DESIGN AND CONSTRUCTION OF ELECTRONIC ALTERNATING CURRENT (AC) POWER CONTROLLER USING PULSE WIDTH MODULATION TECHNIQUE

BY

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DEDICATION

This work is dedicated to late Mama, Mrs. H.I OLADUNMOYE

DECLARATION

I **OLADUNMOYE MORUF OLALEKAN**, 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 copy right to the Federal University of Technology, Minna.

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ABSTRACT

This work is carried out for the purpose of controlling the power supplied into electromechanical devices and resistive heating devices using electronic means thereby regulating their speed and heat output respectively. This is achieved by modulating the width of pulses by a comparator. The pulses control the opening and closing of a power triac. Based on the modulated output, the triac will be open for certain period of time and closed for certain period of time in a periodic manner. This is controlled by the preset standard from the reference voltage fed to the comparator as desired by the user. The triangular pulse fed to the second terminal of comparator is obtained from the voltage across the capacitor connected externally to 555 timer to obtain an ASTABLE configuration of the device. This work is unique in its purpose, as it prevent the loses that are incurred in resistive and reactive controller, cheaper and versatile. It also prevent the wear that is experienced when using mechanical switch since an electronic switch is used

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CHAPTER ONE

1.1 Introduction

The needs of man depend mainly on what he already has, one of the basic need of man in present day is "POWER", which found application in both household and individual activities. Areas where we have applications of ALTERANATING POWER includes: lighting of bulb, driving of electric motors, fans, drilling machines, cranes, heating elements, blowers etc in order to have maximum satisfaction from those machines, man needs a good smooth, reliable and cheap means of controlling power supply to these devices.

Types of power regulation that are existing include:

Transformers wound power regulation, thermostat regulating power etc. however, most forms of power controller employ either a reactive power scheme (using the frequency reactance relationship of inductors, capacitor or both), electromechanical control (relay) or resistive power controls. In implementation employing resistive or reactive power control, a high power loss is incurred as a result of heating loss in the controlling element.

Electromechanical control scheme involves the interrupting the power supply / delivered to the load in a full – off or full-on manner, thus, ruling out the possibility of a smooth control of power [3, 5, 6, 8]

Since, the advent of the state of the art solid state devices such as triac, diacs, thyristors, diodes, various electronics methods of power control have been devised. These solid state methods supposed the older conventional methods of controlling because of their low cost, reliability and versatibility. Electronic means of power control offers a smoother power control; power delivered to the load can also be measured inn bursts.

This methods offers a higher efficiency since an electronic switch is used for the power control unlike other forms of control. The switch (triac) can be controlled electronically, it minimize loss and hence improving the efficiency of the output.

The electronic AC power controller makes use of the pulse – width modulation or dirty cycle variation techniques to achieve the duty cycle is defined as the percentage of digital "high" to digital "low" plus digital "high" pulse – width during a pulse – width modulation (PWM). [7, 8].

Multi-vibrators are very useful devices when it comes to generation of pulses. They have other applications such as storing andn counting circuit. The idea of pube generation by multi-vibrators is employed in this work.

Astable multi-vibrators. (AMV) also known as free running relaxation oscillator, it has no stable state but only two quaxiable states between which it keeps oscillating of it' sown accord without any external excitation. [3, 4, 8].

In realizing this practically, a 555 timer is configured in astable to generate pulses. Although is is the output of pulses (voltage variation) of the capacitor that is used in generating a pulse width modulation in this application, not the output of 555 timer itself (i.e pin 3 output). Once triggered, it continuously generate the pulses, in less triggered off by an external circuit. The output is fed to the input of a comparator which compares it with the input reference voltage set by the uses to generate an output pulse (PWM wave). The pulses are used in controlling the electronic switch triac that controls the supply of power to the load.

1.2 Objectives

The objectives of this work is to have a low cost reliable, lighter, small size and versatile design that gives a smooth control of alternating power supplied to electrical devises (electromechanical and resistive load or any other load that can support discontinuous power delivering). This is applicable in domestic and industrial activities.

(a) House hold/residential application:- electric fans heating elements such as over, heater and many more devices that bring comfort in homes. Greater comfort is achieved if we have smooth control over these devices. Kit also covered energy ad reduces the PHCN billing rates at homes

(b) Industrial applications.- speed control is also important in industries. Devices/appliances such as electric motors, blowers etc require regular speed over a certain period of time. [1,2, 3, 7, 8].

The project was designed using the following components transformers, diodes regulator, capacitors, 555 timer, comparator, Triac. It consists of the power supply unit, ramp generation unit, comparator/amplifier and electronic switch control unit.

1.3 Methodology

The circuit was broken down into sub units/ modules for easy design and construction. The sub system includes:

1. The power supply unit
2. The Ramp generator unit
3. Amplifier / comparator unit
4. Electronic switching unit

They were built separately and later coupled together to give the desired unit system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Control of Electric Power in the Past and Present

In electrical devices, the contol of power is frequently desired as a means of regulation or control or one or more non-electrical parameters such as speed of the motor, the temperature of an oven, the rate of electromechanical process etc.

Many years ago, the desired control of power could be achieved by means of high speed rheostats resistance series with the load variation of rheostats resistance from zero to infinity, permits continuous and smooth control of the load resistance fro zero to infinity. This permits continuous and smooth control of the load voltage and power from their maximum value to zero.

However, the power efficiency was low and mechanical switches used were subjected to be and limited switching speed. This was a major disadvantage. But with the advent of semi-conductors devices, resulted in better means of AC power control.

After the world war II, great progress was made in solid state physics and semi-conductor devices, scientist at all bell laboratories invented the transistor, a solid state device in 1948. This was a great relief as this solid state device replaced many bogus devices especially vacuum tubes, which were active electronic component.

Solid state circuit technology began to make strides in the 1950s and the knowledge of semi – conductors increased. In 1960s, the semi – conductor technologist found a way to put a number of transistors on one silicon water. The transistors were connected together with small metal causing the building block or current modules made this way are called INTERGRATED CIRCUIT. [6].

This advancement in semi-conductor technology has led to discovery of devices such as Diode, Thyristor, Diac and Triac 555 timer is another semi – conductor devices that is useful in generation of pulse in electronic circuit. Also triac, unlike the other semi – conductor devices allows the flow of alternating current through it. With this, solid state can be used as an alternative to the variable resistance approach using mechanical switches control of power.

2.2 Electronic Devices in Power Control

Below are some electronic devices that have been employed in power control:

1. **Thyristor:-** it really comes into its own in both AC and DC current. By means of controlling the conduction time of the devices over each cycle of the mains voltage the power delivered to the load can be varied. This includes two ways;

a) Phase Control:- it is possible to turn the device on at any point in the positive half cycle of the AC supply. The point at which the gate signal is applied (firing angle) controls the amount of current delivered to the load. Altering the firing angle will vary the point at which the thyristor conducts firing at the beginning of the wave will allow almost all the positive half cycle, while it firing towards the end allows only a small fraction to be let through. This is ideal for dimming of light and varying the speed of motor only.

A single thyristor will control the power delivered to a load from zero to half power. For a full wave control, two thyristor are wired, it is applicable to all motor rating, but the problem of firing the gate of the thyristor arises [4, 3].

