CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

An Automatic Voltage Regulator (AVR), also known as a Voltage Stabilizer, is a device which is used to compensate for voltage fluctuations in the mains power supply by maintaining the supply voltage within a constant acceptable range [1]. These fluctuations in the mains supply voltage might be in the form of voltage sags or voltage spikes. Voltage sags might occur as a result of undersized distribution lines, connection of large loads to the network and ground faults. Voltage surges on the other hand might be generated by the disconnection of large loads, increased voltage at the generating plant and atmospheric events. These fluctuations are undesirable and are capable of damaging loads in the power system [2].

The main component which this device commonly uses to achieve this regulation is the Autotransformer [3]. The entire principle of operation of the Automatic Voltage Regulator centers around sensing the mains input voltage value and sending this voltage to the required tapping of the Autotransformer. The Autotransformer proceeds to either step up or step down the voltage, after which this regulated voltage is sent to the output socket of the Automatic Voltage Regulator.

A digital form of an Automatic Voltage Regulator is designed and implemented in this project. This Digital Automatic Voltage Regulator uses a programmed microcontroller as the processor. The microcontroller senses the input mains voltage value and logically selects the correct tapping of the Autotransformer to which this voltage is to be sent to by means of a cascade of relay switches. The microcontroller also makes it possible for the user to monitor the loading of the stabilizer as well as the input and output voltage values of the stabilizer by sensing these values and displaying them on an LCD screen. Load monitoring in an Automatic Voltage Regulator really goes a long way in extending the life span of the device.

1.2 Statement of Problem

In Nigeria today, the voltage supplied to consumers by distribution companies usually falls below or exceeds the conventional supply range of 220 - 250 volts as a result of fault conditions in the power system. This issue of overvoltage and undervoltage poses a huge risk to household devices and industrial equipment designed to operate within this conventional supply voltage range. Hence, an Automatic Voltage Regulator is needed in homes and industries to help maintain the voltage level within the conventional supply range to avoid damage to devices and equipment.

1.3 Aim and Objectives of the Study

The aim of this project is to design and implement a 1 KVA Automatic Voltage Regulator.

The objectives of this project work are:

i. To design and wind a 1KVA autotransformer with 8 tapping.

ii. To design and implement a 5V and 12V DC power supply circuit using resistors, capacitors, diodes, transistors and LM7805 voltage regulator.

iii. To design and implement an input voltage sensing circuit using resistors, capacitors and diodes.

iv. To design and implement an output voltage sensing circuit using resistors, capacitors and diodes.

v. To design and implement a current sensing circuit using a current transformer.

vi. To design and implement a control circuit that uses a PIC 16F876A microcontroller.

vii. To develop a program for the microcontroller using Great Cow Basic (GCB) Compiler.

viii. To design and implement a relay switching circuit using 6 relays.

ix. To implement a display unit using Liquid Crystal Display (LCD).

1.4 Significance of the Study

The design and implementation of an Automatic Voltage Regulator will be of great benefit to:

i. Industries and companies as it will help to protect delicate machines and equipment used in production.

ii. Homes as it will help to protect various household appliances and devices.

iii. Students and scholars for the purpose of research into Automatic Voltage Regulators.

1.5 Scope of the Study

The scope of this project is delimited to:

i. 1 KVA maximum load

ii. 260V maximum input voltage, at 50Hz

iii. 140V minimum input voltage, at 50Hz

iv. Single phase supply

CHAPTER TWO

LITERATURE REVIEW

In order to develop better and more efficient ways of compensating for voltage fluctuations in the mains power supply, a lot of research has been done in the field of automatic voltage regulation over the years. This has resulted in the formulation of different techniques for the design and implementation of automatic voltage regulators.

In [4], an automatic voltage regulator was designed using the principle of servo control. A servo control system is a closed loop system for electric motors. The servo system uses a sensor to sense motor position/speed. Servo control has a feedback circuit which changes the drive power going to motor according to the control input signals and signal from sensors [4]. In this design, the servo motor moves the output wire terminal over a toroidal type autotransformer in either clockwise or anticlockwise direction. This movement of the servo motor in either direction results in an increase or decrease in voltage levels since it varies the voltage per turn of the autotransformer. The control unit of this design uses three operational amplifiers as comparators to control the regulation unit (servo motor and autotransformer) during overvoltage, undervoltage and normal operating conditions. These op-amps sense and compare A.C input and output voltages against a reference 220V (all rectified to their D.C equivalent) to determine what direction to rotate the servo motor and when to stop the rotation. A major drawback to this design is that no provisions were made for overload protection. It also lacks an efficient display system that can help the user monitor the input voltage, output voltage and load power.

In another work [5], a voltage regulator was designed by means of a Constant Voltage Transformer (CVT) also known as a Ferroresonant Transformer. These transformers provide an

A.C output voltage of nearly constant magnitude even when the input voltage changes over a specified range. It is also completely and continuously short circuited in use, without any adverse reaction [5]. Ferroresonance is the property of a transformer design in which the transformer consists of two separate magnetic paths with limited coupling between them. These transformers use a tank circuit composed of a high-voltage resonant winding and a capacitor to produce a nearly constant average output voltage with a varying input current or varying load. The circuit has a primary on one side of a magnet shunt and the tuned circuit coil and secondary on the other side. The regulation is due to magnetic saturation in the section around the secondary [1]. The design of constant voltage transformer basically involves the derivation of its electrical parameters and mechanical parameters. The electrical parameters are associated with capacitance, inductance estimation, regulated voltage input range, short circuit current etc. The mechanical parameters deal with the calculation of core dimensions [5]. One of the downsides of this design is its low efficiency. The efficiency of this regulator is about 80% at full load conditions but can go as low as 60% at lighter loads. This particular work also has a narrow input voltage range of 190 V - 250 V, making it unsuitable for the regulation of lower voltage levels.

In [6], two separate transformers; a step-up transformer and a step-down transformer, are used in carrying out automatic voltage regulation. The step-up transformer is a 225V/238V transformer while the step-down transformer is a 230V/218V transformer. A single operational amplifier is used as a comparator in the control unit. The op-amp switches a transistor, during high voltage conditions, which triggers a double-pole single-throw relay. When the relay is un-triggered (in normally closed position during low voltage conditions), it sends the A.C input voltage to the primary side of the step-up transformer, whereas, when it is triggered (during high voltage conditions), it sends the A.C input voltage to the primary side of the step-down transformer. The secondary terminals of these two transformers are joined together and sent to the stabilizer output socket for the load. This automatic voltage regulator maintains the output voltage between 200V – 250V for voltage fluctuations ranging from 180V – 265V [6]. This design of an automatic voltage regulator is inefficient as it is incapable of narrowing down the output voltage range hence its 200V – 250V output. Another drawback of this design is that it cannot be used in regulating voltages below 180V. Also, no provisions were made in the design for overload protection and the display of input and output voltages for the user.

The proposed automatic voltage regulator in this work will check a lot of deficiencies that have been pointed out in the works above. Some special features of this automatic voltage regulator include:

i. A wide input voltage range of 140V – 260V
ii. A narrow output range of 220V – 250V to ensure a near constant output voltage level.
iii. Overload protection of the automatic voltage regulator from damage resulting from overload conditions, and
iv. A display interface for monitoring the input voltage, output voltage, and load power

CHAPTER THREE

METHODOLOGY

3.1. Block Diagram

The block diagram below shows in schematic form the interconnections between the various units of the automatic voltage regulator.

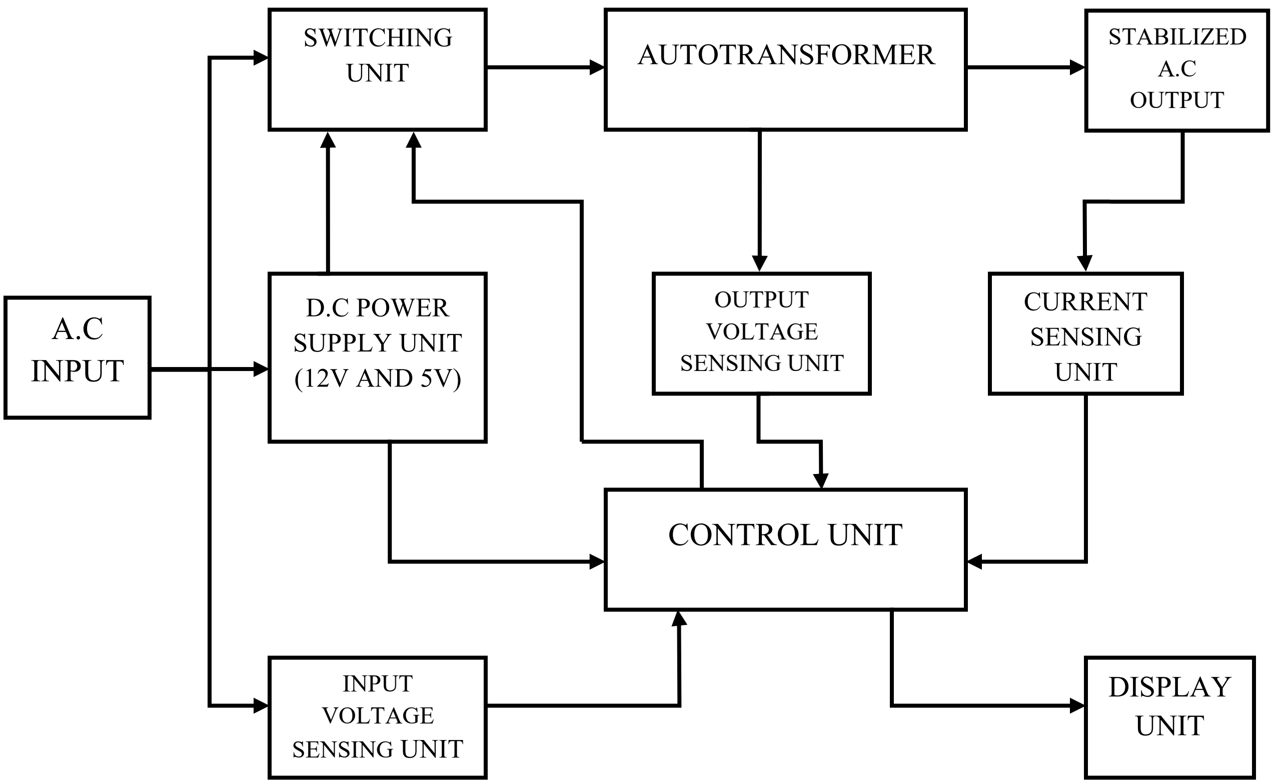


Fig. 3.1: Block Diagram of the Automatic Voltage Regulator Design

In the block diagram above, the unstable A.C input voltage flows into the switching unit, the D.C power supply unit and the input voltage sensing unit. The D.C power supply unit converts the A.C input voltage into a 12 V and 5 V regulated D.C voltage. The 12 V D.C powers the switching unit, while the 5 V D.C powers the control unit and the display unit. The input voltage sensing unit converts the A.C input voltage to its low - range D.C equivalent, and then sends it to the control unit. The control unit processes this signal and uses it to decide on the correct tap of the autotransformer to send the A.C input voltage by switching the relay cascade of the switching unit. The control unit also transmits this signal to the display unit for display purposes. The output voltage from the autotransformer is sent to the output voltage sensing unit. This unit also converts the A.C output voltage to its low - range D.C equivalent and sends it to the control unit for overvoltage protection and for transmission to the display unit. The stabilized voltage from the autotransformer is sent to the automatic voltage regulator socket outlet, for use by the load. The quantity of current drawn by any load is sensed by the current sensing unit, whose output is sent to the control unit. The control unit uses this signal for overload protection of the device and also transmits it to the display unit for the purpose of load monitoring.

