DESIGN, DEVELOPMENT AND ANALYSIS OF MICROCONTROLLER BASED CONSTANT POWER PURIFIER

A Major Project Report

Submitted in Partial Fulfillment of the Requirements

of

MASTER OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

(POWER APPARATUS & SYSTEMS)

By

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Certificate

This is to certify that the Major Project Report entitled "**Design, Development and Analysis of Microcontroller based Constant Power Purifier**" submitted by **Mr. Kadivar Ketan Tribhovan (04MEE004)**, towards the partial fulfillment of the requirements of Master of Technology (Electrical Engineering) in the field of Power Apparatus & Systems of Nirma University of Science and Technology is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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Subject: Dissertation certificate

Mr. KADIVAR KETAN T. participant for **M. Tech Electrical** (Power apparatus and system) final year dissertation programme is awarded the Project **"Design, Development and analysis of Microcontroller based Constant power purifier"** under my active guidance.

I assure his dissertation is satisfactory & project work has been finished by him. His involvement, devotion towards his dissertation work is satisfactory.

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Abstract

Now a day's electricity becomes necessary requirement in industry, home, office, and laboratory or in any other field. Most of the electrical equipments like computer, TV, FAX, heater, electrical motor etc. are designed to operate at constant voltage like 230V ±5%. If voltage is above or below the rated voltage, electrical equipment may get damaged.

We are mainly getting electric supply from generating station, which are far away from our working area. Voltage variation in the incoming supply is major problem of power engineering. Fluctuations are also produced in the incoming supply due to welding and other industry. Some times surges and spikes are found in the supply.

This voltage variation may harmful to our valuable electrical equipment. Due to over voltage winding may get damage. Slight fluctuation in the supply is sufficient to damage program written in the computer. Under voltage is harmful to electrical motor and other machinery.

Constant power purifier is a device, which give constant output voltage in spite of variation in the supply voltage. Its heart is microcontroller based voltage stabilizer, which stabilize the supply voltage. In addition, it also suppresses the surges and spikes by surge arrester circuit. Output voltage of stabilizer remains constant at 230 ± 5%. Its input voltage range is 160V to 290V. In this project SCR are used as switching device and microcontroller is used as triggering device. Microcontroller is used to measure and to control voltage. It corrects the voltage at every half cycle of the supply voltage.

In this project zero crossing switching technology is used. So very less harmonics are produced due to switching. Voltages are stepped up or down by autotransformer. Constant power purifier is applicable for computer, TV, CD player, FAX and all other laboratory and office equipment, which are sensitive to voltage changes.

List of figures:

Chapter 9 driver circuit and control circuit

Chapter 10: Simulation results

Chapter11: Testing results of constant power purifier

Nomenclature:

Vil = min. input voltage

Vih = max. input voltage

Vol = min. output voltage

Voh = max. output voltage

K = Transformation ratio

SCR= Silicon Controlled Rectifier

Ton= on time

Toff= off time

Ih= Holding current

Il = latching current

CPP = Constant Power Purifier

V = voltage

A = ampere

CS = cheap select

WR = write

RD = read

ADC = analog to digital converter

A/D = analog to digital

μc = micro controller

ZCD = zero crossing detector

V = instantaneous voltage

Vm = peak voltage

RAM = random access memory

ROM = read only memory

EA = external enable

RST = reset

X'tal = crystal

INT = interrupt

F = farad (unit of capacitance)

Ω = ohm (unit of resistance)

Hz = hertz (unit of frequency)

VCC = supply voltage of IC

GND = ground

LSB = least significant bit

MSB = most significant bit

1-Ø = single phase

3-Ø = three phase

GTO = gate turn off thyristor

CONTENTS

Chapter 1

Introduction

Introduction:

Power supply quality is of great importance in that correct operation of many appliances depends upon a constant and reliable power source. Voltage variation in the power supply Comes due to following reasons:

- finite impedance of lines, cables and other power system components
- sudden changes of the load on the power system
- voltage fluctuations due to load like welding machines
- The growing numbers of electronic loads, most of them are sensitive to many types of disturbances and paradoxically they usually increase the pollution in the power system due to their poor power circuits.
- Over voltage and under voltage may cause permanent damage to the devices.

A constant power purifier is a device which maintains ac input voltage to any equipment constant irrespective of the voltage fluctuation in the utility lines. It is solid state voltage stabilizer with micro controller based control circuit. AC voltage stabilizer varies from Ferro resonant type to solid state type. The type and design of the stabilizer mainly depends on the power capability, regulation limit, harmonic tolerated, dynamic response, cost etc.

The constant power purifier satisfies most of the requirements. It has fast dynamic response, high power factor, high efficiency and single stage ac- ac conversion, which makes it reliable for used as intelligent power supply conditioning system. Moreover it does not require any kind of filter circuit as in the case of UPS (uninterruptible power supply). It is designed for supply requirements of many kinds of electronics loads.

Chapter 2

Literature Review

When going to start new project first question born in my mind is, from where to start, what are the available methods of ac voltage control, what topology I should use, how can I make my design more efficient etc.

For this I have referred many IEEE papers, magazines and books. From this material I have selected concept of microcontroller based on load tap changer [1]. For the concept of control circuit I have referred references [2] & [3]. The design of control circuit is done with the idea from reference [11]. For driver circuit design I referred solid state on load tap changer [1] & [7]. For control circuit design, operational amplifier and linear integrated circuit is also useful.

For programming of micro controller I have used book "programming and customizing the 8051 micro controller" by Mike Predko and application notes from www.atmel.com. For analysis and driver circuit design I have used the reference [7], [8] & [9]. For design of auto transformer I have used the reference [9].

Chapter 3

Topologies of AC voltage Control

[3.1] Introduction:

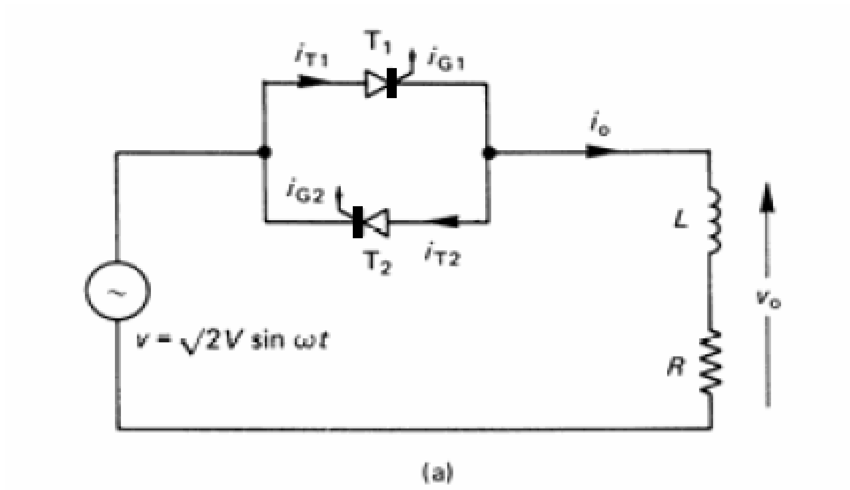
Ac voltage is controlled to obtain desired performance of electrical system. For this purpose an ac voltage controller or regulator is used. The output voltage is either maintained constant, reduced or boosted. These controller have numerous applications, such as electrical heating, electrical welding, speed control of induction motors, voltage stabilizers etc. there are several conventional method by which output voltage can be controlled, such as variable resistor, variable inductor, auto transformer. The various topologies of ac voltage control are as below.

[3.2] On load tap changing transformer:

This method is widely used for controlling voltage of the power transformer and in voltage stabilizer with auto transformer. Tap is changed continuously so that output voltage remains within specified limit. The advantage of this method is that output voltage is purely sinusoidal and power factor is high. The output voltage changes in step with tap changes. The output voltage range depends upon the no. of steps.

[3.3] Integral cycle control:

In this case by closing and opening of a switch, the input voltage reaches the load for a certain period of time (on period). Similarly for a certain period (off period) the switch remains open. In general for integral number of half cycle the switch is closed and load voltage is equal to supply voltage. For other half cycle the switch s is open. So load voltage is zero. That is why this method is called integral cycle control (ICC). To avoid fluctuation in the output voltage (V_o) the closing and opening operation should be fast. Since mechanical switch can not serve the purpose, power semiconductor or thyristor based switches are used. This type of control is used for temperature or other high time constant type system where on-off control does not cause fluctuation in the performance of the system. The main demerit of the ICC is that it introduces sub harmonics in the line current. Each thyristor is switched at the zero crossing of the supply voltage only.



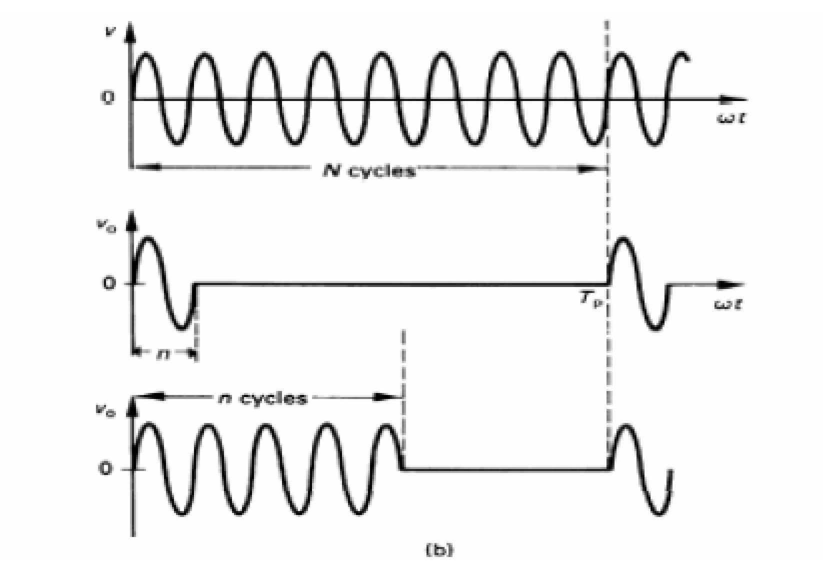


Figure 3.3.1 Integral half-cycle single-phase ac control:

(a) Circuit connection using a triac;

(b) Output voltage waveforms for one-eighth maximum load power and nine-sixteenths maximum power.

If the switch is closed and open for n and m number of cycle respectively, the rms value of output voltage is given by

$Vo = V * \sqrt{n/(n+m)}$

$= V \sqrt{K}$

The output power for a resistive load,

$Po = V_o^2 /R$

$= [n / (n+m)] * V^2/R$

Therefore the power factor,

PF = Output power/ input power

$= \sqrt{K}$

[3.4] Single-phase ac voltage regulator

Figure shows a single-phase thyristor regulator supplying an *L-R* load. The two Thyristor can be replaced by any of the bidirectional conducting and blocking switch Arrangement shown in figure 3.4.2. Equally, in low power applications the two thyristor are usually replaced by a triac. The thyristor gate trigger delay angle is α, as Indicated in figure 3.4.1 (b). The fundamental of the output frequency is the same as the input frequency, $\omega = 2\pi fs$. The thyristor current, shown in figure 3.4.1 (b), is defined by equation, that is

$$L\frac{di}{dt} + Ri = \sqrt{2}V \sin \omega t \quad \text{(V)} \qquad \alpha \le \omega t \le \beta \quad \text{(rad)}$$
$$= 0 \qquad \text{otherwise}$$

eq. [1]

The solution to this first order differential equation has two solutions, depending on the delay angle α relative to the load natural power factor angle,

$$\phi = \tan^{-1} \omega L / R$$

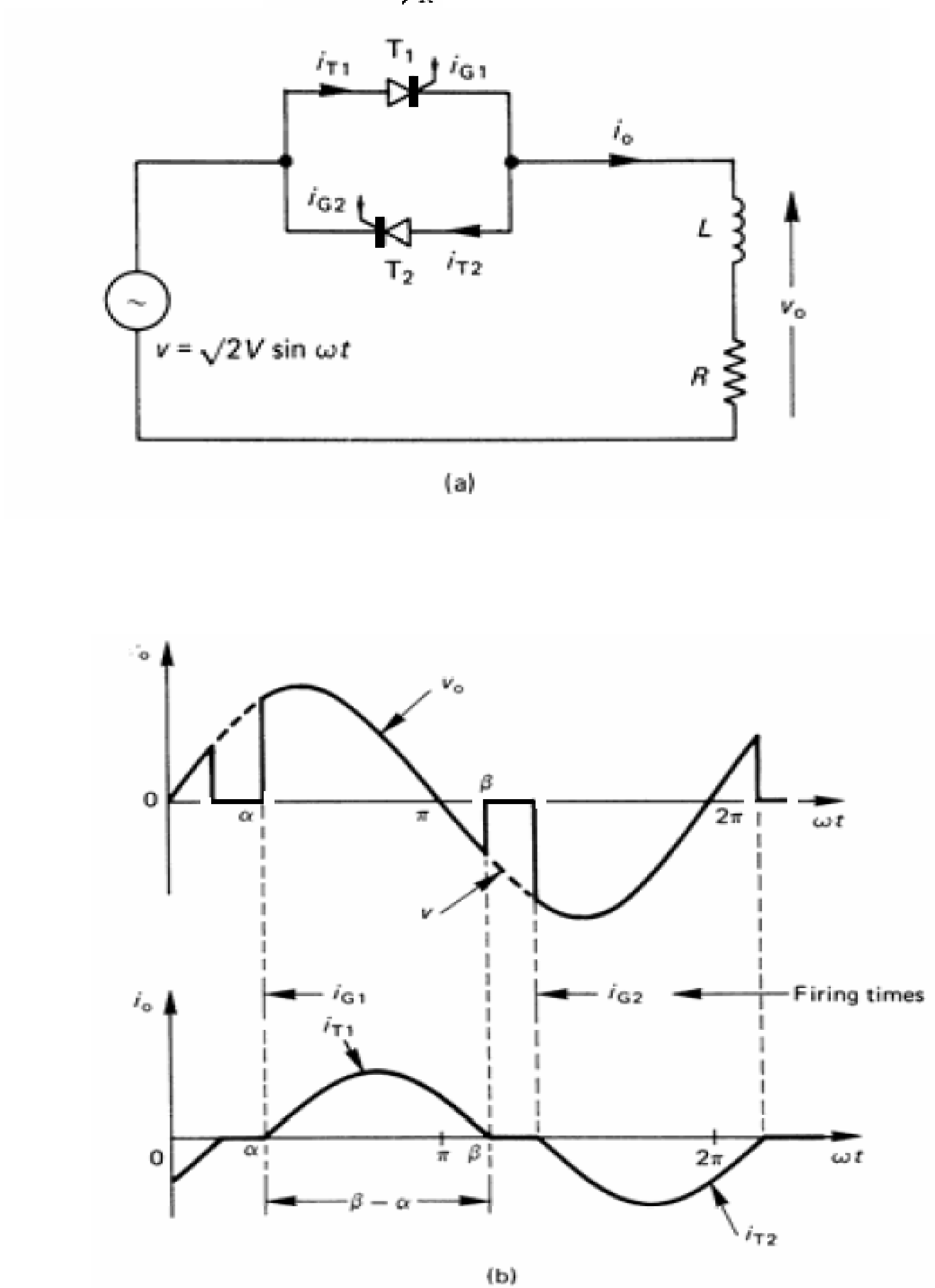


Fig.3.4.1. Single-phase full-wave thyristor ac regulator with an R-L load:
(a) Circuit connection (b) load current and voltage waveforms.

Because of symmetry around the time axis, the mean supply and load, voltages and currents, are zero.

Case 1: α >φ

$$i(\omega t) = \frac{\sqrt{2}V}{Z}\left\{\sin\ (\omega t - \phi)\ -\ \sin(\alpha-\phi)\ e^{-\omega t+\alpha/\tan\phi}\right\} \qquad \text{(A)}$$

$$\alpha \le \omega t \le \beta \qquad \text{(rad)}$$

$$i(\omega t) = 0 \qquad \text{(A)}$$

$$\pi \le \beta \le \omega t \le \pi + \alpha \qquad \text{(rad)}$$

eq. [2] & [3]

When the delay angle exceeds the power factor angle the load current always reaches Zero, thus the differential equation boundary conditions are zero. The solution for *I* is

Where $Z = \sqrt{(R2 + \omega^2 L^2)}$ (ohms) and tan φ = wL/ R

Provided α >φ both regulator thyristors will conduct and load current flows symmetrically as shown in figure 3.4.l (b)

$$\sin(\beta - \phi) = \sin(\alpha - \phi)\ e^{(\alpha-\beta)/\tan\phi}$$

$$V_{rms} = \left[\tfrac{1}{\pi}\int_{\alpha}^{\beta}\left(\sqrt{2}V\right)^2 \sin^2\omega t\ d\omega t\right]^{\frac{1}{2}} = \sqrt{2}V\left[\tfrac{1}{\pi}\int_{\alpha}^{\beta}\left(1-\cos 2\omega t\right)\ d\omega t\right]^{\frac{1}{2}}$$
$$= V\left[\tfrac{1}{\pi}\left\{(\beta-\alpha) - \tfrac{1}{2}(\sin 2\beta - \sin 2\alpha)\right\}\right]^{\frac{1}{2}}$$

eq. [4]

Case 2: α ≤ φ

When α ≤ φ, a pure sinusoidal load current flows, and substitution of α = φ in equation 2 results in

$$i(\omega t) = \frac{\sqrt{2}V}{Z}\sin\ (\omega t - \phi) \qquad \text{(A)}$$
$$\alpha \le \phi \qquad \text{(rad)}$$

eq. [5]

The rms output voltage is *V,* the sinusoidal supply voltage rms value. The power delivered to the load is therefore

$$P_o = I_{rms}^2 R = \frac{V^2}{Z}\cos\phi$$

eq. [6]

If a short duration gate trigger pulse is used and $\alpha < \varphi$, unidirectional load current will result. The device to be turned on is reverse-biased by the conducting device. Thus if the gate pulse ceases before the load current has fallen to zero, only one device conducts. It is therefore usual to employ a continuous gate pulse, or stream of pulses, from α until π, then for $\alpha < \varphi$ a sine wave output current results.

