltage divider consists of two resistors in series or a potentiometer. It is commonly used to create a reference voltage or to get a low voltage signal proportional to the voltage to be measured and may also be used as a signal attenuator at low frequencies.

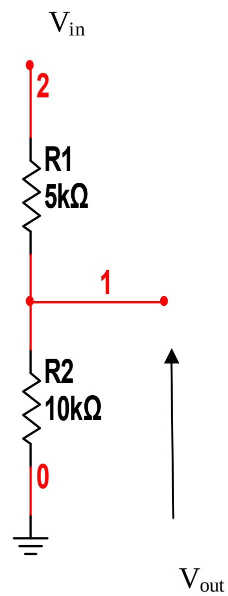


Figure 2.14: Potential divider schematics

$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

2.10 Comparator

A comparator is similar to an op amp. It has two inputs, inverting and non-inverting and an output. But it is specifically designed to compare the voltages between its two inputs. Therefore it operates in a non-linear fashion. The comparator operates open-loop, providing a two-state logic output voltage. These two states represent the sign of the net difference between the two inputs including the effects of the comparator input offset voltage. Therefore, the comparator's output will be logic "1" if the input signal on the non-inverting input exceeds the signal on the inverting input plus the offset voltage, V_{os} and logic "0" for the opposite case. A comparator is normally used in applications where some varying signal level is compared to a fixed level usually a voltage reference. Since it is, in effect, a 1-bit analog-to-digital converter (ADC), the comparator is a basic element in all ADCs.

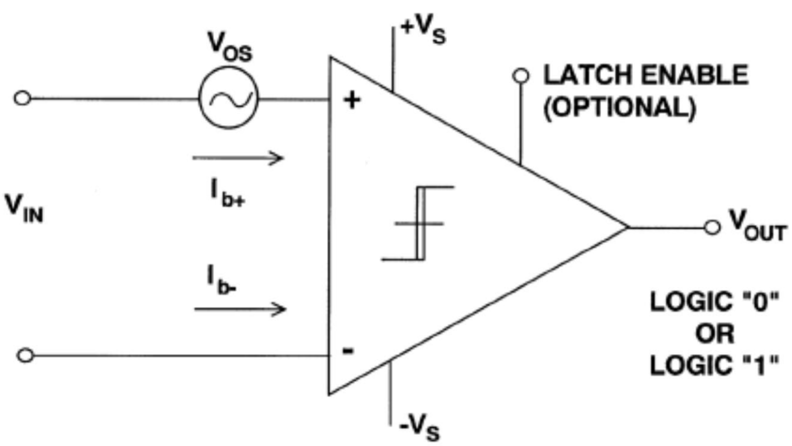


Figure 2.15: Schematic representation of a comparator

An integrated circuit "Voltage Comparator" is equivalent to an Operational Amplifier, Such as the LM358 or LM324, with two NPN transistors added to the output of each amplifier. This arrangement produces an "Open Collector" output for each of the four comparators in an LM339 chip. Each output can sink 15 Milliamps and can withstand voltages of up to 50 Volts. Current will flow through the open collector when the voltage at the non inverting input is lower than the voltage at the inverting input. Current will not flow through the open collector when the voltage at the non inverting input is higher than the voltage at the inverting input.

2.11 RELAYS

A relay is an electrically operated switch. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between and controlled circuits), or where several circuits must be controlled by one signal. There are two major types of relays:

a) Electromechanical relay
b) Solid state relay

2.11.1 Electromechanical relay

An electromechanical 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

Relay construction

An electric current through a conductor will produce a magnetic field at right angles to the direction of electron flow. If that conductor is wrapped into a coil shape, the magnetic field produced will be oriented along the length of the coil. The greater the current, the greater will be the strength of the magnetic field, all other factors being equal. Inductors react against changes in current because of the energy stored in this magnetic field. The magnetic field produced by a coil of current-carrying wire can be used to exert a mechanical force on any magnetic object, just as we can use a permanent magnet to attract magnetic objects, except that this magnet formed by the coil can be turned on or off by switching the current on or off through the coil.