3.2 Autotransformer

A transformer is an electromagnetic device that changes A.C electric power at one voltage level to A.C electric power at another voltage level through the action of a magnetic field. It consists of two or more coils of wire wrapped around a common ferromagnetic core [7]. Transformers are capable of either increasing or decreasing the voltage and current levels of their supply, without modifying its frequency, or the amount of electrical power being transferred from one winding to another via the magnetic circuit.

The physical basis of a transformer is the mutual induction between two circuits linked by a common magnetic flux. If one part of the transformer, is connected to a source of alternating voltage, an alternating flux is set up in the laminated core, most of which is linked with the other coil in which it produces mutually induced electromotive force (Faraday's law). Hence, a voltage is seen across the other coil i.e. the secondary part.

A unique type of transformer is used in the design of this automatic voltage regulator. This type of transformer is known as an autotransformer. An autotransformer is a transformer with only one winding, part of this being common to both primary and secondary [8]. A schematic diagram of an auto transformer is shown below:

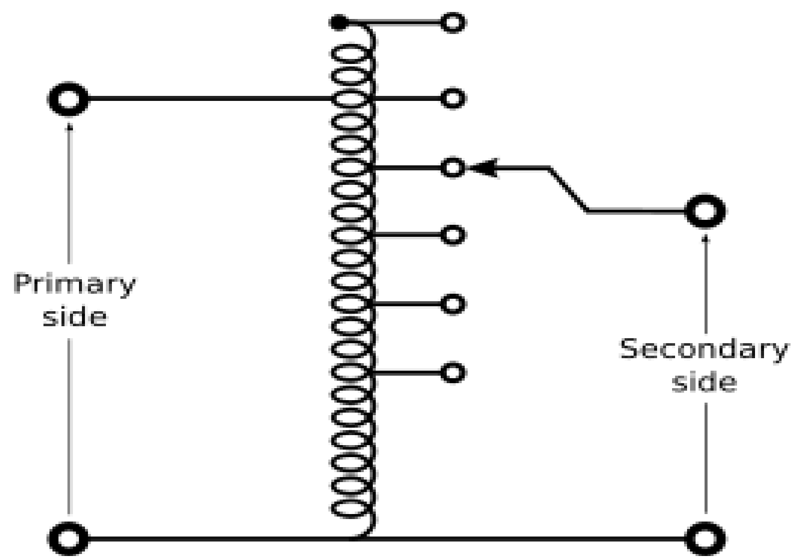


Fig 3.2: Schematic diagram of an autotransformer [8].

The autotransformer can be regarded as the 'heart' of the automatic voltage regulator. This is because it is the device which performs the actual regulation of voltage. In this transformer the primary and secondary turns are not electrically isolated from each other. The primary voltage is applied across two of the terminals, and the secondary voltage taken from two terminals, almost always having one terminal in common with the primary voltage (i.e. the neutral terminal). Since the voltage per turn is the same in both windings, each develops a voltage in proportion to its number of turns. In an autotransformer part of the current flows directly from the input to the output, and only part is transferred inductively, allowing a smaller, lighter, cheaper core to be used as well as requiring only a single winding. However the voltage and current ratio of autotransformers can be formulated the same as other two-winding transformers

3.2.1 Design Calculations for the Autotransformer

The Predetermined Parameters for the autotransformer design are as follows:

- Rating of the Automatic Voltage Regulator $= 1000\text{VA} = 1\text{kVA}$
- Minimum Input voltage to the system $(V_{in\,min}) = 140\text{V}$
- Maximum Input Voltage to the system $(V_{in\,max}) = 260\text{V}$
- Minimum Output voltage of the system $(V_{out\,min}) = 220\text{V}$
- Maximum Ouput voltage of the system $(V_{out\,max}) = 250\text{V}$
- Voltage difference $= 20\text{V}$

Using the dimensions from the core area (centre – limb) of the lamination, ply-wood and glue were used in constructing the coil former of the autotransformer. In order to determine the iron area A_i for the winding calculations, the length and width of the constructed coil former were measured as:

- Length of core former = 6.1cm
- Width of coil former = 5.5cm

$$\text{Iron area, } \text{A}_\text{i} = \text{Length of core former} \times \text{Width of coil former} \tag{3.1}$$

$$\therefore \text{A}_\text{i} = 6.1 \times 5.5 = 34cm^2 = 0.0034m^2$$

In order to determine the size of copper wire to be used for the windings, the maximum allowable output current was determined as follows:

$$\text{Maximum allowable Output Current } (I_{max}) = \frac{Power\ rating\ (in\ kVA)}{Minimum\ Input\ Voltage} \tag{3.2}$$

$$\mathrm{I_{max}} = \frac{1000}{140} = 7.14\mathrm{A}$$

The suitable wire gauge for this current is gauge 19 with a maximum allowable current of 14A. According to [9], this wire gauge has a corresponding copper diameter of 0.91186mm, and an area of 0.65mm^2.

With the wire gauge for winding the transformer determined, the next step is to calculate the number of turns for each voltage. The autotransformer is required to have a voltage difference of 20 V. With the minimum voltage equal to 140V, the transformer taps have voltage values of 140 V, 160 V, 180 V, 200 V, 220 V, 240 V. The detailed calculations that were done to obtain the number of turns required for each voltage tapping are shown below:

From the transformer E.M.F equation,

$$V_n = 4.44 f N B_{max} A_i \tag{3.3}$$

$where; f = 50Hz;$

$$B_{max} = 0.9;$$

$$A_i = \ 0.0034m^2$$

$No.\ of\ turns\ for\ the\ 220\ V\ turn\ will\ be\ given\ by,$

$$V_{220} = 4.44 \times 50 \times 0.9 \times N_{220} \times 0.0034$$

$$220 = 4.44 \times 50 \times 0.9 \times N_{220} \times 0.0034$$

$$\therefore N_{220} = 324\ turns$$

$$Using\ the\ relation: \frac{N_x}{N_{220}} = \frac{V_x}{220}; \tag{3.4}$$

$$where\ x = 30\ V, 140\ V, 160\ V, 180\ V, 200\ V, 240\ V.$$

$$N_{30} = 324 \times \frac{30}{220} = 44\ turns$$

$$N_{140} = 324 \times \frac{140}{220} = 206\ turns$$

$$N_{160} = 324 \times \frac{160}{220} = 235\ turns$$

$$N_{180} = 324 \times \frac{180}{220} = 265\ turns$$

$$N_{200} = 324 \times \frac{200}{220} = 295\ turns$$

$$N_{240} = 324 \times \frac{240}{220} = 353\ turns$$

3.3 D.C Power Supply Unit

The D.C power supply unit performs the function of providing the D.C power required to power all the electronic components in the automatic voltage regulator circuitry. This unit achieves this by stepping down the voltage of the A.C input, converting it into D.C voltage through rectification, filtering the D.C voltage and lastly, regulating it.

The electronic components used in designing this unit are as follows:

Table 3.1: Electronic Components Used in the Design of the D.C Power Supply Unit

S/N	Component Name	Value/Rating/Type
1.	Transformer	220 V / 24 V , 300 mA, 50 Hz
2.	Diodes	1N4007
3.	Capacitors	3300uF (50 V), 2200uF (16V)
4.	Transistor	TIP 31C
5.	Fixed Voltage Regulator	LM7805
6.	Zener Diode	13 V
7.	Resistor	2.2 kΩ

The first stage in the D.C power supply unit involves the stepping down of the A.C input voltage. This process is achieved with the help of a step – down transformer. In this design, a 220V / 24V transformer is used in stepping down the A.C input voltage. The process of stepping down the A.C input voltage is carried out in order to minimize the amount of energy (voltage) that will be dissipated when regulating the voltage to 12V and 5V D.C.

The next stage in the D.C power supply unit involves the rectification of the stepped down A.C input voltage. Rectification is the process of converting alternating current or voltage (A.C), which periodically reverses direction, to direct current or voltage (D.C), which flows in only one direction [10]. In this design, a full wave bridge rectification was applied. Here, four 1N4007 diodes were arranged as shown in Fig. 3.3. 1N4007 diodes were used because of their: high peak repetitive reverse voltage of 1000V, high maximum forward current of 1 A, and surge overload rating of 30A peak [11].

