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Design and Construction of Automatic Voltage Regulator

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***Abstract**: In some developing nations of the world, problem with electric power system and its operation; most often, characterizes the main issue that poses a lifelong and protracted economic decrepitude of those nations. This menace, so to say, reflects on almost all facet of their economy at all times to decelerate productivity. Apart from what seems to be almost 'all - day(s)' generation failure, transmission failure and the associated recurrent total city black-out, voltage-profile degradation among other ailments, contributes in no small measure against what supposes to be a healthy culture of full capacity electricity supply and usage at tertiary power consumption areas - the homes. This work aims at proffering a solution on how power fluctuations can be handled in order to ensure voltage stability for home appliances. And so, a wide and appreciable volume of discussion are made here to precipitate a broad-range of understanding on how to design a hybrid of power and electronic circuits that yields a composite system with the capability of erasing voltage fluctuations and other power related irregularities which afflicts domestic electrical equipments. As a result, the design, construction and functional mechanisms of Autotransformer as the principal power device and electronic control circuits are thoroughly evaluated with greater attention on their principle of operation in order to create a comprehensive knowledge on how to achieve a device that ensures a steady voltage magnitude of 230V within a possible voltage variation range of 90V to 230V.*

***Keywords:** Output voltage selection, Voltage transformation, Relay switching, Voltage regulation*

INTRODUCTION:

The comfort we enjoy from the use of electric appliance in our homes largely depends on the stability of system secondary distribution voltage that extends to our homes - the tertiary distribution and power consumption areas, through the network service cables. With adequate voltage stability at secondary circuit, the life span of our home-used-equipments are obviously extended; since the frequent rise and fall of supply voltage beyond the equipment tolerance, can lead to serious damages on our electrical appliances and the users.

The extent of this fluctuation is often a matter of serious concern in our power system; and from research point of view, there are a lot of natural phenomena that can result such disturbances; hence, the abnormal electric condition in our homes.

Owing to almost hundred percent failures in ability of the system engineers to foster a long lasting solution to these threats, design and construction of electric and electronic operating device to cushion these problems has been of a great safety importance.

As a result, construction of automatic voltage regulator is the bases of the solution to this problem and this is the main objective of this work; as it aims at revealing the possible ways of managing these irregular and erratic voltage changes in our various homes.

However; despite efficiency in operation, it is very important to note that there are still unbridgeable gaps in its performance to match perfection; yet, up till date (in some developing countries of Africa such as Nigeria) home-used voltage stabilizers still remain the only available hope for home apparatus in stabilizing the unsteady behavior of our tertiary voltages. With today's technological advancement, new miniaturized electrical and electronic products continue to emerge and these products require either a very low AC source or DC source for their operation

At work, the noticeable imbalance between the regulator's operational status and the real functional expectation of the designers is always attributed to weakness of its constituting components due to age, deposit of dust particles and some times substandardness of the electronic circuit materials. Also from the view point of the relative position of the inbuilt electronic control panel and transformer device, the transformer may not be completely excused from generating excess heat, which in all operation period could spread across the panel components for a serious abnormal response.

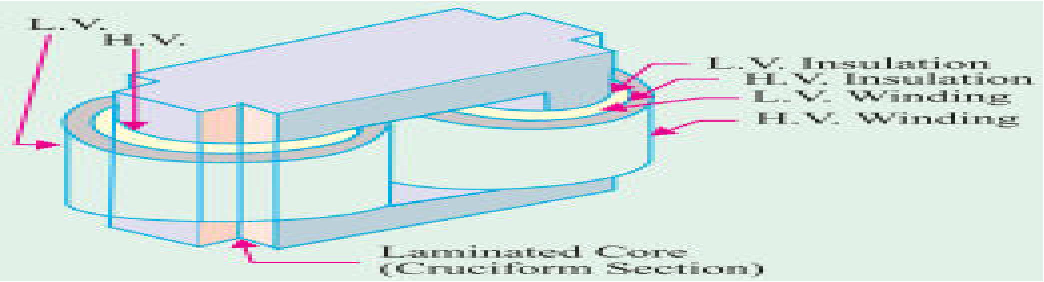
Nevertheless, in spite of the above problems, the home-used voltage regulator continues to enjoy the championship of adequate protection of our home appliances that are socketed to it; thus, providing almost constant voltage magnitude; irrespective of vigorous voltage changes within the distribution system.

1.0 THEORETICAL BACKGROUND

There are several kinds of materials that make up a stabilizer – voltage regulator. They are mainly electrical and electronic components, including other useful fibers and metallic pan that provides a good enclosure for protection of the inner circuit. The regulator casing gives room for easy handling and portability of the entire device. A good number of these functional components can be enlisted to include the following:-

1.10 The transformer:

Transformer in this context is the major power equipment that connects the electric power that feeds the electric appliances at home to the main AC source. It is a magnetic circuit that comprises of two sections of copper winding, the primary and secondary winding as obtained with induction type.



Upper plan view of core type transformer

Core type

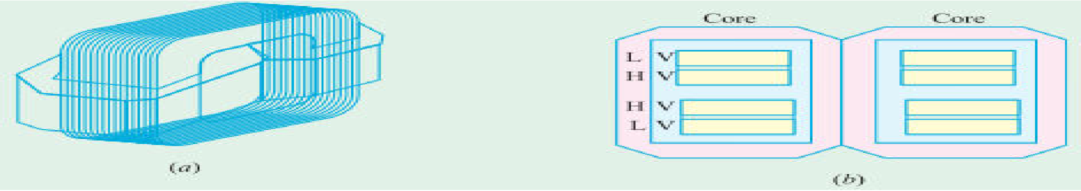


Diagram showing typical view of core and shell type transformers

Fig.1.0

The device can also be made of a continuous winding arrangement out of which many copper wires protrude to develop the multiple output terminals. This is the case with Autotransformer. The electrical inlets of the two types of transformers form the input terminals which serve as the only points into which the electric power at cut-out point is sourced through the distribution board and the wall socket; then into the transformer windings as it is being transformed to the required level at the ramified output terminals. A well built transformer device always consists of the following materials:

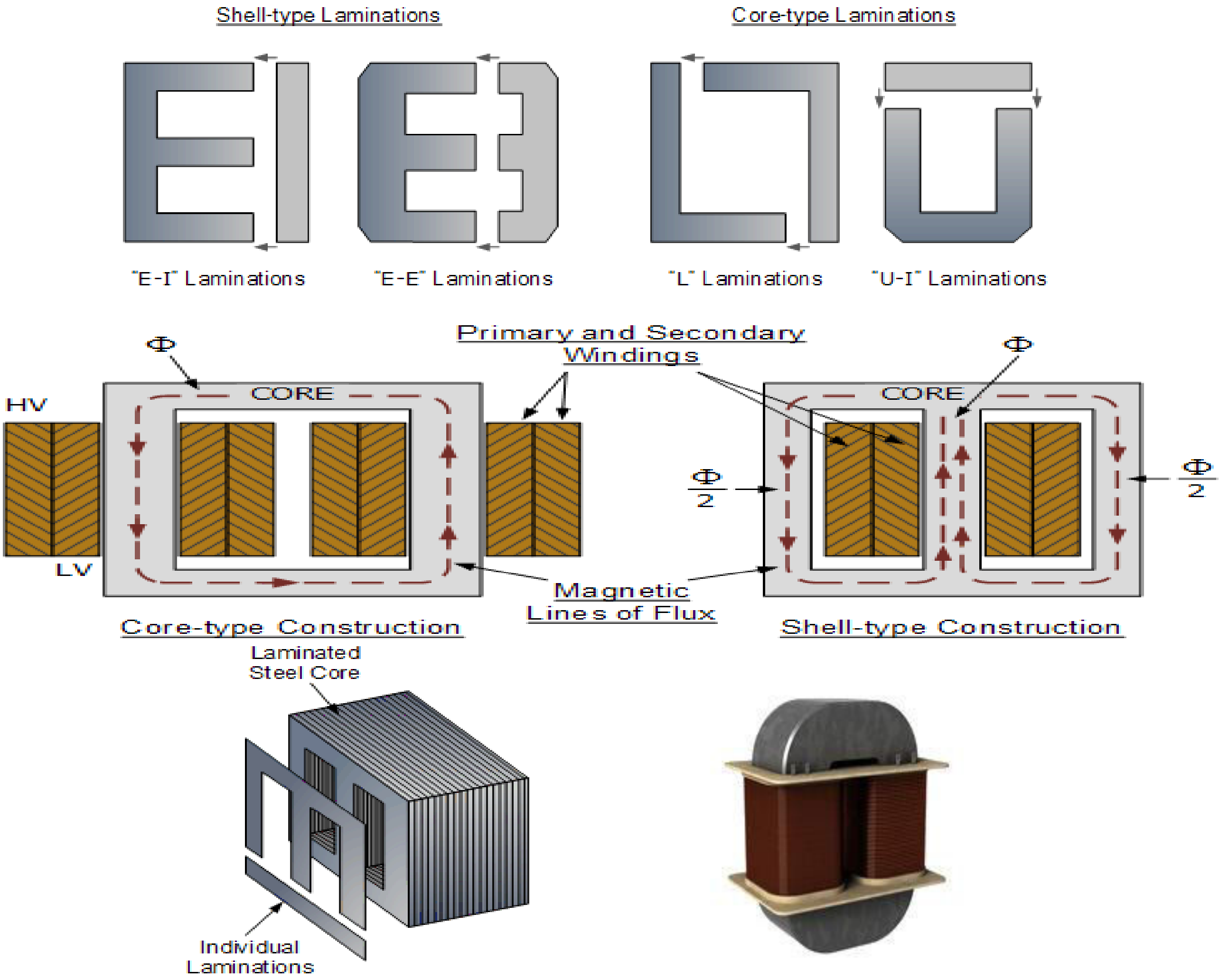
1.20 Copper wire:

This is a conductive path for current flow. Copper wires are graded in units of gauge using American-wire gauge; they are used for transformer construction because of their good conductivity properties and low market cost .Copper wires are always coiled round the transformer core for development of output voltages needed to drive the current into the appliance. The number of copper turnage on the magnetic core determines the magnitude of voltage generated from the winding. Thus, the higher the number of turns, the higher the voltage and vise-versa

1.3 Magnetic core (shell or core type):

Magnetic core can be of shell or core type. It is a collection of carved-out metallic slates of "E", "L" , "U" and "I" shape, designed to establish the transformer's laminated lump. It is from these piles of laminated core that the magnetic flux of the transformer circuit is generated and strengthened for voltage transformation through the flux linkage processes. It is extremely important to note that the degree of flux linkage on the copper windings for voltage transformation is a function of the laminated core size and number.

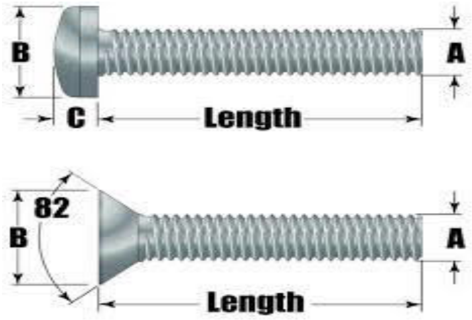
High number of the lamination slices in a core, constitutes a more number of lines of flux and a corresponding high level of voltage magnitude as the electric power alternates sinusoidally about the zero crossing point.



Diagrams showing schematic view of transformer types and lamination parts
Fig 1.2

1.4 Screwing nuts and bolts:

Screwing bolts operate jointly with tightening nuts to ensure firm grip and compactness of lamination slices. The sliced "E" and "I" thin core plate of metallic silicon material can result a lose and weak frame-work when the laminated piles are not properly held together with bolts and nuts; thus, resulting an increased tendency for transformer humming due to vibration.



Diagrams showing varieties of screws used in lamination core tightening and regulator transformer mounting
fig1.3

Apart from creating a firmly held structure of laminated core; another area of important role of these materials is in holding the transformer base against the casing floor after being mounted on a stand. The stand is held tight on the casing pan to allow a good position of the magnetic circuit for accommodation of other voltage regulator accessories. Such accompanying accessories like power relays or contactors are carefully connected to the ramifying output terminals of the transformer; and then, mounted vigilantly on the veroboard of the electronic panel for firmness. These are achieved consequent to availability of enough space between the two circuits (ie control panel and the transformer) as assured by appropriate fixing of the stands on the casing floor using the screwing nuts and bolts.

1.5 Lamination liquid:

One of the major safety precautions taken in transformer building to necessitate durability and effective operation is application of lamination liquid on the device after construction. This is done using a good adhesive and insulating liquid with quick setting and viscous properties that enable proper cementing of the lamination slices to disallow transformer humming. Apart from preventing humming due to vibration in order to enhance solidarity of the whole core, the fluid functions as insulator against eddy current flow across the core. As a result, eddy current losses are effectively controlled, and minor electric shocks prevented from being transferred from the transformer to the casing body of the stabilizer.

1.6 Masking tape:

In transformer construction, Masking tape does two important works that makes it an essential material for transformer building .It possesses some adhesive substances that easy stick on the coil layers during winding; thus, preventing detachment of the paper membrane and consequent loss of insulating function within the winding plane.

Diagram showing a typical picture of masking tape used in transformer winding
fig1.4

Also, as a thin paper membrane, it provides insulation against excess heat transfer and spreading among the layers of the wound coils; and so acts as a heat absorber in the event of heavy load on the transformer which may give rise to surplus current flow and heat dissipation on the wound coils. In all, the adhesive feature and the stiffness of the fiber-like membrane facilitates firmness of the whole coil windings as they gaplessly press close to each other and the surface of transformer bobbin.