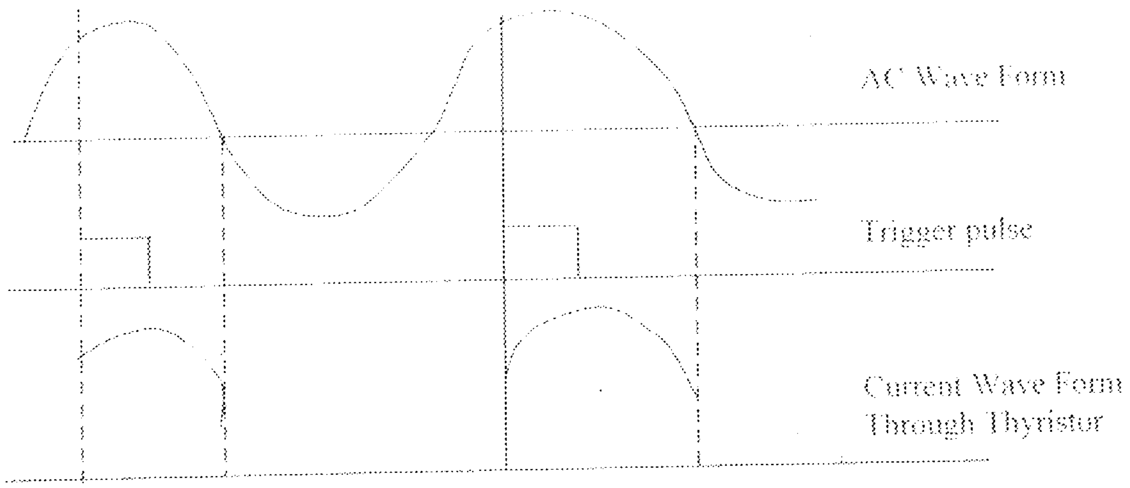


Fig 2.1

b) **Burst Control**: here the gate signal is applied for a number of half cycles and then removed after a certain period, the signal is re – applied and more half cycles let through. Thus the ratio of time on the time off control and determines the amount of power delivered to the circuit it is ideal to control only heating circuit. [5, 4].

2. Chopper Control:- this is used for the speed of motor control, a motor is rapidly and repeatedly connected to and disconnected from a DC supply. Control being imposed by varying the ON/OFF time ratio. [4, 10]

3. Triac:- it is called triac or triode for alternating current. It is an electronic component approximately equivalent to two silicon control rectifiers (thyristor) joined in inverse and their gates connected together, this results in bi- directional electronic switch which can conduct current in either directions. It can be triggered by either a positive or a negative voltage being applied to its gates electrode.

Once triggered, the device continuous to conduct until the current through it drops below a certain threshold value, this makes the triac a very convenient switch for AC circuit, allowing the control of very large power flows with milliampere scale control current. In addition, applying a trigger pulse at a controllable point in an AC cycle allows one to control the percentage of current that flows through the triac to the load (so called phase control) [9, 6].

In the year 2002, Akhindime Ehighai uses the phase control of triac to design and construct a 500WAC power regulator with application as light dimmer.

When triac is used with inductive loads such as fans, there is problem of triac being turn-off correctly at the end of each half cycle of AC power. Hence, a snubber circuit is used to assist this turn off in this project work. It also prevent pre – mature triggering.

2.3 Pulse Width Modulation and Ramp Generation

As said earlier, applying a trigger pulse at a controllable point in an AC cycle allows one to control the percentage current [number of cycles] that flows through the triac to the load. This can also be achieved by the use of PWM.

Pulse – width modulation of a signal or power involves the modulation of its duty cycle to convey information over a communication channel the amount of power sent to a load [5, 8].

It is applicable in telecommunication, power delivery, voltage regulation and audio effect and amplification. In power delivery, PWM can be used to reduce the total amount of power delivered to a load without loses normally incurred when a power service is limited by resistive means. This is because the average power delivered is proportional to the modulation duty cycle. With sufficiently high modulation rate, passive electronic filters can be used to smooth the pulse train and recover an average analogue wave form [8]

Types of PWM include;

a) The pulse center may be fixed in the center of the time window and both edges of the pulse moved to compress or expand the width.

b) The lead edge can be held at the lead edge of window and the tail edge modulated.

c) The tail edge can be fixed and the lead edge modulated [8]

There are different ways/methods of generating PWM, some of which

Includes

I. Delta modulation: the output signal is compared with limits, which corresponds to a reference signal offset by a constant. Every time output signal reaches on the limits the PWM signal changes state.

II. Digital method. many digital circuit can guarantee PWM signals (e.g many microcontrollers have PWM output to control an electrical motor). They normally use a center that increments periodically (it is connected directly or indirectly to the clock of the circuit) and is reset at the end of every period of PWM. When the center value is more than reference value, the PWM changes state from high to low. However, the cost effectiveness will not be achieved using this method.

III. Inter-sective method: the simplest way to generate PWM signals is the inter – sective method, which requires only a saw-tooth or a triangular wave form from (early generated using a simple oscillator) and a comparator, when the value of the reference signal is more than the modulation wave form, the PWM is in the high state, otherwise it is in low state. This is the method employed in this project work [5, 8, 3].

A triangle wave or saw tooth wave is obtained by the use of 55 timer connected is astable configuration

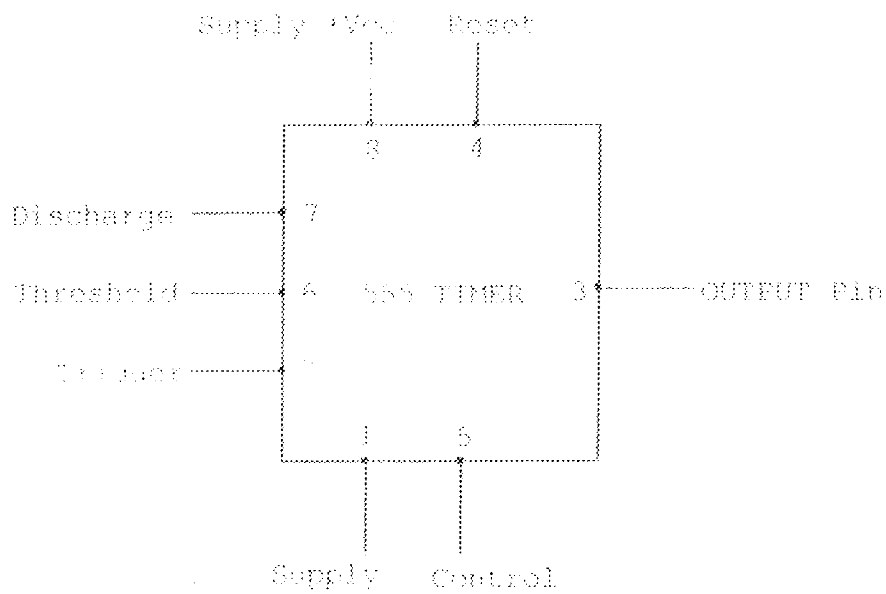


Fig 2.2 Pin out of 555 Timer

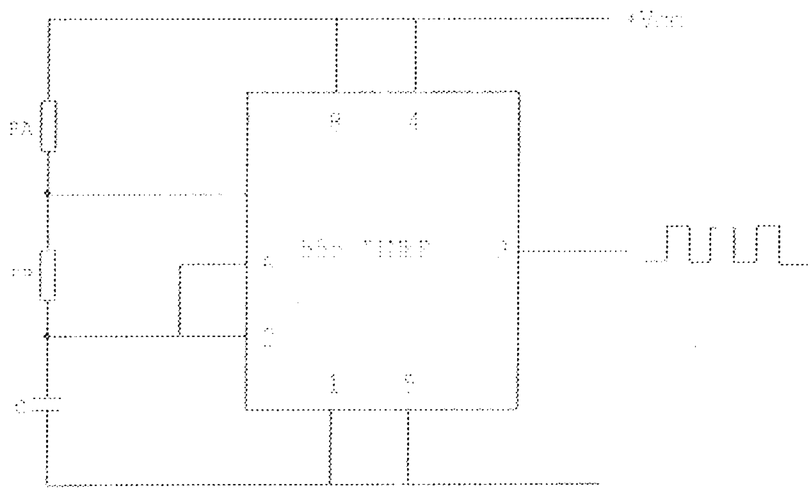


Fig 2.3 555 timer in Astable configuration

The output of pin 3 is a rectangular wave with a period of one high pulse ($+V_{cc}$) plus one low pulse (oV). However, the voltage across the capacitor C behaves such that during the on pulse, the capacitor charges from $1/3V_{cc}$ to $2/3\ V_{cc}$ through R_A and R_B. The changing of capacitor is controlled by pin 2 and 6 such that when the voltage across the capacitor reaches $2/3\ V_{cc}$, the pin 7 using R_B only. This corresponds to off state of be output pin 3 pulses. On discharging to $1/3\ V_{cc}$ again, the pin 7 is disconnected from OV and charging up of capacitor continues. This continues like this in a periodic manner to give a saw tooth wave output voltage being generated continuous by the capacitor. [1, 4,2, 5].