After the A.C voltage has been rectified to D.C, it is filtered through the use of capacitors in order to eliminate the ripples or even out fluctuations still contained in the D.C signal after rectification. In this design, this filtering process was carried out with two 3300µF/50V capacitors as shown in Fig.3.3. These capacitors sufficiently reduce the ripple voltage to about 0.75Vp-p at a frequency of 50Hz.

$$C = \frac{0.7 \times I}{\Delta V \times f} \tag{3.5}$$

where: C = shunt capacitance

I = maximum load current, approximately 0.3A

ΔV = ripple voltage, approximately 0.75Vp-p

f = supply frequency

Using the above relation, the shunt capacitor is calculated to be about 5600µF. Such a capacitor is not available in the local market, hence two 3300µF capacitors were used to give a total capacitance of about 6600µF. Capacitors with voltage ratings of 50 V were used because their ratings were high enough to withstand the peak voltage of the rectified A.C voltage. This peak voltage is given as follows:

$$Peak\ Voltage\ (Vm) = Root\ Mean\ Square\ Voltage\ (Vrms) \times 1.414 \tag{3.6}$$

$$where{:}V(rms) = 30\ V$$

$$V(m) = 30 \times 1.414 = 42.42\ V$$

The final stage in the D.C power supply unit involves the regulation of the filtered D.C voltage. Regulation is the process of ensuring that the output of the D.C power supply unit always maintains a constant voltage level. This is done in order to bring down the D.C power supply voltage to a level that is within the rated voltage of some of the components used in the design.

Voltage regulation is also done to avoid voltage drops in the D.C power supply as components are being added in the circuitry.

There are two stages of regulation which are carried out in this design. The first stage is the 12 V regulation and the second stage is the 5 V regulation. The 12V output is used to power the relays in the switching unit, while the 5V output is used to power the control unit and the display unit.

The 12V regulation setup is a Zener - controlled transistor series voltage regulator, also known as an emitter follower voltage regulator. In this setup, a Zener diode is connected at the base of an NPN transistor connected in an emitter-follower configuration. The reference voltage is provided by the Zener diode and the transistor acts as a variable resistor, whose resistance varies with the operating conditions of base current. In this design, a Zener diode of 13V is used to maintain the base voltage (V_B) of the transistor at 13V. When this is done, the voltage at the emitter (V_E) of the transistor will be given by:

$$V_E = V_B - V_{BE} \tag{3.7}$$

where: $V_B = 13V$

$V_E = 0.7V$ (for a silicon transistor)

$V_E = 13 - 0.7 = 12.3V \simeq 12V$

The transistor used for this 12V regulating circuit is a TIP31C. It is an NPN bipolar junction transistor, and a power transistor that can supply high current to its load. The TIP31C was used in this design because of its: high D.C current gain (h_{FE}) of 50, high collector – base voltage of 100V, high collector current of 3A and improved linearity [12]. A base resistor of 2.2 kΩ is used in delivering current from the collector to the base of the transistor so as to limit the current flow to its base. This is done in order not to exceed its maximum base current of 1 A [12].

The 5V regulation setup simply involves the use of an LM7805 voltage regulator. The LM7805 is a fixed voltage regulator which is commonly used to obtain a regulated +5V D.C voltage from a source. When the regulated 12V is sent into the input terminal of the LM7805, it gives a regulated 5V D.C between its output terminal and the ground terminal. The output of the 5V regulation setup is re-filtered using a 2200uF, 16V capacitor to eliminate any last traces of ripples and fluctuations. This is because the electronic components which are to be powered by the 5V D.C (Microcontroller and Liquid Crystal Display) are highly sensitive to ripples and tend to malfunction if they are powered by an impure D.C.

Fig. 3.3 shows the working circuit diagram of the D.C power supply unit

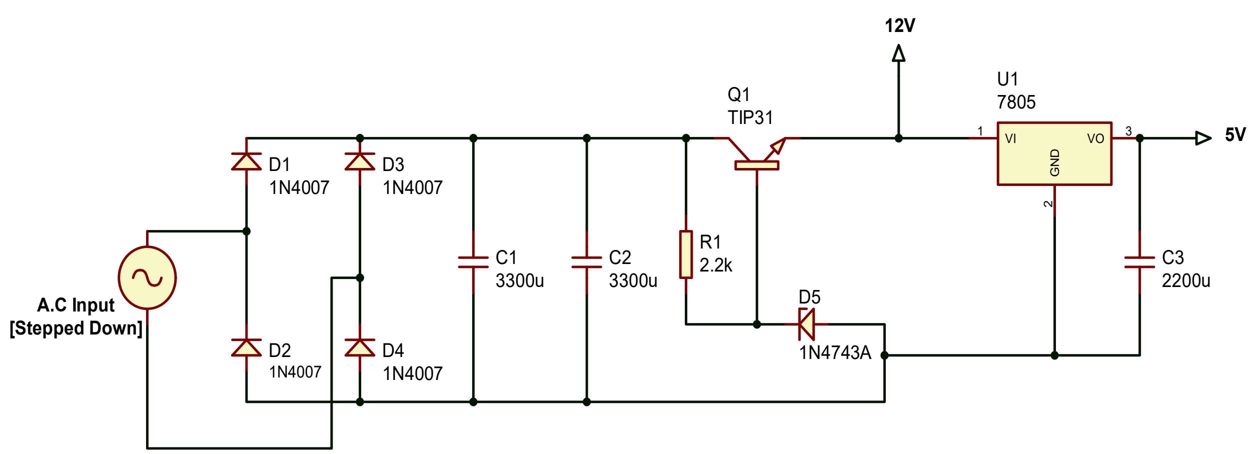


Fig. 3.3: Circuit Diagram of the D.C Power Supply Unit

3.4 Input Voltage Sensing Unit

The input voltage sensing unit performs the function of converting the A.C input voltage into its low – range D.C equivalent (0 – 5V DC) which is acceptable to the microcontroller of the control unit. This unit achieves this by rectifying the A.C input voltage, limiting the current flow in the D.C output obtained, filtering the D.C signal and dropping the voltage using a voltage divider and a variable resistor. The control unit uses the output signal from this circuit to decide on the correct tap of the autotransformer to send the A.C input voltage. That is to say that the accuracy of the voltage regulation to be carried out by the stabilizer depends on the accuracy of the output voltage sent from this unit to the control unit. The control unit also forwards the signal received from this unit to the display unit for display purposes.

The electronic components used in designing this unit are as follows:

Table 3.2: Electronic Components Used in the Design of the Input Voltage Sensing Unit

S/N	**Component Name**	**Value/Rating/Type**
1.	Diodes	1N4007
2.	Capacitors	2.2uF (400 V), 1uF (400V)
3.	Fixed Resistors	220kΩ, 47kΩ
5.	Variable Resistor	10kΩ

In this unit, the A.C input voltage is rectified directly (without being stepped down), using a full wave bridge rectifier consisting of four 1N4007 diodes. After it is rectified, the high current in the D.C output voltage is limited using two 220kΩ resistors connected at both the positive and negative terminals of the circuit. Another diode is also connected in series with the 220kΩ resistor connected to the positive of the supply. This forms a half-wave rectifier thereby further eliminating A.C voltage components in the circuit. The D.C voltage is filtered using a capacitor of 2.2uF/400V. A capacitor of low capacitance is used so as to maintain the originality of the D.C equivalent value to be obtained in this circuit (i.e. to avoid obtaining a false D.C equivalent value as a result of contamination by a high capacitor voltage). This filtering capacitor also has a high voltage rating of 400 V, so as to be able to withstand the high peak values of the A.C input voltages to be sensed. For instance, the peak value of an A.C input voltage of 260 V is given as:

From equation (3.6)

$V(m) = V(rms) \times 1.414$

$where: V(rms) = 260\,V,$

$V(m) = 260 \times 1.414 = 367.64\,V$

The D.C voltage after filtering is dropped using a voltage divider consisting of a 4.7kΩ and a 220kΩ resistor, after which it is re-filtered using a 1uF/400V capacitor. Finally, a 10 kΩ variable resistor is connected in parallel at the output of the circuit, for the purpose of calibrating the A.C input voltage value for the microcontroller.

Unlike in the D.C power supply unit, the input voltage sensing unit does not regulate its output to a constant voltage value. This is because the output is designed to change, varying from 0V to 5V corresponding to the A.C input voltage value. Fig. 3.4 shows the circuit diagram of the input voltage sensing unit.

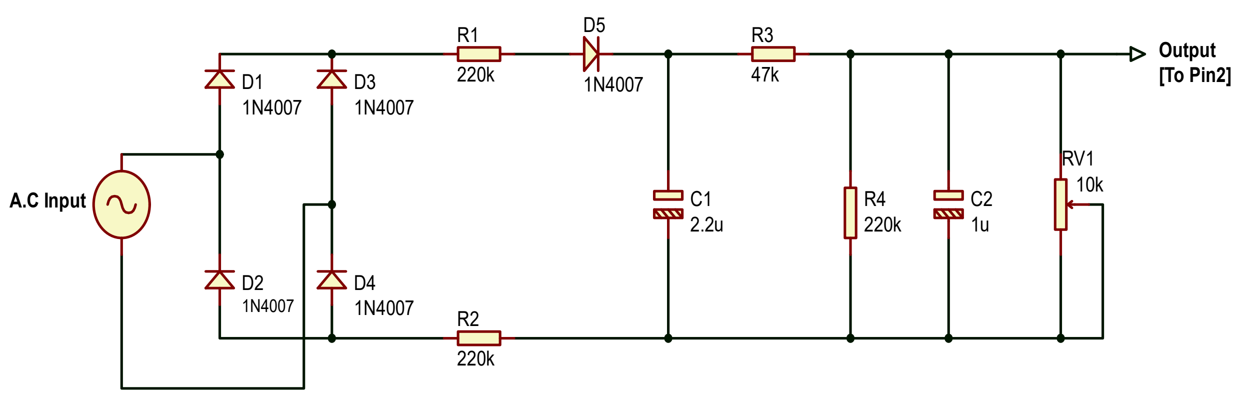


Fig. 3.4: Circuit Diagram of the Input Voltage Sensing Unit

3.5 Output Voltage Sensing Unit

The output voltage sensing unit serves the purpose of converting the A.C output voltage into its low – range D.C equivalent (0 – 5V DC) which is acceptable to the microcontroller of the control unit. This unit is an exact replica of the input voltage sensing unit. The only difference being that it receives its input from the output tap (220 V tap) of the autotransformer. The control unit uses the output signal from this circuit to implement overvoltage protection of the load in the AVR. It also forwards the signal received from this unit to the display unit for display purposes.

The circuit diagram of the output voltage sensing unit is shown in Fig. 3.5.