In both load angle cases, the following equations are valid, except $\beta=\pi + \alpha$ is used for case 2, when $\alpha \le \varphi$.

The rectified mean voltage can be used to determine the thyristor mean current rating.

$$\overline{V}_o = \tfrac{1}{\pi}\int_\alpha^\beta \sqrt{2}\,V\sin\omega t\,d\omega t$$
$$= \sqrt{2}\,V\left[\tfrac{1}{\pi}\{\cos\alpha - \cos\beta\}\right] \qquad \text{(V)}$$

eq. [7]

The mean thyristor current $\overline{I}_{Th} = \tfrac{1}{2}\overline{I}_o = \tfrac{1}{2}\overline{V}_o / R$, that is

$$\overline{I}_{Th} = \frac{\tfrac{1}{2}\overline{V}_o}{R} = \frac{\sqrt{2}\,V}{2R}\left[\tfrac{1}{\pi}\{\cos\alpha - \cos\beta\}\right] \qquad \text{(A)}$$

eq. [8]

The maximum mean thyristor current is for a resistive load, $\alpha = 0$, and $\beta = \pi$, that is

$$\hat{\overline{I}}_{Th} = \sqrt{2}V / \pi R$$

eq. [9]

The rms load current is found by the appropriate integration of equation (2), namely

$$I_{rms} = \left[\frac{1}{\pi} \int_{\alpha}^{\beta} \left(\frac{\sqrt{2}V}{Z} \right)^2 \left\{ \sin\ (\omega t - \phi)\ -\ \sin(\alpha - \phi)\ e^{-\omega t + \alpha / \tan\phi} \right\}^2 d\omega t \ \right]^{1/2}$$

$$= \frac{V}{Z} \left[\frac{1}{\pi} \left(\beta - \alpha - \frac{\sin(\beta - \alpha)}{\cos\phi} \cos(\beta + \alpha + \phi) \right) \right]^{1/2}$$

eq. [10]

The thyristor maximum rms current is given by $I_{Th\ rms} = Io_{rms} / \sqrt{2}$ when $\alpha \le \varphi$, that is

$$I_{Th\ rms} = V / \sqrt{2}Z \qquad \text{eq. [11]}$$

The thyristor forward and reverse voltage blocking ratings are both $\sqrt{2}V$. The fundamental load voltage components are

$$a_1 = \frac{\sqrt{2}\ V}{2\pi} \{\cos 2\alpha - \cos 2\beta\}$$

$$b_1 = \frac{\sqrt{2}\ V}{2\pi} \{2(\beta - \alpha) - \sin 2\beta - \sin 2\alpha\}$$

eq. [12]

If $\alpha \le \varphi$, then continuous load current flows, and equation (12) reduces to $a_1 = 0$ and $b_1 = \sqrt{2}V$, when $\beta = \alpha + \pi$ is substituted.

Advantages:

[1] Phase angle control can be used for fan and pump drive for speed control and constant voltage can be applied by reducing the voltage by varying the firing angle

[2] Only two SCRs or one triac can be used for getting constant voltage

[3] It can be used for heating, surface drying etc.

Disadvantages:

[1] Low order harmonics are generated, which require high cost filter

[2] Power factor reduces as firing angle increases.

[3] Output voltage is not sinusoidal

[3.5] AC voltage controller with PWM control:

` Input power factor of controlled rectifier can be improved by PWM type of control. The naturally commutated thyristor controllers introduce lower order harmonics in both the load and supply side and have low input power factor. The performance of ac voltage controller can be improved by PWM control. the circuit configuration of a single

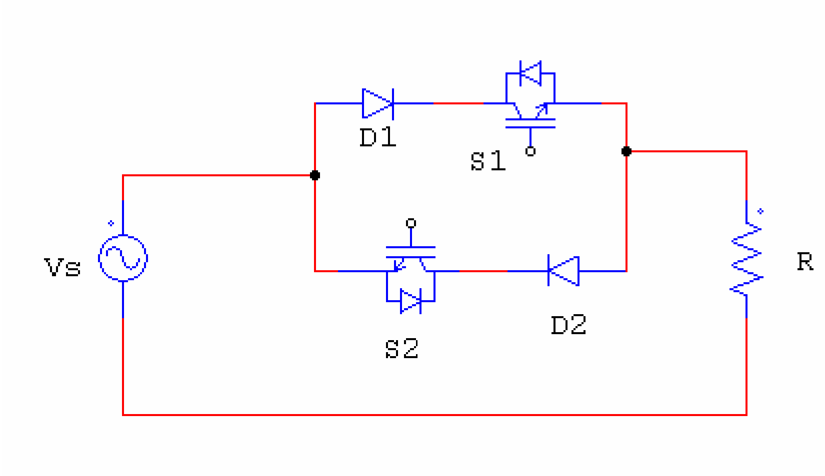


Fig. 3.5.1[a] AC voltage controller circuit

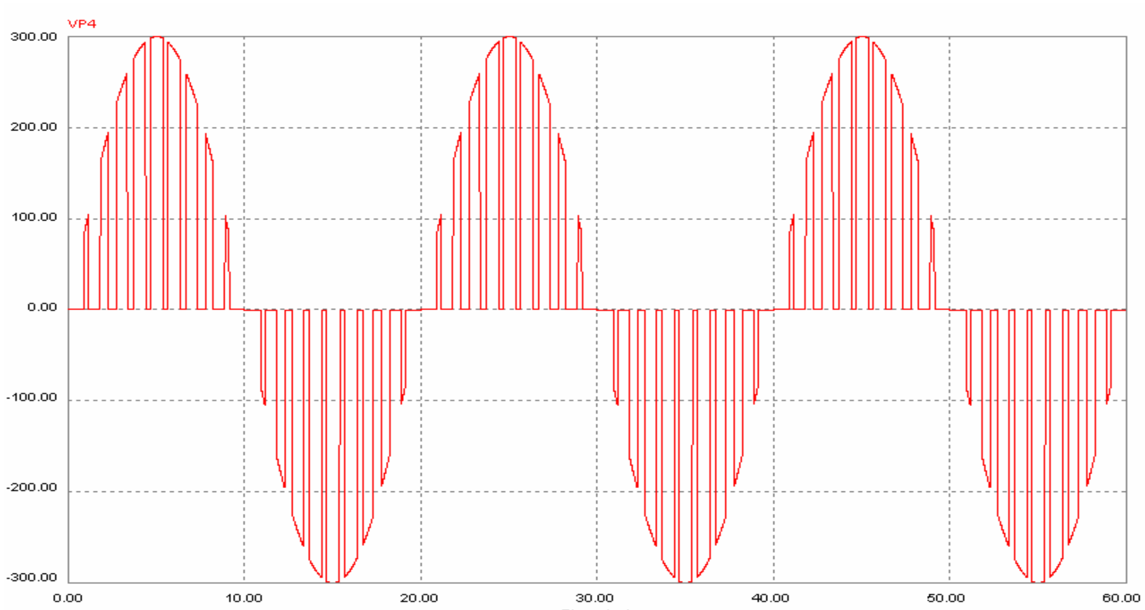


Fig. 3.5.1[b] output voltage waveform

Phase ac voltage controller for PWM control is shown in fig. 6.5.1[a]. The output voltage waveform is shown in fig. 6.5.1[b] switches S1 and S2 are turned on and off several times during the positive and negative half cycle of the input voltage respectively. The power factor of this circuit is very good compared to single pulse voltage controller. The first harmonics occurs at switching frequency. So problem of law order harmonics is eliminated in this case. The low cost filter is sufficient to eliminate this harmonics.

Output voltage is controlled by controlling the duty ratio. This circuit is simulated with SPWM technique. The triangle wave has frequency 1000H and 2V peak amplitude. It is compared with 50 Hz sine wave.

Harmonics spectum:

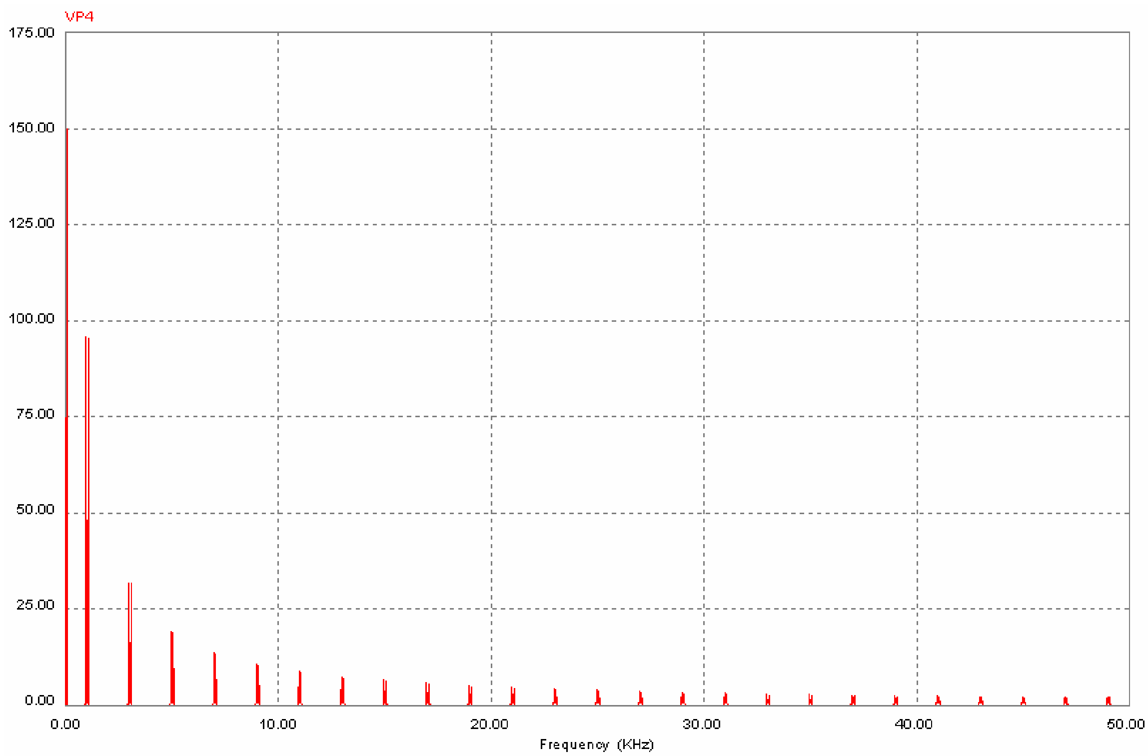


Fig. 3.5.2 harmonics spectrum

Chapter 4
Voltage Stabilizers

[4.1] Introduction:

Voltage stabilizer:

"It is a device, which keep the output voltage constant against variable input voltage."

Types:

There are four types of voltage regulators as follows:

1. Relay based stabilizer.
2. Servo voltage stabilizer
3. Ferro resonant based constant voltage isolation transformer.
4. Thyristor based voltage/ power controller.

[4.2] Relay based stabilizer:

In this type of stabilizer the output voltage held constant using the relay switching through buck boost transformer.

Advantage:

-It overcomes the distortion in the waveforms due to the saturation

-Relay cannot give problem.

Disadvantage:

-Power is off momentarily during relay change over. Sensitive equipment like computer cannot tolerate this interruption.

-Voltage range is limited.

-Accuracy is limited.

[4.3] Servo type voltage stabilizer:

This type of stabilizer uses an advance electronic controlled servo motor concept to govern a motorized variable transformer. Because of motor involved, there is a small delay in voltage correction. However output voltage accuracy is usually $\pm$1% with input voltage changes of up to $\pm$50%.

This type of technology tends to be extremely effective when considering large three-phase application, as it is able to maintain its accuracy of all these phases, deposit of input voltage balance and load balance at any power factor. They are also able to withstand large inrush current, normally experienced with inductive loads, however due to the mechanics of this type of stabilizer, periodic maintenance is required.

ADVANTAGES:

Quit accurate as it resolutions in the voltage across each turn of the coil. This resolution depends on core size.

DISADVANTAGES:

1. It tends to hunt if the i/p voltage fluctuates too often.
2. It acts slowly and can't adjust to sudden shots or dips of main voltage.
3. It requires more servicing.
4. Not reliable.

[4.4] FERRO RESONANT STABILIZER:

PRINCIPLE:

A saturating core is used to keep the o/p voltage constant even though the i/p voltage had variation over and below the rated nominal voltage.

ADVANTAGE:

-No moving parts

-Very reliable

-Long life

DISADVANTAGE:

-The output voltage waveforms in such type of stabilizer have distortion due to the saturation effect.

[4.5] THYRISTOR BASED VOLTAGE/POWER CONTROLLER:

Principle:

The output voltage is held constant by selecting appropriate tapping of the auto-transformer.

Capacity: 350VA to 6 KVA

Thyristor based voltage/Power controller is the ideal power conditioning system based on Thyristor and unique digitally controlled.

BLOCK DIAGRAM:

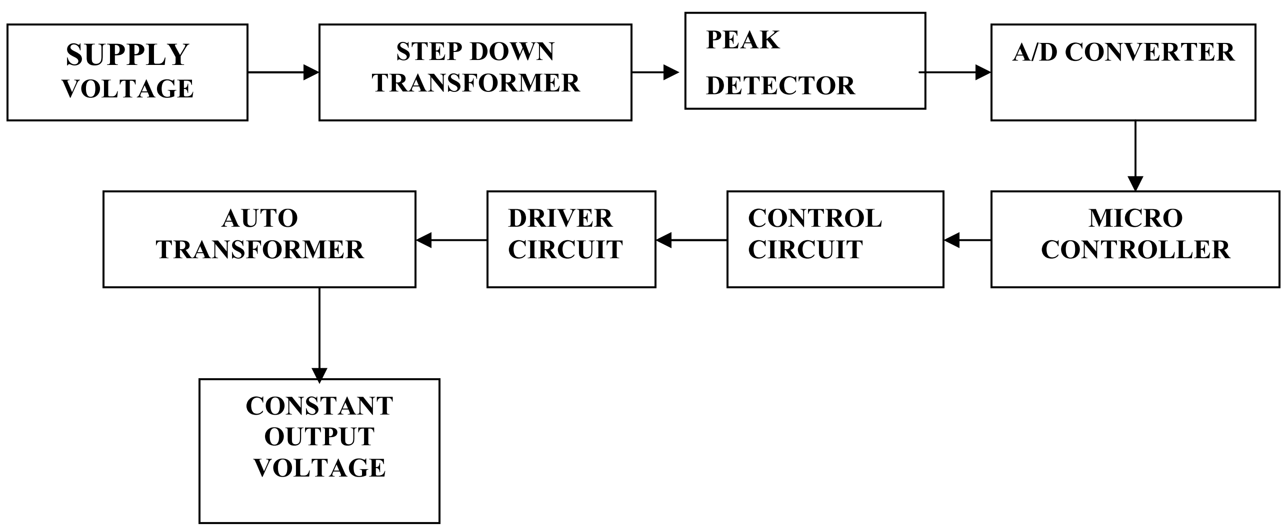


Fig 4.4.1 Block diagram of working of microcontroller based CPP.

Microcontroller is used to sense the input voltage and to trigger the appropriate SCR corresponding to input voltage. Microcontroller reduced the control circuit and also increase the correction rate.

Thyristors are triggered at zero crossing of the supply current. So harmonics produced due to switching are very less. Thyristors are commutated due to natural commutation.

There are also another protection circuits to reduced surges and spikes.

ADVANTAGES:

[1] Microcontroller based circuit.

[2] Zero crossing switching technology.

[3] Less harmonics generates.

[4] No EMI/RFI due to zero crossing switching.

[5] High correction rate.

[6] High efficiency.

[7] Maintenance free device.

DISADVANTAGES:

[1] Surge suppression is less as compared to CVT.

[2] High cost.

Salient features:

- No moving parts, longer life, maintenance free, acoustic noise free, light weight and compact size.
- Digital logic IC and solid state Thyristor based circuitry.
- Zero crossing switching technology.

- Pure sine wave output.
- No EM/RF interference.
- Inbuilt surge and spike suppressor circuitry.
- Very high efficiency.
- High power factor.

Application:

- LAN/File servers
- Intercoms, photo copier, fax & Telex
- Medical electronic equipment.
- Process control instruments.
- CNC based machine
- Computer, TV, Communication system.

Chapter 5
Autotransformer

[5.1] Introduction:

The operational principle and general construction of auto transformer is same as that of conventional transformer. The auto transformer differs from a conventional two winding transformer in a way in which the primary and secondary are inter related. In a conventional two winding transformer, the primary and secondary winding are completely insulated from each other but are magnetically linked by a common core. In the auto transformer, apart of the single continuous winding is common to primary and secondary. The single winding is wound on a single laminated silicon steel core and therefore, both primary and secondary section of this one winding are on the same magnetic circuit.