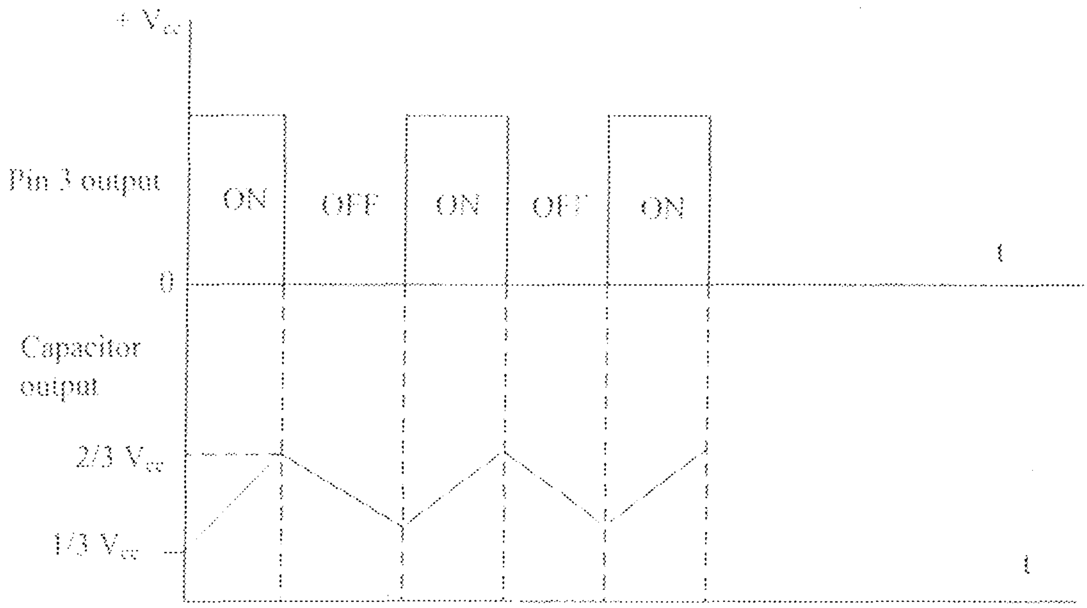


Fig 2.4 The output voltage of pin 3 of 555 and voltage output of capacitor.

Buffer circuitry [unity follower] is an OP – Amp that produces a gain of unity without any phase reversal. It is called buffer or isolation amplifier because it allows input voltage (Vin) to be transferred as output voltage V_o while at the same time preventing the load resistance R_L from loading down the input source. This is used in this project design to feed the saw- tooth wave and reference wave to the comparator [3].

The comparator on the other hand is circuit which compares to signals or voltage level to generate either an on state or off state at the output. This is the bases of pulse modulation techniques employed in this project design.

CHAPTER THREE

3.0 Design and Implementation

As said earlier for proper analysis and design of the electronic alternating current power controller, it was broken down smaller sub – units it includes:

1. The Power Supply Unit
2. The Ramp Generated Unit
3. Amplifier/Comparator Unit
4. Alternating current switching Unit

3.1 The Power Supply Unit

Most of the electronic devices and circuit require a direct current (DC) source for their operation. The main aim of this unit is to provide a constant regulated 12v DC supply to power the system. In order words, the output voltage from the unit remains 12v, irrespective of either variation in AC voltage supply, temperature, time or any other factor that may affect the output voltage. It is otherwise known as rectifier circuit.

Dry cells and batteries are one form of DC source; they have advantages of being portable and ripple free. However, they are subjected to the following limitations.

1. Their voltages are low
2. They need frequent replacement
3. They are expensive compared to conventional DC supply since domestic AC power is most economical and most convenient, hence the need to convert the alternating voltage (usually smaller value) by rectification. There are different types of rectifier circuit which are:

(a) Single phase half wave rectifier

(b) Full wave bridge circuit

(c) Full wave [center tapped transformer is used].

(d) 3-Phase half wave rectifier etc. [2, 3]

For the purpose of this project, full wave bridge rectifier is used. Although full wave rectification can also be achieved using two diodes and center tapped transformer, but the efficiency is low compared with bridge rectifier. The bridge rectifier circuit enables the full secondary voltage to be effectively impressed across the load and does away with the necessity of using center taped secondary windings.

It consists of a step down transformer, bridge rectifier filter capacitor and 12v voltage regulator.

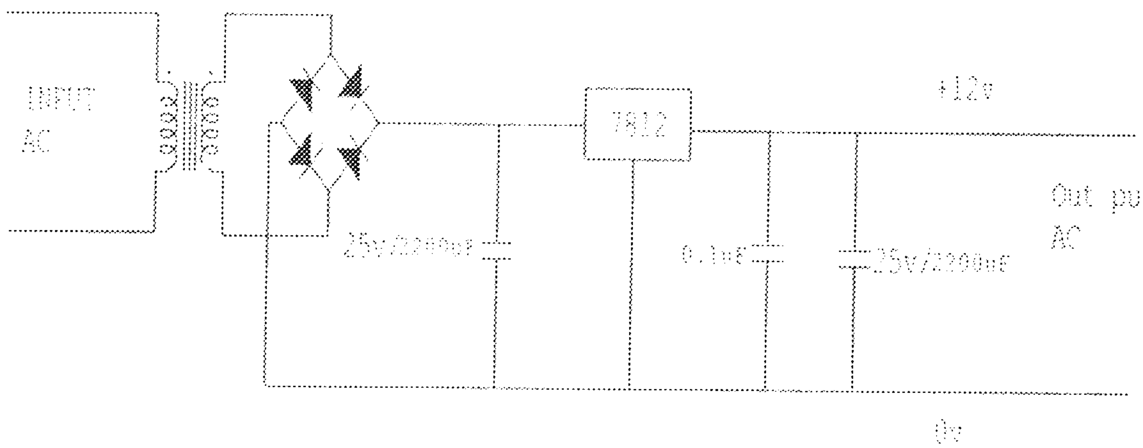


Fig 3.1 Regulated DC power supply

The operation is based on the principle that, on positive half cycle, i.e when J is positive, diodes D_1 and D_2 are forward biased. Current flows through the path JKLMN on negative half cycles, J goes negative with respect to N, this forward biased diodes D_3 and D_4, current flow through NLMKJ.

The transformer is a step down 240/12v, 0.5A, i.e it gives an output voltages of 12v (AC) at the secondary side for 240v(AC) input supply at primary.

The transformer turns ratio R_T is given as

$$R_T = \frac{\text{Secondary Voltage}}{\text{Primary voltage}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Let

V_s = secondary voltage

V_p = Primary Voltage

V3 = 12v

Vp = 240v

$$R_T = \frac{12}{240} = \frac{1}{20}$$

The transformer ratio is 20:1

For the bridge rectifier

Let ;

V_{rms} = voltage at the secondary side of the transformer (12v)

V_{max} = peak voltage

Vmax = Vrms $\sqrt{2}$

Where $\sqrt{2}$ is the scaling factor for converting from root mean square voltage to peak voltage.