1.7 Metallic Angle:

Most of the voltage regulator’s transformers are not built with flat and straight metals that are usually bent and structured in a manner to build a standing frame for a support. Rather they are clamped on angular metals that are cut and arranged into a frame-work mounted as a strong stand that provides a lasting support to the magnetic circuit.

Diagram showing angular metals used for transformer building

Fig1.5

Naturally, the angular metals for transformer frame are usually different from the straight and flat type in that the former are industrially manufactured with some carved- out openings for reduction of weight and aesthetic purposes.

Diagram of some packed angular metal used in transformer building

Fig1.6

In normal practice, these openings are essentially used as screw holes for mounting the transformer whose base is strongly bolted against the casing floor. The clear distinction attached on the two categories of metals is seen from their different structural outlook and application. While the angular metal is angular in nature and is used mostly for core type transformer; the flat type is evenly plane, with the feet bent during fabrication and are frequently used for shell type transformer construction.

1.8 Electronic panel:

This is the regulatory center of the voltage stabilizer equipment that maintains a seemingly constant voltage output of the regulator. On the other hand, it is the transformer multiple terminal selector, with several connected relays. The relay terminals that are usually designed for normally opening and closing functions are so carefully configured that the rapid opening and closing behavior, due to erratic changes of the voltage magnitude, does not bridge the auto-transformer terminals to avoid short- circuiting. Of course, such is mostly attention demanding during the course of circuit design, and with a careful mathematical calculation, proper selection of transformer terminals is always an easily achieved task at the comparator input terminals.

I break the entire unit of panel composition into the following segments for easy understanding:

1. Step –down transformer
2. Rectifying diodes
3. Filtering capacitors
4. Power section

2.0 STEP DOWN TRANSFORMER:

This is an important component of the regulator that is functionally complimentary to electronic control panel since all power input to the subsequent sections of the step down transformer are sourced from this device. Functionally, step down transformer, as the name implies, is a segment of low voltage transformation. For the fact that small-voltage- accepting electronic components in the panel do not require bulk voltage magnitude for operation, the need for stepping down the voltage becomes very necessary in order to maintain a very small amount of electric power that is within the manufacturing recommended operation limit for the electronic components.

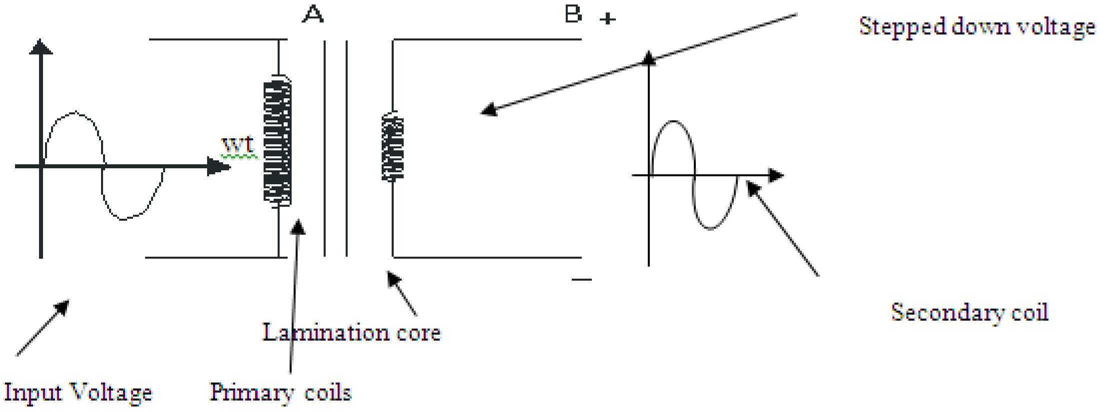


Diagram showing step down transformer for regulator panel.

Fig 2.0

To achieve this, the primary side of the device is wound with a higher number of turns than the secondary, leaving the output winding with fewer turns. This is mathematically estimated to obtain a relative quantity of the secondary winding on the bases of number of copper wire turning with respect to the voltage (turn per volt concept) developed on the two sides of the transformer winding – primary and secondary.

2.1 Rectifier:

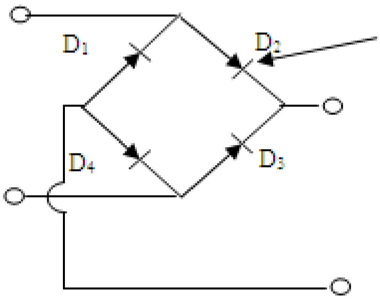


Diagram showing connection of diodes for bridge rectifier formation
fig 8

As shown above, diodes are connected in such manner to achieve rectification. The connection depicts the configuration of a bridge rectifier which permits the passage of current via the anode to cathode of diode devices. And so, in each of the two half wave cycles, a partial rectification is done which upon completion of

the full wave cycle emerges a rectified full wave signal ready for filtration via the capacitor component (not shown)

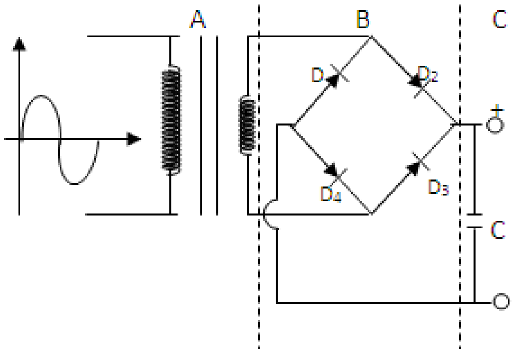


Diagram showing the rectification of the transformer output voltage
Fig 2.1

By definition, rectification is a process by which a full or half wave alternating signal is converted to a dc signal using rectifiers as major conversion components. Alternatively, the definition to a lay man could refer to extracting out the shocking property (i.e. alternating property) and or the frequency feature of the ac signal to leave a fairly constant DC signal as an output.

Let us look into the graphical explanation of the operational mechanism of the four rectifying diodes in the bridge unit

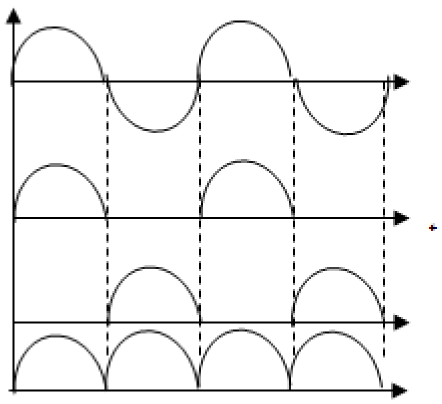


Diagram showing operational mode of D_2, D_4, D_1, D_3 diodes
Fig 2.2

2.2 Functional Mechanism of the Rectifying Diodes

In positive half cycle, diode D_2 is forward biased and the current I_{D2} passes through and across the load if connected. It flows through the returning path to forward bias diode D_4 and enters into the negative polarity of the transformer terminal. As a result; the total current wave across any load (if connected across the circuit) at positive half cycle on the circuit will be ($I_{D2} + I_{D4}$) just as shown on the graph. It is important to know that, in this period, it is only D_2 and D_4 that are forward biased to allow currents I_{D2} and I_{D4} along the circuit back to negative polarity of the transformer through the returning path. All throughout these periods diodes D_1 and D_3 are reverse biased and cannot contribute to the currents across any connected load.