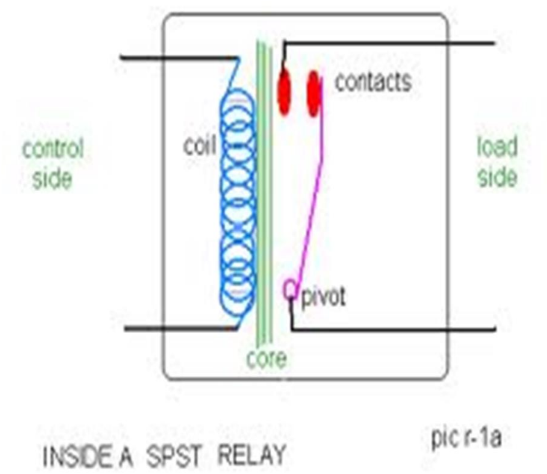


Figure 2.16: Schematic of electromechanical relay

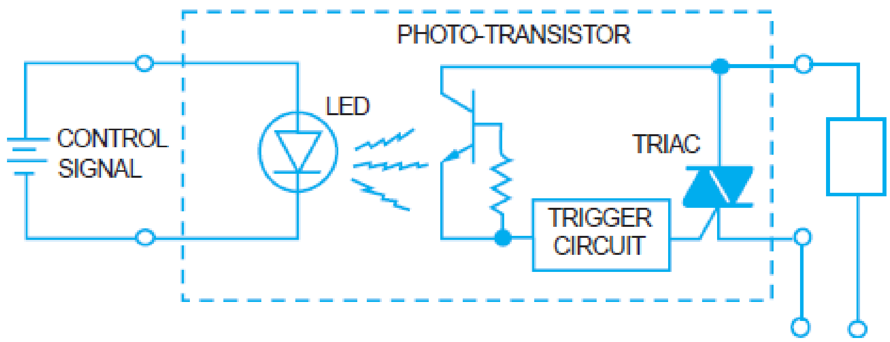
Solenoids can be used to electrically open door latches, open or shut valves, move robotic limbs, and even actuate electric switch mechanisms. However, if a solenoid is used to actuate a set of switch contacts it is called the relay.

Relays are extremely useful when we have a need to control a large amount of current and/or voltage with a small electrical signal. The relay coil which produces the magnetic field may only consume fractions of a watt of power, while the contacts closed or opened by that magnetic field may be able to conduct hundreds of times that amount of power to a load. In effect, a relay acts as a binary (on or off) amplifier.

Relay contacts may be open-air pads of metal alloy, mercury tubes, or even magnetic reeds, just as with other types of switches. The choice of contacts in a relay depends on the same factors which dictate contact choice in other types of switches. Open-air contacts are the best for high-current applications, but their tendency to corrode and spark may cause problems in some industrial environments. Mercury and reed contacts are sparkless and won't corrode, but they tend to be limited in current-carrying capacity.

2.11.2 Solid-state relays

As versatile as electromechanical relays can be, they do suffer many limitations. They can be expensive to build, have a limited contact cycle life, take up a lot of room, and switch slowly, compared to modern semiconductor devices. These limitations are especially true for large power contactor relays. To address these limitations, solid-state relays, which use an SCR, TRIAC, or transistor output instead of mechanical contacts to switch the controlled power, are used. The output device (SCR, TRIAC, or transistor) is optically-coupled to an LED light source inside the relay. The relay is turned on by energizing this LED, usually with low-voltage DC power. This optical isolation between input to output rivals the best that electromechanical relays can offer



. ac power

Figure 2.17: Schematic representation of a solid state relay

Being solid-state devices, there are no moving parts to wear out, and they are able to switch on and off much faster than any mechanical relay armature can move. There is no sparking between contacts, and no problems with contact corrosion.

One significant advantage of a solid-state SCR or TRIAC relay over an electromechanical device is its natural tendency to open the AC circuit only at a point of zero load current.

Because SCR's and TRIAC's are thyristors, their inherent hysteresis maintains circuit continuity after the LED is de-energized until the AC current falls below a threshold value that is holding current. In practical terms what this means is the circuit will never be interrupted in the middle of a sine wave peak. Such untimely interruptions in a circuit containing substantial inductance would normally produce large voltage spikes due to the sudden magnetic field collapse around the inductance. This will not happen in a circuit broken by an SCR or TRIAC. This feature is called zero-crossover switching.