The auto transformer is of two types in construction. In one type of auto transformer, there is a continuous winding with taps brought out at conventional points, determined by the designed secondary voltages and other of auto transformer, there are two or more distinct coils, which are electrically connected to form a continuous winding, in either case, the same law governing conventional two winding transformers apply equally well to auto transformer.

In auto transformer only a part of the power input is transferred from the primary to secondary by transformer action, while the reminder is transferred directly from the primary to secondary sides electrically. The relative amounts of power transferred and power conductively transferred depends upon the ratio of transformation. The main advantage of auto transformer is saving of material and cost. The auto transformer with tapings is used in voltage stabilizer to make the output voltage constant as mentioned in this project. The selection of taping is done through logic circuitry.

[5.2] Selection of voltage range:

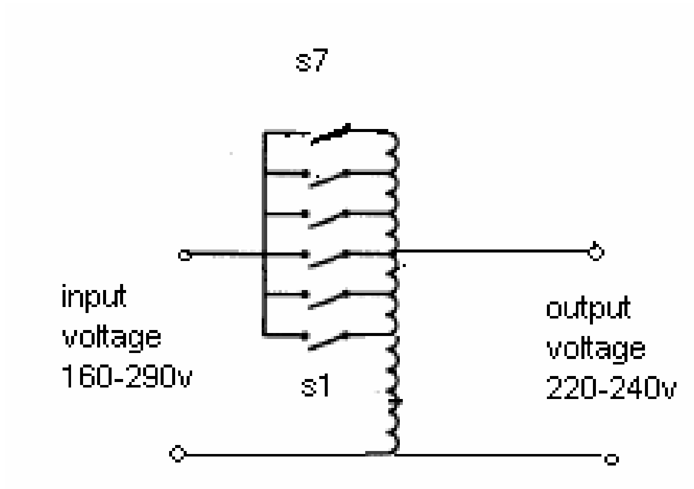


Fig.[5.1] Autotransformer with tap changing arrangement

Input voltage: 175V to 284V

Output voltage: 220V to 240V

Let Vil = min. input voltage of the corresponding tap

Vih = max. Input voltage of the corresponding tap.

Vol = min. output voltage (=220V) at the output side.

Voh = max output voltage (=240V) at the output side.

K = Transformation ratio

Voltage stabilizer works in the range of 175V to 284V.

-So at first tap min. voltage can be applied is 175V.

-Select transformation ratio K1 such that min. output voltage Vol=220V.

-Output voltage should not exceed 240V.

-Therefore max. Input voltage that can be applied on first tap is…..

$$V_{il1} = K_1 * V_{ol}$$

$$K_1 = V_{il1} / V_{ol}$$

$= 175/220$

$K_1 = 0.8$

$V_{ih1} = K_1 * V_{oh}$

$= 0.81 * 240$

$= 191V$

-Therefore max. input voltage, , that can be applied on first tap is 191V

-Therefore first switch will be operate in the range of 175V-191V. At that time other switch will be off.

For tapping 2:

-If input voltage is higher than 191V than second switch will be on & other switch will be off.

-The voltage range on the second tapping can be found in the similar way…

$V_{il2} = K_2 * V_{ol}$

$K_2 = V_{il2} / V_{ol}$

$= 191/220$

$K_2 = 0.87$

$V_{ih2} = K_2 * V_{oh}$

$= 0.79 * 240$

$= 209V$

The voltage range on the second tapping is 191V-209V

For tapping 3:

-If input voltage is higher than 209V than third switch will be on & other switch will be off.

-The voltage range on the third tapping can be found in the similar way…

$$V_{il3} = K_3 * V_{ol}$$

$$K_3 = V_{il3} / V_{ol}$$

$$= 209/220$$

$$K_3 = 0.95$$

$$V_{ih3} = K_3 * V_{oh}$$

$$= 0.95 * 240$$

$$= 228V$$

The voltage range on the third tapping is 209V-228V

For tapping 4:

-If input voltage is higher than 228V than fourth switch will be on & other switch will be off.

-The voltage range on the fourth tapping can be found in the similar way…

$$V_{il4} = K4 * V_{ol}$$

$$K_4 = V_{il4} / V_{ol}$$

$$= 228/220$$

$$K_4 = 1.036$$

$$V_{ih4} = K_4 * V_{oh}$$

$$= 1.036 * 240$$

$$= 249V$$

The voltage range on the fourth tapping is 228V-249V

For tapping 5:

-If input voltage is higher than 249V than fifth switch will be on & other switch will be off.

-The voltage range on the fifth tapping can be found in the similar way…

$$V_{il5} = K_5 * V_{ol}$$

$$K_5 = V_{il5} / V_{ol}$$

$$= 249/220$$

$$K_5 = 1.0875$$

$$V_{ih5} = K_5 * V_{oh}$$

$$= 1.0875 * 240$$

$$= 261V$$

The voltage range on the fifth tapping is 249V-261V

<u>For tapping 6:</u>

-If input voltage is higher than 261V than sixth switch will be on & other switch will be off.

-The voltage range on the sixth tapping can be found in the similar way…

$$V_{il6} = K_6 * V_{ol}$$

$$K_6 = V_{il6} / V_{ol}$$

$$= 261/220$$

$$K_6 = 1.19$$

$$V_{ih6} = K_6 * V_{oh}$$

$$= 1.19 * 240$$

$$= 284.72V$$

The voltage range on the sixth tapping is 261V-285V

Therefore stabilizer will work in the range of 175V-285V for six stepping.

[5.3] Transformer design:

Rating: 1.5KVA, 300V, 6A, power factor=0.85

Voltage per turn can be found out by selecting proper value of K in the following equation

$$E_t = k * \sqrt{Q}$$

Taking k=0.28 for small single phase shell type transformer

$$E_t = 0.28*\sqrt{1.5}$$
$$= 0.35V$$

Flux in the central limb,

$$\Phi_m = E_t / (4.44*f)$$
`
$$= 0.35/ (4.44*50)$$
$$= 1.57* 10^{-3}\ W_b$$

Taking flux density 1.09 W_b /m^2 for single phase shell type transformer, net iron area of the core will be

$$A_i = \Phi_m / B_m$$

$$=1.57 * 10^{-3}/1.09$$
$$= 1440 * 10^{-6}$$

$= 1440\ mm^2$

Let us take staking factor 0.9 for laminated core gross iron area

$A_{gi} = 1440/0.9$

$= 1600\ mm^2$

Taking the ratio b/2a=1; where b= depth of core, a= width of side limb,

$b/2a = 1600\ mm^2$

width of central limb 2a= 40mm

depth of frame b= 1*2a

= 40mm

the side limb carry half of the flux and therefore their width is equal to half of the width of central limb or width of the side limb a=20mm

Design of winding:

Taking efficiency of the auto transformer 95%

Ip =1500/ (0.95*178)

=8.87 A

This current is divided into two part, 7.27A goes to secondary winding, where load is connected and 1.6A goes to common winding.

Therefore current through the winding is 7.27A

Taking current density $\delta = 5A / mm^2$

$A_p = 7.27/5$

$= 1.45$ mm

Therefore nearest standard size of wire is 1.42 mm diameter and 17 gauge

Taking the same current density in the common winding, current in the common winding,

$A_c = 1.65 / 5$

$= 0.33\ mm^2$

Taking the nearest value of conductor area = 0.292 mm^2, diameter= 0.610mm, 23 gauge

<u>Window dimension</u>:

-Diameter of primary conductor is 1.45mm & diameter of insulated conductor 1.5mm
-Diameter of insulated conductor in the common winding is 0.685mm [=0.61+0.075]
-Height of bobbin = 54mm
-No. of turns in one layer =78.83
-Common wire has 536 turns, so total 7 layers are required of diameter 0.685mm
Remaining 247 turns are of diameter 1.49mm (=1.42+0.075)
-So in vertical height we can accommodate 36 conductor
- So other 7 layers are of 1.49mm conductor required.

Taking 1.3mm insulation thickness between winding and core

Total width of window required

$W_w = (7*0.685 + 7*1.49 + 2*1.3)$

$= 17.825$mm

$= 18$mm

Area of window

$Aw = 56*18$

$= 1008\ mm^2$

area of conductor,

$ac = [0.685*536 + 1.49*247]$

$= 367.16 + 368.03$

$= 735.19\ mm^2$

window space factor,

K_w = copper area in the window / total window area

= 735.19 / 1008

= 0.729

Chapter 6
Control circuit design

[6.1] Introduction:

Control circuit in this project mainly serves three functions in this project:

[1] Measurement of the line voltage:

In this portion first voltage is stepped down by step down transformer. Then this voltage is applied to A/D converter via peak detector or rectifier. A/D converter converts analog voltage into digital voltage. This voltage is applied to input port of micro controller. Depending upon program Microcontroller measures the input voltage.

[2] Selection of the taping of auto transformer:

From measurement Microcontroller select particular tapping of auto transformer by giving zero crossing pulses to triac, connected tom taping of Microcontroller.

[3] Generating Zero crossing pulses:

In this project triacs are working as static switches. To trigger the triac at zero crossing of the voltage wave, zero crossing pulses are required.

[6.2] PEAK DETECTOR:

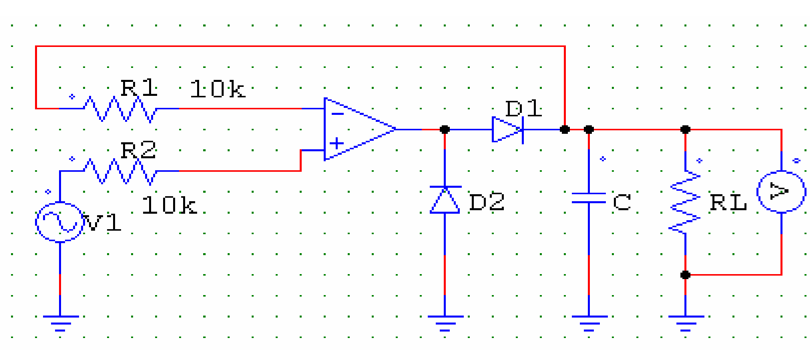


Fig. 6.2.1 circuit diagram of peak detector

Fig. 6.2.1 shows a peak detector that measures the positive peak value of the sine wave input. During the positive half cycle of $V_{in,}$ the output of the op-amp drives D1 on, charging capacitor C to the positive peak value V_p of the input voltage $V_{in.}$ Thus when D1 is forward biased, the op-amp operates as a voltage follower. On the other hand, during the negative half cycle of V_{in} diode D1 is reversed biased, and voltage across C is retained. The only discharge path for C is through $R_{l.}$ Since the input bias current I_b is negligible. For proper operation of the circuit, the charging time constant (CR_d) and discharging time constant (CR_l) must satisfy the following condition:

$$CR_d \leq T/10 \quad [1]$$

Where R_d = Resistance of the forward biased diode, 100Ω, typically

T= Time period of the input waveform

And

$$CR_l \geq 10T \quad [2]$$

Where R_l is load resistor.

If R_l is very small so that eq. [2] cannot be satisfied, use a buffer (voltage follower) between capacitor C and resistor R_l . Although a 741- type op-amp is used in the circuit, a high speed precision type op-amp such as μA771 or μA714 may be desirable in critical operation. The resistor R is used to protect the op-amp against the excessive discharge currents, especially when the power supply is switched off. The resistor R_{om} =R minimize the offset problem caused by input currents. In addition, diode D2 conduct during the negative half cycle of Vin and hence prevents the op-amp from going into negative saturation. This in turn helps to reduce the recovery time of the op-amp. Negative peaks of input signal Vin can be detected simply by reversing diodes D1 and D2.

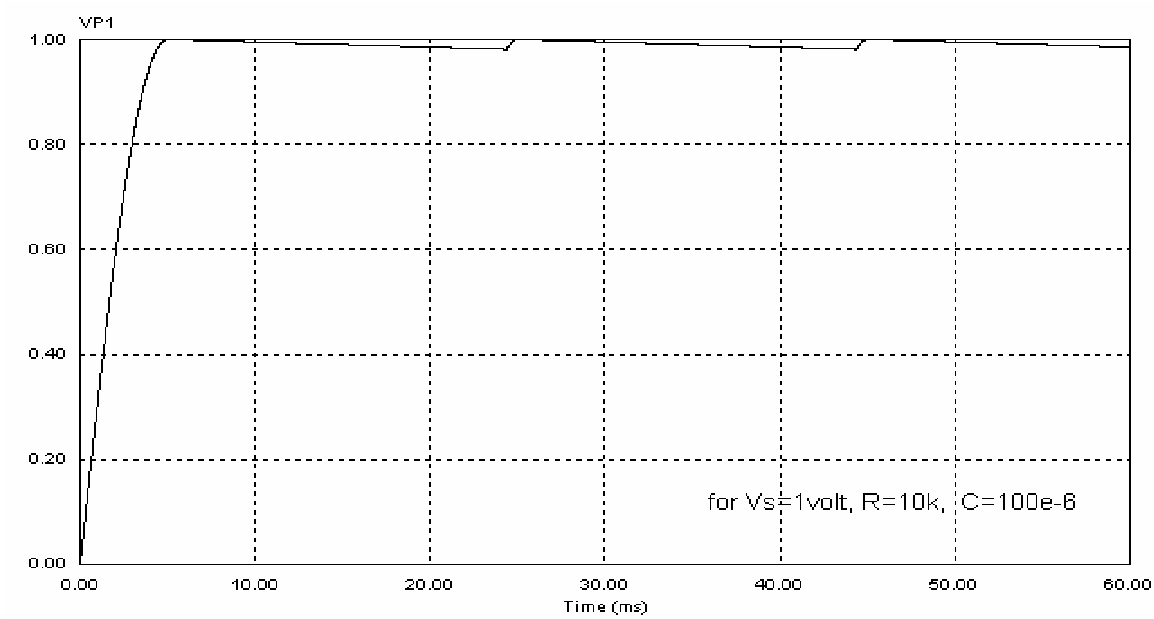


Fig.6.2.2 Output waveform of peak detector

As shown in the wave form peak detector give dc voltage corresponding to peak value of the ac voltage. the dynamic response of this circuit is very poor because for correct output, discharging time of 100uf capacitor is 10T. So peak detector can not responses rapid changes in the input wave. Therefore peak detector has been obsolete from the circuit and program has been written of the function of peak detector. By programming its response time is increased from 0.2s to 10ms.

[6.3] Zero crossing switching circuit:

Fig.5.3.1 shows a zero crossing detector circuit. This circuit generates pulses at the zero crossing of the ac voltage waveforms. In this circuit ac voltage is rectified with full wave rectifier. This rectified dc voltage have peak value around 16.97V. This rectified dc voltage is compared with fix 1 volt dc. Fix dc voltage is applied at the non inverting terminal of the comparator rectified dc voltage is applied at the inverting terminal of the comparator LM324.