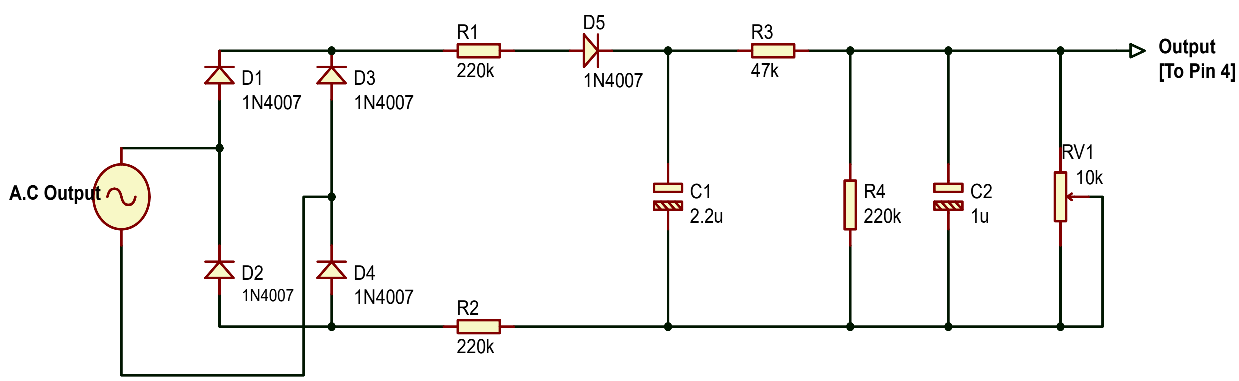


Fig. 3.5: Circuit Diagram of the Output Voltage Sensing Unit

3.6 Current Sensing Unit

The purpose of the current sensing unit is to monitor the current drawn by loads connected to the automatic voltage regulator. Since the output voltage of the AVR is relatively constant, these current values are a near accurate representation of the load power consumption. This unit represents these current values in the form of voltage values which the microcontroller can easily work with. The control unit uses the signal it receives from this unit to implement overload protection thereby protecting the AVR from damage. The control unit also transmits the signal received from this unit to the display unit for display purposes.

The electronic components used in designing this unit are as follows:

Table 3.3: Electronic Components Used in the Design of the Current Sensing Unit

S/N	Component Name	Value/Rating/Type
1.	Current Transformer	-
2.	Diodes	1N4007
3.	Capacitors	47uF / 25V
4.	Variable Resistor	10kΩ

The major component in the current sensing circuit is a current sensing device known as a current transformer. A current transformer (CT) is a type of transformer that is used to measure alternating current (A.C). This device produces a current in its secondary which is proportional to any current that flows in its primary. The output wire of the AVR passes through the primary winding of this device, such that any current drawn by any load is sensed in the secondary winding of this device. The circuit diagram for the current sensing unit is shown in Fig 3.6.

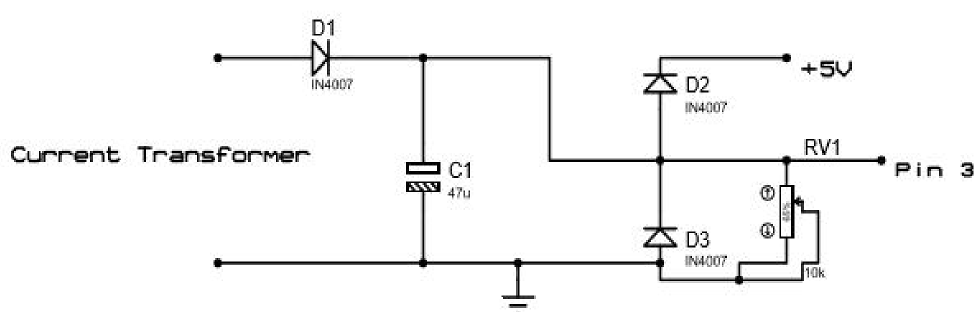


Fig. 3.6: Circuit Diagram of the Current Sensing Unit

After the current transformer has sensed the current, the A.C voltage from the secondary or output of the current transformer is passed through a 1N4007 diode to undergo a half wave rectification. After it has been rectified, a 47uF/25V capacitor is used to filter the signal and eliminate ripples and fluctuations. The signal is then passed through a clipping circuit consisting of two 1N4007 diodes and a +5V reference. This clipping circuit is designed to prevent the output signal of the current sensing circuit from exceeding the reference voltage level of +5V, so as to ensure the safety of the microcontroller. A 10kΩ variable resistor is also connected in parallel at the end of this circuit for the sake of load calibration with the microcontroller.

3.7 Control Unit

The control unit is the 'brain' of the automatic voltage regulator. It is the unit that does the decision making and implements automation in the operation of the automatic voltage regulator. The control unit performs three major functions in the design which are as follows:

i. It is the section of the design that governs the relay switching unit and hence the tap changing of the autotransformer. It uses the signal received from the input voltage sensing unit to decide on the correct tapping of the autotransformer to send the A.C input voltage, and then switches the relay cascade to that effect.

ii. It oversees the overload protection of the automatic voltage regulator. The control unit uses the signal received from the current sensing unit to detect when the automatic voltage regulator is overloaded. When an overload occurs, it turns off the output relay of the relay switching unit in order to protect the automatic voltage regulator from damage.

iii. It also provides the display unit with the information that it displays. The control unit receives signals from the input voltage sensing unit, output voltage sensing unit and the current sensing unit and processes these signals in order to determine the A.C input voltage, A.C output voltage and load power respectively. It then sends these values to the display unit to be printed on an LCD screen for the user.

The electronic components used in the design of the control unit are as follows:

Table 3.4: Electronic Components Used in the Design of the Control Unit

S/N	Component Name	Value/Rating/Type
1.	Microcontroller	PIC16F876A
2.	Fixed Resistors	6.8kΩ, 4.7kΩ, 1kΩ
3.	Crystal Oscillator	20MHz
4.	Capacitors	22pF
5.	Transistors	BD135
6.	Diode	1N4148

The main component of the control unit is the microcontroller. Microcontrollers are small computers on a single integrated circuit. They contain one or more CPUs (processor cores) along with memory and programmable input/output peripherals. They are used to achieve automatic control in various products, devices and embedded systems [13]. A PIC16F876A microcontroller is used in this automatic voltage regulator. A PIC16F876A microcontroller is a 28 - Pin Enhanced Flash Microcontroller. This microcontroller was chosen because it has a total number of input/output (I/O) ports (5 analog inputs and 22 digital I/O) which satisfies the number needed for this project. It also has a sufficiently low cost when compared to other microcontrollers and is readily available. The PIC16F876A has the following main features [14]:

i. Low-power, high-speed Flash/Electrically Erasable Programmable Read Only Memory (EEPROM) technology.

ii. 10-bit, up to 8-channel Analog-to-Digital Converter (A/D)

iii. Maximum Crystal Speed of 20MHz

iv. Wide operating voltage range of 2.0V to 5.5V

v. I/O Ports: Ports A, B, C

vi. Flash Program Memory of up to 8K × 14 words

vii. Data Memory (RAM) of up to 368 × 8 bytes

viii. EEPROM Data Memory of up to 256 × 8 bytes

ix. Analog Comparator module with two analog comparators

The pin diagram of the PIC16F876A microcontroller is as follows:

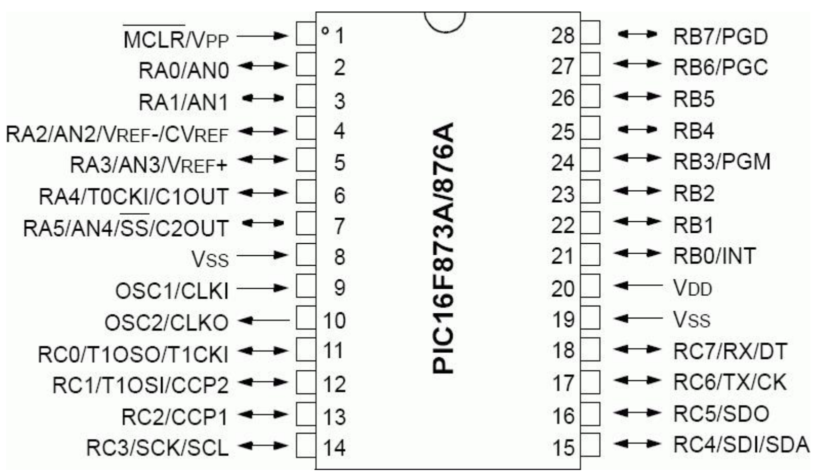


Fig. 3.7: Pin Diagram of the PIC16F876A Microcontroller [14].

Table 3.5: Pin Descriptions for the PIC16F876A Microcontroller [14].

S/N	Pin Name	Pin Number	Description
1.	MCLR/V_{PP}: MCLR V_{PP}	1	Master Clear Reset or programming voltage: Master Clear (Reset) input is an active low reset to the device.

			Programming voltage input.
2.	RA0/AN0 - RA5/AN4: RA0 – RA5 AN0 – AN5	2 - 7	PORTA bidirectional I/O port: PORTA Digital I/O PORTA Analog input 0 - 5
3.	V_{SS}	8, 19	.
4.	OSC1/CLKI	9	Oscillator crystal input or external clock source input. This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.
5.	OSC2/CLKO	10	Oscillator crystal output or external clock source output.
6.	RC0 – RC7	11 - 18	PORTC Digital I/O port.
7.	V_{DD}	20	Positive supply for logic and I/O pins.
8.	RB0 – RB7	21 - 28	PORTB Digital I/O port.

In this design, ports: AN0, AN1 and AN2 are used in receiving analog voltage signals from the input voltage sensing circuit, current sensing circuit and output voltage sensing circuit respectively. Ports RC0 – RC5 are used in switching relays A – F of the relay switching unit respectively. Ports RB1 – RB6 are used in sending data signals to the LCD of the display unit and finally, port RB0 is used in controlling the buzzer. Hence a total of 16 input/output (I/O) ports of the microcontroller are used in this design.

An external oscillator circuit made up of a 20 MHz crystal oscillator and two 22pF capacitors are connected between pin 9 and 10 of the microcontroller. A crystal oscillator is an electronic oscillator circuit that uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a precise frequency [15]. It is used to generate clock pulses required for the synchronization of all the internal operations of the microcontroller [16].

A 20MHz crystal oscillator could be used because it was equal to, but not greater than the maximum crystal speed of the microcontroller which is 20MHz.