In the negative half cycle, diode D_1 is forward biased, allowing current I_{D1} along the circuit, which flows through the returning path to forward bias D_3 as it passes into the transformer terminal. Diodes D_2 and D_4 make no impact in current contribution in negative half cycle due to their reverse bias mode. Thus; the total current wave along the circuit in the negative half cycle amounts to ($I_{D1} + I_{D3}$) just as shown in the graph.

Therefore; the combination of the current waves due to the two half cycles results a series of periodically generated positive half waves indicated as ($I_{D1} + I_{D3}$) + ($I_{D2} + I_{D1}$) in the diagram.

2.3 Filtering Capacitor

From elementary understanding of the component, capacitor allows a momentary passage of dc current, during which it stores charges virtually to full capacity and eventually disallows the dc current flow, and continues to manifest the built in voltage due to the built up charges. These charges are quite susceptible to instantaneous run-down (discharge) should there be any conductor connected across the terminals. It is the spontaneous charging and discharging of the component that constitutes filtration. Therefore; capacitance value of the component should be carefully chosen within a limit of considerable smoothing performance.

The principal aim for filtration is to remove the ripple segment of the ac component. Ripples are the unwanted product of rectification that contaminates the expected electric voltage that goes to the input of control panel. It initiates faulty judgment of the comparator that erroneously triggers the transistors for wrong relay switching. As a consequence, the output terminals of the Auto-transform become untimely selected even when there is no voltage fluctuation reason for a switching action.

Among other important circuits that require capacitor application include the following:

1. timing circuit
2. amplifier circuit
3. alarm triggering circuit
4. Digital displays e t c

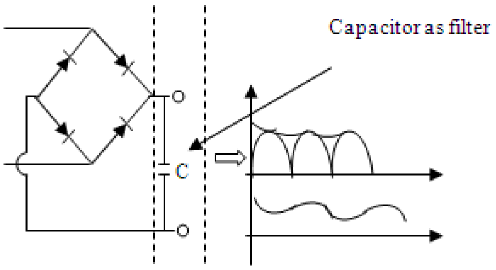


Diagram showing the ripple filtration using capacitor.
Fig 2.3

We can now introduce and explain other various important aspect of control panel of the regulator, starting with voltage sensor unit.

2.4 Sensor Unit

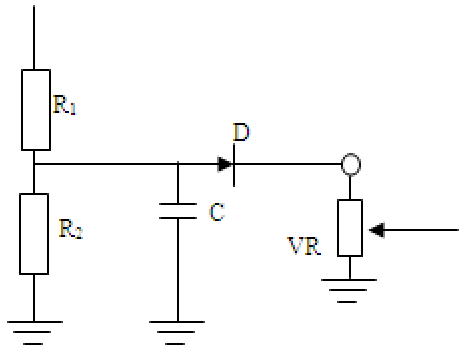


Diagram showing the sensor unit section of the panel
Fig 2.4

Sensor is the most sensitive unit of voltage regulator control panel. Its sensitivity is highly required since it is the only area where variation of the external line voltage is reported for adequate signal conditioning and sampling, prior to comparator evaluation. The evaluation here is executed on the two comparator terminals - inventing and non-inventing pins; in order to determine the suitability of the in-coming varying signal in energizing the comparator.

From the diagram above, the in-coming ac voltage of 230v is carefully divided between R_1 and R_2. This is another step- down point for the large ac voltage which leaves a small manageable fraction to the following sections. The variable resistor functions to limit the subsequent current by diverting a good proportion to the ground so as to reduce risk of component damage

Capacitor C ensures stability against excessive variation of the coming voltage. A choice of suitable capacitance should be fairly made to accommodate appropriate voltage swing for appreciable sensitivity.

Subsequent to the capacitor is a diode. This removes slight frequency component during positive half wave swing.

2.5 Comparator Circuit:

Of course, integrated circuit like the comparator device LM 324 is a single IC component by physical observation, and a single device of multiple miniaturized circuits embedded within the casing for diversity of operation depending on the desired configuration and intended purpose.

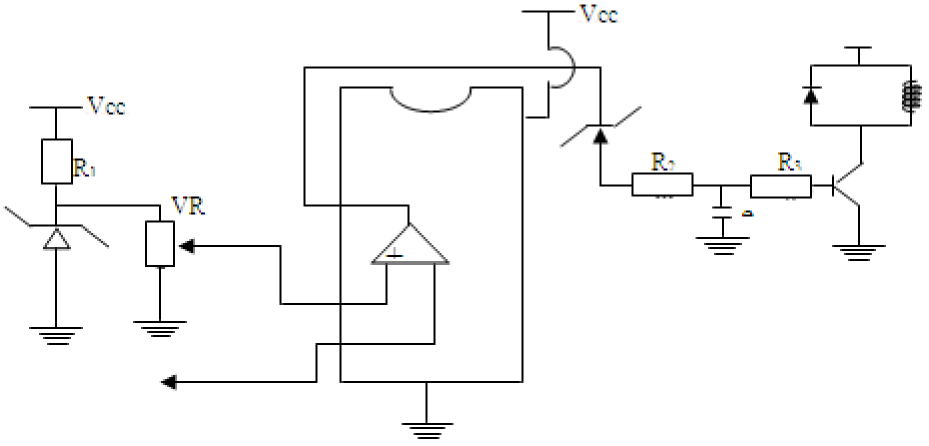


Diagram showing the comparator and sensor circuit arrangement
Fig2.5

This circuit works in company of other components such as variable resistor, zener diodes, paper or ceramic capacitors, transistors etc. While the non–inventing or inventing input pins of the comparator is tied to the in-coming varying voltage from the sensor; the complementary pin ties to the regulated voltage in order to enable the comparator switch as the voltage at the non-inverting pin becomes greater than that at the inverting pin. At the outputs of the comparators are transistors which are meant to drive the relays connected to them whenever their logic response is 1.

Preceding the transistor is a coupling circuit, composed of parallel combination of resistor and capacitor which determines how fast the switching response of the drivers would be using the numerical value of the time constant – CR_2. The higher the RC value, the lesser the time that will be taken to drive the current via the transistor's collector – emitter junction to switch the relay.