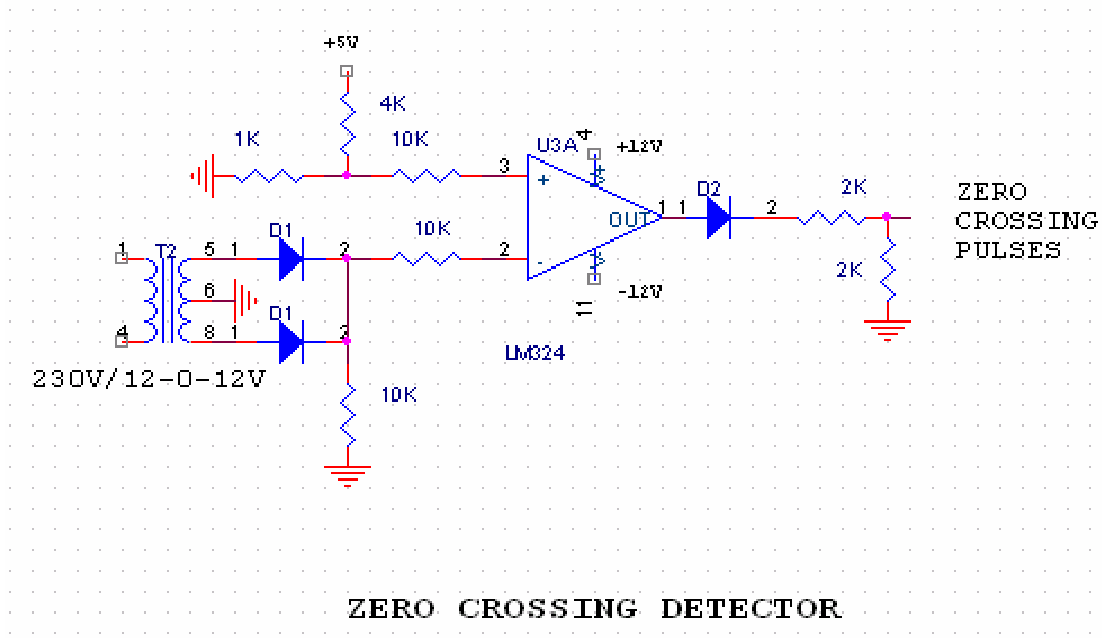


Fig. 6.3.1 Zero crossing switching circuit

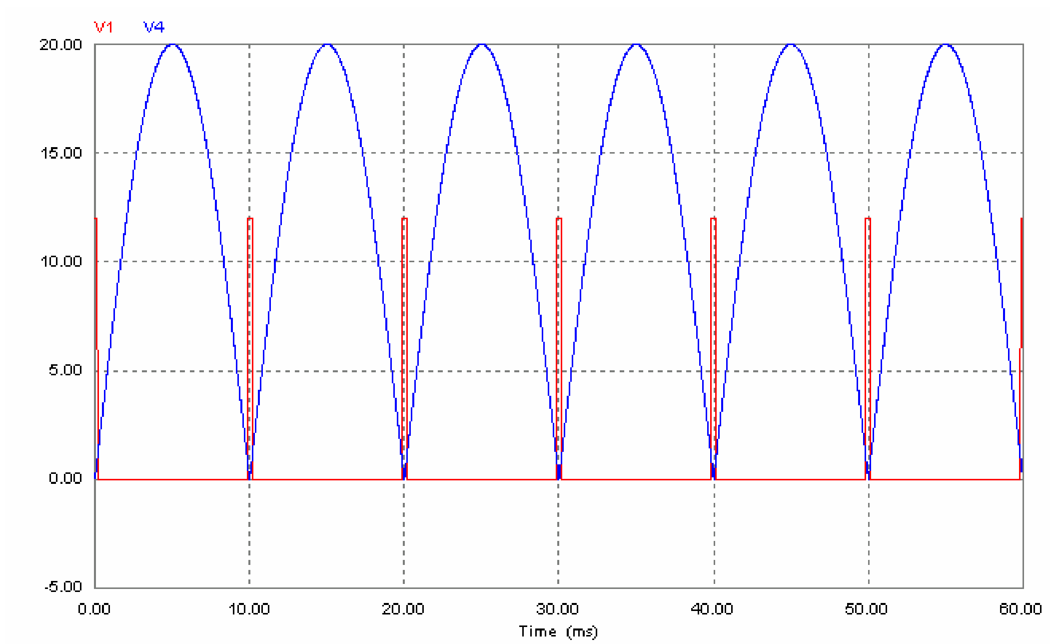


Fig. 6.3.2 output waveform of zero crossing switching circuit

When fix voltage is higher than rectified voltage, output will be positive saturation voltage of the LM324, otherwise output will be negative saturation voltage. A diode is connected at the output of comparator. It blocks the negative saturation voltage. So when fix 1 volt is higher than varying dc voltage pulse will be generated, otherwise output will be zero. Two resistor forms a voltage divider circuit that gives 1 volt from 7805IC.

$$V2 = [R2 / (R1 + R2)] * V$$
$$= [1K / (1K+4K)] * 5$$
$$= 1V$$

The pulse width can be found from the following equations:

The times the output remains high will be double when output reaches 1 volt from 0 volt. Therefore by finding the time of instantaneous voltage, we can find the pulse width. This time can be found out by the instantaneous equation of voltage.

Let, v = instantaneous dc voltage

V_m = peak dc voltage

f = supply frequency

w = 2Πf

$$v=Vm \sin wt$$
$$1 = 12 * \sqrt{2} * \sin 2\Pi ft$$
$$1 = 16.97 \sin (100 \Pi t)$$
$$100 \Pi t = \sin^{-1}(1/16.97)$$
$$= \sin^{-1}(0.059)$$
$$t= 1.87 * 10^{-4} \text{ sec}$$
$$t = 0.187 \text{ mili second}$$

Therefore pulse width will be double of this time.

$$Ton = 2*t$$
$$= 2 * 0.187 *10-3$$
$$= 0.375 \text{ ms}$$

$= 375.36\ \mu s$

This is sufficient pulse width for triggering triacs and scrs. Thus pulse width depends upon frequency, supply voltage and fix dc voltage. We can vary the pulse width by varying fix dc voltage.

[6.4] Control circuit with peak detector in the circuit:

Fig. 8.4.1 shows control circuit diagram of CPP. The initial part of the circuit is Peak detector that have discussed. Output of peak detector goes to A/D converter, Which convert i/p voltage to digital voltage. The output of which is goes to input port of micro controller. The input voltage is measured by microcontroller and according to that triggering appropriate triac controls input voltage. Microcontroller gives triggering signal to AND gate. Output pin of AND gate is connected to driver circuit's optocoupler

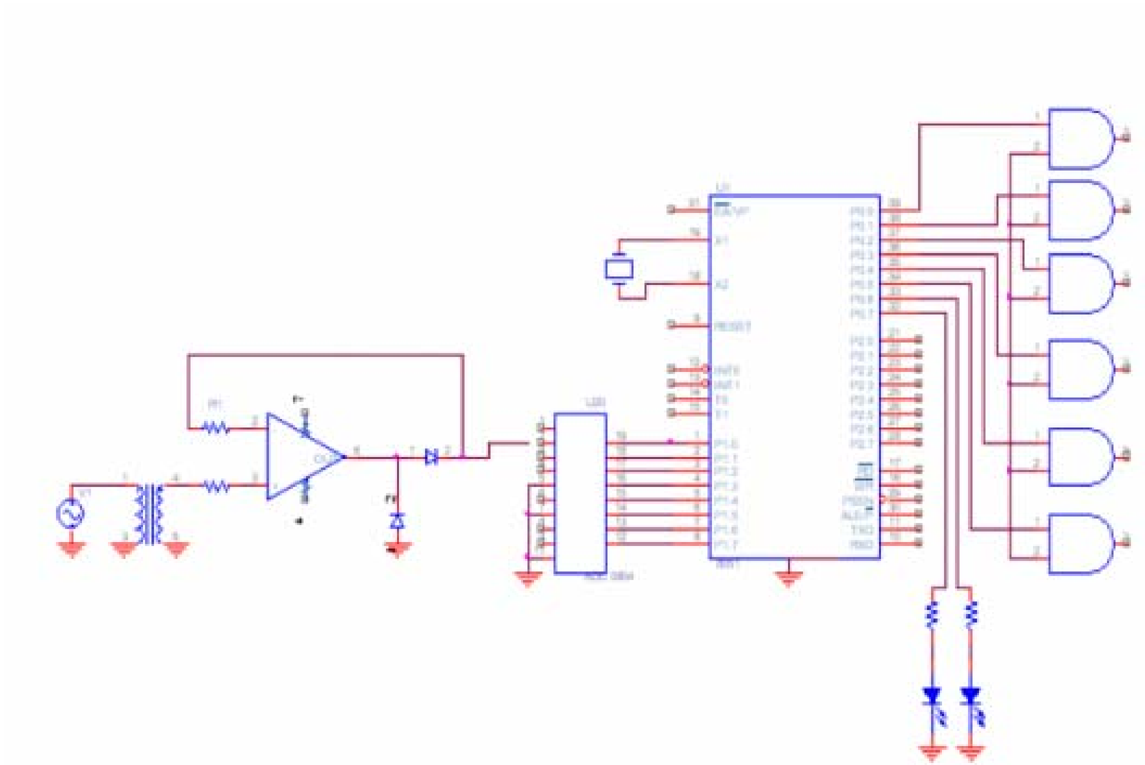


Fig.6.4.1 Control circuit diagram with peak detector in the circuit

.

The above circuit though works accurately, but its dynamic response is poor. The main reason for this disadvantage is peak detector. So, finally peak detector is eliminated from the circuit and the function of the peak detector is programmed. The modified circuit is shown below.

[6.5] Control circuit diagram without peak detector in the circuit

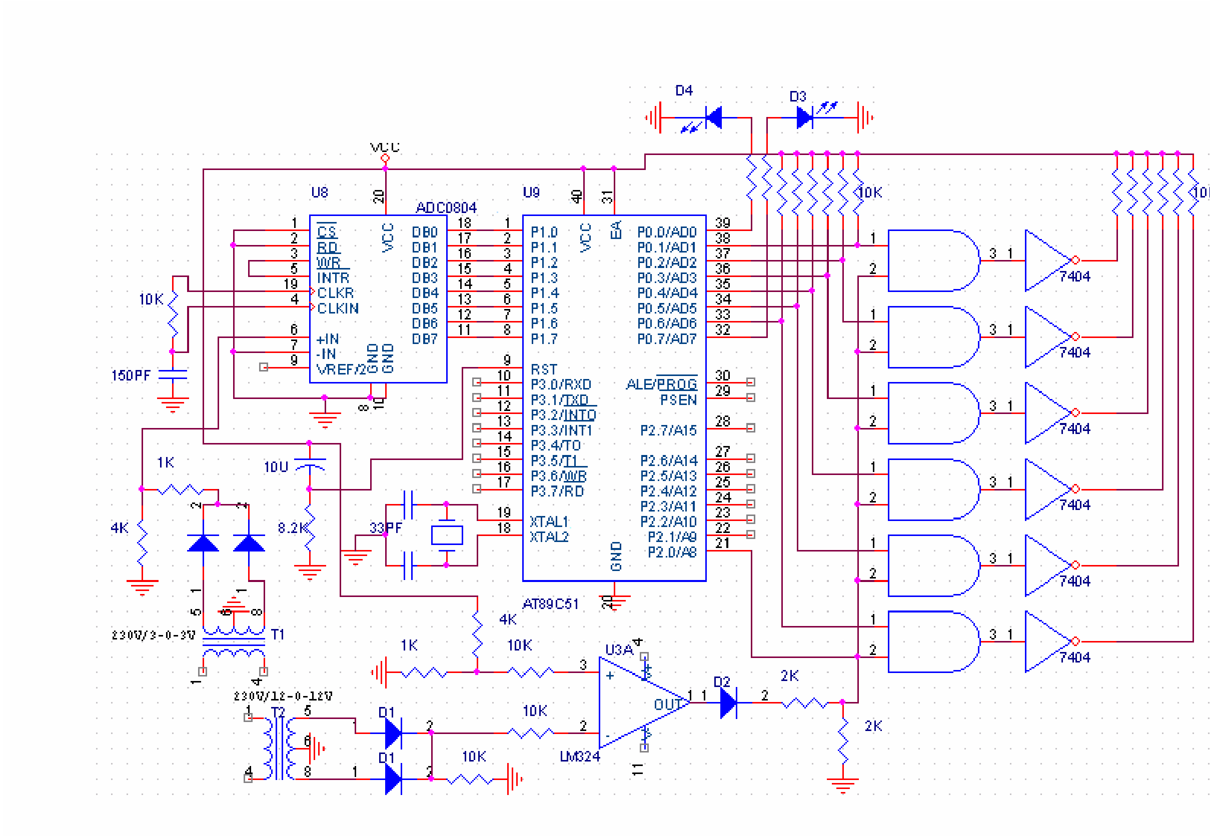


fig 6.5.1 Control circuit without peak detector in the circuit

fig 6.5.1 shows the control circuit of the project. There are two transformers in the circuit. 230V / 3-0-3V is a sensing transformer. This transformer senses the input voltage. It steps down the voltage in the above ratio. Two diodes rectify this voltage. The rectified voltage should lie in the input voltage range of the of a/d converter. Here in this case peak value of the rectified voltage should be less than 5 volt for correct operation of the circuit. When mains voltage is 285V, the highest voltage for which CPP is designed. With 230 / 3-0-3V transformer the peak value of the rectified voltage will be,

$$V_p = \sqrt{2} * 285 * 3 /230$$
$$= 5.25V$$

So, analog input voltage to the a/d converter is higher than VCC. To reduce the voltage we are using voltage divider of 4KΩ and 1KΩ. So input voltage to the a/d converter will reduce by…

$$V_{i/p} = 5.25 * 4/ (1+4)$$
$$= 4.2V$$

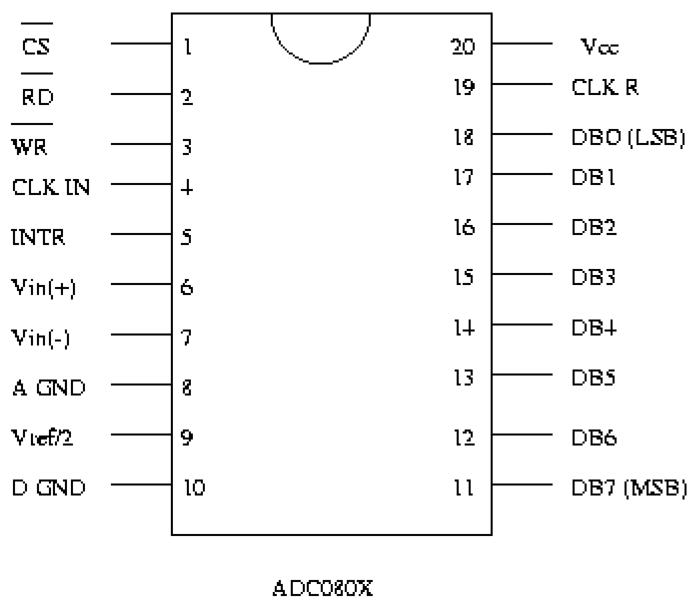


Fig. 6.5.2 Pin diagram of A/D converter

This analog voltage is converted into digital voltage by a/d converter ADC0804. The a/d converter works on the principle of successive approximation techniques.

Let N be the number of bits, for the A/D converter, the output is calculated as:

For example, if Vref = 5 V, Vin = 3.2 V, N = 8 bits, Vo = 256/5*3.2 = 163.84 = 10100011 (binary).

The ADC080X series of chips are inexpensive 8bit successive approximation A/D converter. The logic inputs and output are compatible with both TTL and CMOS, and the outputs have tri-state capability. The chips are general purpose ADCs that can be used as stand alone converter or interfaced with microcontroller, microprocessor or computer. They accept differential inputs for increased common mode noise rejection capability. The digitalized output thus measures the voltage difference V_{in+} - V_{in-}.

The clock can originate from either an external or internal source. The self-clocking option uses an on chip oscillator (with Schmitt – trigger timing input), in combination with an external resistor and capacitor that determine the period.

When CS pin goes low the chip will be enabled. Otherwise it ignore every input. The converter is started by having CS AND wr simultaneously low. On the high to low transition of wr input, the internal SAR latches and the shift resistor stages are resets and the intr output will be set high as long as the cs input and wr input remain low, The a/d will remain in a reset state. Conversion will start from 1 to 8 clock periods after one of this inputs makes a low to high transition. After the required no. of clock pulses to complete the conversion, a read operation will clear the intr line high again. The device may be operated in free running mode by connecting intr to the wr input with CS=0.to ensure start up under all possible condition, an external WR pulse is required during the first power up cycle.

In this project ADC0804 is working in free running mode The resistor and capacitors connected to pin 19 & pin 4,are used for generating internal clock cycle of 640 KHz. with 8888 conversion per second. Analog and digital GND are combined at every change of 19.53 mv in the input, output will be changed from 0 to 1

The A/D converter can be tested by connecting LEDs with resistors at the output pin of A/D converter.

Error in the voltage measurement:

There is 8 bit A/D converter in this project. Therefore accuracy of A/D will be

Accuracy = $5/2^8$

= 20 mv

Therefore output will be change for every 20mv change in input. Hence output of A/D converter will be change for every change in peak detector value

= 20mv * 10.3/8.1

= 24.84mv

Hence output of A/D converter will change for every change supply voltage

=24.84*223 / (3*1000)

= 1.85V

Therefore output of a/d converter will not change till there is change of 1.85V in supply voltage occurs. Hence error in measurement is 1.85V. For getting higher accuracy we can go for higher bits of A/D converter.

Chapter 7

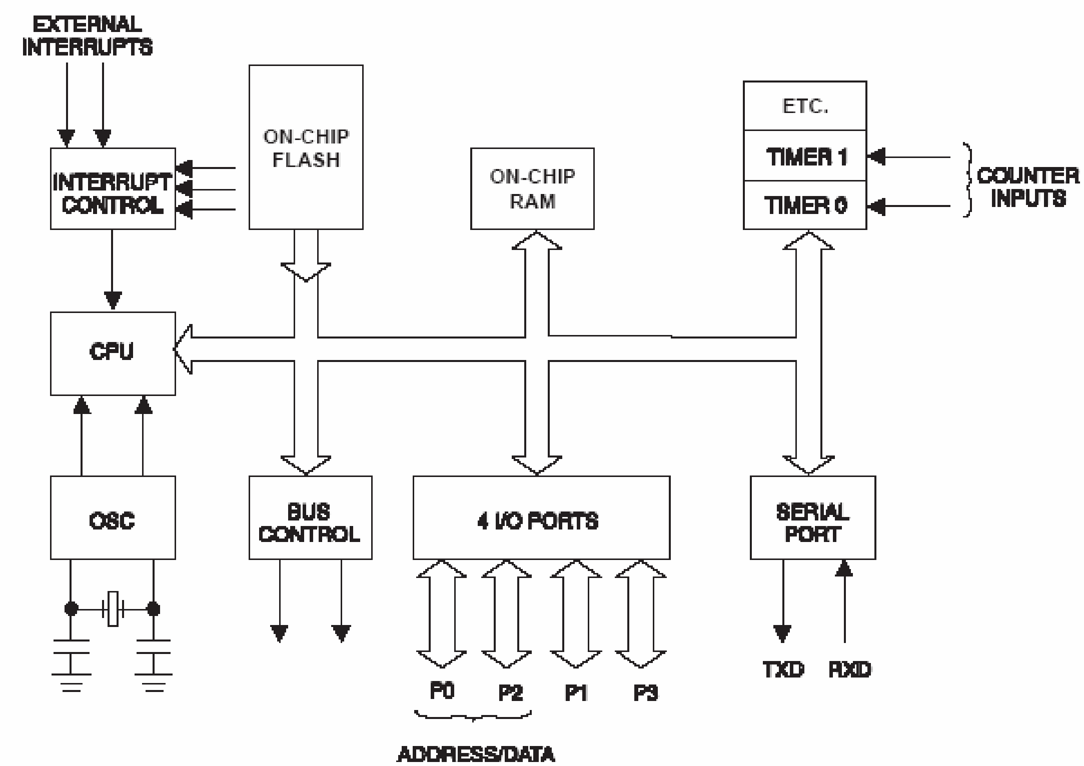
Architectural Overview of AT89C51 Microcontroller

[7.1] Introduction:

In this project micro controller AT89C51 is used as controlling device. It has advanced feature than 8051 micro controller. In this chapter architecture of microcontroller, separation of program memory and data memory, input output ports etc are described. This study of architecture is useful in programming of micro controller.