Ports RC0 – RC5 of the microcontroller, which are used in switching relays A – F, are pulled down to ground using 6.8kΩ resistors. This is done in order to ensure that these output pins are kept low (0) until the microcontroller gives out a high (1) through them. A 6.8kΩ resistor is used for the pull-down because of the 1kΩ transistor base resistors connected in series with the output pins. A sufficiently higher resistance of 6.8kΩ ensures that nearly all the current from the output pin of the microcontroller flows through the 1kΩ base resistors when the output pins give out a high. This is because current always tends to flow through the path of least resistance.

The Master Clear Reset input pin (MCLR) is also pulled up to the +5V supply using a 4.7kΩ resistor. This pin is an active low reset pin for the microcontroller. Hence, it is pulled up to ensure that the MCLR pin never receives a low by error to avoid any interruption of the microcontroller program.

Port RB0 of the microcontroller, which controls the buzzer, is connected through the anode of a 1N4148 fast switching diode. This is done to ensure that the high frequency pulses which supply the buzzer are free from ground impurities. A fast switching diode was used to keep up with the fast switching pulses from the microcontroller.

Finally, BD135 NPN transistors are connected to the ends of Ports RC0 – RC5 of the microcontroller, which are used in switching relays A – F. This is done in order to amplify the current used in switching the relays. The emitters of the transistors are connected to ground while the collectors are connected to one end of the coils of their respective relays. A BD135 NPN transistor has a maximum base current rating of 0.5A [17]. Hence, a 1kΩ resistor is used in each of Ports RC0 – RC5 to ensure that the current fed to the base of the transistor is less than 0.5A.

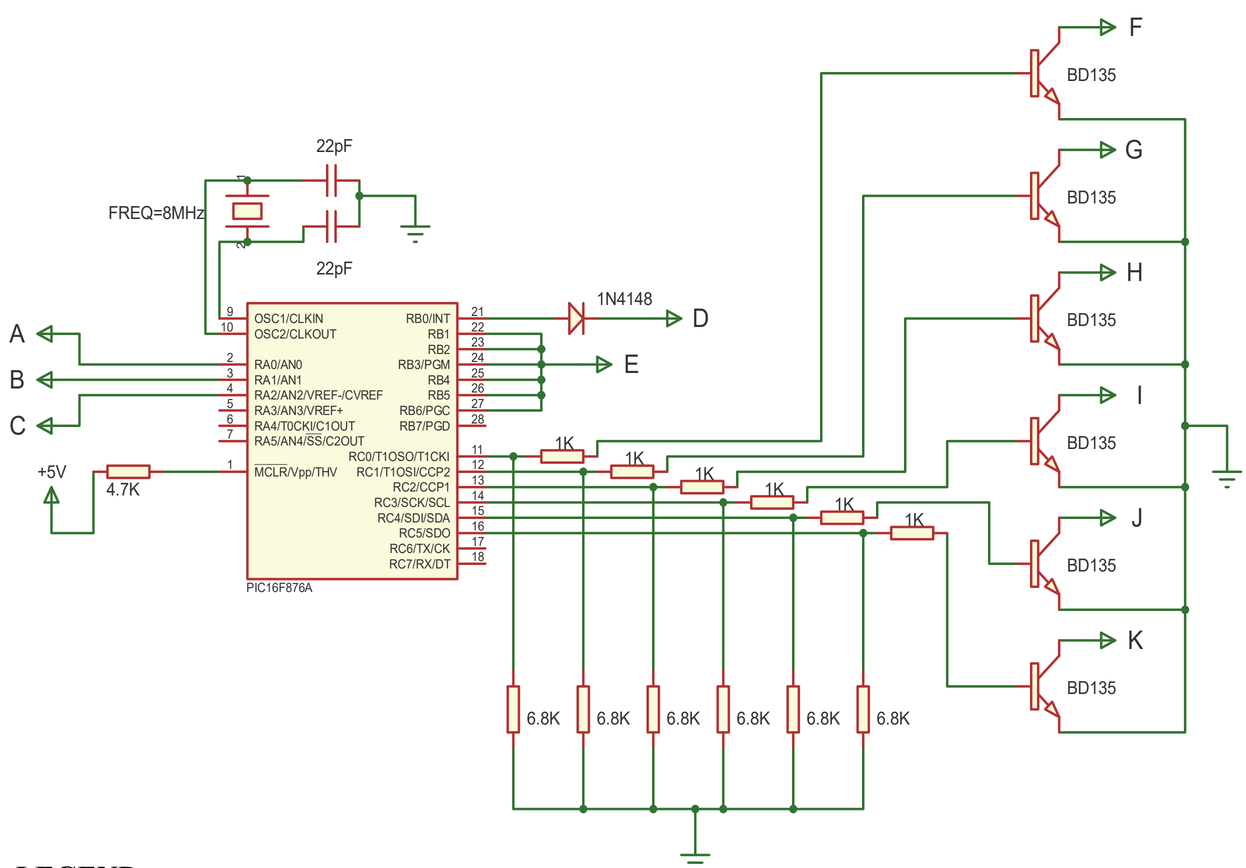
The base current realized is given by:

Base current (I_B) = Voltage from microcontroller (V) / Resistance of resistor (R)

$I_B = 5\ V / 1000\Omega$

$I_B = 0.005\ A$

The circuit diagram for the control unit of the automatic voltage regulator is shown as follows:



LEGEND:

A = A.C INPUT VOLTAGE SENSING CIRCUIT	D = BUZZER	G = COIL OF RELAY B	J = COIL OF RELAY E
B = CURRENT SENSING CIRCUIT	E = DISPLAY CIRCUIT	H = COIL OF RELAY C	K = COIL OF RELAY F
C = A.C OUTPUT VOLTAGE SENSING CIRCUIT	F = COIL OF RELAY A	I = COIL OF RELAY D	

Fig 3.8: Circuit Diagram for the Control Unit of the Automatic Voltage Regulator

The PIC16F876A microcontroller used in this work is programmed using Great Cow Basic Compiler. The program for the design can be seen in Appendix I at the end of this work.

3.8 Switching Unit

The function of the switching unit is to direct the A.C input voltages to different taps of the autotransformer subject to the command from the control unit. In this unit, six relay switches are cascaded with one another and interfaced with the taps of the autotransformer, in such a way that the switching of each of the relays sends the A.C input voltage to a different tap of the autotransformer.

The electronic components used in the design of the switching unit are as follows:

Table 3.6: Electronic Components Used in the Design of the Switching Unit

S/N	Component Name	Value/Rating/Type
1.	Relays	12V/10A
2.	Capacitors	100uF (25V)
3.	Diodes	1N4007
4.	Light Emitting Diodes (LEDs)	-

The major component in this circuit is the electromechanical relay. This relay switches a common terminal between the normally open terminal (NO) and the normally closed terminal (NC) when its coil is energized and de-energized respectively. Energizing the relay implies applying its rated voltage (12V DC) across the terminals of the coil. Therefore connecting one terminal of the coil to either a positive bias or a negative bias, and a negative or positive bias on the other terminal will switch the relay ON or OFF. This is the principle behind the relay's operation.

The 100uF/25V capacitor is connected to remove stray signals that tend to energize the relay even when no signal is sent to the base of the switching transistor (false excitation). The 1N4007 diode functions as a freewheeling diode between the coil terminals of the relay. A freewheeling diode is used to eliminate voltage spikes seen across an inductive load when its supply current is suddenly reduced or interrupted. The lighting emitting diode (LED) indicates that the relay has switched from its original position (normally closed) to a new position (normally open). Fig 3.9 shows the operation and biasing of a single electromechanical relay.

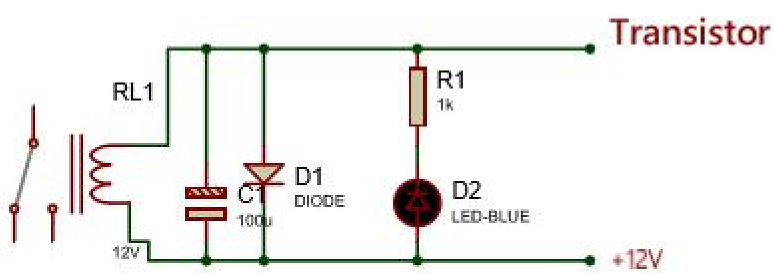


Fig 3.9: Single electromechanical relay biasing topology

From the above diagram, a constant +12V D.C is supplied to one of the coil terminals of the relay. This implies that the relay now only needs a negative signal (ground) at the other terminal of the coil for it to be energized. This negative signal is supplied by the BD135 NPN transistor of the control unit, if the required current (I_B) is sent from the microcontroller to the base of the transistor. Once this happens, the coil terminals of the relay become energized and move the common of the relay from the normally closed position, to the normally open position. The circuit diagram of the switching unit is shown in Fig. 3.10.