2.6 Comparator Window Setting:

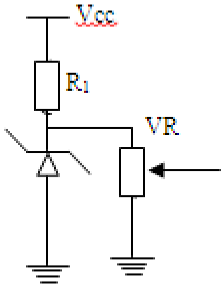


Diagram showing window setting circuit of the comparator
Fig 2.6

As shown in fig.1.6, the comparator always enjoys a relative operational companionship with window setting circuit. The circuit determines the level at which the in-coming voltage magnitude should rise for correct switching of the comparator. The small voltage magnitude from Vcc in this circuit is always set constant through the zener diode and resistor R_1. The varying voltage from the sensing circuit always goes up and down in amplitudes, and is used to set the switching event, depending on which of the signal impinges either the inverting or non inverting terminal of the comparator. The zener diode is another voltage regulating device. The variable resistor VR sources from the zener diode voltage, which could be varied to a level suitable for comparison with the incoming sensor voltage; hence, the bases for transistor switching by the comparator.

2.7 Transistor/Relay Circuit:

The circuit arrangement below is inerasable aspect of regulator control panel. The switching action and transformer terminal selection is aided by this circuit

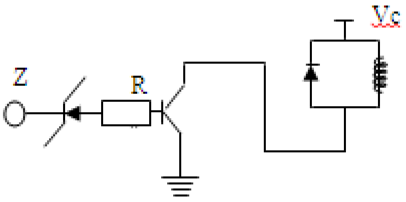


Diagram showing relay/transistor circuit arrangement

Fig2.7

The zener diode, Z ensures that the voltage from comparator output, intended for transistor switching, does not reduce below its voltage rating before it passes base current for transistor switching. The resistor is a current limiter, which does not permit excessive current flow to the risk of the transistor.

3.0 DESIGN AND CONTRACTION

The main design of this work is allocated this area of the thesis. We begin by focusing on the various components that give rise to the complete realization of the work. Identifying their respective values will be a good thing, in attempt to permit imitation, should any one desires to practically make a copy of this product.

3.1 Component Values:

1. Transformer construction –Auto-transformer:
   a. Lamination core of “ E” and ” I” shapes
   b. Copper wire – gauge 17 (AWG)
   c. Insulating materials- Masking tape
   d. lamination liquid
   e. Metal standing frame – angular frame
2. Internal wiring:
   a. Casing socket – 13AMP
   b. Fuse – 13AMP
   c. Two voltmeters for input and output
   d. Telephone wires for voltmeter, Vero or bread board connection
   e. Light emitting diodes for voltage level indication
3. Control Panel:
   a. Bridge diodes-IN4001
   b. Voltage regulators-7815
   c. Variable resistors
   d. Comparators – LM324
   e. Zener diodes
   f. Diodes
   g. Transistors – TIP42
   i. Relays – 15V DC
   j. Capacitors
   k. LED
   l. Vero board
   m. Resistors

Note that all the component values are as indicated on the schematic diagram of the control panel below.

3.2 Control Panel Building

As shown in the diagram, the panel sources power form AC output of the transformer, and the step down output is rectified, filtered of the ripples and regulated to obtain a fairly stable dc voltage taken as VCC to the electronic components. The 24v output of the transformer is regulated to 15V DC after rectification. I decided to dualize this section to avoid over loading each of the 15V DC source, and more importantly to make adequate and sufficient amount of voltage and current available to the components. The smoothing capacitor is electrolytic and is chosen to 1000uf capacitance for better filtration reason. I install 35V to give a tolerance of 20v against unexpected rise in voltage from the source; thus, helping to prevent a possible break down of the filtering capacitor at a large sudden system voltage surge .The figure below shows the diagram of the typical power section of the constructed voltage stabilizer- regulator

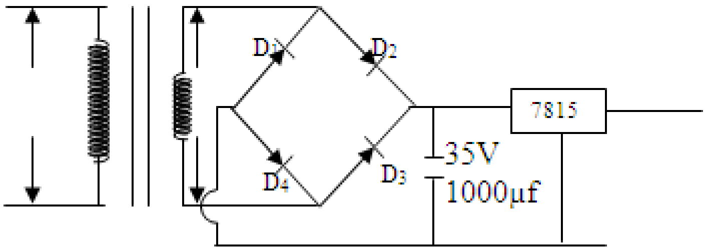


Diagram showing the power section of the panel

Fig3.1

3.3 Voltage sensing unit:

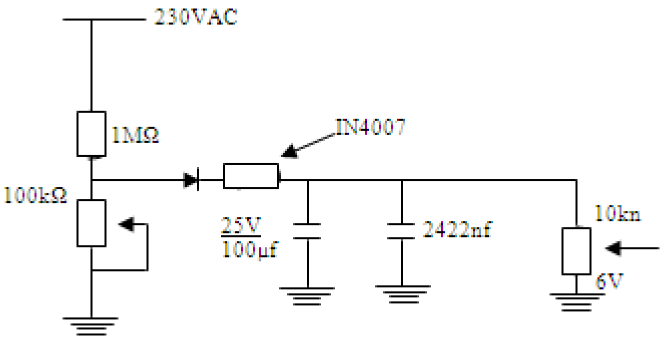


Diagram showing the sensor circuit arrangement
fig 3.2

Voltage regulator depends immensely on the reliability of the sensor unit for effective operation. Therefore, the sensor sees the changing behavior of the line voltage at the outlet socket and quickly relates the development to the comparator. The comparator senses the fluctuating voltage and switches the transistor at its output. Actually, the unit originates directly from 230v of the transformer input; reason being to enable the unstable voltage at the regulator input be registered on the panel for effective control.

The voltage is split into smaller unit to avoid damages to the subsequent modules. This is done with voltage divider, using 1MΩ and l00kΩ variable resistors. The connection of the variable resistor in such a mode on the diagram reduces excess current against damages, and the reduced current passes through the serially connected diode and resistor in order to be partly rectified. The subsequent capacitor aids speedy signal transfer to the adjoining circuit; and the speed is determined by time constant formula, 0.693RC.