Vdcr = DC voltage rectifier (output voltage of rectifier)

$$= \frac{2V\,max}{\pi} \quad \ldots\ldots\ldots\ldots\ldots\ldots [2, 3]$$

$$= \frac{2 \times Vrms\sqrt{2}}{\pi}$$

$= \frac{2 \cdot 12 \cdot \sqrt{2}}{\pi}$

$= 10.80v$

Efficiency (η) of the rectifier is given as

$\eta = \frac{DC\ power}{AC\ power} \times 100$ ---------------- [2, 3]

$= \frac{Vdc}{Vrms} \times 100$

$= \frac{10.80}{12} \times 100 = 90.03\%$

$= 90\%$

There is always an AC ripple in a rectified output

Vrac = the ripple constant

$Vrac = \sqrt{V^2_{rms} - V^2_{DC}}$ ---------------------- [2, 3]

$= \sqrt{12^2 - 10.8^2}$

$= 5.23v$

Therefore, the ripple factor

$= \frac{Vrac}{Vdc}$

$= \frac{5.23v}{10.8v}$

$= 0.484 = 48.4\%$

The output of the rectifier is now passed across a 25v 22000μF smoothening capacitor to reduce the AC ripple superimposed on the rectifier output to the maximum. A high value capacitor is chosen because it gives the following effects.

1. Increases the regulated DC voltage to the required value

2. Reduces the ripple voltage better to smaller value

3. Increases the peak current in the load.

For the filtered DC voltage output:

Vrms = 12v (Transformer secondary voltage)

For a conducting diode, 0.7v is drop on it, however two diodes are conducting at a time in this instance, hence drop on diodes is 1.4v (2×0.7v) such that

$$V_{max} = (12\sqrt{2} - 1.4)v$$

$$= 16.97 - 1.4$$

$$= 15.57v$$

$$V_{DC} = \frac{V_{max}}{1 + \frac{1}{4FCR_l}}$$

Where

V_{DC} is the filtered DC voltage

F is frequency of supply

C is the value of smoothening capacitor

R_l is the DC load on rectifier

Since only the capacitor and regulator are connected to the rectifier, the capacitor is an open load at DC, therefore, the effective resistance R_L is the regulator resistance given as 10kΩ by the manufacturer.

$$V_{DC} = \frac{15.57}{1 + \frac{1}{4 \times 50 \times 2200 \times 10^{-6} \times 10{,}000}}$$

$$= \frac{15.57}{1 + \frac{1}{4 \times 50 \times 22}}$$

$$= \frac{15.57}{1 + 0.000273}$$

$= 15.57v$

Therefore, 15.57v DC is passed to the regulator from the filter capacitor.

A 7812 12 – volt voltage regulator is used. This provides a constant voltage of 12v at the output. The 2200μF capacitor connected across the output of the regulator is to improve the transient response and keep the impedence at high frequency.

The 0.1μF capacitor was incorporated due to a considerable distance between the filter circuit and regulator, this help to filter the noise. [1, 2, 3].

3.2 The Ramp Generator

The design work is based on inter-sective pulse width modulation, in this mode of PWM, a continuously varying voltage is compared with a reference voltage and depending on which is greater of the two, the comparator switches to reflect.

For a comparator

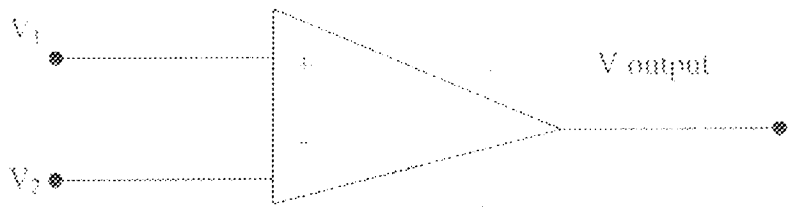


Fig 3.2 Comparator

If $V_1 > V_2$; V_o = high

If $V_1 < V_2$; V_0 = low

Assuming V_1 is steady and V_2 takes on a value V_2 (max) to $V_{2\,(min)} \leq V_1 \leq V_{2\,(max)}$, every time V_2 intersects V_1 the comparator changes state to reflect the inequality.

The period of time before $V_{2\,(min)}$ intersects V_1 gives the on – time of the PWM wave, the period of time before V_2 rises above V_1 to $V_{2(max)}$ and back to $V_{2(min)}$ gives the off – time of PWM wave.

Hence, by varying the DC reference voltage, the ON – OFF time of the generated PWM wave can be accurately controlled.

This demands a voltage $V_{2(min)}$ cyclically as shown below;

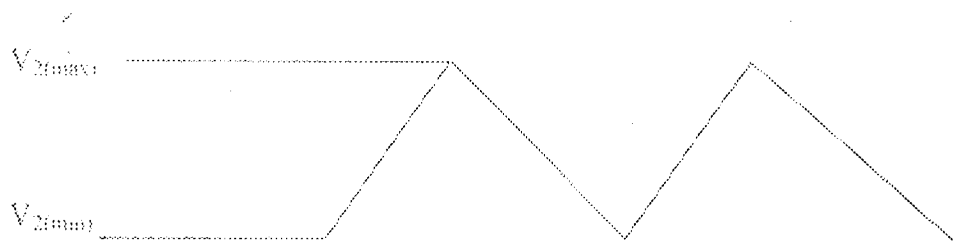


Fig 3.3 saw tooth wave

The wave form can be derived from a saw-tooth or triangle wave generator. It can also be gotten from across a capacitor, charged by a constant current source in which case, a ramp wave form results.

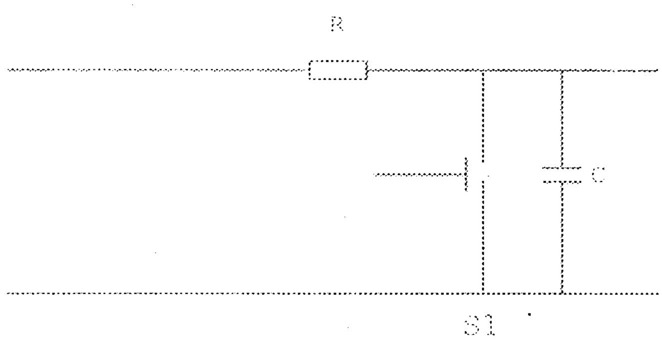


Fig 3.4a RC combination switch

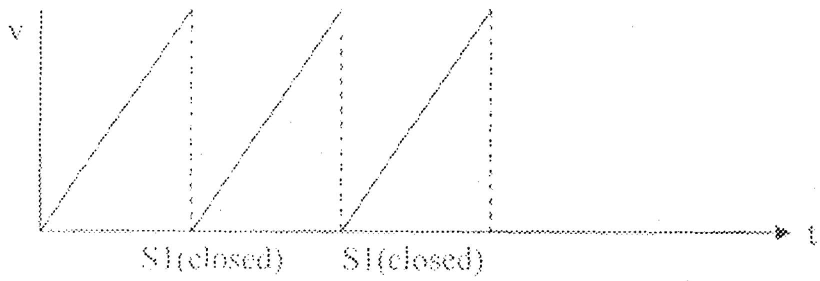


Fig 3.4b output wave form of RC combination

By keeping the value of the capacitor low, a very accurate ramp waveform is obtained. The cyclic nature of V_2 demands that a circuit capable of charging and discharging a capacitor be used. This is the basis of relaxation oscillation i.e oscillators where oscillation frequency are determined by the values RC – timing components

Common energy example is the ASTABLE OSCILLATION wired using an Op – Amp as shown below:

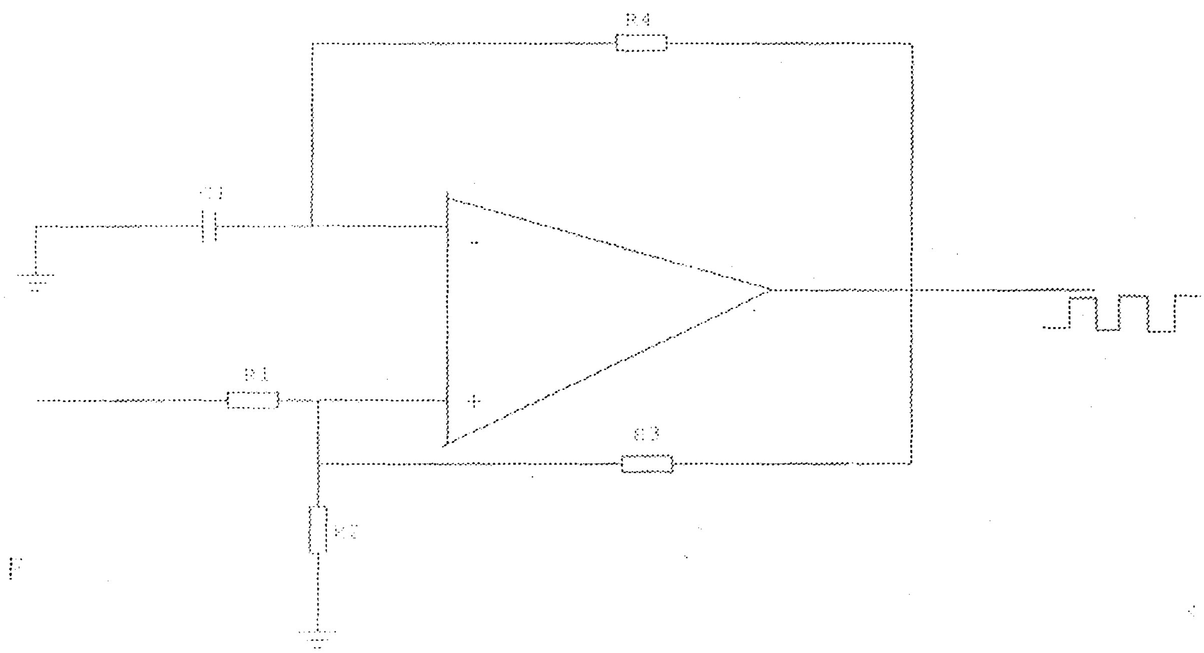


Fig 3.5 astable oscillator wired using OP-Amp

Assuming as power op – amp, Vo is in the high state, C charge up through R4 until Vc is greater than V at which instant Vo switches low and C starts discharging through R4 again. At a second Vr level determined by the relative resistance of the network formed by R1, R2 and R3, Vc falls lesser than V+ causing Vo to switch high . C starts charging through R4 again, the cycle repeating indefinitely.

The voltage Vc, across, the capacitor is given by

$$V_c = V\,(1-e^{-t/Rc})$$

This yield a value of Vc that is exponential with respect to time. The voltage Vc across the capacitor is approximately saw-tooth in nature and can utilized for PWM wave generation .

An astable oscillator is used for the generation of the cyclic voltage, the device used being an integrated circuit 555 oscillator. The frequency is set to a sub multiple of the mains frequency, as a value of 1Hz was chosen since this yields a period high enough for the intended design. The 555 is configured astable operation as shown below [1, 2, 3, 4]

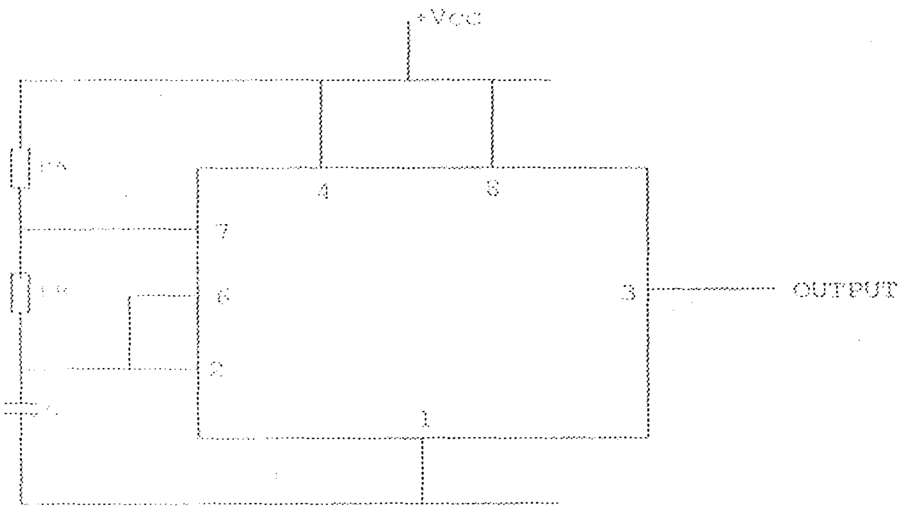


Fig 3.6 555 timer in astable configuration

At $+V_{cc}$, the capacitor C charges from $1/3V_{cc}$ to $2/3V_{cc}$ through R_A and R_B, this gives the on time of the pulse generated i.e

$$Ton = 0.7c\,(R_A + R_B)$$

$$Toff = 0.7cR_B$$

Time for one complete cycle T is thus

$$T = Ton + Toff$$

$$= 0.7c\,(RA + RB) + 0.7RB\,C$$

$$= 0.7cRA + 0.7Crb + 0.7cRb$$

$$= 0.7c\,(Ra + 2RB)$$

but, frequency $F = \frac{1}{T}$

$$F = \frac{1}{0.7c(RA + 2RB)} = \frac{1.44}{C(RA + 2RB)}$$

Therefore, the frequency of oscillation is given by

$$F = \frac{1.44}{(RA + 2RB)C}\ Hz \ldots\ldots\ldots\ldots\ldots\ldots(1.4)$$

The voltage Vc across the capacitor rises from 1/3Vcc to 2/3Vcc before discharging back to 1/3Vcc cyclically. A wide control range is needed for accurate power control, hence the value of the capacitor voltage has to be wide. To achieve this, a high value of Vcc is chosen i.e 12v. for a Vcc of 12v, the capacitor voltage has a minimum value of 12/3 (4v) and maximum voltage has a translating into 0% and 100% power delivery.

$V_c(min) = 1/3V_{cc} = 1/3(12) = 4v$

$V_{cc}(max) = 2/3V_{cc} = 2/3(12) = 8v$

To match the above voltage range, a variable DC level of minimum value of 4v and maximum value of 8v is needed.

The DC reference voltage is generated by the potential divider network shown below

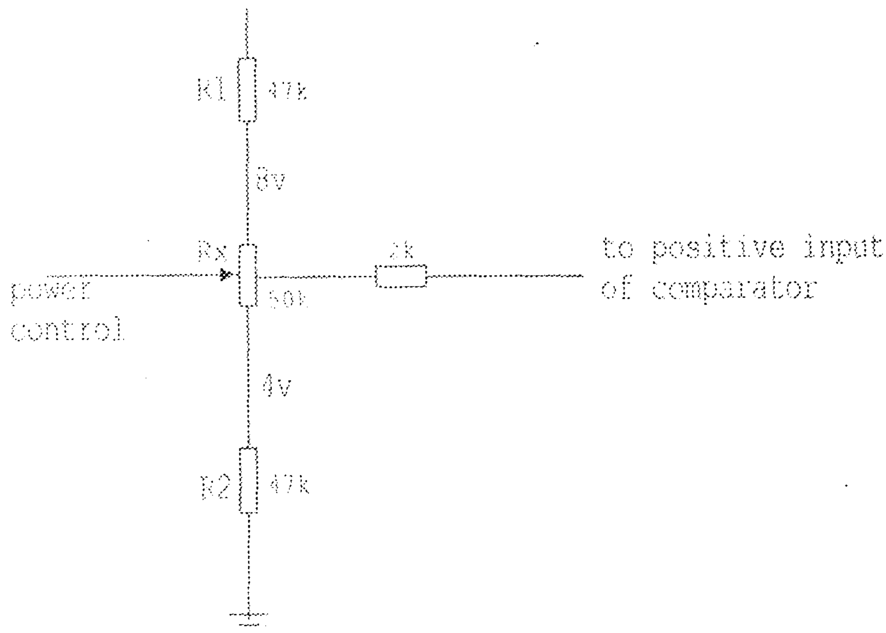


Fig 3.7 potential divider generating DC voltage

From the above diagram, voltage at any point indicated is given as;

$$V_{ref} = \left(\frac{R2 + Rx}{R1 + Rxm + R2}\right) 12v$$

$$\left(\frac{47 + Rx}{47 + 50 + 47}\right)12v$$

$$= \left(\frac{47 + Rx}{144}\right) 12v$$

Where Rx can take values from 0, 12.5k ----------------50k. Rxm is the maximum value of Rx obtainable.