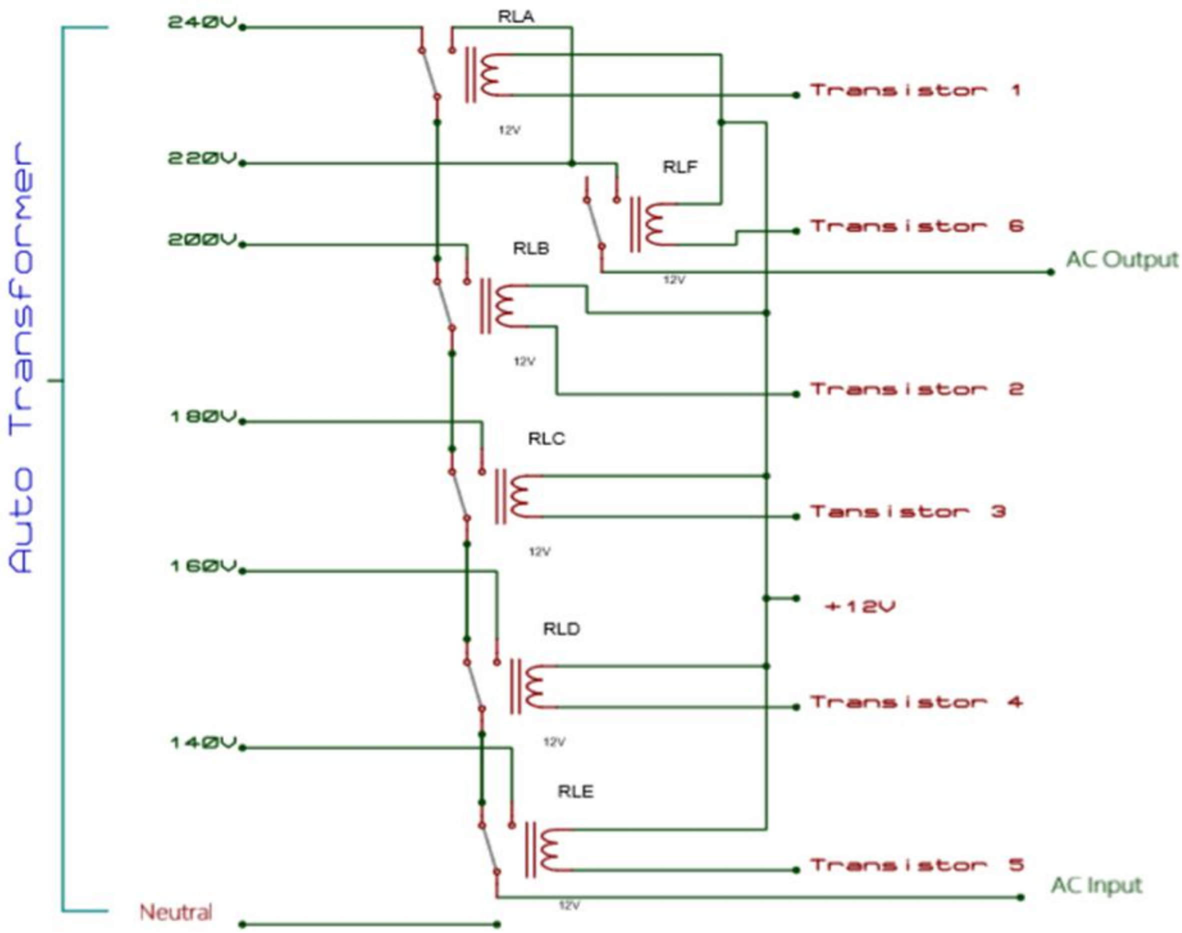


Fig. 3.10: Circuit Diagram of the Switching Unit

3.9 Display Unit:

The display unit serves as an interface for the user to observe the working conditions of the automatic voltage regulator. It receives command instructions of what to do and what to display from the control unit (microcontroller). The display unit is made up of the following electronic components:

Table 3.7: Electronic Components Used in the Design of the Display Unit

S/N	Component Name	Value/Rating/Type
1.	Liquid Crystal Display (LCD)	16 × 2 Characters LCD
2.	Fixed Resistors	1.5kΩ, 330Ω

Liquid Crystal Display (LCD) screen is an electronic display module. A 16 × 2 Characters LCD is a very basic module that is commonly used in many devices and circuits. ‘16 × 2 characters’ means it can display 16 characters per line and has 2 such lines. In this LCD, each character is displayed in a 5 × 7 pixel matrix. This LCD has two registers, namely; the Command Register and the Data Register [18].

The command register stores the command instructions given to the LCD. A command is an instruction given to the LCD to do a predefined task like initializing, clearing the screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed [18].

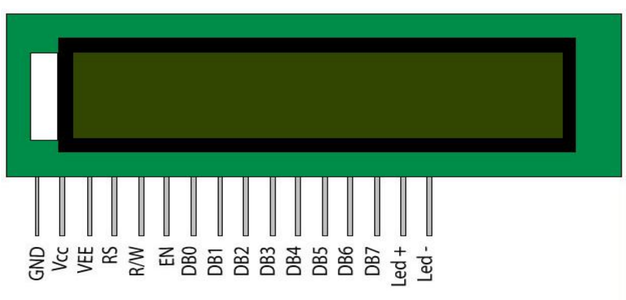


Fig. 3.11: A 16 × 2 Characters LCD [18].

Table 3.8: Pin Configurations of a 16 × 2 Characters LCD [18].

Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	V_{CC}
3	Contrast adjustment; through a variable resistor	V_{EE}
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

In this work, the LCD is used in a 4-pin mode. This means that only 4 out of the 8-bit data pins are interfaced with the microcontroller.

The contrast of a 16 × 2 Characters LCD varies from minimum to maximum by supplying 0 volts to 5 volts to its V_{EE} pin. The contrast of the LCD in this work is set by supplying 0.9V to the V_{EE} pin using a voltage divider. The voltage divider consists of a 1.5kΩ and a 330Ω resistor with an input voltage of +5 volts.

The circuit diagram for the display unit is shown below:

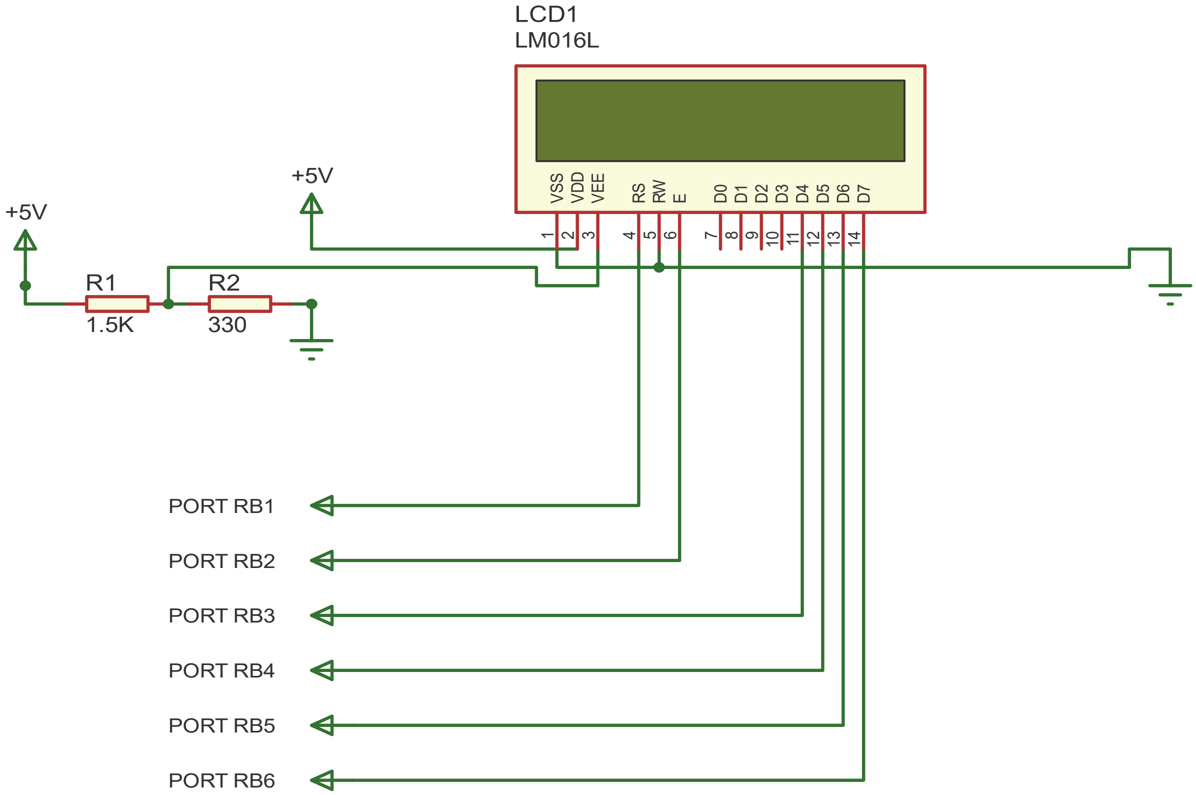


Fig 3.12: Circuit Diagram for the Display Unit

CHAPTER FOUR

RESULTS, ANALYSIS AND DISCUSSIONS

4.1 Results from the Autotransformer Unit

At the end of the implementation of this unit, the autotransformer had 8 taps consisting of the: Neutral tap, 30 V tap, 140 V tap, 160 V tap, 180 V tap, 200 V tap, 220 V tap and 240 V tap. In order to affirm the accuracy of our windings and calculations, a rated voltage of 220 V was applied to the 220 V tap of the autotransformer, and the voltage values of the other taps were read using a voltmeter. The voltage readings obtained were found to correspond with the rated voltages of the respective taps, hence, affirming the fact that no surplus turns were made during the winding.

The following tests were conducted on the autotransformer to ascertain its various operating parameters:

i. Open Circuit Test
ii. Short Circuit Test

4.1.1 Open Circuit Test

The purpose of the open circuit test is to determine the no-load current and core loss of a transformer, because of which their no-load parameters are determined. This test is usually performed on the primary side (low voltage side) of the transformer while the secondary side (high voltage side) is left open circuited. The 140 V tap of the autotransformer was used as the primary side (any of the input taps below the 220 V tap could have been used) and the 220 V tap was used as the secondary side.

A wattmeter, an ammeter and a voltmeter were connected to the 140 V tap of the autotransformer. A rated voltage of 140 V was applied to the 140 V tap with the help of a variac. Since the autotransformer is open circuited in the secondary, there is no output, hence the input power here consists of core losses and copper losses in the transformer during no load condition. The no-load current in the autotransformer is very small and because the copper loss in the primary is proportional to the square of this current, it is negligible. Hence, the wattmeter reading is assumed to be equal to the core loss in the autotransformer. Rated voltage of 140 V was applied to the 140 V tap in order to ensure that normal flux was set up, hence normal iron losses will occur and is measured using the wattmeter. The ammeter was used to measure the no load current while the voltmeter was used to measure the applied voltage.

