DESIGN AND CONSTRUCTION OF A LOAD MONITORING DEVICE

BY

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NOVEMBER, 2011

DECLARATION

I Ojo, Yemi declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

Ojo, Yemi
(Student)

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CERTIFICATION

This is to certify that this project titled "Design and Construction of a Load Monitoring Device" was carried out by Ojo Yemi with matriculation number 2006/24418EE, and submitted to the Department of Electrical and Electronics Engineering, Federal University of Technology, Minna in partial fulfillment of the requirements for the award of Bachelor degree in Engineering (B. Eng.).

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DEDICATION

I dedicate this project work to my late dad, Mr. Kayode Ojo.

ACKNOWLEDGEMENTS

My sincere gratitude goes to the Almighty God for the wisdom, knowledge and understanding He bestows on me. I also appreciate Him for the perfect health and financial provision accorded me during the course of my studies.

My profound gratitude goes to my project supervisor, Engr. Dr. M. N. Nwohu for his constructive criticisms and advice making this project work a success.

My appreciation goes to my dear parents Mr. and Mrs. Kayode Ojo for their sacrifice. I am also grateful to my siblings Yomi, Omolola, Bola, and Iyanu for their encouragement and support.

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Finally, I acknowledge the friendship of Moshood, Chimezie, Martha, Segun, Mayor, Paul, Daniel, Basil, Rehoboth family, B. S. F. family, Mabel and others not mentioned.

ABSTRACT

This project work was carried out to monitor the load level of a power unit and also to make an alert when there is an overload. The device was designed to tolerate load with power in the range below 1000W. The work was carried out by dividing it into modules for ease accomplishment. The modules were power module, voltage divider module, switching module and alarm module. The voltage value obtained from the loading circuit was compared with the reference voltage of the comparator to activate a relay and an alarm simultaneously. When a load above 1000W was connected at the loading point, it caused the activation of the relay, disconnecting the load from the mains supply and at the same time activating alarm to make an alert.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Preamble

Monitoring is the act of observing. Earlier, monitoring of load level in electrical engineering is carried out manually by putting people in place to observe which makes it inefficient. With advancement in technology, this can be carried out by designing circuits using sensitive electronic components, thereby improving the efficiency.

Consequently, this project work does the act of monitoring a load, and then act in accordance to the information it obtains. It has the maximum load it can tolerate before taking its action. The action it takes is tripping off and on when a load that exceeds its tolerance level is connected to its loading point. The Load Monitoring Device has two major sections.

1. Loading unit: this is where the load is connected to be powered.
2. The comparison unit: this is the section that involves the comparator. The comparator compares two voltage levels for the monitoring (observation) of the load level at the loading unit. The two voltage levels are from the loading circuit and the reference voltage connected to the non-inverting and inverting terminal of an operational amplifier. In essence, the comparator serves as the 'brain' of this project work.

It can be incorporated into power systems to monitor load and make an alert by triggering an alarm.

1.2 Aim/objectives

1. To monitor the load of a power unit.
2. To alert the electricity user when there is an overload.

1.3 Project justification

It has been observed that electrical power designs and systems suffer from being overloaded often unknowingly by the users. This, therefore, reduces their life span and reliability. To make alert whenever these systems are overloaded, this electrical monitor has been designed and constructed.

1.4 Scope and limitations

The project work is designed to tolerate load with power in a range below 1000W. When the power of the load connected exceeds this limit, the unit trips on and off accompanied by an alarm to make alert for proper action to be taken. Domestic loads should always be connected at the loading point in order not to exceed the current capacity of the transformer. A monostable multivibrator is incorporated into the unit to prevent frequent rapid tripping.

1.5 Project outline

The project report is made up of five chapters. Chapter one is the introduction which covers the preamble of the work, aim/objectives, project justification, scope and limitations. In chapter two, the literature review was carried out. It comprises of the historical and theoretical background. Chapter three gives the details on the methodology, design analysis, precautions and working principle. Chapter four composes of the tests, results obtained and the discussion of the results. The conclusion and recommendation is done in chapter five. Finally, sources of materials used were cited in the reference.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Historical background

George W. Hart, Ed Kern and Fred Schwepper of Massachusetts Institute of Technology in the early 1980s with finding from the Electrical Power Research Institute invented the Non-Intrusive Load Monitoring (NILM). The NILM is a process for analyzing changes in the voltage and current going into a house and deducing what appliances are used in the house as well as their individual energy consumption. Electrical meters with NILM technology are used by utility companies to survey the specific uses of electrical power in different homes. NILM is considered a low cost alternative to attaching individual monitors on each appliance. The basic process of the NILM was described in the U.S Patent 4858, 141 [1].

Also, L.K. Norford, S.B. Leeb, D. Luo and S.R Shaw Massachusetts Institute of Technology described a low-cost approach to obtain and analyze electrical power that is very useful for load monitoring [2].

The Load Monitoring Device is therefore designed by considering changes in voltage through a power system when overloaded to monitor the capacity of load and then make an alert by triggering an alarm.

2.2 Theoretical background

The theoretical background of the electronic components used in different modules of this project work is discussed taking into consideration their characteristics.

2.2.1 Transformer

A transformer is a static (or stationary) piece of apparatus by means of which electric power in one circuit is transformed into electric power of the same frequency in another circuit

[3]. It is an electrical device consisting of one coil of wire placed in close proximity to another coil, used to couple two alternating-current (AC) circuits together by employing the induction between the coils [4]. The two coils possess high mutual inductance. If one coil is connected to a source of alternating voltage, an alternating flux is set up in the laminated core in which it produces mutually induced e.m.f (according to Faraday's Laws of Electromagnetic induction $e = m\frac{dI}{dt}$) [3]. The coil connected to the power source is called the primary coil, and the other coil is known as secondary. A transformer in which the secondary voltage is higher than the primary is called a step-up transformer; if the secondary voltage is less than the primary, the device is known as a step-down transformer. The product of current and voltage is constant in each set of coils, so that in a step-up transformer, the voltage increase in the secondary is accompanied by a corresponding decrease in the current [4]. The transformation ratio of a transformer is giving by the formula below.

$$\frac{V_S}{V_P} = \frac{N_S}{N_P} = \frac{I_P}{I_S}$$

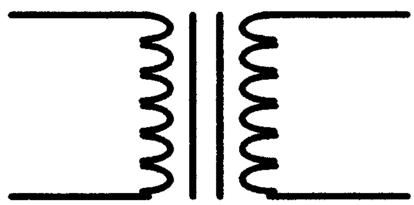

Figure 1: Circuit symbol of a transformer

2.2.2 Diode

In electronics, a diode is a two-terminal electronic component that conducts electric current in only one direction. This is a crystalline piece of semiconductor connected to two electrical terminals. The most common function of a diode is to allow an electric current to pass in one direction (called the diode's forward direction), while blocking current in the opposite direction (the reverse direction). Thus, the diode can be thought of as an electronic version of a check valve. This unidirectional behaviour is called rectification, and is used to convert alternating current to direct current.

However, diodes can have more complicated behaviour than this simple on-off action. This is due to their complex non-linear electrical characteristics, which can be tailored by varying the construction of their P-N junction. These are exploited in special purpose diodes that perform many different functions. For example, specialized diodes are used to regulate voltage (Zener diodes), to electronically tune radio and TV receivers (varactor diodes), to generate radio frequency oscillations (tunnel diodes), and to produce light (light emitting diodes). Tunnel diodes exhibit negative resistance, which makes them useful in some types of circuits. Diodes were the first semiconductor electronic devices.

The discovery of crystals' rectifying abilities was made by German physicist Ferdinand Braun in 1874. Today most diodes are made of silicon, but other semiconductors such as germanium are sometimes used. In the case of silicon diode, the forward bias voltage is 0.7V while that of germanium is 0.3V. The diode used in this project work is the silicon P-N junction type [5].