One disadvantage of solid state relays is their tendency to fail "shorted" on their outputs, while electromechanical relay contacts tend to fail "open." In either case, it is possible for a relay to fail in the other mode, but these are the most common failures. Because a "fail-open" state is generally considered safer than a "fail-closed" state, electromechanical relays are still favoured over their solid-state counterparts in many applications.

CHAPTER THREE: DESIGN AND IMPLEMENTATION

3.1 Design of DC power supply

3.1.1 Transformer

The transformer was selected on the basis of its voltage output and the current output as per the requirement of the project. The power transformer chosen was a shell type step-down transformer. Its ratings were 240V to 12V at 500mA current. Its primary current was calculated using the power formula

Power in = Power out

$$V_{in}I_{in} = V_oI_o$$

$$I_{in} = \frac{V_{out}}{V_{in}} I_{out}$$

$$= \frac{12*0.5}{240}$$

=25mA

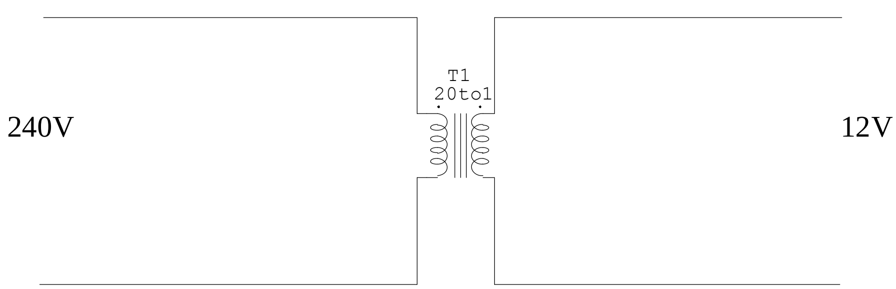


Figure 3.1: Transformer circuit

3.1.2 RECTIFIER

A full wave bridge rectifier was designed using 1N4007 diodes. It converted the steped down AC voltage from the transformer into a pulsating DC voltage. I mainly chose the 1N4007 diodes because of their low forward drop and high surge current capability. The ratings of the 1N4007 diodes were: V_{rms} = 700v, V_{fm} = 1.1V and I_f = 1A.

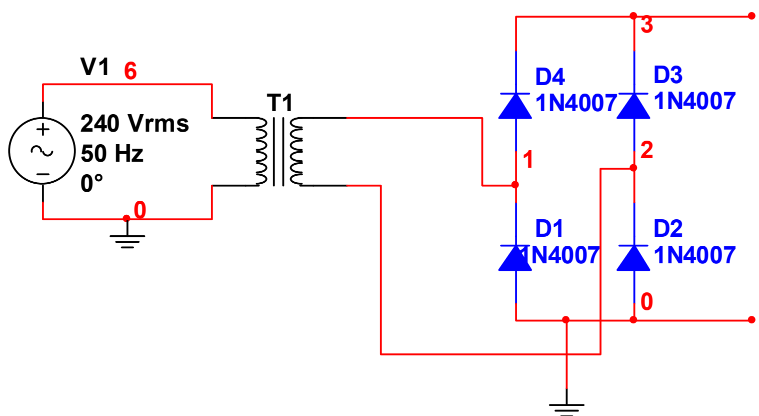


Figure 3.2: Full wave rectification circuit

3.1.3 FILTER

A shunt electrolytic capacitor was used to minimize the ripples present in the rectified voltage. The value of the capacitor used was 320microfarads. The value was supposed to be calculated using the formula

$$C= \text{[illegible]}$$

But since the value of the load resistance was not a specific value. The 320microfarads capacitor was chosen to meet the various loads demand

3.1.4 IC Voltage regulator

This regulator was used since it offers an economical and easier way to obtain a regulated voltage. It also offers an internal over current and thermal protection. The LM7812 IC voltage regulator was chosen to provide a positive regulated voltage of 12V.