Block Diagram

Figure 1. Block Diagram of the AT89C core



[7.2] Features:

The At89C51has following features:

• 8-Bit CPU Optimized for Control Applications
• Extensive Boolean Processing Capabilities (Single-Bit Logic)
• On-Chip Flash Program Memory
• On-Chip Data RAM
• Bidirectional and Individually Addressable I/O Lines
• Multiple 16-Bit Timer/Counters
• Full Duplex UART
• Multiple Source/Vector/Priority Interrupt Structure
• On-Chip Clock Oscillator
• On-chip EEPROM (AT89S series)
• SPI Serial Bus Interface (AT89S Series)
• Watchdog Timer (AT89S Series)

The basic architectural structure of the AT89C51 core

[7.3] Memory Organization

Logical Separation of Program Data Memory

All Atmel Flash microcontrollers have separate address spaces for program and data memory, as shown in Figure 3. The logical separation of program and data memory allows the data memory to be accessed by 8-bit addresses, which can be more quickly stored and manipulated by an 8-bit CPU. Nevertheless, 16-bit data memory addresses can also be generated through the DPTR register.

Program memory can only be read. There can be up to 64K bytes of directly addressable program memory. The read strobe for external program memory is the Program Store Enable signal (PSEN).

Data memory occupies a separate address space from program memory. Up to 64K bytes of external memory can be directly addressed in the external data memory space. The CPU generates read and write signals, RD and WR, during external data memory accesses.

External program memory and external data memory can be combined by applying the RD and PSEN signals to the input of an AND gate and using the output of the gate as the read strobe to the external program/data memory.

Program Memory

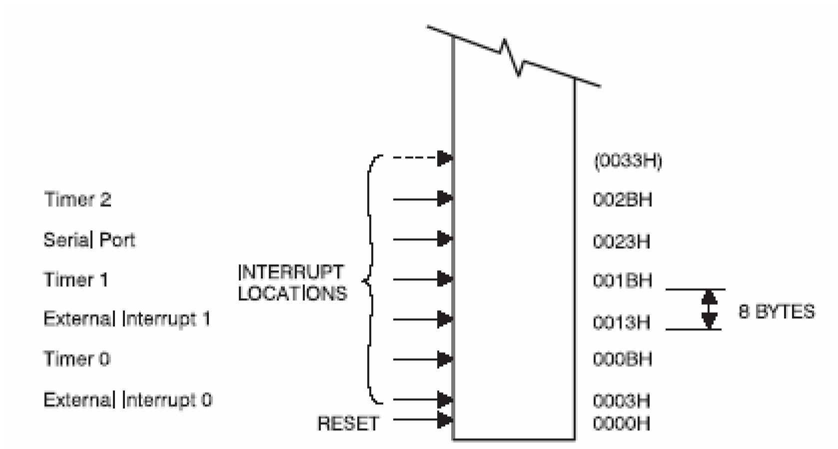
Figure 7.3.1 shows a map of the lower part of the program memory. After reset, the CPU begins execution from location 0000H.

As shown in Figure 7.3.1, each interrupt is assigned a fixed location in program memory. The interrupt causes the CPU to jump to that location, where it executes the service routine. External Interrupt 0, for example, is assigned to location 0003H. If External Interrupt 0 is used, its service routine must begin at location 0003H. If the interrupt is not used, its service location is available as general purpose program memory. The interrupt service locations are spaced at 8-byte intervals: 0003H for External Interrupt 0, 000BH for Timer 0, 0013H for External Interrupt 1, 001BH for Timer 1, and so on. If an interrupt service routine is short enough (as is often the case in control applications), it can reside entirely within that 8-byte interval. Longer service routines can use a jump instruction to skip over subsequent interrupt locations, if other interrupts are in use.

The lowest addresses of program memory can be either in the on-chip Flash or in an external memory. To make this selection, strap the External Access (EA) pin to either VCC or GND.

For example, in the AT89C51 with 4K bytes of on-chip Flash, if the EA pin is strapped to VCC, program fetches to addresses 0000H through 0FFFH are directed to the internal Flash. Program fetches to addresses 1000H through FFFFH are directed to external memory. In the AT89C52 (8K bytes Flash), EA = VCC selects addresses 0000H through 1FFFH to be internal and addresses 2000H through FFFFH to be external. If the EA pin is strapped to GND, all program fetches are directed to external memory. The read strobe to external memory, PSEN, is used for all external program fetches. Internal program fetches do not activate PSEN.

Fig7.3.1**.** Program Memory



Data Memory

The right half of Fig shows the internal and external data memory spaces available on Atmel's Flash microcontrollers. Figure 6 shows a hardware configuration for ccessing up to 2K bytes of external RAM. In this case, the CPU executes from internal Flash. Port 0 serves as a multiplexed address/data bus to the RAM, and 3 lines of Port 2 are used to page the RAM. The CPU generates RD and WR signals as needed during external RAM accesses. You can assign up to 64K bytes of external data memory. External data memory addresses can be either 1 or 2 bytes wide. One-byte addresses are often used in conjunction with one or more other I/O lines to page the RAM, as shown in Figure. Two-byte addresses can also be used, in which case the high address byte is emitted at Port 2.

Internal data memory is shown in Figure 7. The memory space is divided into three blocks, which are generally referred to as the Lower 128, the Upper 128, and SFR space

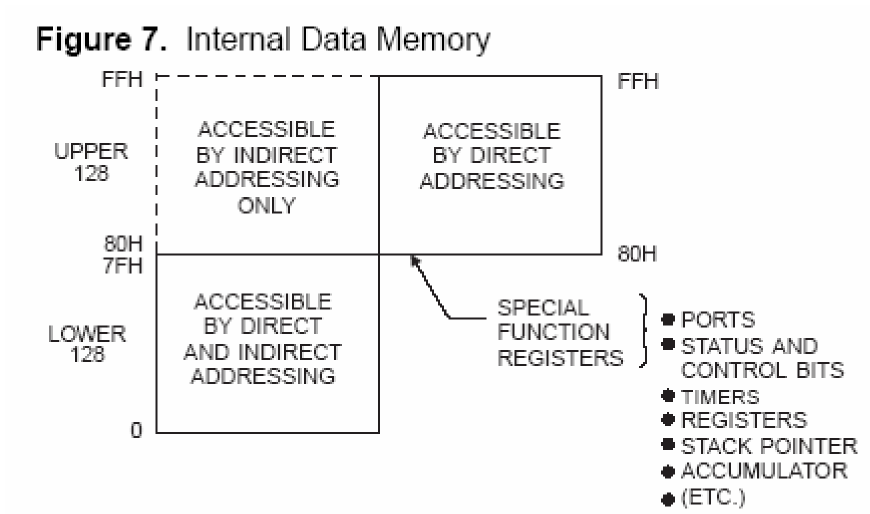
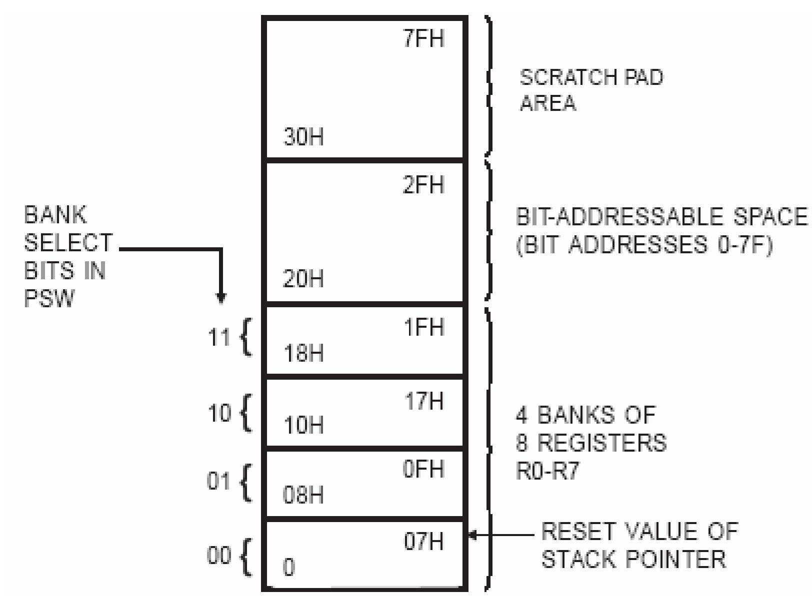


Fig. 7.3.2 the Lower 128 Bytes of Internal RAM



Internal data memory addresses are always 1 byte wide, which implies an address space of only 256 bytes. However, the addressing modes for internal RAM can in fact accommodate 384 bytes. Direct addresses higher than 7FH access one memory space, and indirect addresses higher than 7FH access a different memory space. Thus, Figure 7 shows the Upper 128 and SFR space occupying the same block of addresses, 80H through FFH, although they are physically separate entities. Figure 8 shows how the lower 128 bytes of RAM are mapped. The lowest 32 bytes are grouped into 4 banks of 8 registers. Program instructions call out these registers as R0 through R7. Two bits in the Program Status Word (PSW) select which register bank is in use. This architecture allows more efficient use of code space, since register instructions are shorter than instructions that use direct addressing.

The next 16 bytes above the register banks form a block of bit-addressable memory space. The microcontroller instruction set includes a wide selection of single-bit instructions, and these instructions can directly address the 128 bits in this area. These bit addresses are 00H through 7FH. All of the bytes in the Lower 128 can be accessed by either direct or indirect addressing. The Upper 128 (Figure 9) can only be accessed by indirect addressing. The Upper 128 bytes of RAM are only in the devices with 256 bytes of RAM.

[7.4] Port configuration

Port 0

Port 0 is an 8-bit open-drain bi-directional I/O port. As an output port, each pin can sink eight TTL inputs. When 1s are written to port 0 pins, the pins can be used as high mpedance inputs. Port 0 may also be configured to be the multiplexed loworder address/data bus during accesses to external program and data memory. In this mode P0 has internal pullups.

Port 0 also receives the code bytes during Flash programming, and outputs the code bytes during program verification. External pullups are required during program verification.

Port 1

Port 1 is an 8-bit bi-directional I/O port with internal pullups. The Port 1 output buffers can sink/source four TTL inputs. When 1s are written to Port 1 pins they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current (IIL) because of the internal pullups.

Port 1 also receives the low-order address bytes during Flash programming and verification.

Port 2

Port 2 is an 8-bit bi-directional I/O port with internal pullups. The Port 2 output buffers can sink/source four TTL inputs. When 1s are written to Port 2 pins they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current (IIL) because of the internal pullups.

Port 2 emits the high-order address byte du ing fetches from external program memory and during accesses to external data memory that use 16-bit addresses (MOVX @ DPTR). In this application, it uses strong internal pullups when emitting 1s. During accesses to external data memory that use 8-bit addresses (MOVX @ RI), Port 2 emits the contents of the P2 Special Function Register. Port 2 also receives the high-order address bits and some control signals during Flash programming and verification.

Port 3

Port 3 is an 8-bit bi-directional I/O port with internal pullups. The Port 3 output buffers can sink/source four TTL inputs. When 1s are written to Port 3 pins they are pulled high by the internal pullups and can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (IIL) because of the pullups. IIL) Port 3 also serves the functions of various special features of the AT89C51 as listed below:

Port 3 also receives some control signals for Flash programming and verification.

Port Pin Alternate Functions

P3.0 RXD (serial input port)
P3.1 TXD (serial output port)
P3.2 INT0 (external interrupt 0)
P3.3 INT1 (external interrupt 1)
P3.4 T0 (timer 0 external input)
P3.5 T1 (timer 1 external input)
P3.6 WR (external data memory write strobe)
P3.7 RD (external data memory read strobe)

RST

Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device.

ALE/PROG

Address Latch Enable output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input (PROG) during Flash programming.

In normal operation ALE is emitted at a constant rate of 1/6 the oscillator frequency, and may be used for external timing or clocking purposes. Note, however, that one ALE pulse is skipped during each access to external Data Memory. If desired, ALE operation can be disabled by setting bit 0 of SFR location 8EH. With the bit set, ALE is active only during a MOVX or MOVC instruction. Otherwise, the pin is weakly pulled high. Setting the LE-disable bit has no effect if the microcontroller is in external execution mode.

Chapter 8

Microcontroller based Programming

[8.1] flow chart of control strategy:

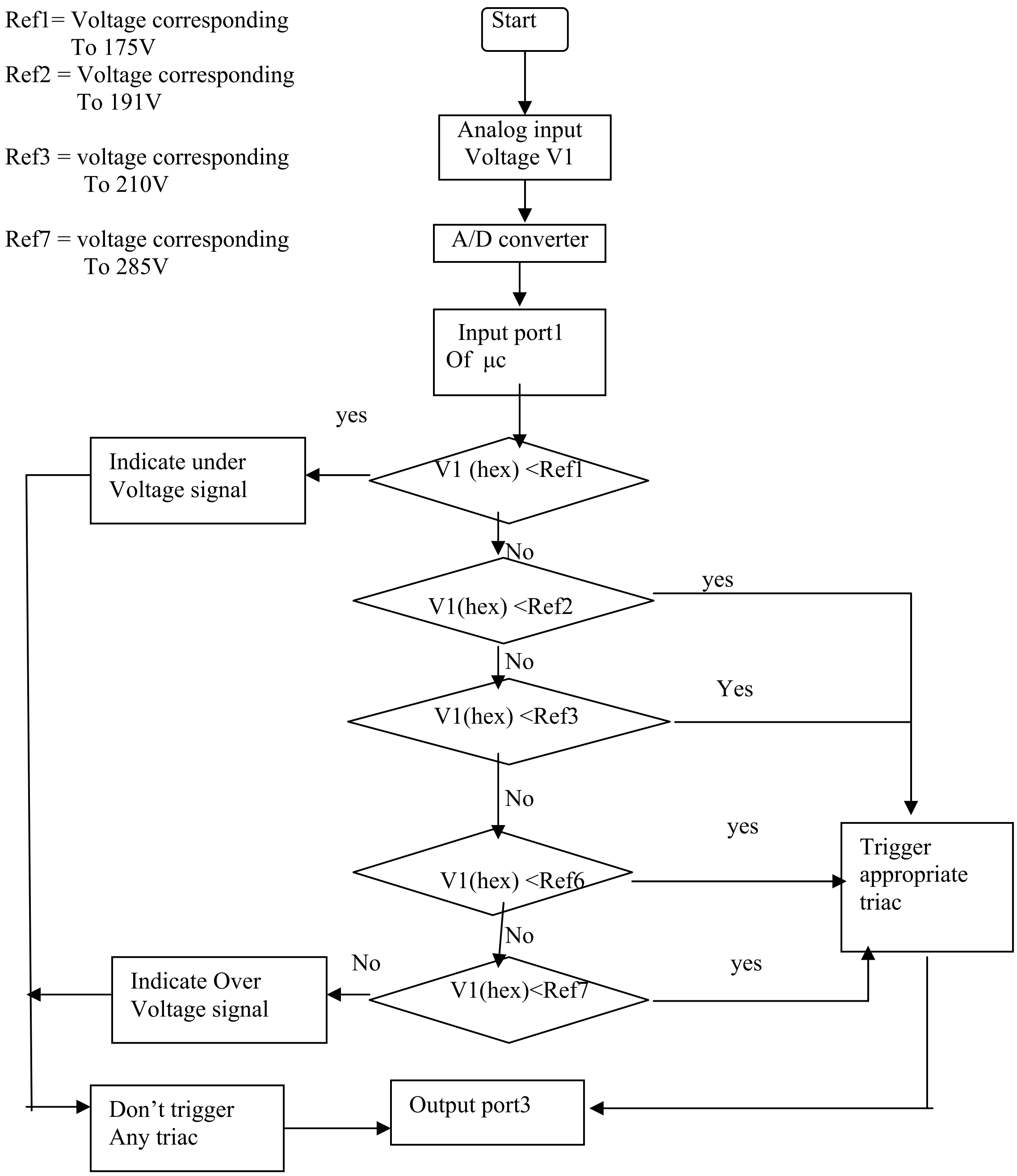


FIG.8.1 FLOWCHART OF WORKING OF MICROCONTROLLER BASED CPP

[8.2] Working of the program:

Fig. 6.1 shows a flowchart of working of microcontroller based constant power purifier with peak detector in the circuit. First of all mains voltage is first stepped down by step down transformer 0f 230/3-0-3V. This voltage is applied to peak detector. The output voltage of peak detector is DC voltage equal to peak value of AC voltage. The working of peak detector is shown in chapter 8. As the supply voltage changes output also changes.