3.3 Amplifier/Comparator

A non inverting buffer is used to buffer Vc and Vref as shown below

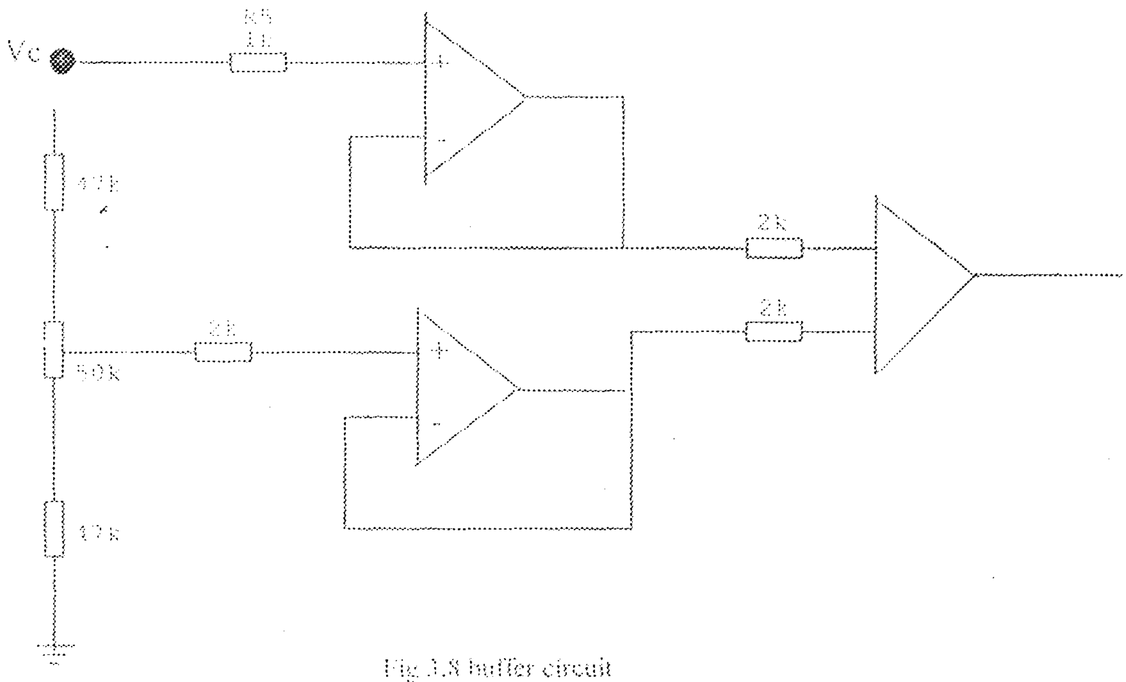


Fig 3.8 buffer circuit

Buffering of the two voltage sources is needed to present a zero impedance voltage source to the to the comparator, otherwise, the necessary control will not be realized. For a given value of Vref say 5v the PWM wave output approximates the plot shown below;   Vc

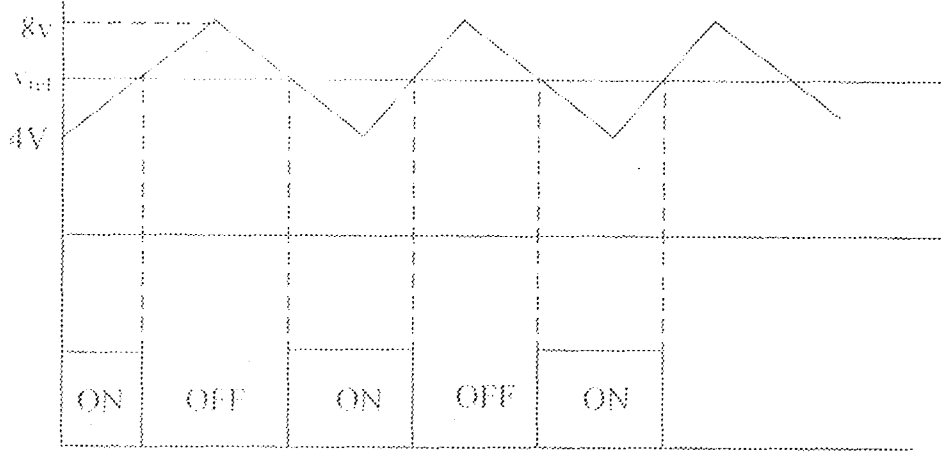


Fig 3.9 PWM wave output

The PWM wave has a power density that is directly proportional to Ton. Therefore by varying Vref the duty cycle of the wave is varied and hence, the power contained in the wave.

A plot of the power control of potentiometer resisteance is shown below.

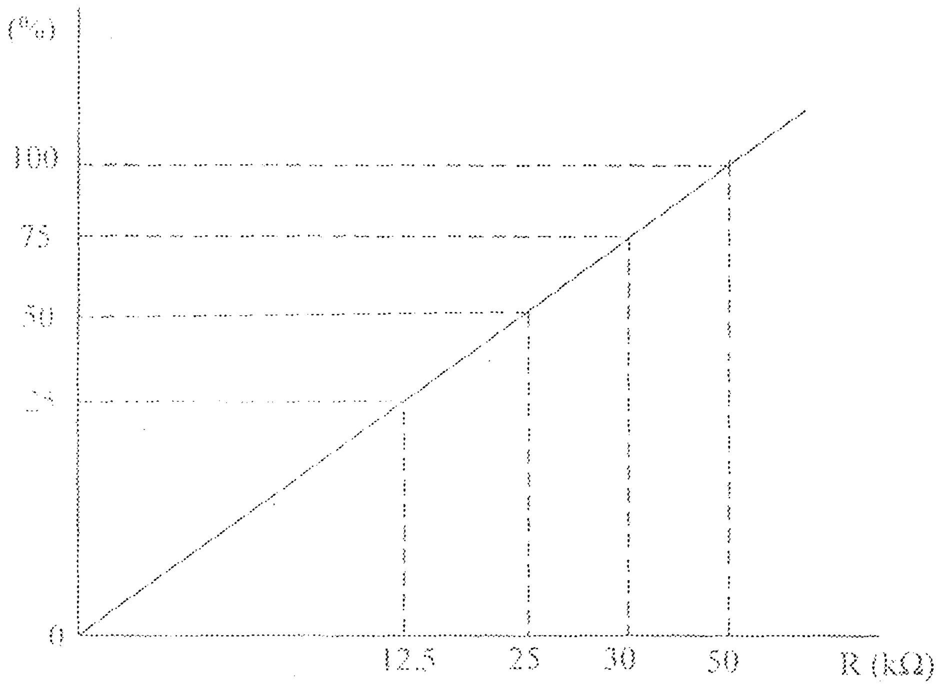


Fig 3.10 plot of power control of potentiometer resistance

The PWM wave drives an AC switch through an Opto triac as shown below:

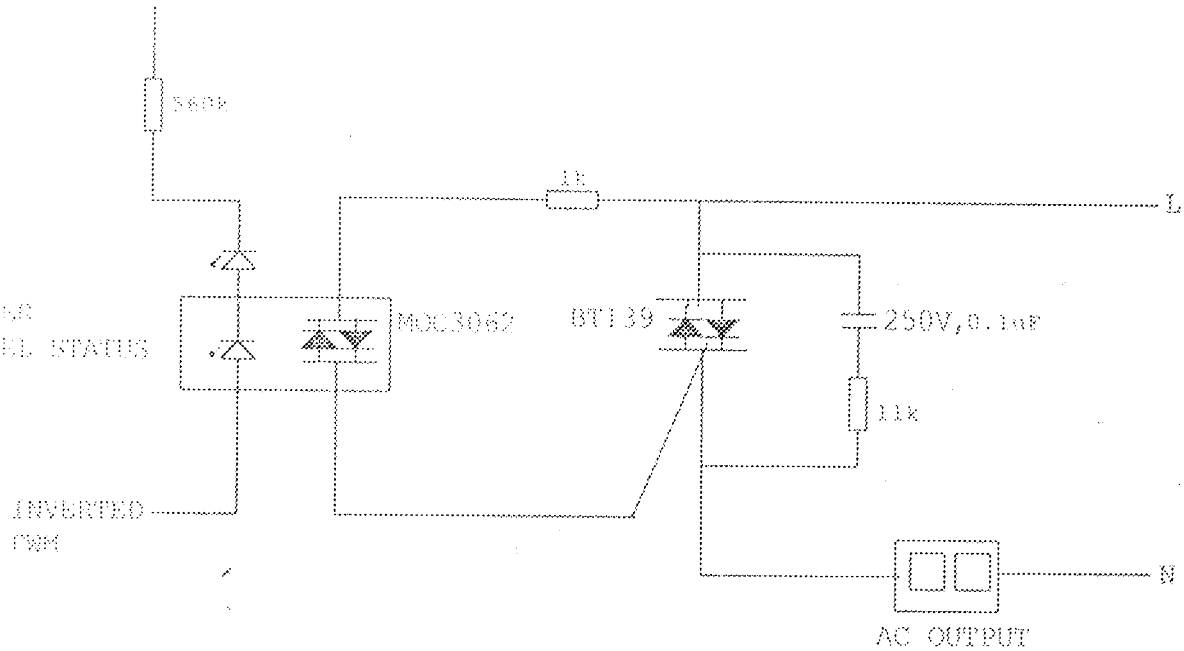


Fig 3.11 PWM driving an AC switch through an Opto Triac

3.4 Switch

The AC switch comprises an Moc3062 opto – triac and a BT139 16A power triac. The 3062 is a zero- crossingn opto – triac with an internal infrared light emitting diode. If the LED is forward – biased, it light shines on the photo triac which it is in close contact inside the package, thus, when the LED is ON, the photo triac is ON. The photo triac is connected via a 1kΩ resistor from the 240v AC input to the gate of the BT139.

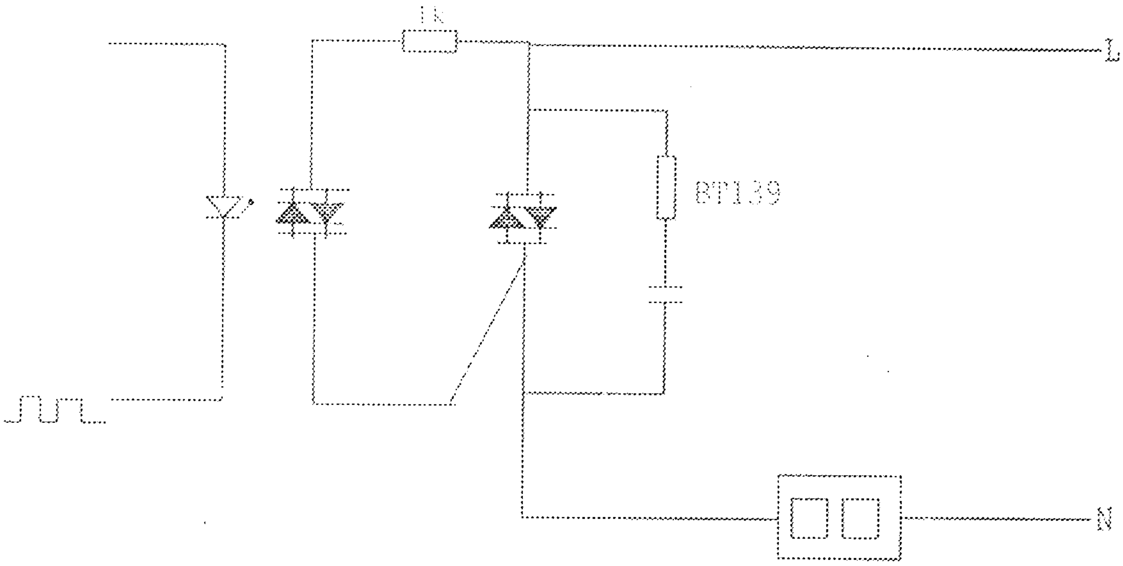
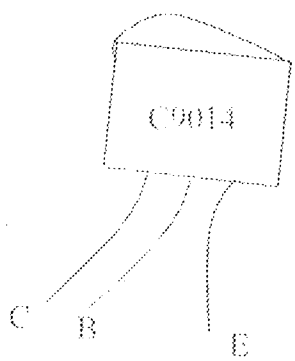


Fig 3.12 AC switch triac

From the diagram BT139 is controlled by the opto – triac. Thus by modulating the ON – OFF time of the opto – triac, the ON – OFF times of the power triac is also directly modulated.

The PWM drive is fed to the base of an NPN silicon transistor, C9014



F_T = 200mHz
I_{cmax} = 150mA
H_{fe} (DC) = 340

Fig 3.13 NPN silicon transistor

The transistor is connected in series with the opto triac as shown below.

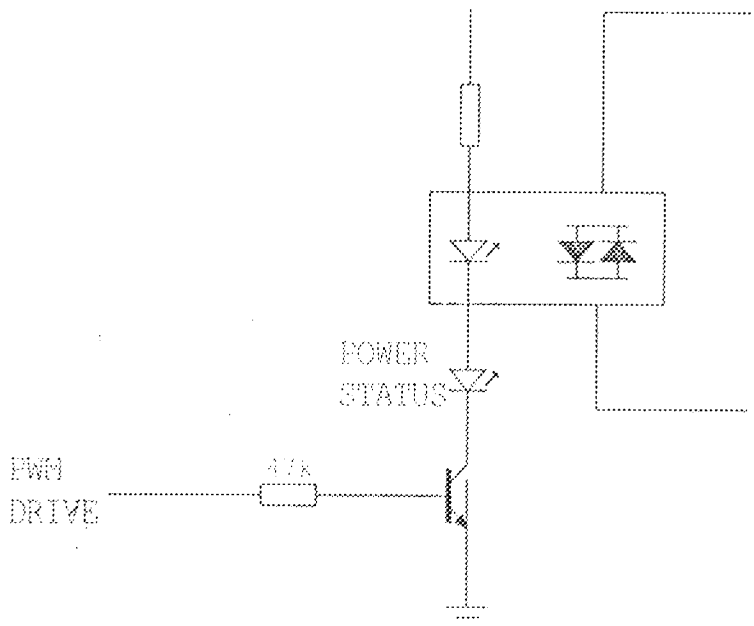
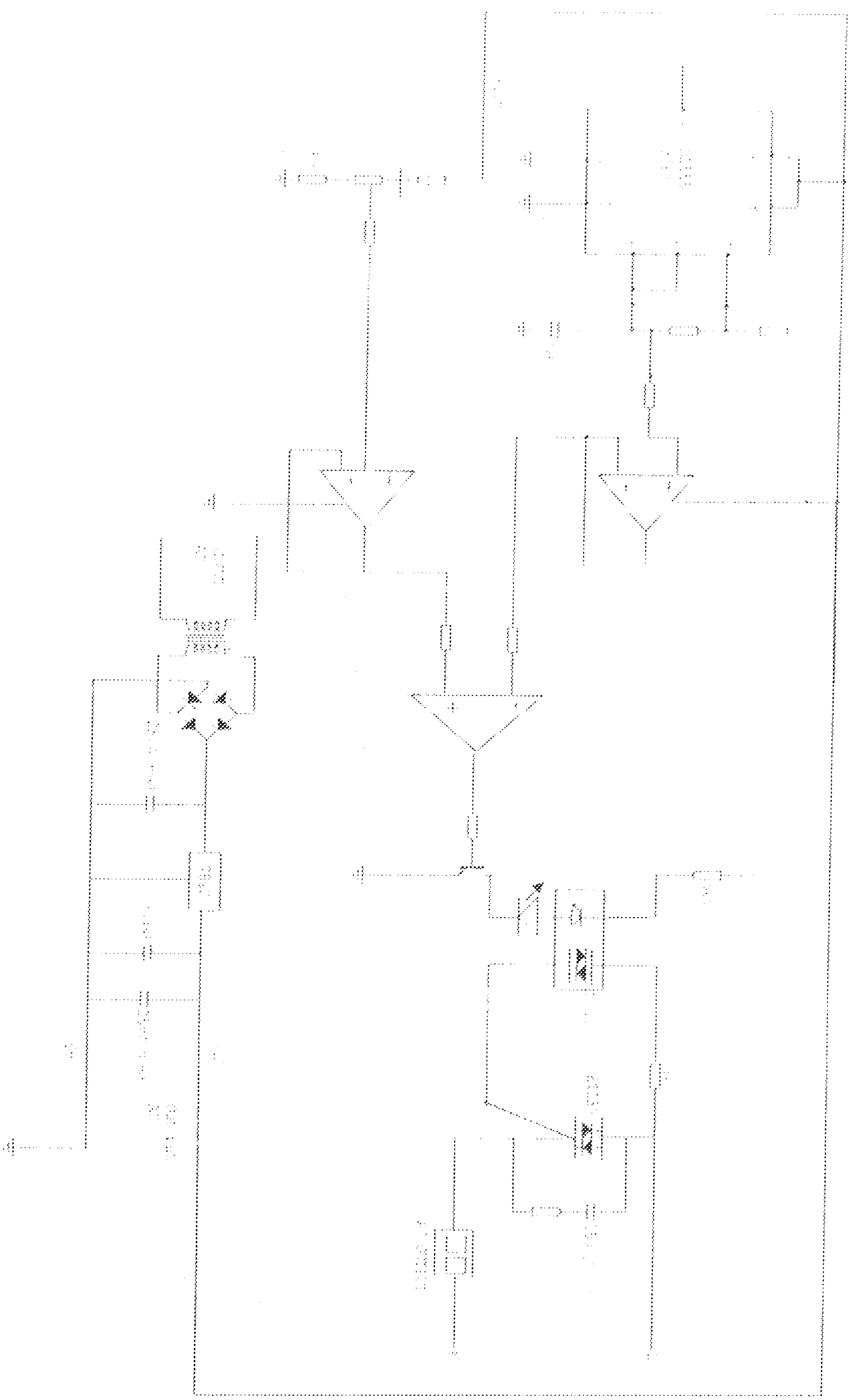