Figure 2: Circuit symbol of a p-n junction diode

2.2.3 Capacitor

A capacitor (formerly known as condenser) is a device for storing electric charge. A capacitor is a passive electronic component consisting of a pair of conductors separated by a dielectric (insulator). When there is a potential difference (voltage) across the conductors, a static electric field develops across the dielectric, causing positive charge to collect on one plate and negative charge on the other plate. Energy is stored in the electrostatic field. An ideal capacitor is characterized by a single constant value, capacitance, measured in farads. This is the ratio of the electric charge on each conductor to the potential difference between them.

Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass, in filter networks, for smoothing the output of power supplies, in the resonant circuits that tune radios to particular frequencies and for many other purposes. The capacitance is greatest when there is a narrow separation between large areas of conductor; hence, capacitor conductors are often called "plates", referring to an early means of construction [6]. In this project work, the electrolytic (polarized type) and polystyrene (non-polarized type) capacitors were used.

Figure 3: Circuit symbol of a non-polarize capacitor

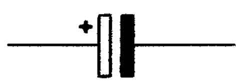

Figure 4: Circuit symbol of a polarize capacitor

2.2.4 Resistors

A resistor is a two-terminal passive electronic component which implements electrical resistance as a circuit element. When a voltage V is applied across the terminals of a resistor, a current I will flow through the resistor in direct proportion to that voltage. This constant of proportionality is called conductance, G. The reciprocal of the conductance is known as the resistance R, since, with a given voltage V, a larger value of R further "resists" the flow of current I as given by Ohm's law. Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in most electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel-chrome). Resistors are also implemented within integrated circuits, particularly analog devices [7].

Figure 5: Circuit symbol of a resistor

2.2.5 Voltage comparator

A voltage comparator is type of operational amplifier operated without a feedback resistance. It consists of the inverting, non-inverting and output terminal. A comparator circuit accepts input of linear voltages when one input is less than or greater than the second. The output is a digital signal that stays at a high voltage level when the non-inverting (+) input is greater than the voltage at the inverting (-) and switches to a lower voltage level when the non-inverting input voltage goes below the inverting input voltage [8]. The voltage comparator was implemented using LM358.

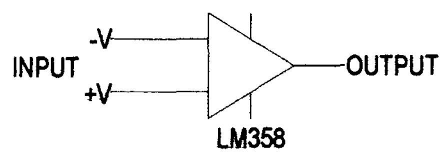

Figure 6: Circuit symbol of an opamp

2.2.6 Relay

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field which attracts a lever and changes the switch contacts. The coil current can be on or off, so relays have two switch positions and must have double throw (changeover) switch contacts. Relays allow one circuit to switch a second circuit which can be completely separate from the first. There is no electrical connection inside the relay between the two circuits; the link is magnetic and mechanical. The coil of a relay passes a relatively large current, typically 30mA for a 12V relay, but it can be as much as 100mA for relays designed to operate from lower voltages. Most ICs (chips) cannot provide this current and a transistor is usually used to amplify the small IC current to the larger value required for the relay coil. Relays are usually single pole double throw (SPDT) or double pole double throw (DPDT) but they can have many more sets of switch contacts [9].

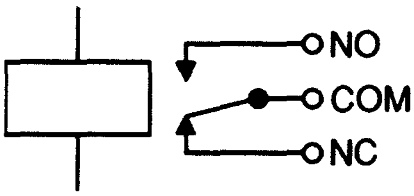

Figure 7: Circuit symbol of a relay

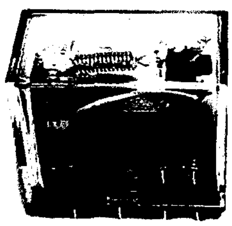

Plate I: Relay

2.2.7 Transistor

In a transistor, a combination of two junctions may be used to achieve amplification. One type, called the n-p-n junction transistor, consists of a very thin layer of p-type material between two sections of n-type material. To permit the forward flow of current across the n-p junction, the emitter has a small negative voltage with respect to the p-type layer, or base component that controls the electron flow. The n-type material in the output circuit serves as the collector element, which has a large positive voltage with respect to the base to prevent reverse current flow. Electrons moving from the emitter to the base are attracted to the positively charged collector, and flow through the output circuit. The input impedance or resistance to current flow, between the emitter and the base is low, whereas the output impedance between collector and base is high. Therefore, small changes in the voltage of the base cause large changes in the voltage drop across the collector resistance, making this type of transistor an effective amplifier.

It can also be used as switches when operated in the cut-off and saturation region [10].

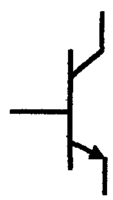

Figure 8: Circuit symbol of a transistor

2.2.8 Voltage regulator

Voltage regulators comprise a class of widely used ICs. The three-terminal voltage regulator is a fixed voltage regulator that has an unregulated dc input voltage V_i applied to one input terminal, a regulated output dc voltage V_o from a second terminal, and the third terminal connected to ground. Whereas the input voltage may vary over some permissible voltage range and the output load may vary over some acceptable range, the output voltage remains constant within specified voltage variation limits. These limitations are spelled out in the manufacturer's specification sheets [8].

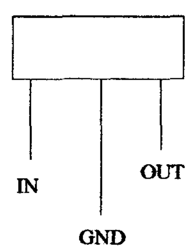

Figure 9: Circuit symbol of voltage regulator

2.2.9 555 Timer IC

This is a popular versatile analog-digital integrated circuit. The IC is made of a combination of linear comparators and digital flip-flops. The entire circuit is usually housed in an eight-pin package as shown in Plate II. A series connection of three resistors sets the reference voltage levels to the two comparators at $2V_{cc}/3$ and $V_{cc}/3$, the output of these comparators settings or resetting the flip-flop unit. The output of the flip-flop circuit is then brought out through an output amplifier stage. The flip-flop circuit also operates a transistor inside the IC, the transistor collector usually being driven low to discharge a capacitor. 555 timer can be operated in the astable and monostable mode [8].

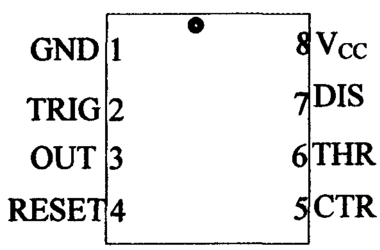

Figure 10: Pin out diagram

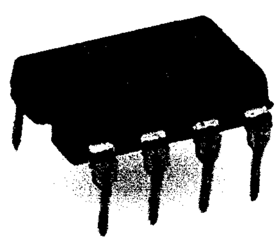

Plate II: 555 dual in line package

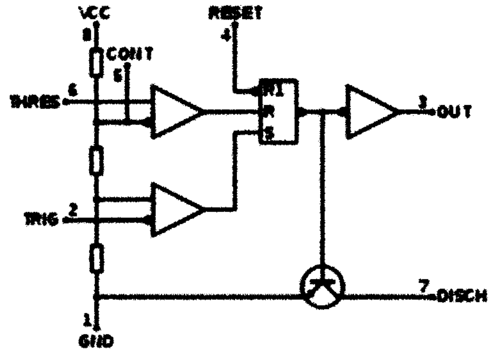

Figure 11: Internal circuitry of 555 timer

CHAPTER THREE

3.0 DESIGN AND IMPLEMENTATION

3.1 Methodology

The project work was carried out by dividing it into four modules. These four modules are:

I. Power module.

II. Voltage divider module.

III. Switching module.

IV. Alarm module.

The circuit block diagram is as shown below.