Output of peak detector is applied to A/D converter. A/D converter converts analog voltage corresponding to digital voltage. Suppose analog voltage is V1. Then output of A/D converter is V1 (hex), which is 8 bit digital value. The A/D converter is connected to the input port 1 of micro controller. From input port, this value is copied to accumulator. Then by program this value is compared with reference 8 bit hex value. The lowest voltage available from the CPP is 175 volt. So ref1 is the 8bit digital value corresponding to 175V. In a same way ref2 corresponding to 191V.

Reference value	Ref1	Ref2	Ref3	Ref4	Ref5	Ref6	Ref7
Corresponding voltage (V)	175	191	209	228	249	261	285

Table 8.1: reference value and corresponding voltage

If the voltage is less is less than 175V then output 8 bit digital value of A/D converter will be less than ref1. So, micro controller will send the value 0000 0001 at port 0. LSB and MSB pin of port 0 is connected with U/V and O/V under voltage LEDs respectively as shown in the control circuit chapter. The remaining 6 pin is connected to 6 AND gate’s one of the two pin. The other pin of all this AND gate is connected to zero crossing pulse generating circuit. When zero crossing pulse will anded with 0 the output of AND gate will be zero. So any triac would not get pulses and load is disconnected from the supply. The same thing happens in the case of voltage above 285V. In that case micro controller sends 1000 0000 to output port.

If the voltage is between 175V to 191V micro controller will send 0000 0010 value to the output port. So first AND gate's pin will be high and remaining will be low. So when zero crossing pulse arrive only first and gate will generate the pulse and remaining AND gates have zero output. So as per control circuit only first triac will be triggered And voltage will step up to 220V. If the voltage exceeds 191V then second triac will be triggered and remaining will be off. In this way only one triac would be triggered corresponding to input voltage.

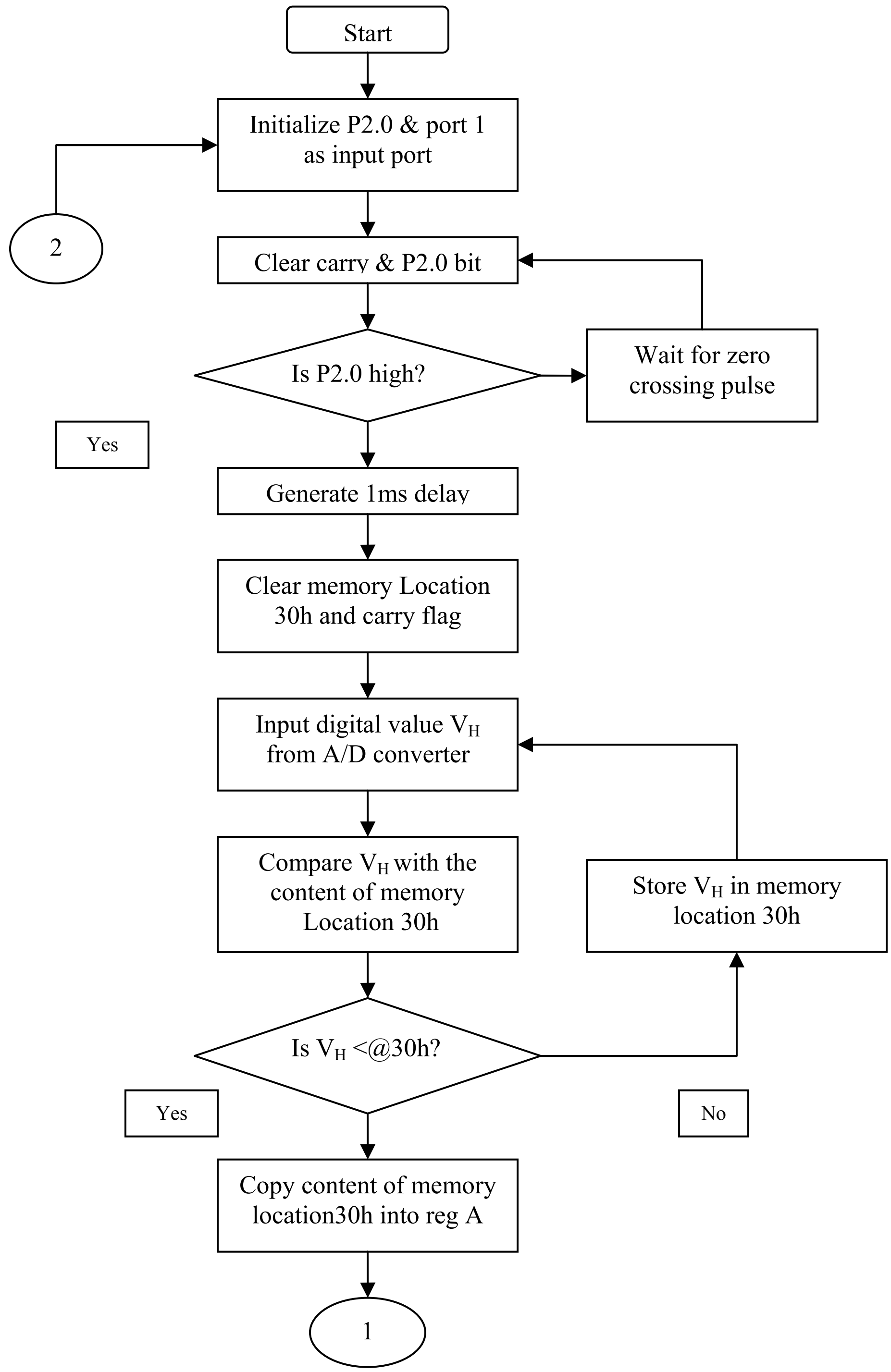
[8.3] Program written in micro controller AT89C51:

```
        . org 0000h
start:  clr c                   ; clear carry flag
        clr a                   ; clear accumulator
        mov 21h,#01h            ; 01h= 0000 0001 U/V signal
        mov 22h,#02h            ; 02h= 0000 0010 select first triac
        mov 23h,#04h            ; 04h= 0000 0100 select third triac
        mov 24h,#08h            ; 08h= 0000 1000 select third triac
        mov 25h,#10h            ; 10h= 0001 0000 select fourth triac
        mov 26h,#20h            ; 20h= 0010 0000 select fifth triac
        mov 27h,#40h            ; 40h= 0100 0000 select sixth  triac
        mov 28h,#80h            ; 80h= 1000 0000 O/V signal

        mov 90h,#FFh            ; port 1 work as input port
        mov A,90h               ; move data from port 1 to acc
        mov 20h,a               ; copy content of accumulator to memory
                                  location 20h
```

```
        cjne A,#X1 ,H1          ; compare input voltage with lower voltage
                                  range 175V.
    H1: jc K1                   ; If input voltage is less than 175V go to
                                  loop  K1
      cjne A,#X2,H2             ; compare input voltage with 192V

H2:     jc K2                   ; if input voltage is less than 192V go to
        cjne A,#X3,H3             loop K2 (range 178V –192)

H3:     jc K3                   ; (range 192-210)
        cjne A,#X4,H4

H4:     jc k4                     ; (range 210–230)
        cjne A,#X5,H5

H5:     jc k5                     ; (range 230V – 249)
        cjne A, #X6,H6

H6:     jc k6                     ; (range 249V –261V)
        cjne A,#X7,H7

H7:     jc K7                     ; (range 261V –285V)

        jmp K8
K1:     setb 0A0h                 ; give under voltage signal
        jmp Here
K2:    mov A, 21h                 ; selection of triac1
       mov  0B0, A
       jmp Here
K3:    mov A, 22h                 ; selection of triac2
       mov  0B0, A
```

```
        jmp Here

K4:     mov A, 23h                          ; selection of triac3
        mov  0B0, A
        jmp Here

K5:     mov A, 24h                          ; selection of triac4
        mov  0B0, A
        jmp Here

K6:     mov A, 25h                          ; selection of triac5
        mov  0B0, A
        jmp Here

K7:     mov A, 26h                          ; selection of triac6
        mov  0B0, A
        jmp Here

K8:     setb 0A1                            ; give over voltage signal
        jmp here

Here:  jmp start
```

[8.4] Flow chart of the program execution for control circuit without peak detector



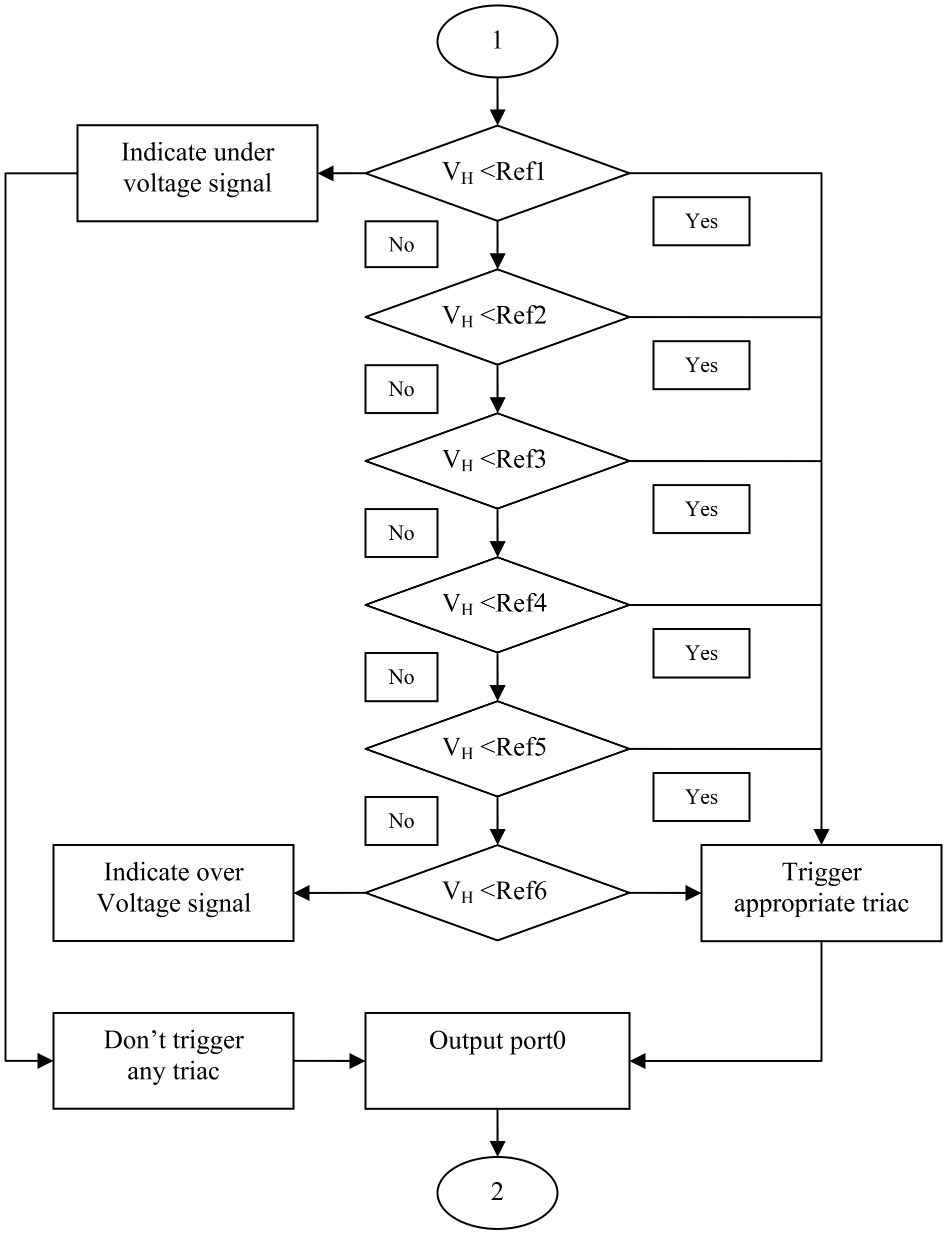


Fig.8.4.1 flowchart of working of microcontroller based CPP

Program written in micro controller without peak detector in the circuit:

```
.org 0000h

     start:  mov p2, #0ffh          ;port 2 work as input port
             clr c                  ;clear carry bit for zero crossing pulse
             mov c, p2.0            ; copy P2.0 into the carry flag
             jc delay               ; test the carry flag
             ljmp start             ; wait for pulse
    delay:   mov r0, #0ffh          ; generate delay of 1.024 ms
       d1:   nop
             nop
             djnz r0, d1
      adc:   clr c                  ; peak detection loop starts from here
             mov 30h, #00h          ; clear 30h for storing peak value
      dhk:   mov p1, #0ffh          ; port 1 receive data from ADC
             mov a, p1              ; store P1 in register A
             cjne a, 30h, here      ; compare ACC with content of 30h
     here:   jc end                 ; if acc content is less than that of 30h go to
                                    ; end
             mov 30h, a
             ljmp dhk
      end:   clr c
             clr a
             mov 21h, #01h
             mov 22h, #02h
             mov 23h, #04h
             mov 24h, #08h
             mov 25h, #10h
             mov 26h, #20h
```

```
mov 27h, #40h
mov 28h, #80h
mov a, 30h
           mov 20h, a
           cjne a, #8fh, h1
h1:      jc k1
           cjne a, #9bh, h2
h2:      jc k2
           cjne a, #0b0h, h3
h3:      jc k3
           cjne a, #0bbh, h4
h4:      jc k4
           cjne a, #0cah, h5
h5:      jc k5
           cjne a, #0d2h, h6
h6:      jc k6
           cjne a, #0e6h, h7
h7:      jc k7
            ljmp k8
k1:      mov 80h, 21h
 ljmp start
k2:      mov 80h, 22h
 ljmp start
k3:      mov 80h, 23h
 ljmp start
k4:      mov 80h, 24h
 ljmp start
k5:      mov 80h, 25h
 ljmp start
k6:      mov 80h, 26h
 ljmp start
```

```
k7:     mov 80h, 27h
 ljmp start
k8:     mov 80h, 28h
 ljmp start
```

Chapter 9

Driver circuit & power circuit

[9.1] Introduction:

For operating Thyristors as switch an appropriate gate voltage or base current must be applied. The control voltage should be applied between the gate and cathode in case of SCR and between gate and MT1 in case of triac. The importance of applying gating voltage to a transistor between its gate and source is more, rather than applying it between its gate and common ground. There are basically two ways of floating or isolating the control or gate signal with respect to ground.

-Pulse Transformer

-Optocouplers

[9.2] Pulse transformer:

Pulse transformers have one primary winding and can have one or more secondary windings. Multiple secondary windings allow simultaneous gating signals to series and parallel connected SCRs. The transformer should have a very small leakage Inductance and the rise time of the output pulse should be very small. At a relatively long pulse and low switching frequency, the transformer would saturate and its output would be distorted.

[9.3] Optocoupler:

Optocoupler combine Gallium-Arsenide -Diode infrared Source and a silicon photo-transistor or Optically-Coupled Silicon Triac Driver (Bilateral switch).

The rise and fall times of phototransistors are small, with typical values of turn on time t_{on} =2 to 5µs and turn off time t_{off} =300ns. These turn on and turn off times limit the high frequency applications. In this project MOC 3021 optocoupler IC is used for providing isolation between control circuit and driver circuit.

[9.4] Functional Description:

In thyristor converters, different potentials exist at terminals. The power circuit is subjected to a high voltage, usually greater than 100V, and the gate circuit is held at a low voltage, typical 12V to 30V. An isolation circuit is required between an individual thyristor and its gate-pulse-generating circuit. Either pulse transformers or Optocouplers can accomplish the isolation. An optocoupler could be a phototransistor or photo-SCR. A short pulse to the input of an infrared LED turns on the phototransistor. T1 and the power thyristor T_L are triggered.

A sample isolation arrangement with optocoupler is shown in fig.

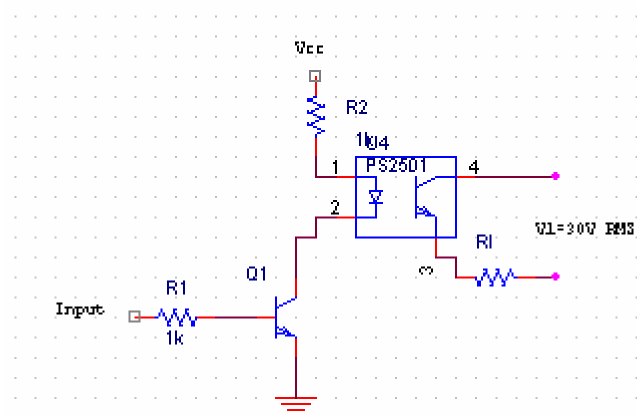


Fig. 9.4.1 circuit diagram of optocoupler

When a pulse of adequate voltage is applied to the base of switching transistor, the transistor will saturate, photo diode will radiate. Thus, a silicon phototransistor or

Optically-Coupled Silicon Triac Driver (Bilateral switch) will induce some voltages. That can be measured in the voltmeter. This voltage can be applied to the further circuitry.

[9.5] Triac based Driver Circuit:

General Description:

The major drawback of an SCR is that it can conduct current in one direction only. Therefore, an SCR can only control D.C. Power forward biased half cycles of a.c. in a load. However, in an a.c. system, it is often desirable and necessary to exercise control over both positive and negative half cycles. For this purpose Triac is used.

A triac is a three terminal semiconductor-switching device, which can control alternating current in a load. Transistors are popularly used as a switching device. The triac is a three terminal semiconductor for controlling current in either direction. When the voltage is reversed and a negative voltage is applied to the gate, the right SCR conducts. Minimum holding current, I_h, must be maintained in order to keep a triac conducting.