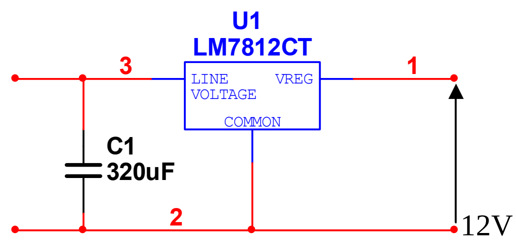


Figure 3.3:IC voltage regulator circuit

3.2 Comparators

The comparators used were LM339 which is a quad differential comparator which can operate over a wide range of supply voltage and also has a wide input differential range which is equal to the maximum rated supply voltage. Other advantages include

a. High precision comparators
b. Reduced VOS drift over temperature
c. Eliminates need for dual supplies
d. Allows sensing near GND
e. Compatible with all forms of logic
f. Power drain suitable for battery operation

The comparators compared the reference voltages and provided an output to the analyzer display hence displaying the various voltage levels. The comparators also control the relays, that is when comparator detects an over voltage, the normally closed relay is energized and it opens hence power is cut to the electrical devices. When the comparator detect a normal voltage the normally open relay is energized closing it hence power is delivered to the machine.

3.3 Potentiometer

The reference circuit was implemented using two 20kq potentiometers that could be varied to vary the levels of voltage classified into three classes that is under voltage, normal voltage and over voltage. These were the main control elements in the circuit as the variation in their levels controlled the level of under voltage, normal voltage and over voltage.

3.4 LED Display

Three LEDs were used in the analyzer to indicate the three different voltage levels. They were GaAsP red, GaAsP green and GaAsP blue. They had a V_{Fmax}=2.6V and I_{Fmax}=20mA hence protection resistors of 2.2kq hence ensuring the current is always below the maximum current.

$$\square = \frac{\square\square\ \square\square}{\square}$$

$$= \frac{\square\square\square\ \square.\square}{\square\square}$$

$$=9.4mA$$

The 9.4mA current well below I_{Fmax} of 20mA, hence the LEDs were working in a safe range.

3.5 Relays

Solid state relays were used because of their many advantages over the electromechanical relays. Two solid state relays were used: one normally close and one normally open relay. The normally closed solid state relay was used for controlling over-voltage. The relay was controlled by the comparator and operated like normally closed switch which was opened by the comparator whenever an over-voltage was detected. The second relay was a normally opened relay that was also controlled by the second comparator and operated like a normally open switch and closed whenever a normal voltage was detected by the comparator. Their control voltage rating was 3-30V DC and current was 1mA.

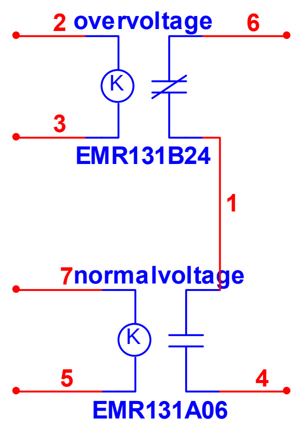


Figure 3. 4: relays circuit diagram

The relays were connected in series such that if there was an over-voltage, the normally closed relay opened and no power is delivered to the load. The normally open relay ensured that power was only delivered to load when there was normal supply otherwise the relay was open. The relay also ensured that should there be a problem with the analyzer or protection unit or maybe the fuse blew up no power will be transmitted to the load and the major aim of electrical equipment protection will always be ensured.

The mains voltage analyzer and power control units were connected together as one unit.