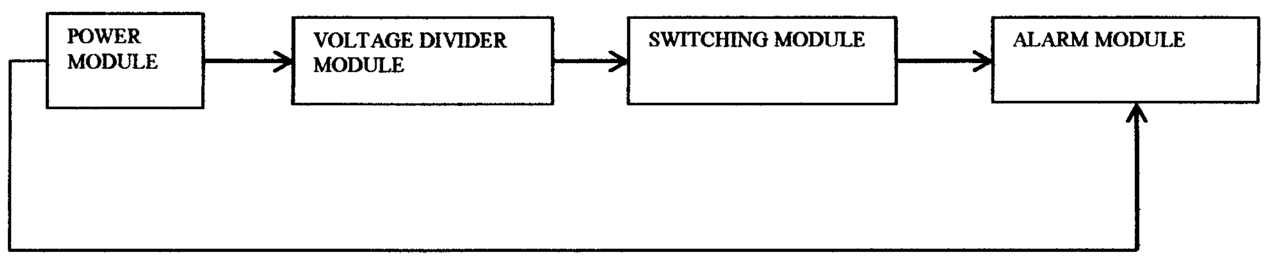

Figure 12: Circuit block diagram

3.2 Design analysis

3.2.1 Power module

The power module has the following sections.

I. Voltage transformation.

II. Voltage rectification.

III. Filtering.

IV. Voltage regulation.

V. Loading unit.

3.2.1.1 Voltage transformation

A step down voltage transformer was used for the voltage transformation.

Primary voltage, $V_P = 220V_{rms}$

Secondary voltage, $V_S = 15V_{rms}$

Primary current, $= I_P$

Secondary current, $I_S = 500mA$

The primary current can be calculated as follows.

Using the transformation formula [4]

$$\frac{V_P}{V_S} = \frac{I_S}{I_P} \quad (1)$$

$$I_P = \frac{V_S}{V_P} \times I_S$$

$$I_P = \frac{15}{220} \times 500 \times 10^{-3}$$

$$I_P = 34mA$$

3.2.1.2 Voltage rectification

During the positive half-cycle of the ac input, D_1 and D_3 conduct being forward-biased and current flows through R_L. As a result, positive half-cycle of the voltage appears across R_L. During the negative half-cycle, D_2 and D_4 conduct and current flows through R_L in the same direction. It means that both half-cycles of the input ac supply are utilized. Of course, this rectified output consists of a dc component and many ac components of diminishing amplitudes. The forward-biased voltage of a silicon diode is 0.7V which was used in this project work [3].

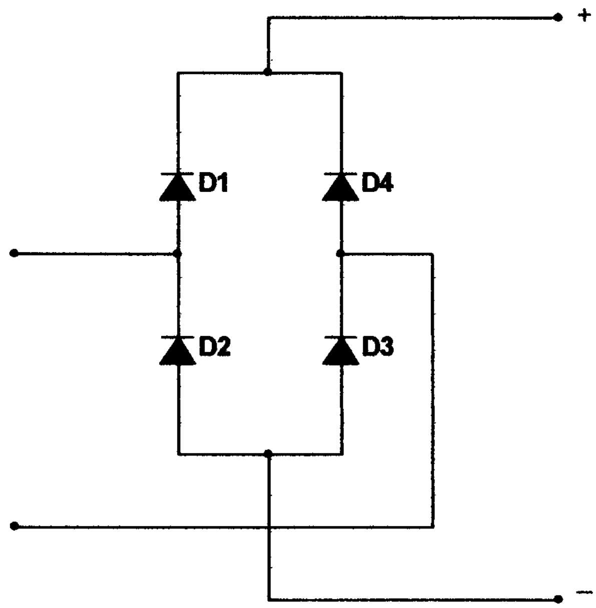

Figure 13: Bridge rectifier

The dc output voltage is calculated as follows.

$$V_L = V_O - V_d \tag{2}$$

$$V_L = \sqrt{2}V_S - V_d \tag{3}$$

where $V_S = 15V$ *and* $V_d = 0.7V$

$$V_L = 15 \times \sqrt{2} - 2 \times 0.7$$

$$V_L = 19.81V$$

$$V_{dc} = \frac{2V_L}{\pi} \tag{4}$$

$$V_{dc} = 2 \times \frac{19.81}{3.143}$$

$$V_{dc} = 12.61V$$

3.2.1.3 Filtering

A suitable single capacitor C is connected across the rectifier and in parallel with the load R_L to achieve filtering action. A capacitor has the basic property of opposing changes in voltage. Hence a bigger capacitor would tend to reduce the ripple magnitude. It has been found that increasing the capacitor size increases V_{dc} towards the limiting value; reduces the magnitude of ripple voltage; reduces the time of flow current pulse through the diode and increases the peak current in the diode [3].

In order to achieve a stable dc voltage output suitable for this design, the ripple factor was set to a very low value. Therefore, a ripple factor (γ) of 0.015% was arbitrarily chosen. Also, the load R_L to be connected in parallel with a capacitor was set at 9.7kΩ in order to be able to estimate the value of the capacitor required. It is computed as follows.

Using the full-wave ripple factor formula [3].

$$\gamma = \frac{1}{4\sqrt{3} fCR_L} \tag{5}$$

Hence,

$$C = \frac{1}{4\sqrt{3} fR_L \gamma}$$

$$where \quad f = 50Hz$$

$$C = \frac{1}{4 \times \sqrt{3} \times 50 \times 9.7 \times 10^3 \times 0.00015}$$

$$C = \frac{1}{504.026785}$$

$$C = 1.9840 \times 10^{-3}$$

$$C = 1984 \times 10^{-6} F = 1984 \mu F$$

Hence, the available capacitor value in market close to 1984µF is 2200µF. Therefore 2200µF capacitor was used for the filtering.

3.2.1.4 Voltage regulation

The voltage regulator used in this project is 7812 which gives a fixed 12V output. A capacitor of 1000µF was connected to its output terminal for further smoothing [3].

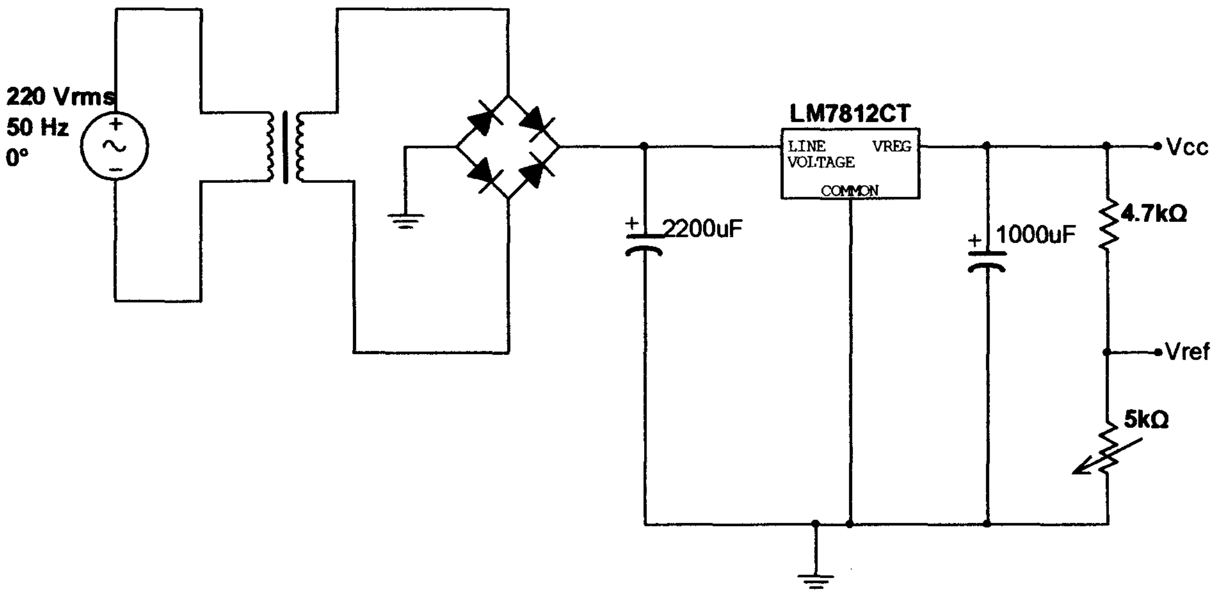

Figure 14: Power module

3.2.1.5 Loading unit

The load is connected through a 13A socket with a transformer connected in series with it. This gives various voltage levels as the load is being varied. The size of the primary coil of the transformer is adequate to handle possible high current values passing through it.