3.4 Operation Mechanism of the Comparator

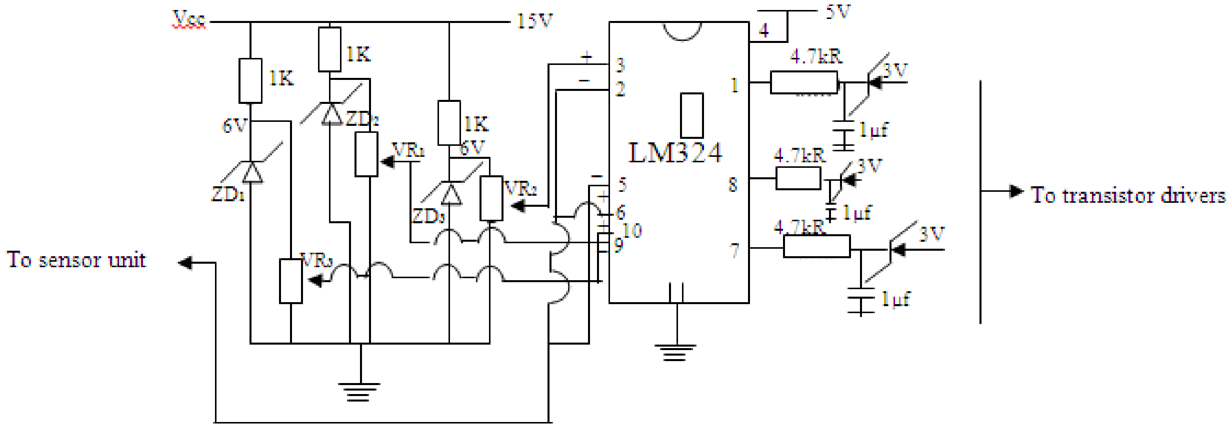


Diagram showing the comparator circuit
Fig3.3

$Z_{D1} = Z_{D2} = Z_{D3} = 6V$ zener diode
$V_{R1} = V_{R2} = V_{R3} = 10K$ variable resistor
From the diagram the 15v Vcc is dropped down to 6v by the zener diode using 1k resistors. The incoming varying voltage at sensor line is 6v, and is connected to pin 2, 6 and 10 of the op-amp. Pin 3, 5 are connected to the variable resistors for their respective fixed voltage of 4.5v, 3.3v and 7.0v.

Conventionally, the normal operating voltage is 230v. Since the voltage at the autotransformer terminals ranges from 230v, 290v to 360v, the corresponding op- amp switching voltages are set to 7.0v, 4.5 and 3.3v.

In the choice of voltage for the transformer terminal, 60V difference is considered between any two adjacent producing terminals. This is done so that when the transformer terminal voltage decreases by 60V, the 230V output terminal drops to 170V, and 290V terminal drops to 230V and be selected by the relay assigned to it; thus, releasing 230V at the regulator output socket. At this time the 360V terminal will drop to 300V. Again when another 60V drop is encountered on the line, it will show on the transformer's terminal voltages as follows: 170V at the input will drop to 110V, 230V terminal will drop to 170V while 300V will drop to 240V which is a bit convenient value to be conveyed to the output socket by the assigned relay. In the same manner the small input comparator voltages drop in corresponding way to necessitate relay switching that brings about the terminal selection at the transformer output.

The recommendable characteristic of this work is its special feature of step-up capability when there is up to 60V drop on the line which reflects at the transformer input and output voltages. At this moment, all the connected appliances at the regulator output experiences low voltage and power supply should there be no means of upgrading the voltage at the socket.

The essence of voltage window setting to 7.0v, 4.5v and 3.3v is to realize the above events. At any time that the input voltage comes down from 230V to 170v, the 6v sensor voltage must decrease below 4.5v to make 290 terminals to experience 230v. When it decrease further than 3.3v, the 360V terminal runs with 230v and the input voltage will then decrease by 120v, leaving behind only 110v to run the autotransformer.

On the contrary, the state of the system supply equally degenerates in reverse order, that instead of the usual unwanted decrement, the voltage may detrimentally surge up far above 230v. In this case, the sensor voltage will correspondingly rise slightly above 7.0v on the inverting input of op-am. This causes the relay to select the step down terminal of the transformer which now must have increased to 230v.

3.5 Relay Arrangement

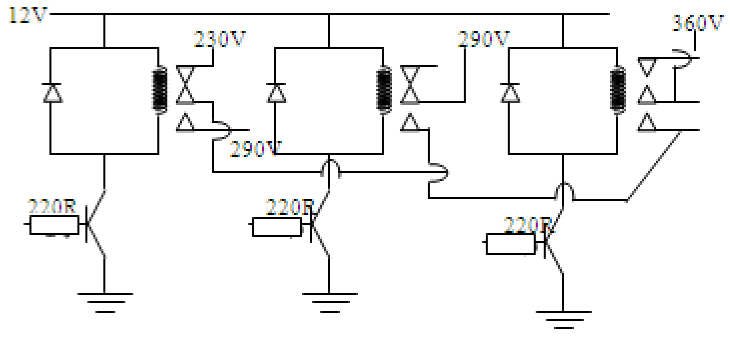


Diagram showing transistor/relay connection
fig 3.4

It is the relay logic circuit arrangement that brings in the sumptuous function of the regulator panel which attracts beauty to the performance of the regulator. The terminals–NO (normally open) and NC (normally close) are connected in a manner to allow proper coordination of the relays in a bid to escape the bridging of autotransformer output terminal; and still maintain a continuous and serial link that transfers a voltage magnitude of 230V to the load.

The relay switching takes place when the transistors base sees a forward biasing voltage that is greater or equal to 0.6v for NPN transistor. The voltage above 0.6v for the transistor, must always be considered within the thermal limit tolerance of the transistor's base–emitter junction, in order to avoid damages. Also, it is often an appreciable practice, to protect the transistors with resistors so as to prevent excess heat occurrence at the PN junctions.

When all these precautions are observed, the transistor drivers obviously become effective witching device that drive the relays "on and off " depending on the set voltage values on the comparator as well as the prevailing manner of voltage variation on the line.

4.0 PRINCIPLE OF TRANSFORMER OPERATION

Transformer is a stationary device whose electric power on the primary is transformed to electric power of the same frequency on the secondary side of the circuit. The secondary voltage can be decreased or increased in proportion to decrease or increase of the voltage magnitude in the primary. This feature is as a result of mutual induction between the primary and secondary winding. Common magnetic flux that flows through the laminated core is responsible for this induction as it alternates during the full electric cycle.

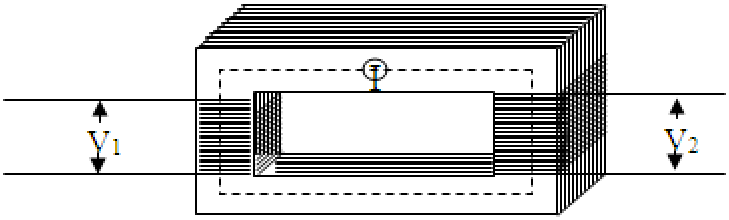


Diagram showing transformer core and the flux lines
fig 4.0

Induction transformer can be referred as a static magnetic circuit or device of two or more layers of inductive coils-windings which are electrically separated but magnetically connected through the magnetic flux in the laminated core. Connection of the input terminals of the transformer into the AC source sets up a magnetic flux in the core; and most of these flux do link the transformer coils to produce an induced e.m.f which according to faraday's law of electromagnetic induction can be expressed as

$E = Nd\Phi_m /dt$

4.1 Transformer Construction:

In transformer construction, appropriate care is always taken to achieve conveniently working device that is devoid of errors which can result electrical faults. The coils are properly insulated from one other and from the laminated core around which they are wound.

A good transformer construction always ends in assembling a structure that will give effective support for, a balance standing, when mounted on the ground.