The following readings were obtained at the end of the test:

Wattmeter reading, $\mathbf{W_O = 24\ W}$ **(Core loss)**

Voltmeter reading, $\mathbf{V_1 = 140\ V}$

Ammeter reading, $\mathbf{I_O = 251\ mA}$

The following parameters were calculated using the readings obtained from the test:

i. No-load power factor, $\cos \varphi_O = W_O / V_1 I_O$

$$\cos \varphi_O = 24 / (140 \times 251 \times 10^{-3})$$

$$\mathbf{\cos \varphi_O = 0.68\ (\varphi_O = 47.16\ ^\circ)}$$

ii. Magnetizing component of no-load current, $I_M = I_O \sin \varphi_O$

$$I_M = 251 \times 10^{-3} \times \sin 47.16\ ^\circ$$

$$\mathbf{I_M = 0.18\ A}$$

iii. Core loss component of no-load current, $I_W = I_O \cos \varphi_O$

$$I_W = 251 \times 10^{-3} \times 0.68$$

$$\mathbf{I_W = 0.17\ A}$$

iv. Equivalent exciting resistance, $R_O = V_1 / I_W$

$$R_O = 140 / 0.17$$

$$\mathbf{R_O = 823.5\ \Omega}$$

v. Equivalent exciting reactance, $X_O = V_1 / I_M$

$$X_O = 140 / 0.18$$

$$\mathbf{X_O = 777.8\ \Omega}$$

vi. Exciting Impedance, $Z_O = (R_O^2 + X_O^2)^{0.5}$

$$Z_O = (823.5^2 + 777.8^2)^{0.5}$$

$$\mathbf{Z_O = 1132.8\ \Omega}$$

vii. Exciting Admittance, $Y_O = 1 / Z_O$

$$Y_O = 1 / 1132.8$$

$$\mathbf{Y_O = 8.83 \times 10^{-4}\ \Omega^{-1}}$$

4.1.2 Short Circuit Test

A short circuit test is performed on a transformer in order to determine the copper loss at full load, the equivalent resistance, impedance, and leakage reactance. The test is usually conducted on the high voltage side (secondary side) of the transformer where the low voltage side (primary side) is short circuited by a thick conductor or through an ammeter (which serves the additional purpose of indicating load current). The 220 V tap of the autotransformer was used as the high voltage side while the 180 V tap was used as the low voltage side (any of the input taps below the 220 V tap could have been used).

A wattmeter, an ammeter and a voltmeter were connected to the 220 V tap of the autotransformer. With the help of a variac, applied voltage is slowly increased to about 5 to 10% of the rated voltage of the high voltage winding (22 V) thereby causing full load current to flow from both the secondary and the primary winding of the transformer. At this point, the readings of the wattmeter, ammeter and voltmeter are taken. As the voltage applied for full load current in short circuit test on the autotransformer is quite small compared to the rated voltage of the high voltage side of the transformer, the iron losses can be taken as negligible. Hence, the wattmeter is assumed to record only the full load copper loss in the autotransformer. The ammeter reading gives the primary equivalent of full load current while the voltmeter indicates the applied voltage.

The following readings were obtained at the end of the test:

Wattmeter reading, $\mathbf{W_C = 43\ W}$ **(Copper loss)**

Voltmeter reading, $\mathbf{V_{SC} = 22\ V}$

Ammeter reading, $\mathbf{I_{SC} = 7.28\ A}$

The following parameters were calculated using the readings obtained from the test:

i. Equivalent resistance referred to the secondary side, $R_{O2} = W_C / I_{SC}^2$

$$R_{O2} = 43 / (7.28)^2$$

$$\mathbf{R_{O2} = 0.81\ \Omega}$$

ii. Equivalent impedance referred to the secondary side, $Z_{O2} = V_{SC} / I_{SC}$

$$Z_{O2} = 22 / 7.28$$

$Z_{O2} = 3.02\ \Omega$

iii. Equivalent reactance referred to the secondary side, $X_{O2} = (Z_{O2}^2 - R_{O2}^2)^{0.5}$

$X_{O2} = (3.02^2 – 0.81^2)^{0.5}$

$X_{O2} = 2.91\ \Omega$

Hence, the efficiency of the autotransformer is given by;

η = rated VA × power factor / (rated VA × power factor) + losses

$\eta = (1000 \times 0.68) / (1000 \times 0.68) + (24 + 43)$

$\eta = 0.91$ or 91%

The wattage of the autotransformer is given by:

Wattage = rated VA × power factor × efficiency

Wattage = 1000 × 0.68 × 0.91 = **618.8 W**

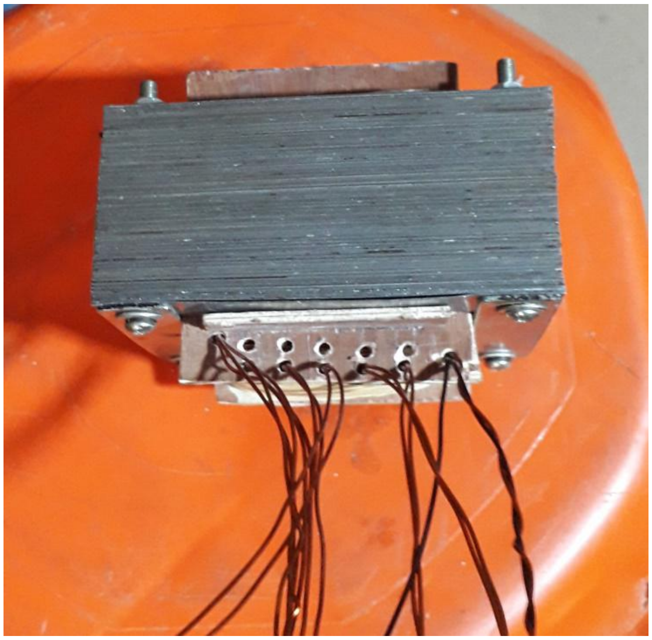


Fig 4.1: Implemented Autotransformer

4.2 Results from the D.C Power Supply Circuit

At the end of the implementation of this unit, key points in the circuit were tested using a voltmeter to ensure that the voltage values obtained at these points were as calculated. The following values were obtained at 30 V A.C input voltages:

i. Voltage after rectification and filtering = **37.50 V**

ii. Voltage at the base of the TIP 31C transistor for 12V regulation = **13.33 V**

iii. Voltage at the emitter (output) of the TIP 31C transistor for 12V regulation = **12.57 V**

iv. Voltage at the output of the 7805 voltage regulator for 5V regulation = **4.90 V**

The readings obtained above were as desired from our calculations.

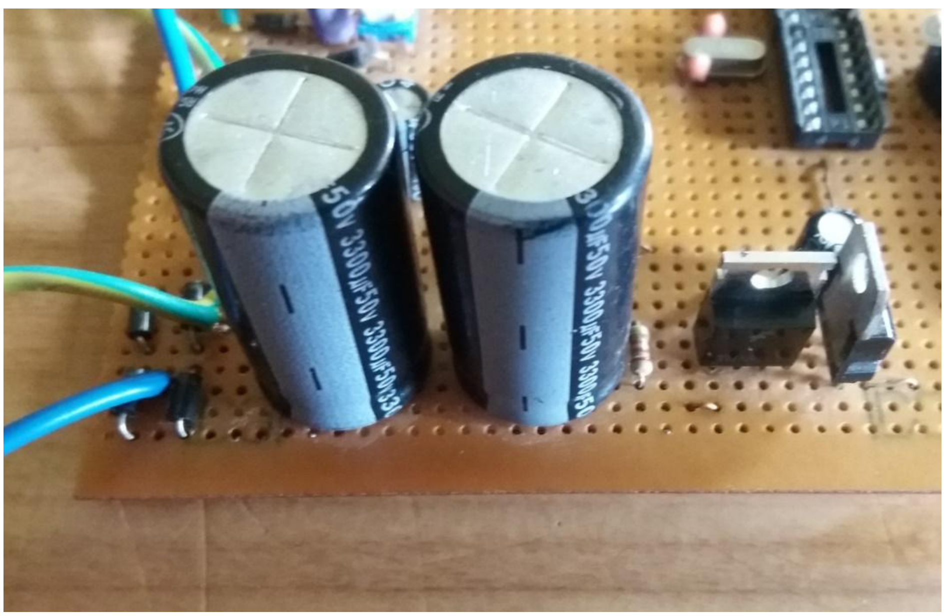


Fig 4.2: Implemented D.C Power Supply Circuit

4.3 Results from the Input Voltage Sensing Circuit

After the implementation of this circuit, the voltage at the output of the circuit was measured at different A.C input voltages using a voltmeter. This was to ensure that at the maximum and minimum A.C input voltages of the stabilizer (260 V and 140 V respectively), the output voltage in this circuit did not exceed the 0 – 5 V D.C range, which is the maximum voltage range the microcontroller can work with. The values obtained from the measurement are as follows:

i. At 140 V:

   Voltage at output could be varied from **0 – 2.52 V**

ii. At 260 V:

   Voltage at output could be varied from **0 – 4.68 V**

The above voltage ranges lie within the 0 – 5 V D.C range. Hence, 260 V and 140 V A.C could be fed successfully into this circuit without damaging the microcontroller.

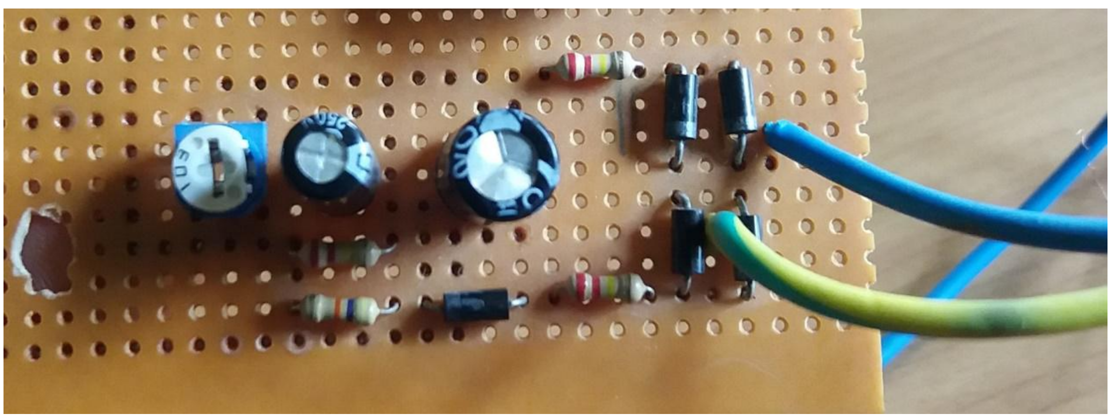


Fig 4.3: Implemented Input Voltage Sensing Circuit

4.4 Results from the Output Voltage Sensing Circuit

This circuit is identical to the input voltage sensing circuit. Its output voltage was also tested with a voltmeter. This was done also to ensure that at the maximum and minimum A.C output voltages of the stabilizer (220 V and 250 V respectively), the output voltage in this circuit did not exceed the 0 – 5 V D.C range, which is the maximum voltage range the microcontroller can work with. The values obtained from these measurements are as follows:

i. At 220 V:

Voltage at output could be varied from **0 – 3.96 V**

ii. At 250 V:

Voltage at output could be varied from **0 – 4.50V**

The above voltage ranges lie within the 0 – 5 V D.C range. Hence, 220 V and 250 V A.C could be fed successfully into this circuit without damaging the microcontroller.