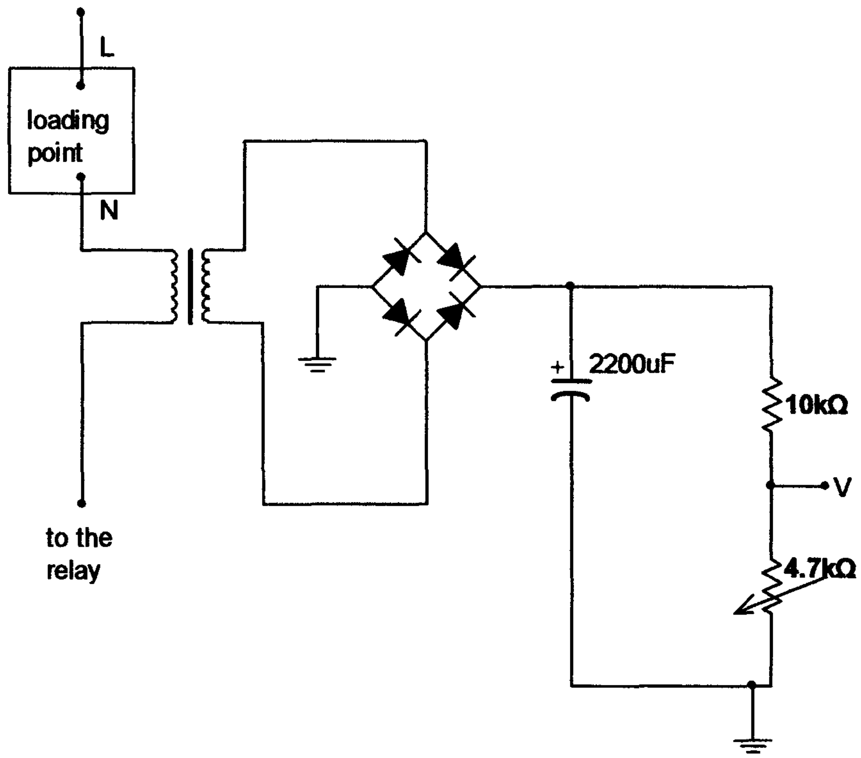

Figure 15: Loading unit

3.2.2 Voltage divider module

The voltage divider was achieved by connecting two resistors in series across V_{CC} and then applying voltage divider theorem giving by the formula below [3].

$$V_1 = \frac{R_1}{R_1 + R_2} \times V \tag{6}$$

The V_{ref} for this design was set at 3.58V. The R_2 was arbitrarily chosen to be 4.7kΩ in order to be able to estimate the required value of R_1 needed to achieve the value set for V_{ref}. The value of V_{CC} is 12V since 7812 voltage regulator was used. Hence, to calculate for R_1, the voltage divider theorem was applied as follows.

$$V_1 = \frac{R_1}{R_1 + R_2} \times V$$

where $V_1 = V_{ref}$ *and* $V = V_{CC}$

$$V_{ref} = \frac{R_1}{R_1 + R_2} \times V_{CC} \tag{7}$$

Hence, making R_1 subject of the formula

$$R_1 = \frac{V_{ref} \times R_2}{V_{CC} - V_{ref}}$$

$$R_1 = \frac{3.58 \times 4.7 \times 10^3}{12 - 3.58}$$

$$R_1 = 2304.9\Omega$$

$$R_1 \approx 2.3k\Omega$$

For this reason, a variable resistor of 5kΩ was chosen for R_1 so as to be able to cover the range of the resistor value calculated above.

The voltage obtained from the loading unit was also divided and connected to the non-inverting input of the opamp. If say a load up to the maximum limit is connected, voltage greater than the V_{ref} is achieved.

3.2.3 Switching module

The switching module consists of the comparator and a transistor. The comparator used is LM358 while the transistor is C1815 NPN type. The LM358 was chosen for its sensitivity to changes in voltage level at its inputs. To limit the current going into the base of the transistor, 1kΩ resistor was used [3].

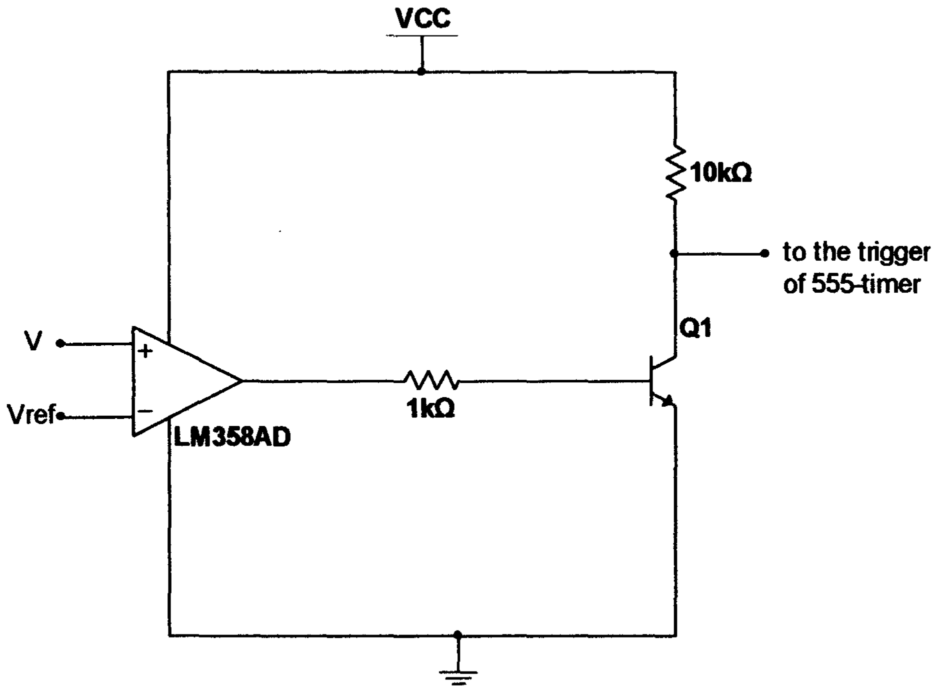

Figure 16: Switching module

3.2.4 Alarm module

This module has the following.

I. Monostable multivibrator.

II. Relay.

III. Buzzer.

3.2.4.1 Monostable multivibrator

This was achieved by using a 555 timer IC in the monostable mode. The operation time of the monostable multivibrator required for this design was set at 110s. Therefore, setting the value of the capacitor arbitrarily to 100μF, the value of resistor required was calculated as follows.

Using the monostable time of operation formula [8].

$$t = 1.1 \times RC \quad (8)$$

Hence, making R subject of the formula

$$R = \frac{t}{1.1 \times C}$$

$$R = \frac{110}{1.1 \times 100 \times 10^{-6}}$$

$$R = 1 \times 10^{6} \Omega$$

$$R = 1M\Omega$$

Therefore, 1MΩ resistor was used with 100μF capacitor to achieve the set 110s operation time.