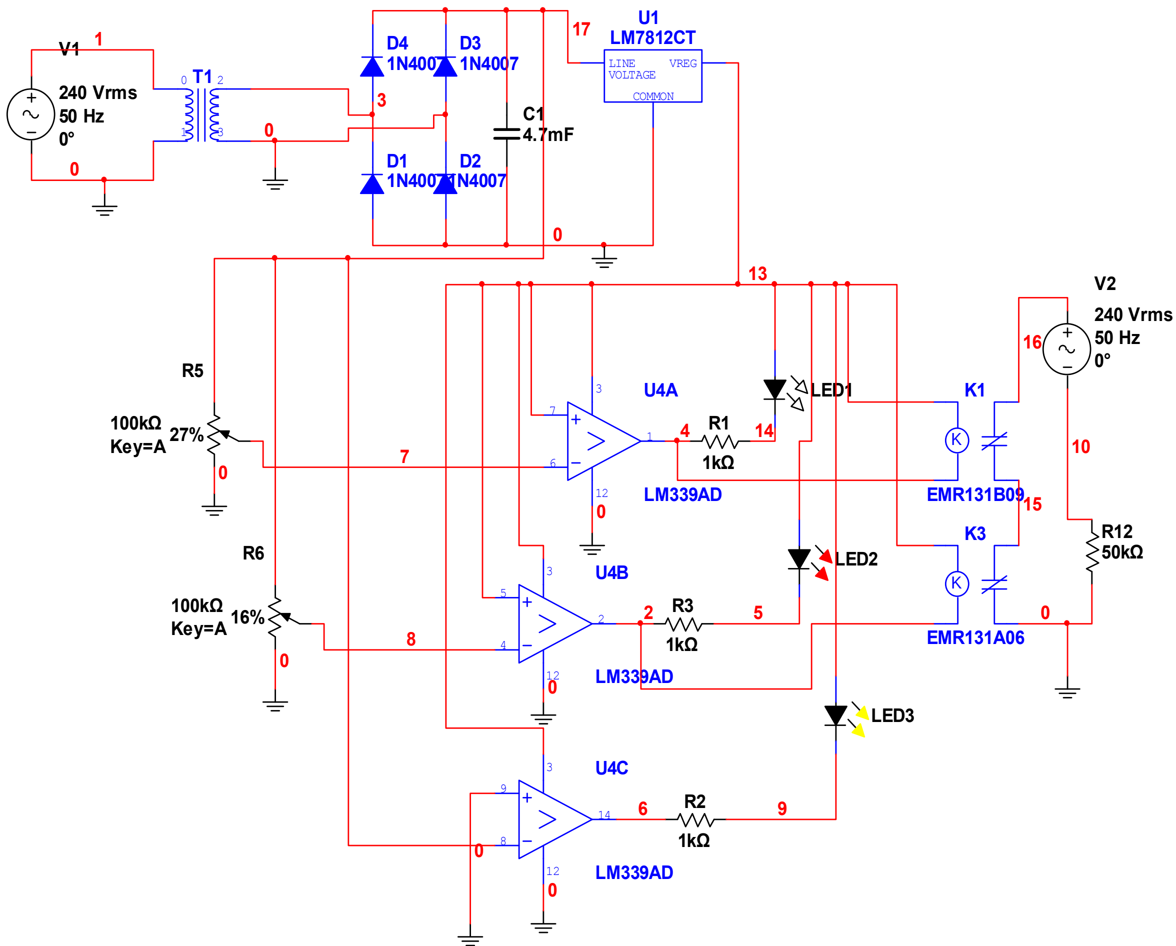


Figure 3.5: Mains voltage analyzer and power control unit circuit diagram

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 TESTING

Testing was done for both the Mains voltage analyzer and power control unit.

For testing purposes under voltage was taken to be below 220V and normal voltage to be between 220V and 250V. Over voltage was chosen to be any Mains voltage above 250V. This setting was achieved by varying the potentiometer for both normal voltage and over voltage accordingly.

For a normal voltage supply of 240V, the theoretical value was supposed to be:

$$= \frac{240}{20} * \sqrt{2}$$

$$=16.97V\ dc$$

But due to voltage drop in diodes and other losses the rectified dc voltage measured was 16.07V. The voltage comparators in the analyzer part compared the unregulated dc voltage and the regulated dc voltage from IC 7812. The IC voltage regulator theoretically gives a regulated voltage of 12V. The regulated voltage was measured to be 12.2V using an oscilloscope.