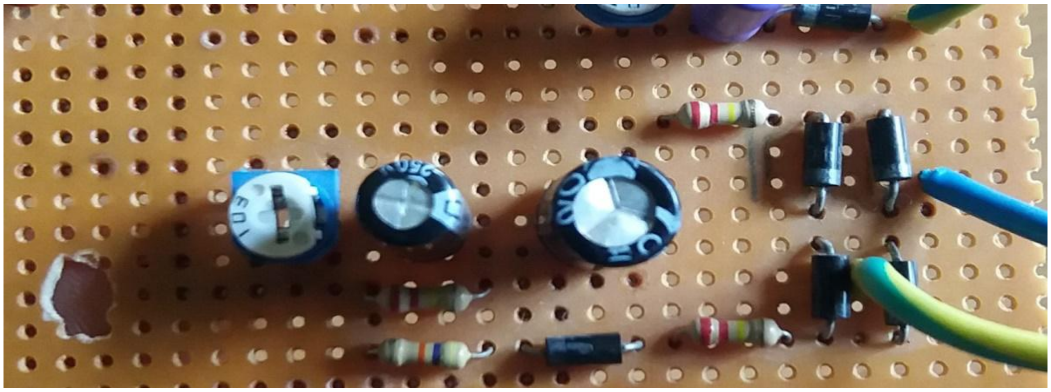


Fig 4.4: Implemented Output Voltage Sensing Circuit

4.5 Results from the Current Sensing Circuit

At the end of the implementation of this unit, the voltage values of key areas in this circuit were measured using a voltmeter. The following values were obtained:

At a load of 60 W and A.C output voltage of 227 V,

- Voltage output from current transformer = 0.2 V

At a load of 500 W and A.C output voltage of 227 V,

- Voltage output from current transformer = 1.67 V

The output voltages obtained above lie very much within the 0 – 5 V D.C range. Hence, the microcontroller is safe from damage.

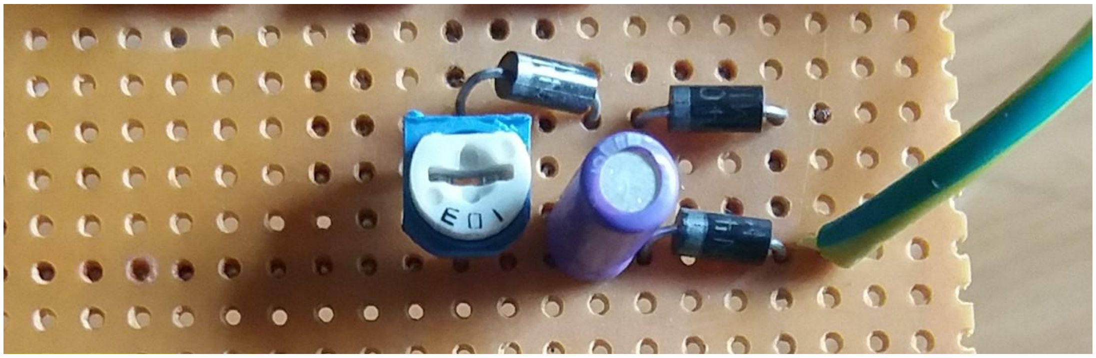


Fig 4.5: Implemented A.C Output Voltage Sensing Circuit

4.6 Results from the Control Circuit

After the careful implementing of the control circuit, it was tested to verify whether the microcontroller was responding properly to the code it was programmed with. In order to carry out this test, the input signals received from the input voltage sensing circuit was varied using the variable resistor placed at the output of this circuit. As the resistor at the output of the input voltage sensing circuit was varied gradually, different combinations of transistors at the outputs of the microcontroller were being switched as a result of a **4.2 V** DC that was being sent out through ports (RC0 – RC5) of the microcontroller. This indicates that the microcontroller responds well to the code it was programmed with.

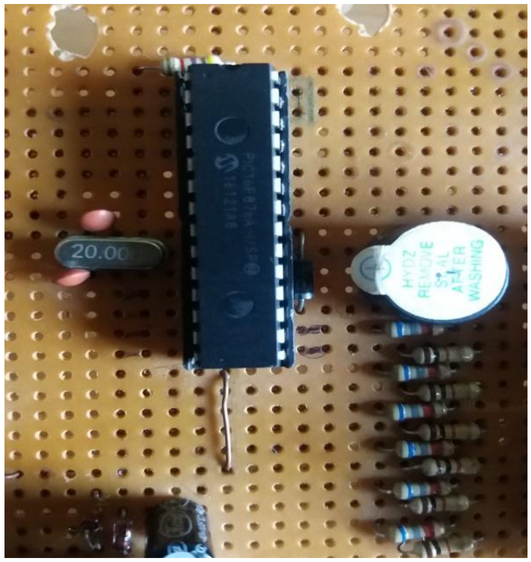


Fig 4.6: Implemented Control Circuit

4.7 Results from the Program Development Using Great Cow Basic Compiler

After the program for the microcontroller was written, it was successfully compiled indicating that there were no bugs or errors in the code. The hex file created from the compilation of the program was burnt into the microcontroller using a Pickit2 programmer. This program can be seen in Appendix I of this work.

4.8 Results from the Relay Switching Circuit

At the end of the implementation of this circuit, the coil terminals of the relays were connected to their respective switching transistors in the control unit. By gradually varying the output of the A.C input sensing unit, different combinations of transistors along with their respective relays were being switched by the microcontroller. This affirmed the fact that the relay switching circuit was properly connected.

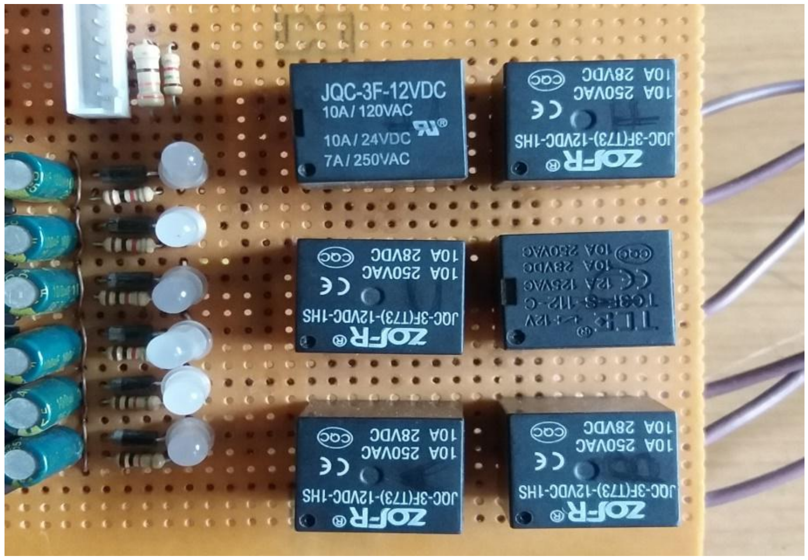


Fig 4.8: Implemented Relay Switching Circuit

4.9 Results from the Display Circuit

When the implementation of the display circuit was complete, it was connected to the microcontroller of the control unit. When the circuits were powered, the LCD displayed the A.C input value, A.C output value and load value as it was programmed to. These values also varied as the output of their respective circuits were being varied. The contrast of the LCD was also seen to be mild as was designed using the voltage divider to the V_{EE}. Hence, the display unit was found to be working in very good condition.

Fig 4.9: Implemented Display Circuit

4.10 Testing of the Final Work

The finished automatic voltage regulator was tested using a variac. The variac was first set to 140 V and then connected to the A.C input of the automatic voltage regulator. This voltage was regulated by the automatic voltage regulator and an output of 221 V was measured at its socket outlet at its outlet and was displayed likewise on the LCD screen. This same process was repeated for 160 V, 180 V, 200 V, 220 V, 240 V and 260 V and the voltages measured at the socket outlet all lied within 220 V – 250 V. Different sizes of loads were also plugged into the automatic voltage regulator and it powered them comfortably. Therefore, the implemented automatic voltage regulator was found to be working in very good condition.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Compensating for voltage fluctuations in the mains power supply is a very critical need which must be satisfied in every household and industry, if the lives of their various electrical systems are going to be safeguarded. Hence, a 1KVA Automatic Voltage Regulator (AVR) is designed and implemented in this work to satisfy this very critical need.

The Automatic Voltage Regulator designed in this work has a number of units/sections which all work hand in hand to make the operation of the AVR possible. These units include the autotransformer unit, the D.C power supply unit, the input voltage sensing unit, the output voltage sensing unit, the current sensing unit, the control unit, the switching unit and the display unit. These units were all carefully designed, implemented and coupled together to form the AVR. The special features of the AVR produced in this work include:

i. A wide input voltage range of 140V – 260V

ii. A narrow output range of 220V – 250V to ensure a near constant output voltage level.

iii. Overload protection of the automatic voltage regulator from damage resulting from overload conditions, and

iv. A display interface for monitoring the input voltage, output voltage, and load power

5.2 Recommendations

For the sake of future research in the design and implementation of Automatic Voltage Regulators, the following recommendations are proposed:

i. Electronic switches such as Thyristors should be used in place of electromechanical switches (relays) in designing the switching unit. This will help to improve the efficiency of the switching unit and shorten the response time of the AVR.

ii. Provisions should be made for the protection of the AVR against short-circuits in the load. This will help to ensure that the autotransformer is adequately protected from damage on the event of a short circuit.

iii. An efficient temperature monitoring and control system should be introduced in the design to help protect the internal components of the AVR against the harmful effects of overheating.

iv. Finally, an isolated D.C power supply pack should be used to supply the 12V and 5V regulated voltages to the various electronic components in the circuitry. This will help to ensure a more steady power supply even at very low A.C input voltage.

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