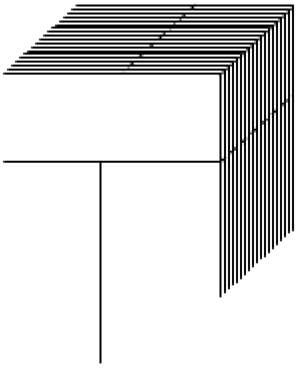


Diagram showing a cut -out section of the transformer core
Fig4.1

In transformer building, the cores are constructed of laminated silicon metallic material, well assembled to produce a continuous magnetic path with minimum air gap

The laminated sheets of silicon metal are specially treated at manufacturing stage to achieve high permeability and low hysteresis and copper losses. The essence of core lamination is to reduce eddy current. The thickness of the lamination metal may vary from 0.35mm for a frequency of 50Hz to 0.5mm for a frequency of 25Hz.The diagram above shows a sort of laminated core slices that are carefully cut and separated from a fully and completely packed transformer E-I-core of a voltage regulator.

4.2 Types of Transformer:

Generally, transformers can be basically classified into two distinct natures that are different by structure, with two different shapes that are categorized into two different names, shell and core type transformer.

A picture of small unit induction/shell type transformer used in some home electric appliance

Fig4.2

4.3 Core Type Transformer:

In a small size core type transformer, a rectangular core is always used with cylindrical coil which are either circular or flat (e.g. flat copper for arc welding transformer construction).

The long cylindrical coils are often used in most cases due to their tough mechanical strength.

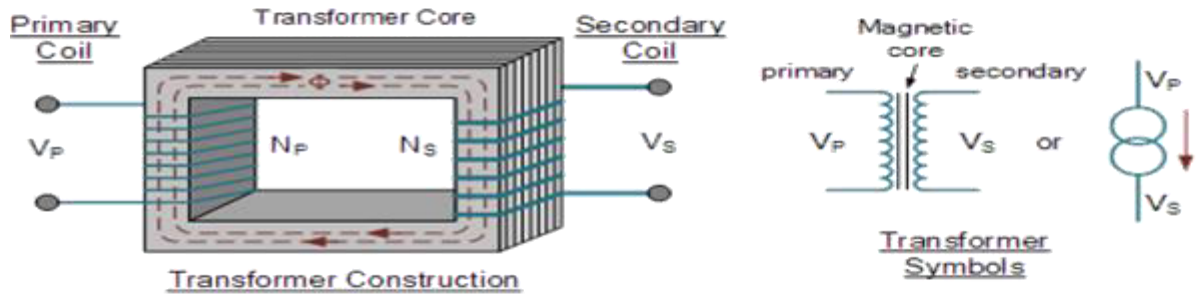


Diagram showing a schematic view of a core type transformer/symbols
Fig4.3

5.0 TRANSFORMER EQUATION

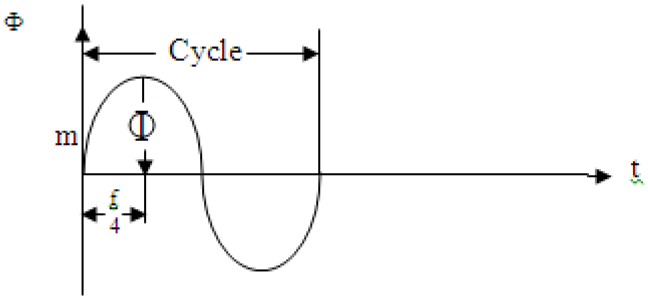


Diagram showing the wave flux of the transformer
Fig4.4

Let N_p = No of turns in primary
N_s = No of turns in secondary
Φ_m = maximum flux in Weber
F = frequency of ac input in Hz
Always rate of change of flux = Φ_m /1/4f (wb)
Average emf /turn = 4f Φ_m voltS
rms value /average value =1.11
r.m.s value of emf/turn = 1.11 x 4f Φ_m = 4.44 f Φ_m
But, E =4.44FN_s Φ_m
=4.44FN_s A B_m

Similarly, we can still derive the root mean square value of the electromotive force of the transformer as shown bellow, considering the fact that the transformer is examined under ideal condition.

$E = Nd\Phi_m /dt$
$E = N . \omega .\Phi_m . \ COS\omega t$
$E_{max} = N . \omega .\Phi_m$
$E_{rms} = N /2^{1/2} \Phi_m$
$E_{rms} = 2\pi /2^{1/2} \Phi_m f N$
$E_{rms} = 4.44 \Phi_m f N$

All the parameters still retain their definition as stated above

Therefore, under lossless and no load condition
$V_P = E_P$
$E_S = V_S$
VOLTAGE TRANSFORMATION RATIO
$E_S N_P = E_P N_S$

$$\frac{E_S}{E_P} = \frac{N_S}{N_P} = K$$

K=voltage transformation ratio

If $N_S > N_P$ ie K>1, then the transformer is called step up transformer
If $N_S < N_P$ ie K<1, the transformer is a step down transformer.
Input VA = output VA
$V_P I_P = V_S I_S$
$I_S/I_P = V_P/V_S$
This shows that the current is in inverse ratio of the voltage in the transformer.

As the mathematical illustration above shows, the turn ratio of the transformer determines the step-up and step-down status of the device. If the transformation ratio is lesser than one, ie n< 1,then N_S is greater than N_P and the transformer is categorized as a step-up transformer. However, if the reverse is the case then the device is a step-down transformer. In this case N_S must be greater than N_P.

In a situation where both N_p and N_s are of the same number of turns, then the transformer can be referred as isolation transformer. In this transformer, Voltage and current magnitude of the two sides are equal and the transformation ratio must be equal to unity, n = 1.

6.0 Efficiency in Induction Transformer

Input power = Output power + Losses
$V_P I_P = V_S I_S$ + Losses
Eff. = KVA/ IVcosα
= [Output Power / Input Power] x 100/1
= [(Input Power – Losses) / (Input Power)] x 100/1

$$= [1 - (\text{Losses}) / \text{Input Power}] \times 100/1$$

It is good to note that transformer does not have any moving part as its body component. Therefore, the wind-age and fictional losses are not accounted for when considering the losses that reduce the device's efficiency while in operation. The main losses that are obtainable with this device is electrical in nature, and so, we have copper or ohmic losses owing to the flowing current that causes the heat which the device experiences when it is working .This is the product of coil resistance and the square of the moving current on the coil winding (I^2R).Another type of loss apart from cu loss is iron loss which is hysteresis in nature and can be accounted for due to the molecular composition of the metallic material with which the laminated core is manufactured.

The impart of losses in all engineering equipments does not make a good effect on the efficiency of the devices. Transformer device, among other electrical equipments is not exempted; therefore, the degree of transformer usefulness, rating from efficiency is highly reduced by the iron and copper losses. In effect, all the electrical input at the primary side of the device are not always harnessed at the output following the electrical losses within the circuit.