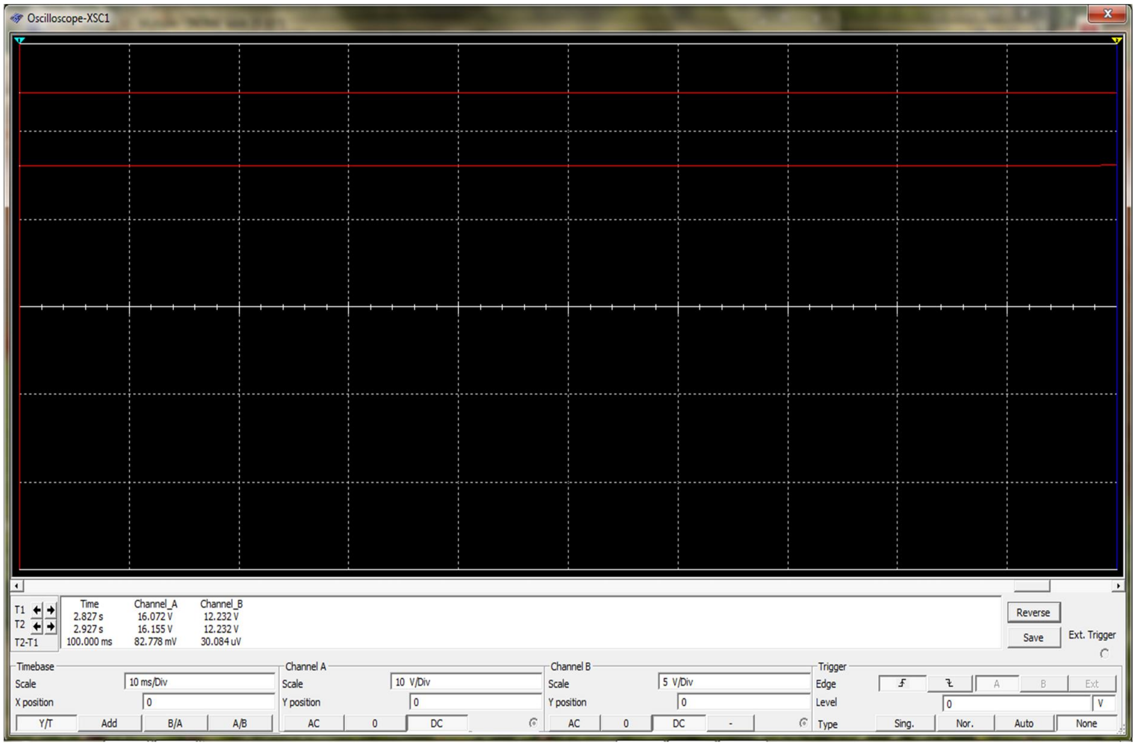


Figure 4.1: Unregulated and regulated dc voltage waveforms

4.1.1 Mains voltage analyzer

The mains voltage analyzer worked as designed. For under voltage the yellow LED lit indicating a low voltage was present in the Mains.

For normal voltage both the yellow and green LED lit indicating a normal voltage was present in the mains.

Testing for over voltage had the red, green and yellow LED lit. This showed the presence of an over voltage.

4.1.2 Power control unit

The power control unit worked well when it was tested. Voltage was delivered to the load when a normal voltage was applied since the normally open relay was closed completing the circuit and the normally closed relay remained normally closed since it was not energised.

When an under voltage was applied the normally closed relay remained closed while the normally open relay also remained open hence the load was not energised.

When an over voltage was applied the normally closed relay was energised and hence opened, while the normally closed relay

4.2 LIMITATION

The main limitation was that when under voltage was below 165V , the IC 7812 voltage regulator did not produce a regulated 12V dc voltage hence it led to errors in the analyzer part of the project.

Also when over voltage was too high, the fuse blew up hence very high voltage could not be analyzed.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The project worked quite well and all the objectives were met except for small errors, for example when under voltage was below 165V. The Mains voltage analyzer and power control unit designed was economical and easily repairable in case of faults hence would be very much applicable in small and Jua-kali industries.

5.2 RECOMMENDATIONS

The project could be improved further by including a 12V dc battery that would provide the reference voltage and would also provide dc power to comparator and relays during very low voltage periods hence ensuring the analyzer worked perfectly.

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