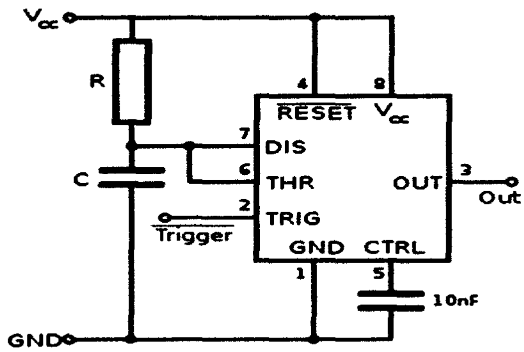

Figure 17: 555 monostable multivibrator

3.2.4.2 Relay

A relay that is sensitive and also can handle high current was needed. Therefore, a 12V relay with current handling capacity of 30A was used. The magnetizing current of the relay was calculated as follows.

$V_{CC} = 12V$, Coil resistance, $R = 156\Omega$

$$I = \frac{V_{CC}}{R} \tag{9}$$

$$I = \frac{12}{156}$$

$I = 76mA$

The current supplied by the 555 timer of the monostable multivibrator gives a maximum output current of 200mA [9]. Therefore, 200mA was enough to magnetize the coil. The relay was operated by a transistor acting as the switch. A diode was connected in a reverse bias mode across the relay for protection as shown in Figure 18.

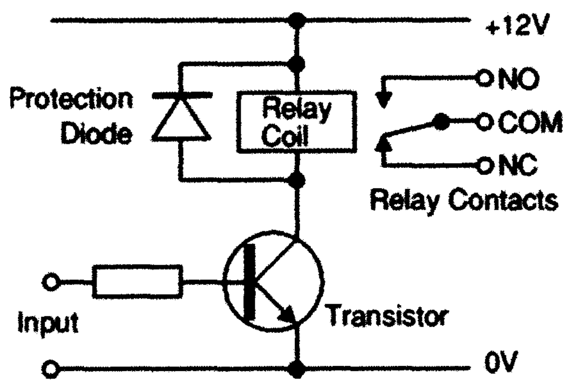

Figure 18: Relay connection

3.2.4.2 Buzzer

The buzzer gives the tone for the alarm. The operating voltage range of the buzzer used is 3 to 24V and can handle 200mA. It was connected across the relay.

3.3 Implementation of the project work

The components needed to achieve the construction of the project work were purchased and first constructed on the bread board. It was then transferred to the Vero board with each component soldered properly. The permanent construction is exhibited in Plate III.

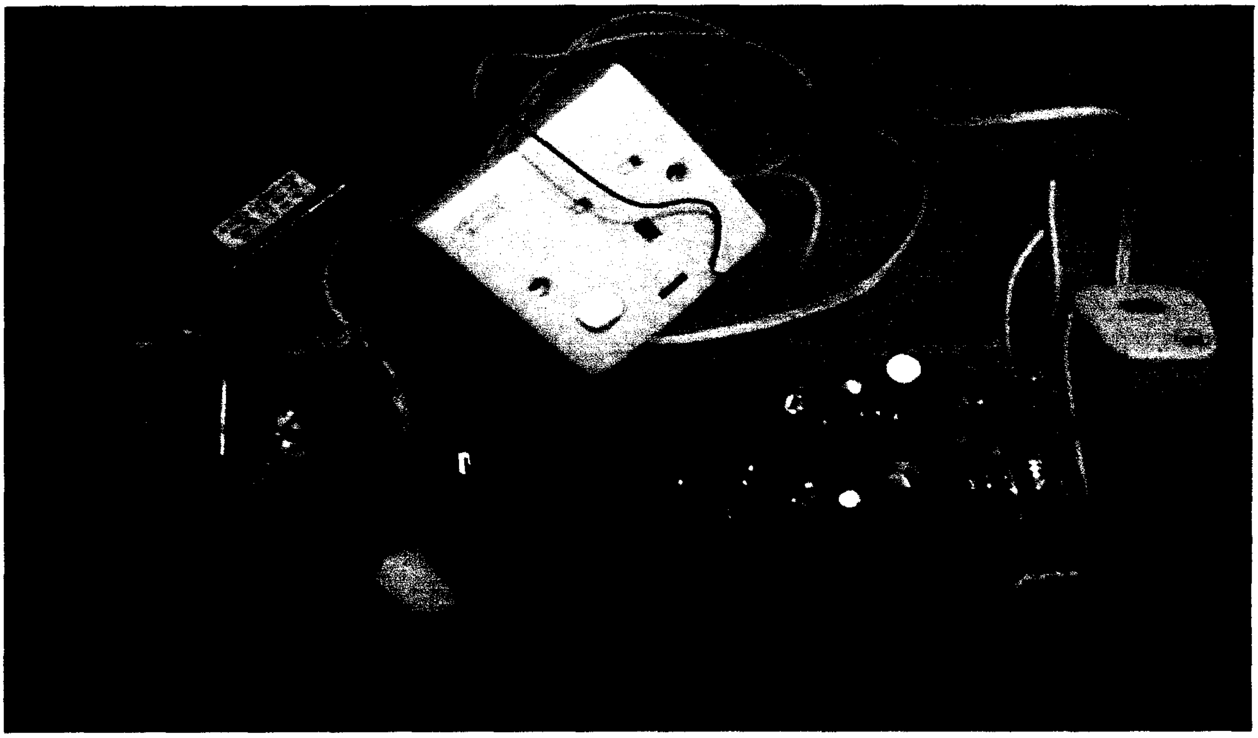

Plate III: Permanent construction

3.4 Precautions

1. When the relay was soldered to the Vero board, much heat was not applied to its pins. This was to prevent their weakening which can lead to partial contact hence making the relay not sensitive enough.
2. A PN junction diode was connected in the reverse bias mode across the relay. It protects the relay, transistors and ICs from the sudden collapse of the magnetizing field when the current is off.
3. In connecting, the polarity of the component was maintained in order to prevent over heating that can lead to their damage or low performance.
4. Proper isolation of nodes was made to prevent short circuiting.

5. Each component was properly soldered to prevent partial contacts.
6. Components with high quality and proper specifications were used to ensure the reliability of the project.

3.5 Working principle

When a load is connected, current flows through the primary coil of the transformer hence inducing a voltage at its output. The voltage is divided and passed on to the non-inverting input of the opamp. If, say, the maximum limit of load (1000W) is connected the non-inverting voltage goes higher than the V_{ref}, causing the comparator to switch low driving the transistor to cut-off. This then triggers the monostable multivibrator to go to the off-state driving the transistor low. It trips off the relay simultaneously making the alarm to come on to give an alert. If the maximum limit of load is not disconnected from the power point, the system continue to come on and off with the alarm. However, when the maximum limit of load is disconnected, the tripping and the alarm stop while the monostable off-time runs out.