An ideal transformer is assumed loss free, as a result; the efficiency is said to be 100% .This means that an ideal transformer can convey all the power at its primary circuit to the secondary side without suffering any electric power loss.

In reality, ideal transformer is always a fiction since there is often times power loss problem even at no load when the transformer struggles to build up the magnetic flux upon which the e.m.f at the output depends. And the inrush magnetizing current that sustains the functions of the device cannot be completely blameless of power losses. Nevertheless, a well constructed transformer should be built on a reasonable value of efficiency for optimum performance and efficiency value of 94% to 96% at full load is admirable.

CONCLUSION

Looking at the explanation details as an account of the basic operational phenomenon that leads to accomplishment of voltage regulation in this work, a good understanding of the thesis can obviously show that the autotransformer and the electronic panel are the two major key units that drive the device. While, the transformer serves as the major nucleus for power and voltage transformation, the electronic panel automates the terminal selection to initiate the required 230V transfer onto the regulator outlet. The operation of these components is, of course, the force that moves the regulator into action. The regulator is designed to monitor the 230V on the secondary circuit of the power network which it sees through the cut-out on the meter board. The 230V is at the same time fed to the connected home- equipments via the regulator output-socket. It is necessary to state at this point that the steady 230V needed at the stabilizer outlet is relatively plausible following the logical selection of the autotransformer multiple output voltages which is meant to occur within two consecutive voltage drops at a magnitude value of 60V.

Diagrams showing different views of the inner circuitry and casing of automatic voltage regulator

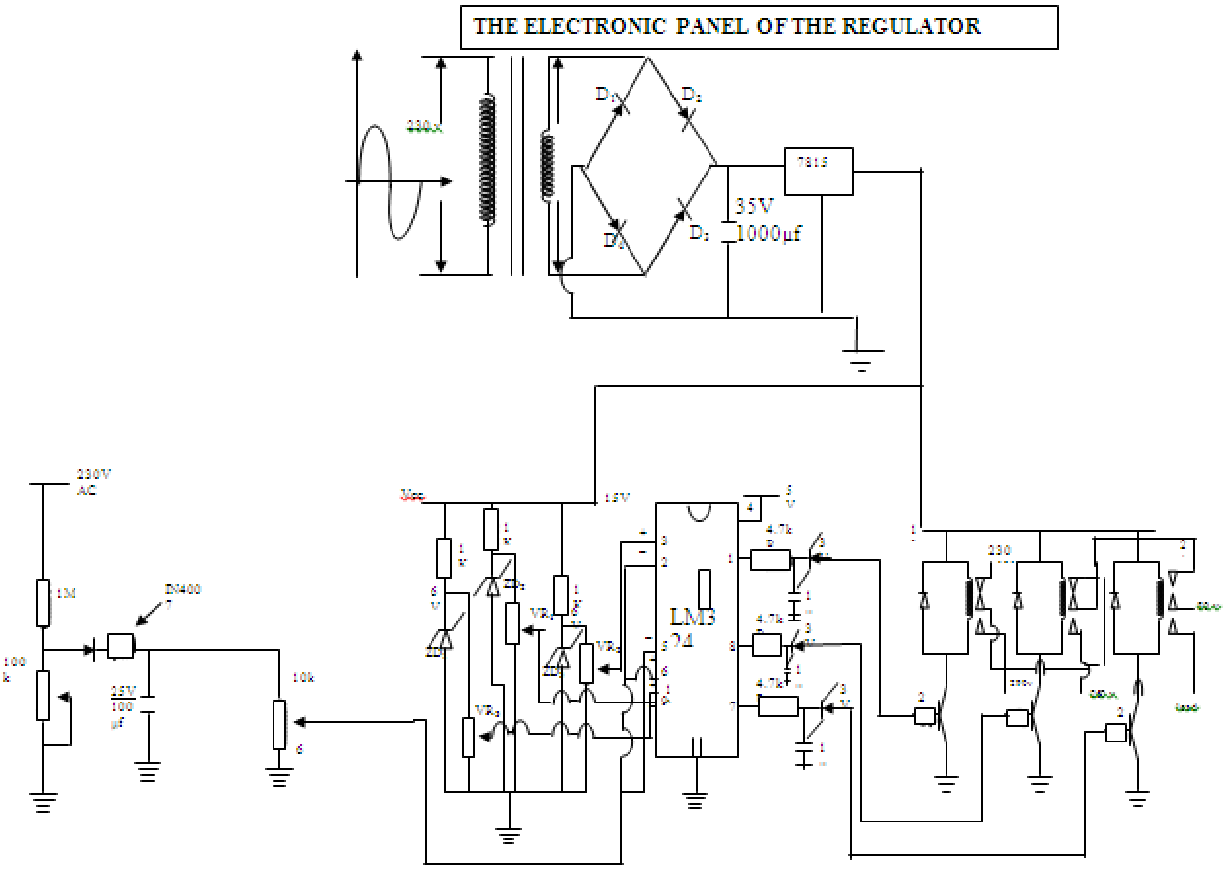


Fig.6.1
Diagram showing electronic circuit of regulator

Schematic Diagram of the Autotransformer

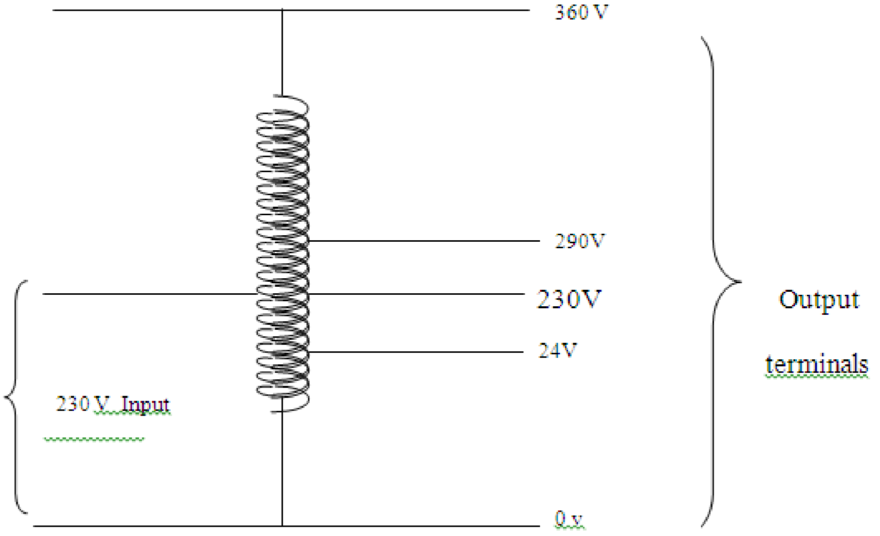


Fig 6.2
Diagram showing the circuit of the Autotransformer

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