Fig 3.14 transistor and Opto triac combination circuit

LED 1 provides a visual indication of the load power. The load power is directly proportional to the flash rate of the LED. When LED is fully ON, load power is 100% and when fully OFF, the load power is 0% when the LED flashes, the relative ON – OFF time of the LED gives an indication of the average power delivered to the load.

The power switches used "BT139" is a 16 – Amp triac configured for operation in quadriant I. Its ON – OFF time is modulated by the PWM wave. Ann RC snuber network connected across it is to prevent false triggering due to high dv/dt transients.

Its gates current is typically 10MA.



CHAPTER FOUR

4.0 Tests, Results and Discussion

Each of the modules/units was simulated one after the other. The complete circuit was also simulated, with the value of components used in design put into consideration. The modules were then constructed on the breadboard each of them tested before they were now coupled together. The complete circuit was also tested on the bread board multimeter was used to measure the output of each stage and each value were compared with the value expected from design specification the final circuit was transferred on to the veroboard.

4.1 Test and Results

The idea here is to ensure that the appropriate percentage of total available power (AC power supplied to the load) [electromechanical devices or resistive heating element] depending on the users desire. Also the power delivered to each section must be accurate so as to prevent the damage to the electronic components and in turns the device itself. The following readings were taken using multimeter at different stage and compared with the value prescribed in the designs specification.

Table 4.1

Modules/subsystem	Expected value from design	Value measured
Output of secondary side of transformer	12v AC supply	12v AC supply
Rectified output	12v DC supply	12v DC supply
Regulated DC output		

Potentiometer setting (%)	Output of the comparator
25%	25%
30%	30.1%
75%	74.5%
100%	99.8%

It was latter tested with fan and electric heater. While testing with fan (example of electromechanical devices), when the potentiometer was set to the highest value, the fan was at maximum speed, the LED that provide a form of visual indication of the percentages of power delivered to the load was fully ON, i.e not flashing at all. When set to a value below 100%, the LED started flashing at high rate and the speed of fan reduces. On reducing the position of the potentiometer to a lesser value, the rate of flashing of LED reduces more and the speed also reduces.

Also, test was done with an electric heating element, although this takes time to notice the effect of different position of potentiometer with the heating output of the heating element. The potentiometer was set to different position and the time taken by the heating element to boil same quality of water under a fairly same environmental conduction was monitored. When set to 100% power delivery, lesser time was taken to boil the same quality of water as compared to when set to lower value. This is summarized in the table. Shown below

Table 4.2

Potentiometer setting (%)	Time taken to boil ½ litter of water (min)
Power = 100	2
Power < 100	3.5
Power < 100	5.5

Note:- that the above time depends on the AC power supplied by PHCN which fluctuates between 170v and 200v.

4.2 Discussion of Results

From the above results obtained and within the limit of experimental error, it shows that when the control is set to 100% power delivery all the available AC power will be allowed delivered to the load (e.g we have maximum speed in electromechanical devices like motor) also, the position of the controls determines the net power supplied to the load as it may be required by the user.

4.3 Limitations

1. It is applicable to only electromechanical devices and resistive devices. It is not applicable to lamps and cooling system (that was compressor) where the alternating current cycle must not be cut – off completely or interrupted.

2. It is an analogue implementation.

3. problem of providing the visual display of power by the use of oscilloscope

CHAPTER FIVE

5.1 Conclusion

To a larger extent, the objective of this project work has been achieved. By electronic means, the control of power has been achieved which is a better device in terms of reliability, cost, versatility and energy conservation. With application in controlling the speed of electromechanical devices (e.g. Alternating current motor) and resistive heating devices, the speed of motor was controlled and the heat dissipated by heating devices (e.g. oven, heater) was controlled simply by modulating the pulse that controls the ON and OFF of the power triac.

5.2 Recommendation

- The circuit can be improved on so that it will also regulate the intensity of lamp. This may require a timing circuitry that will determine the time at which the AC signal crosses the zero axis, this is because the dimming and brightening of light involves the changing of phase angle (phase angle firing).
- Further research can provide a means of adapting it to cooling systems that are using compressor. The compressor does not support the interruption of power supply into it and this is the basis of control adopted by this design.
- Better and custom made AC power controller should be mass produced to suit the Nigeria market and product.
- Enlighten the populace on the need for conservation of electrical power and energy
- Encouraging our local industry by the government and the populace by patronizing their goods and give rooms for improvement

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BILL OF MATERIALS

SN	COMPONENTS	UNIT PRICE (N)	UNIT	COST PRICE (N)
1	Power diode	10	4	40
2	Capacitor	10	3	30
3	Regulator	80	1	80
4	Light emitting diode	150	2	20
5	Transformer 220/12v	80	1	150
6	NE 555 3083	100	1	80
7	LM 324	40	1	100
8	MOC 30652	50	1	40
9	BT 139 Power triac	20	1	40
10	Socket outlet	20	1	20
11	Casing	100	1	100
			TOTAL	700

MANUAL OF OPERATION

- Plug the electronic AC power controller to alternating current source.
- Switch on the ON button
- The amber LED indicates that the device is powered
- Plug the appliances (AC motor, heating devices etc) to the socket outlet of the device
- Control the power delivered to the load using the control knob of the power controlling device. The rate of flashing of red LED indicate the average power delivered to the load.