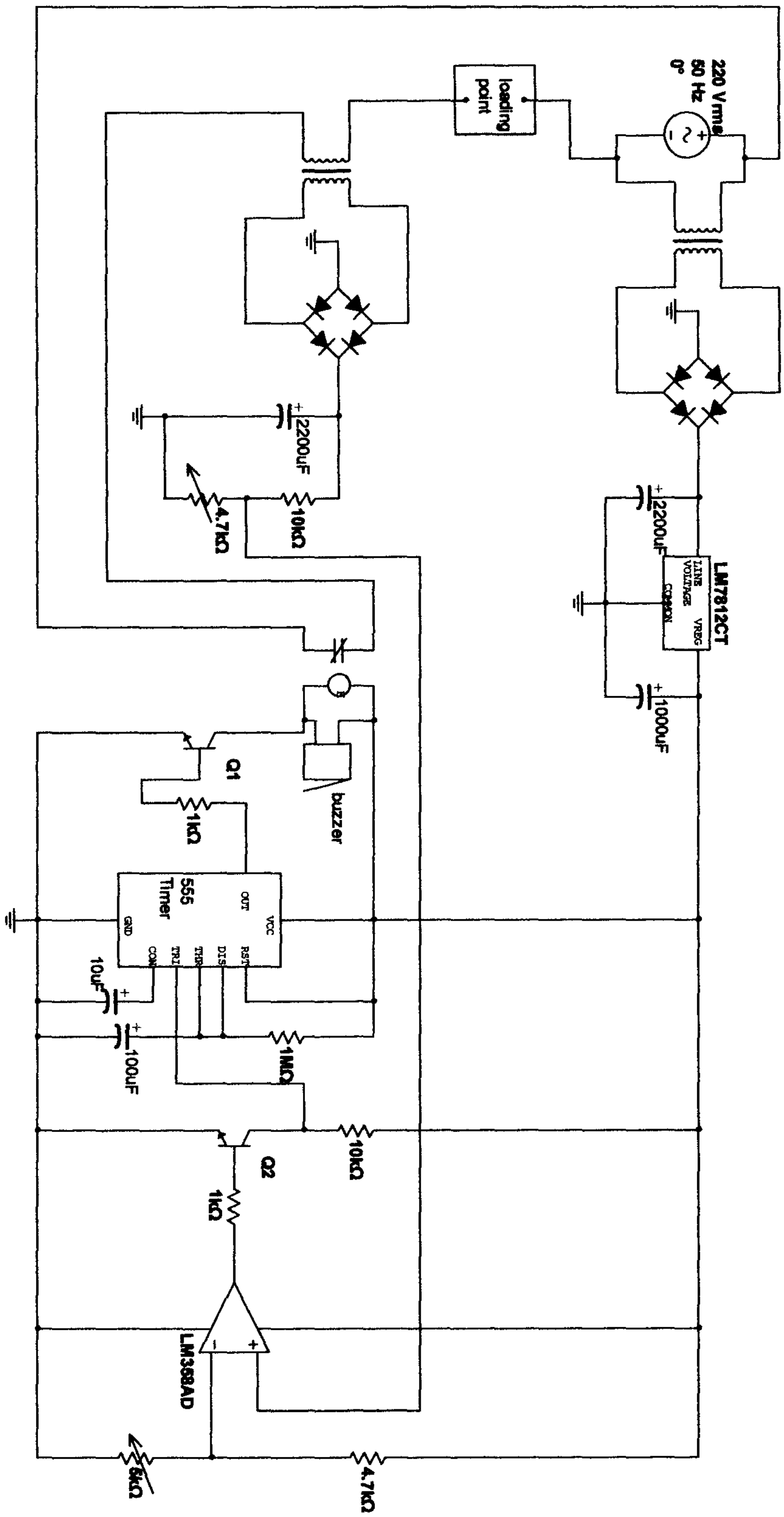

Figure 19: Complete circuit diagram

CHAPTER FOUR

4.0 TESTS, RESULTS AND DISCUSSIONS

4.1 Simulation and results

In the course of carrying out this project work, the circuit was first simulated on a computer software application (MULTISM). This was to enhance adequate analysis and testing to ascertain proper functioning of the circuit. The circuit was then constructed on the breadboard having in mind what has been simulated, after which the components were transferred to the Vero board. The results obtained from the simulation are shown accordingly.

4.1.1 Transformer primary voltage

The transformer primary voltage was tested and measured by connecting a multimeter across its primary terminals. The peak value obtained was 311V ($220V_{rms}$). An oscilloscope was also connected across its primary terminal to obtain its waveform. It is shown in Plate IV

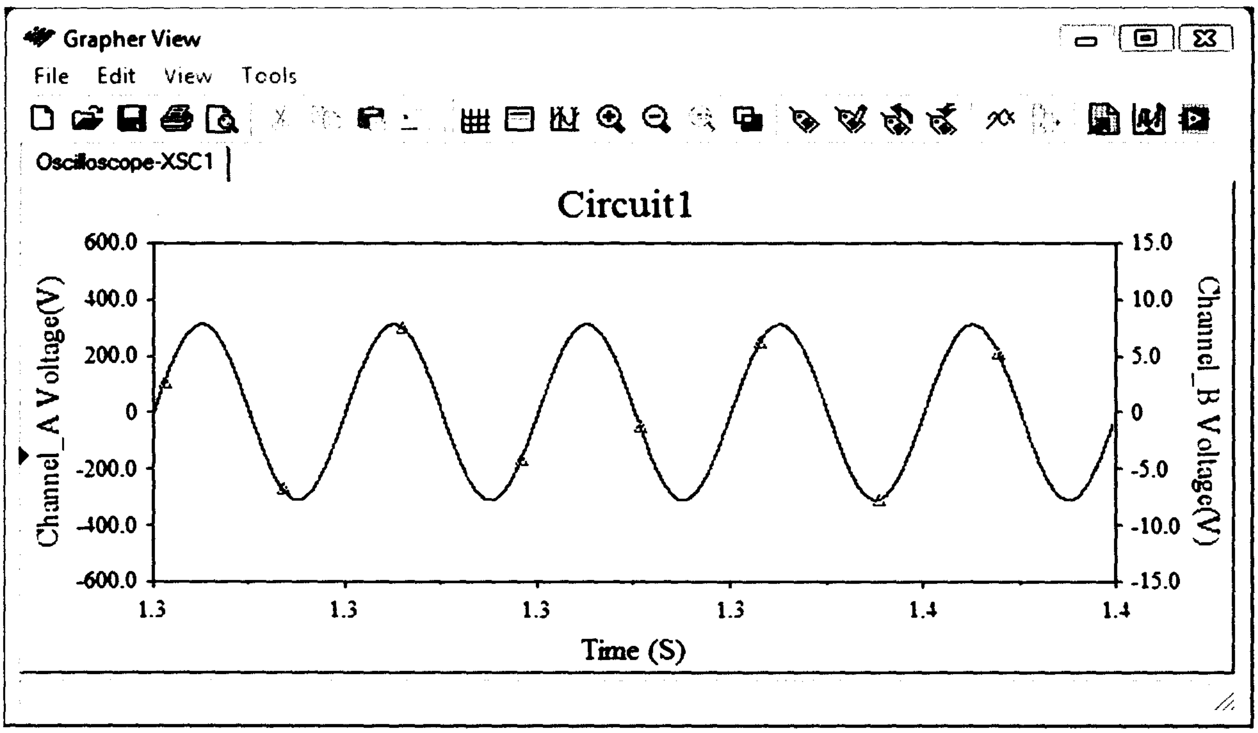

Plate IV: Transformer primary voltage waveform

4.1.2 Transformer secondary voltage

The transformer secondary voltage was tested and measured by connecting a multimeter across its secondary terminals. The peak value obtained was 21V ($15V_{rms}$). An oscilloscope was also connected across its secondary terminal to obtain its waveform. It is shown in Plate V.

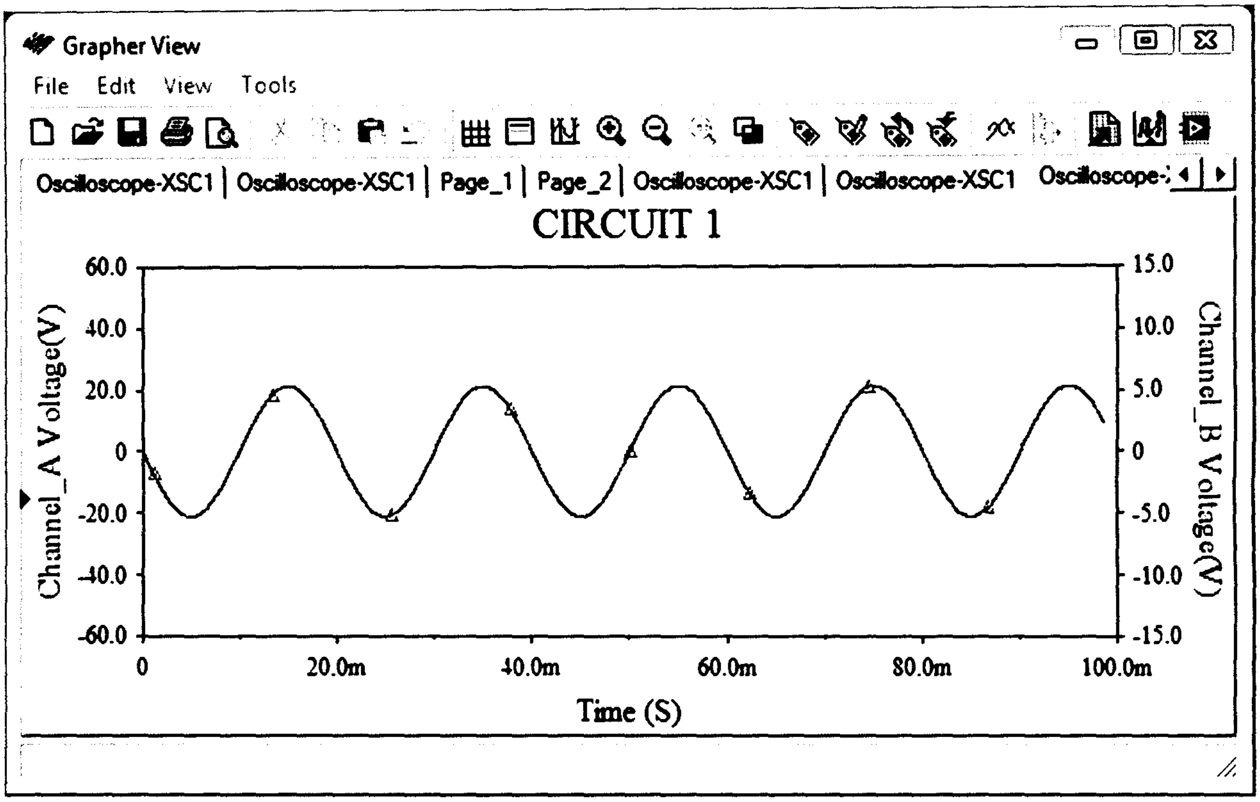

Plate V: Transformer secondary voltage waveform

4.1.3 Rectified voltage

The rectified voltage was tested and measured by connecting a multimeter across the output terminals of the bridge rectifier. The voltage obtained was a varying dc signal with a peak value of 21V ($13.50V_{dc}$). An oscilloscope was also connected across the terminals to obtain its waveform. It is shown in Plate VI.

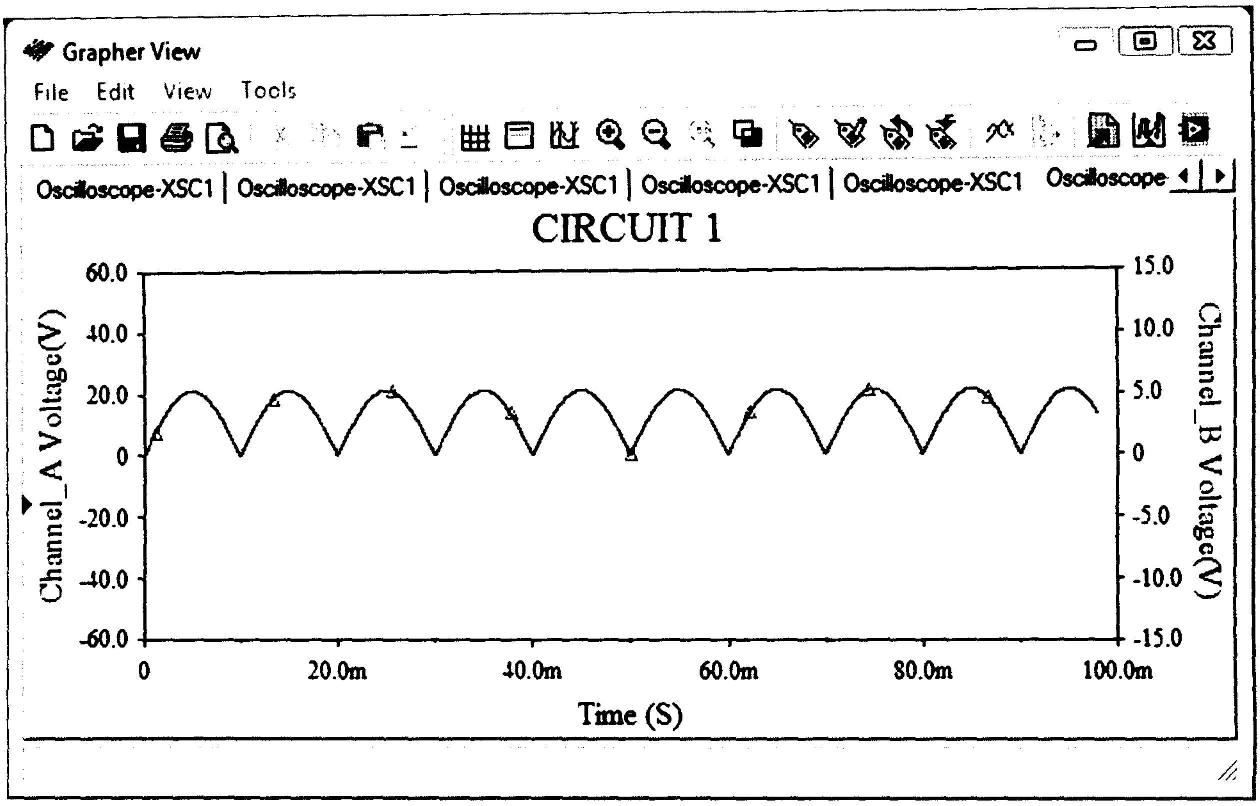

Plate VI: Rectified voltage waveform

4.1.4 Filtered voltage

The filtered voltage was tested and measured by connecting a multimeter across the smoothing capacitor. The value obtained was 19.951V. An oscilloscope was also connected across it to obtain its waveform. It is shown in Plate VII.

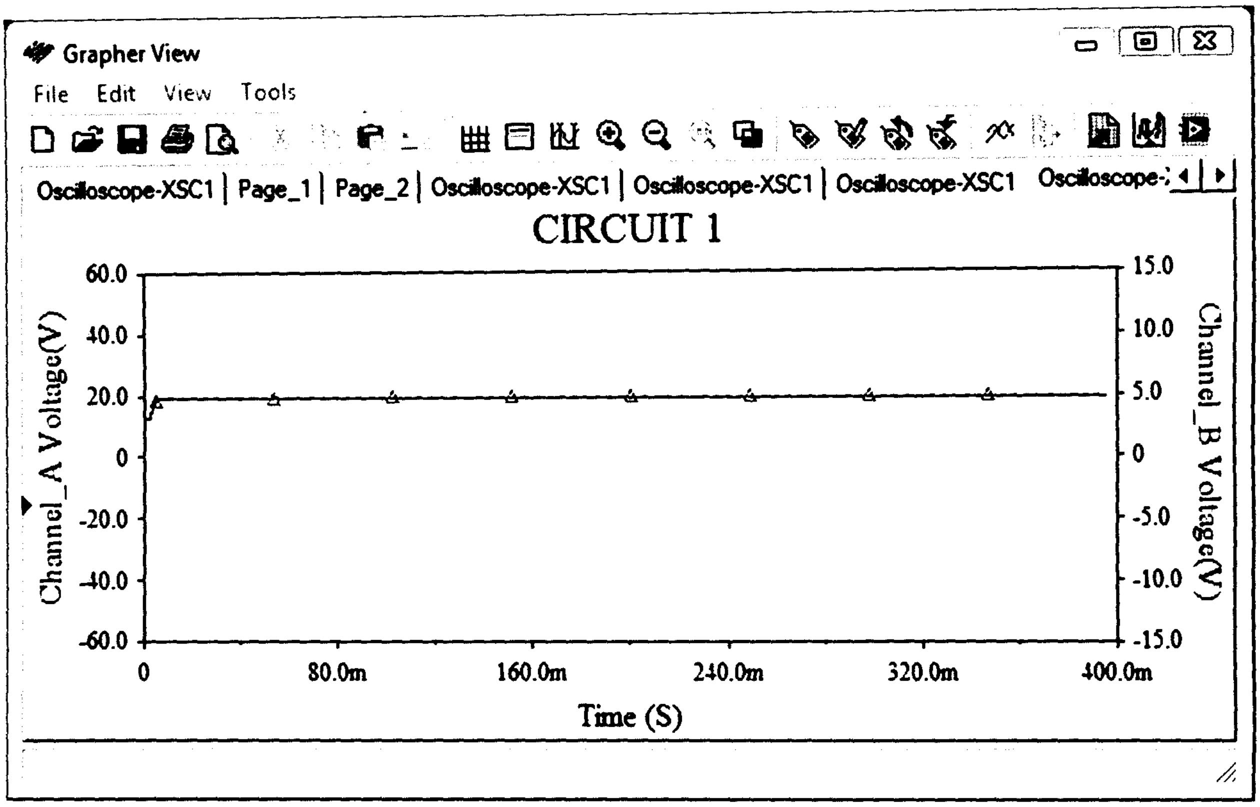

Plate VII: Filtered voltage waveform

4.1.5 Regulated voltage

The regulated voltage was tested and measured by connecting a multimeter across the output terminal of the 7812 voltage regulator. The value obtained was 11.879V. An oscilloscope was also connected to obtain the waveform. It is shown in Plate VIII.

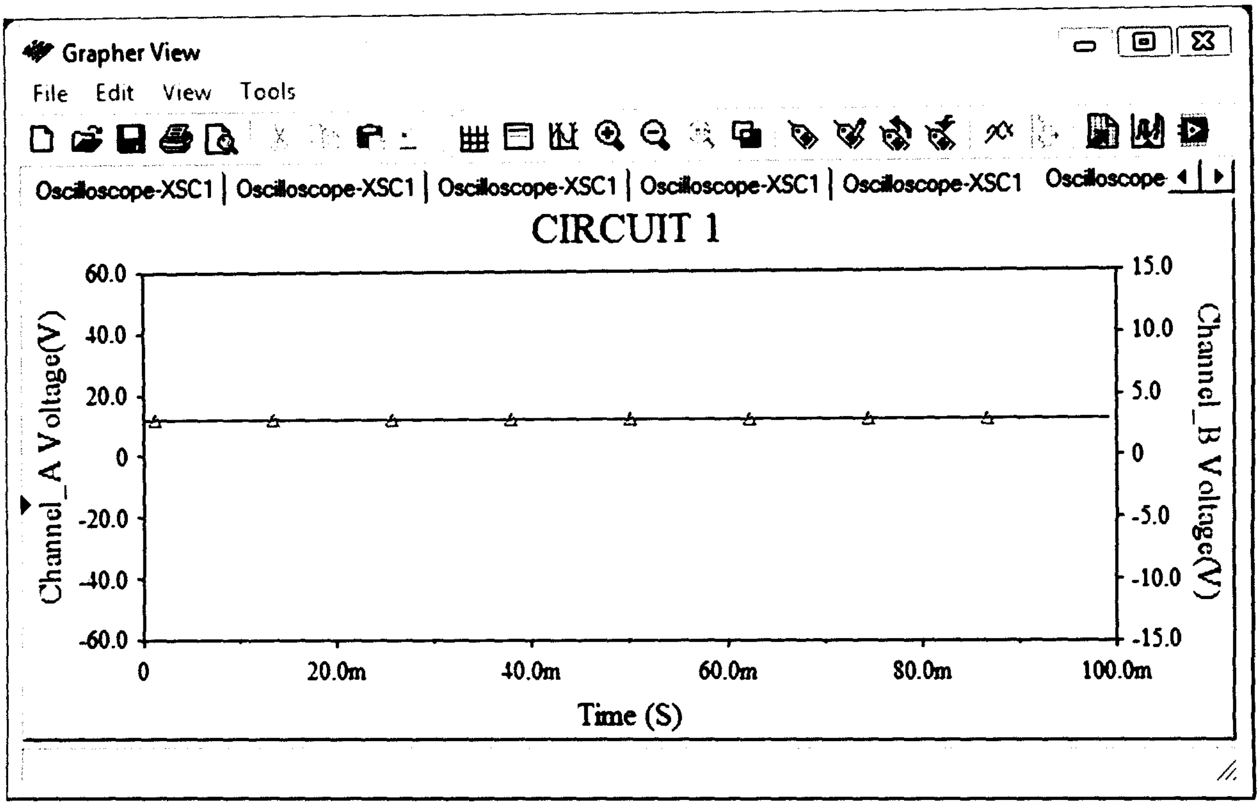

Plate VIII: Regulated voltage waveform

4.2 Construction and test

The project work was constructed on the breadboard before being transferred to the Vero board taking necessary precautions as stated in the previous chapter. The modules were tested using a digital multimeter. The mains supply voltage was $220V_{rms}$ (or 311V peak value). The test results are shown subsequently.

A. **Power module**

Table 1: Power module voltages

S/NO	DESCRIPTION OF MEASURED QUANTITIES	VOLTAGES
1	Transformer primary voltage	$220V_{rms}$
2	Transformer secondary voltage	$15V_{rms}$
3	Rectified voltage	$13.50V_{dc}$
4	Regulated voltage	$11.88V_{dc}$

B. **Switching voltages when comparator output is low**

Table 2: Switching voltages when comparator output is low

S/NO	DESCRIPTION OF MEASURED QUANTITIES	VOLTAGES
1	Opamp output voltage	46mV
2	Q1 base voltage	46mV
3	Q2 base voltage	7mV

C. Switching voltages when comparator output is high

Table 3: Switching voltages when comparator output is high

S/NO	DESCRIPTION OF MEASURED QUANTITIES	VOLTAGES
1	Opamp output voltage	121mV
2	Q1 base voltage	121mV
3	Q2 base voltage	818mV

4.3 Discussion of results

The voltage obtained from the source is a sinusoidal sine signal. The output from the secondary terminals of the transformer is also a sinusoidal sine signal. These voltages have no fixed polarity, hence showing that the two signals are alternating in nature.

The voltage value obtained at the secondary terminals of the transformer was less than that obtained at the primary terminals. This confirmed that the transformer is a step-down type.

The voltage signal obtained after the bridge rectifier is a full-wave rectified sine wave which has a fixed polarity. It implies that full rectification took place and it is therefore a dc signal.

The voltage value obtained at the output of the voltage regulator did not vary with fluctuations at the mains. This confirmed the voltage regulation and besides, the signal is dc in nature.

When the voltage at the non-inverting input was less than the reference voltage, the voltage value obtained at the comparator's output showed that it was at the low state. When the voltage at the non-inverting input was higher than the reference voltage, the voltage value obtained at the comparator's output showed that it was at the high state.

More so, the voltages obtained at the base of the transistors when the comparator output was low and high showed that they acted as switches. The voltage and current value obtained at the collector of the second transistor confirmed that it can actually activate the relay.

The voltage values obtained at the non-inverting input of the opamp increased with the increase in load until the voltage level exceeded the reference voltage, this was when the maximum limit of load was connected, hence activating the relay and the alarm.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

At the end of this project work, the following conclusions were made in accordance to the objectives.

i. The load level alert in a power system was achieved.

ii. The monitoring of load at the power unit was achieved.

5.2 Recommendations

i. This project work can safely handle domestic loads. Therefore a type having high power capacity can be constructed to handle industrial loads.

ii. Improvement can be made on this project work so that it will remain off as long as the limit load is still connected.

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