A triac operates in the same way as the SCR however it operates in both a forward and reverse direction. Obviously exceeding the break over voltage can also trigger a triac. This is not normally employed in triac operation. The break over voltage is usually considered a design limitation. One other major limitation, as with the SCR, is dv/dt, which is the rate of rise of voltage with respect to time. A triac can be switched into conduction by a large dv/dt. Typical application are in phase control, inverter design, AC switching, relay replacement, etc.

Major considerations when specifying a triac:

- Forward and reverse break over voltage
- Maximum current
- Minimum holding current
- Gate voltage and gate current trigger requirements
- Switching speed

- Maximum dv/dt

Functional description:

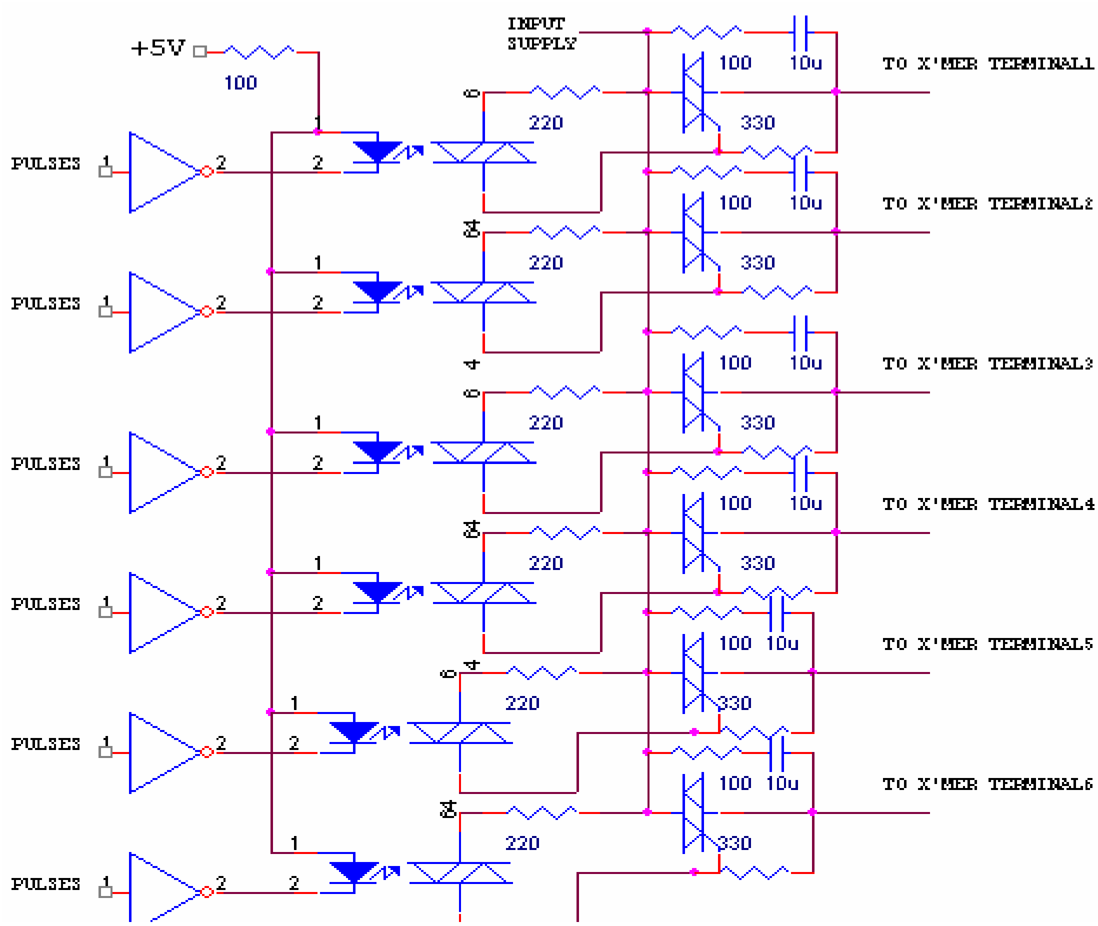


Fig. 9.5.1 triac based driver circuit

As per the control circuit design pulses will be obtained from output pin of any one AND gate. Thus inverted zero crossing pulses will be obtained from the any one output pin of inverted buffer IC 7404. Other pin of this IC will remain high. Output of this IC is applied to cathode terminal to opto-coupler MOC3021. The anode terminal of all stages is connected to +5V. So when inverted zero crossing pulses comes to the cathode pin, only that diode will conduct. So this stage will get selected. Opto coupler applied trigger pulse to triac. In this circuit main voltage is applied to MT2 terminals of all triacs. The MT1 terminals of all triacs are connected to tapings of auto transformer. So when only one triac is triggered, mains voltage is applied to that tapping of auto transformer. And corresponding to that voltage is stepped up or down.

[9.6] power supply circuit:

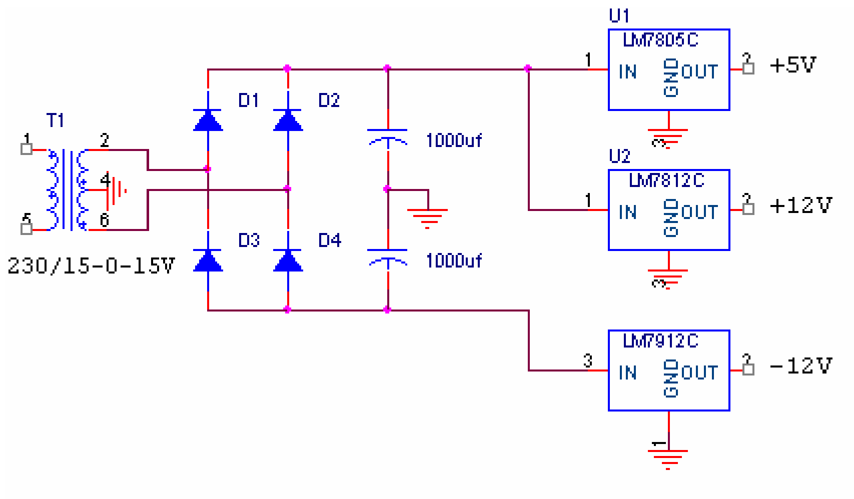


Fig. 9.6.1 Power supply circuit

Fig. shows power supply circuit for control card. First of all supply voltage is stepped down by 230/15-0-15V transformer. This voltage is rectified by diode bridge circuit. The output voltage is filtered by 1000µF/630V capacitor. The output of capacitor is connected with 7805, 7812& 7912IC. 7805IC gives +5V for control circuit's ICs. +12V and -12V is obtained from 7812 and 7912 ICs. This supply is used for LM324 comparator ICs.

Chapter 10

Simulation Results

[10.1] Simulation Result of peak detector:

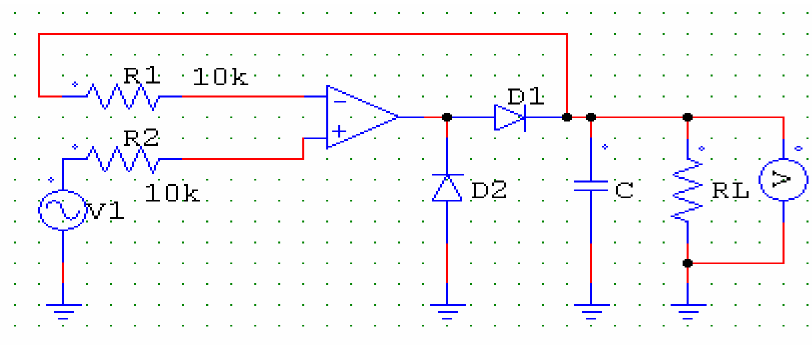


fig. 10.1.1 Circuit diagram of peak detector

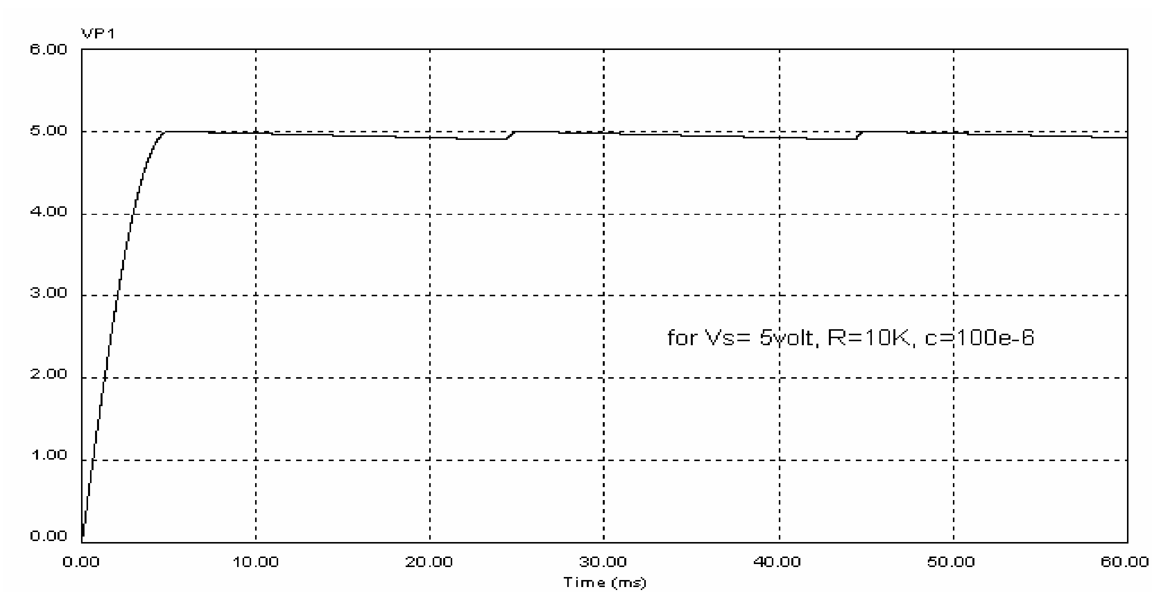


Fig. 10.1.2 simulation result of peak detector

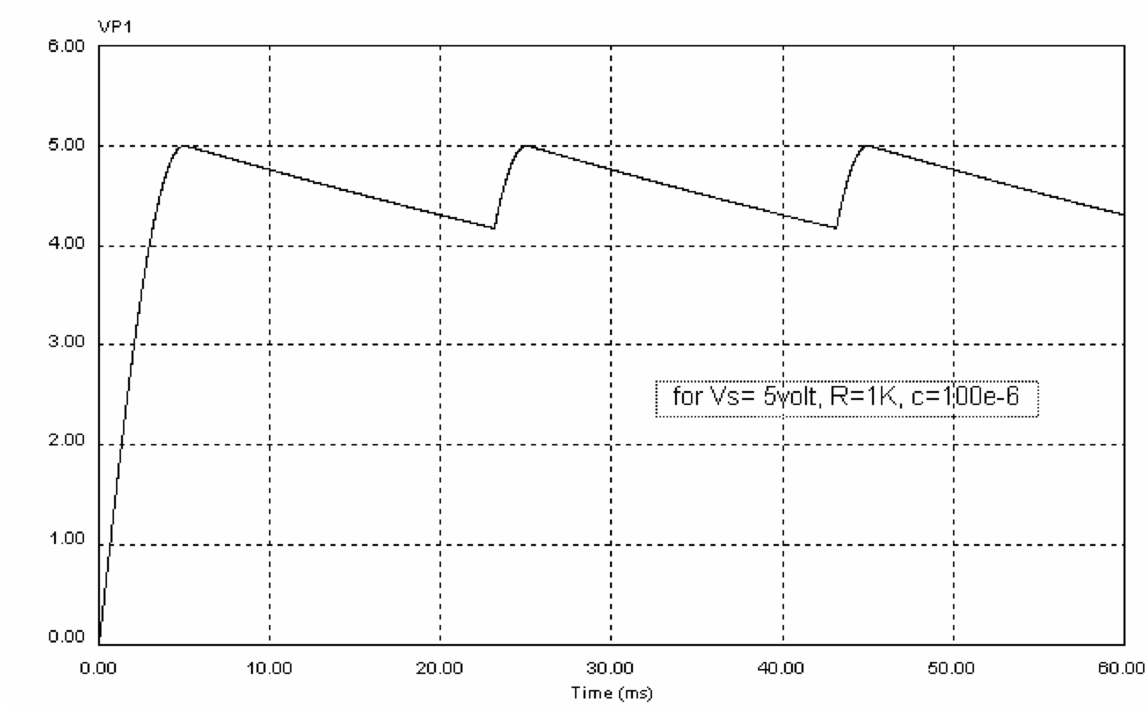


Fig. 10.1.3 Simulation result of peak detector

[10.2] Simulation result of zero crossing switching circuit:

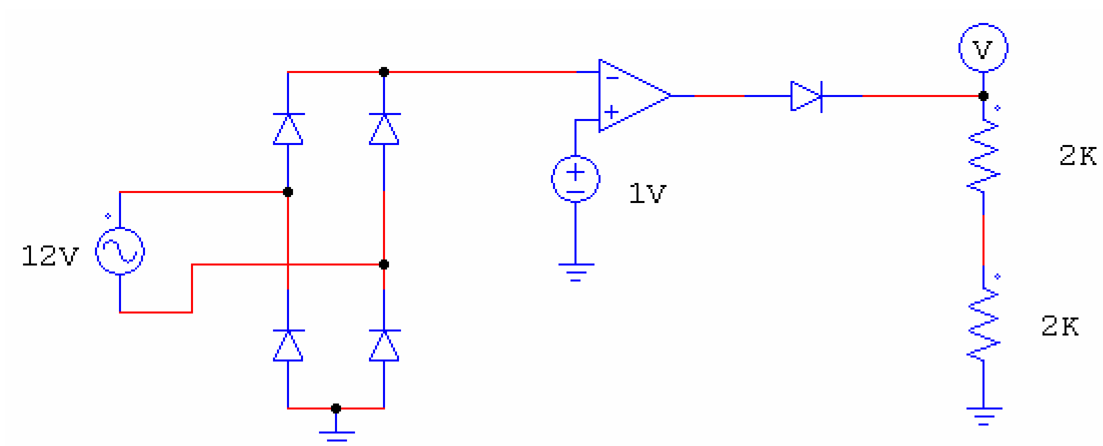


Fig.10.2.1 circuit diagram of zero crossing switching circuit

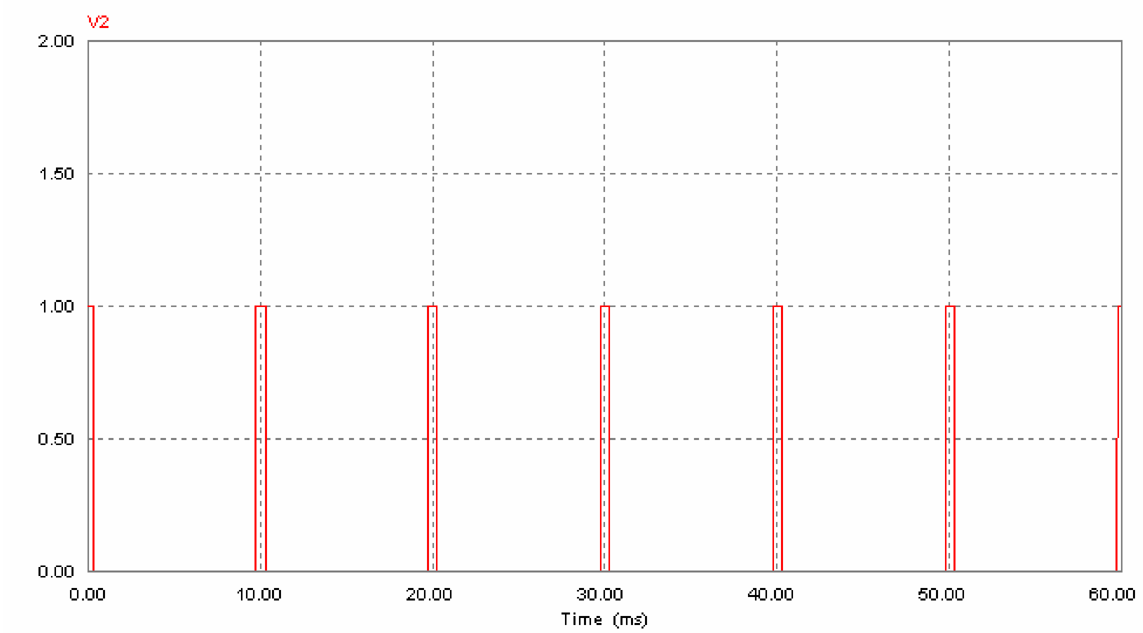


Fig.10.2.2 zero crossing pulses

[10.3] Simulation results of inverted buffer driver:

`

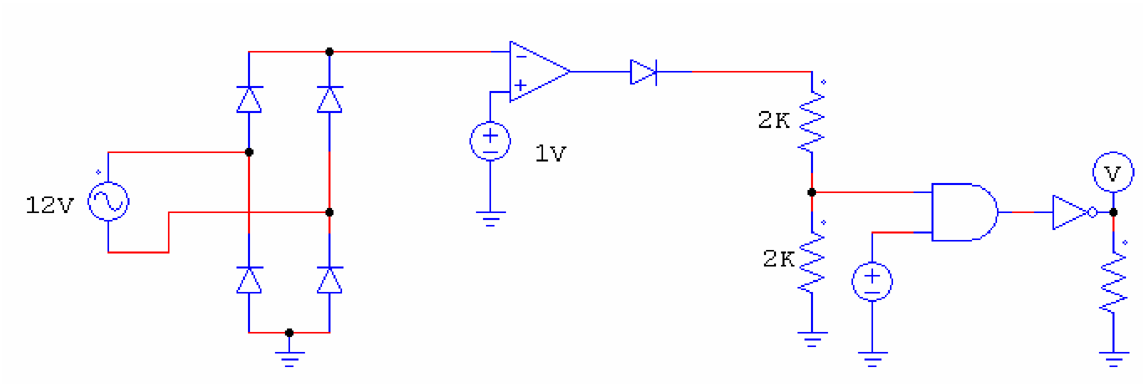


Fig.10.3.1 Inverted buffer driver with zero crossing detector

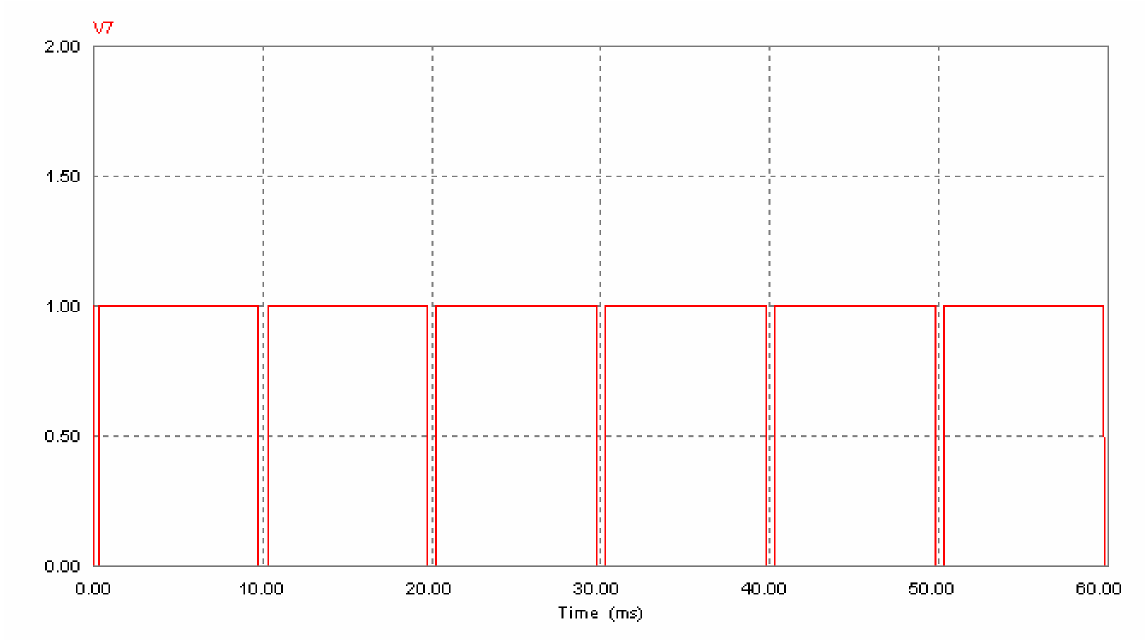


Fig. 10.3.2 Output of inverted buffer driver

Chapter 11

Test Results of Constant Power Purifier

[11.1] Introduction:

` This chapter shows the testing of auto transformer, control circuit and driver circuit. It matches with the simulation result as shown in chapter 9. the tables given below shows the testing result of auto transformer.

[11.2] Testing Results of Auto transformer:

RATING:

[1] Output: 1.5KVA [2] Voltage: 300V [3] Current: 6A [4] Efficiency= 95%

[11.2.1] Voltage and turns of the auto transformer:

NO. OF TAPPING	VOLTAGE(VOLT)	TURNS(NO.)
1^{ST}	187.0	536
2^{ND}	201.3	579
3^{RD}	220.8	634
4^{TH}	230.9	662
5^{TH}	241.9	694
6^{TH}	250.0	717
7^{TH}	279.5	783

[11.2.2] Testing results of auto transformer:

TAPPING NO.	OUTPUT VOLTAGE ON THE TAPPING		
	220	230	240
1^{ST}	178.0	187.0	194.2
2^{ND}	194.0	201.3	210.0
3^{RD}	212.0	220.8	229.5
4^{TH}	222.7	230.9	239.5
5^{TH}	232.0	241.9	251.0
6^{TH}	240.0	250.0	259.5
7^{TH}	263.0	279.5	283.7

[11.2.3] Testing results of A/D converter:

Input voltages	Output voltages	Peak value	Voltages after drop in diode	Voltage divider's output	A/D converter's output
178	2.740	3.875	3.175	2.540	81
192	2.954	4.178	3.478	2.782	8E
210	3.222	4.557	3.857	3.085	9D
230	3.510	4.964	4.264	3.471	AE
250	3.800	5.374	4.674	3.739	BF
260	3.940	5.572	4.872	3.898	C7
285	4.280	6.053	5.353	4.282	DA

In the above table input voltage is mains voltage. Output voltage is voltage of the 230/3-0-3V sensing transformer. Peak value is peak value of dc rectified voltages. The next column shows the voltage after the drop of 0.7V occurs in rectifier diode. The next column shows the voltage reduced by voltage divider. The last column shows 8 bit output of A/D converter.

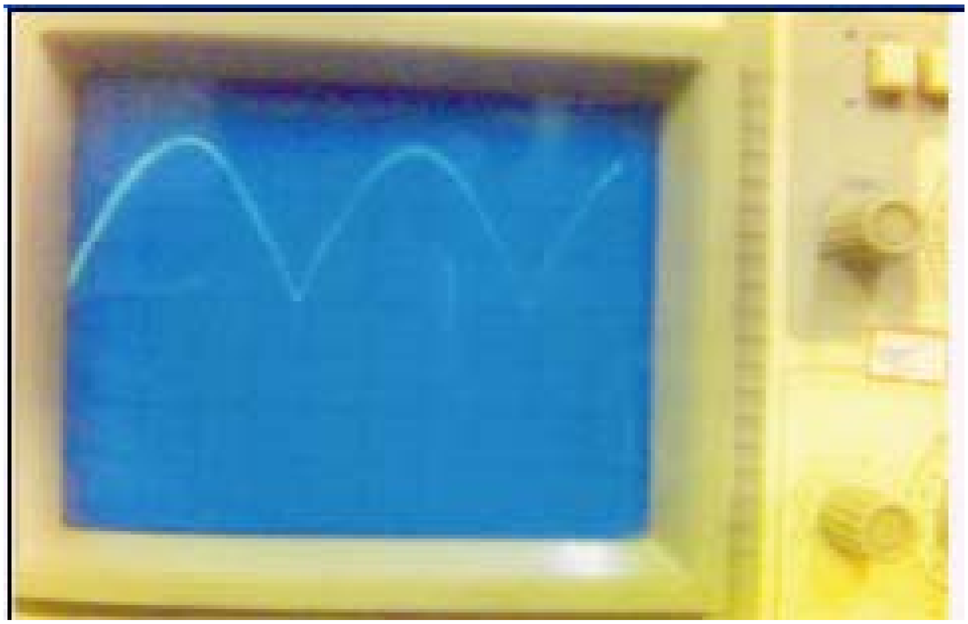
[11.2.4] Testing results of Auto transformer on load:

Input voltage	Output at no load	Output at 1500W
180	226	221
200	228	222
220	229	226
240	228	225
260	225	222
280	238	236

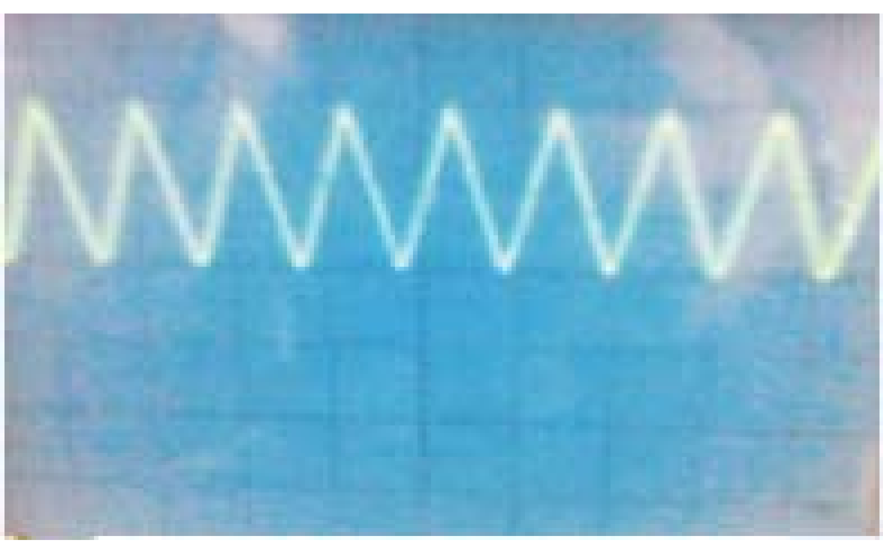
The above table shows voltages at load and voltages at no load. We can see that output voltage remains in the band of 220V to 240V against the voltage changes from 180 to 280V. Voltage regulation on load is also within limit.

[11.3] Various waveforms of Constant Power Purifier

[11.3.1] Input voltage to a/d converter 0804IC

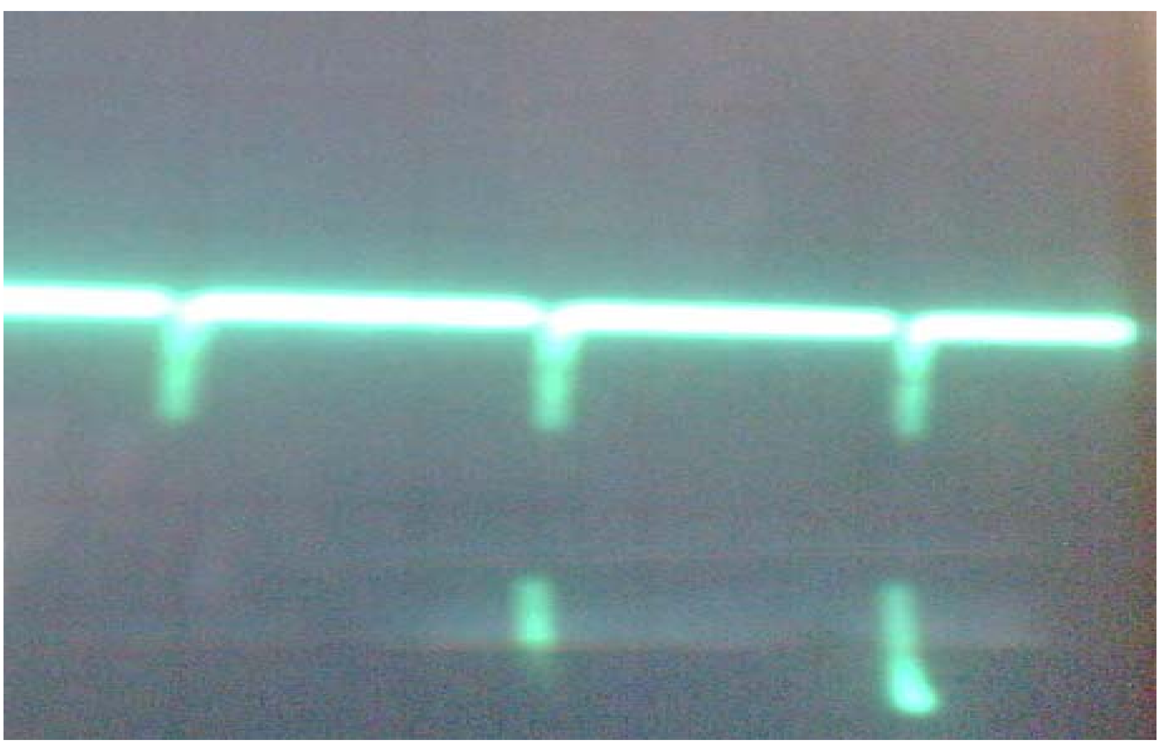


[11.3.2] Clock signal for A/D converter at pin no. 4



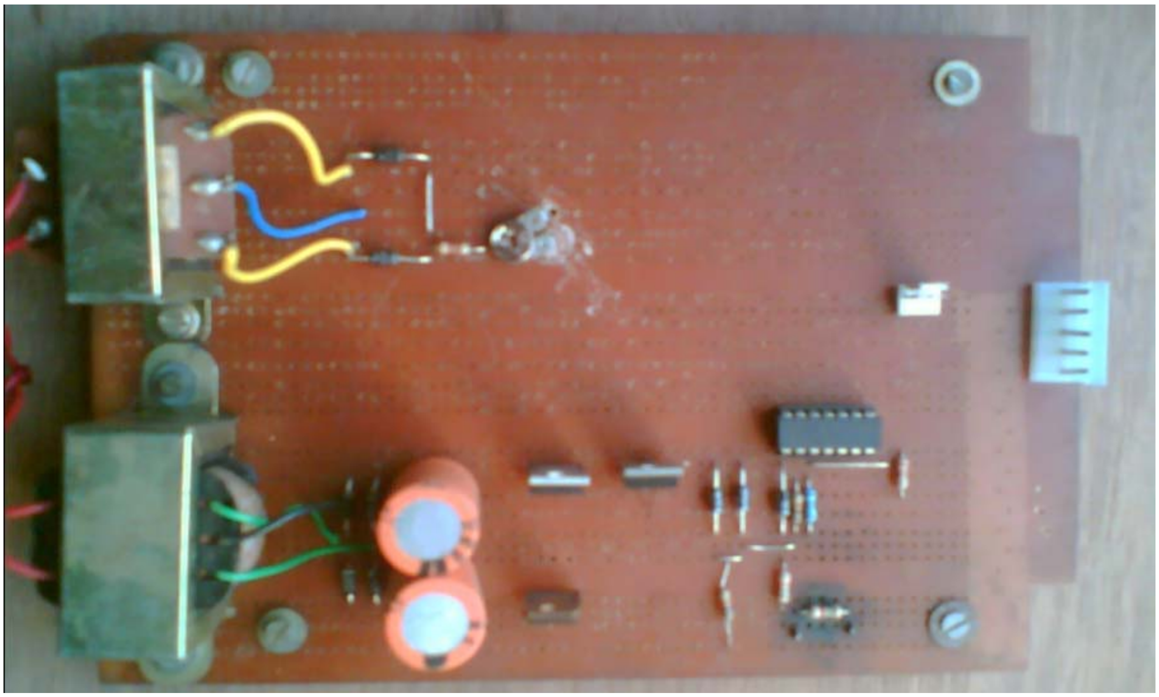
[11.3.3] Waveforms of zero crossing Pulses circuit

[11.3.4] Output waveform of buffer inverter 7404IC:

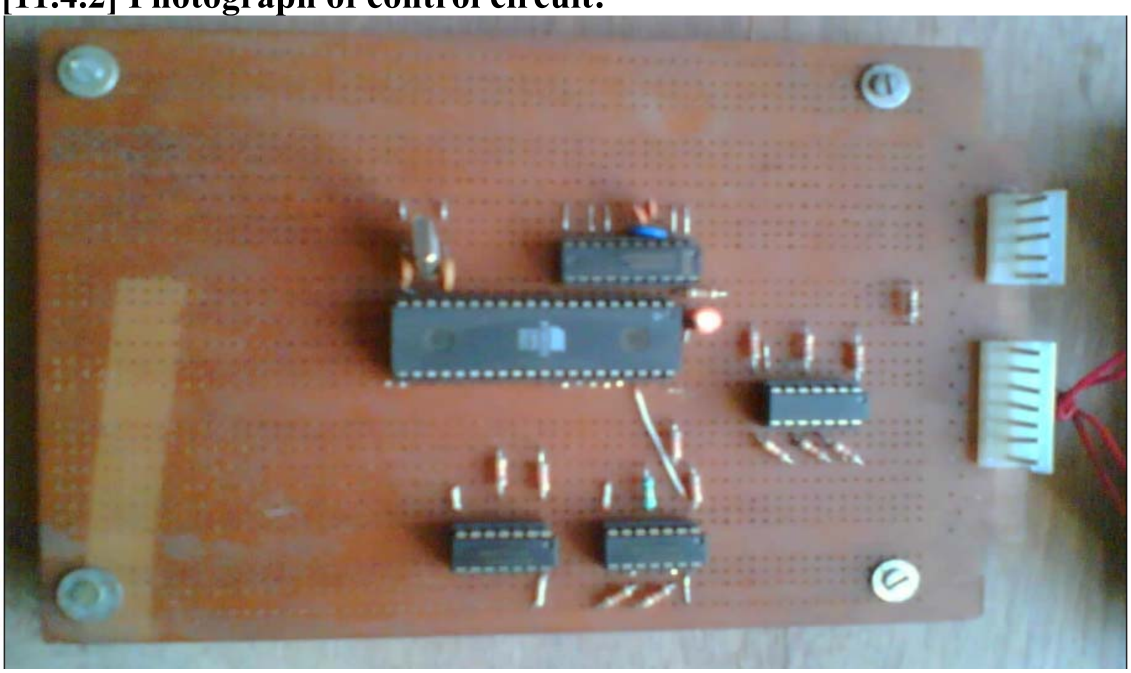


[11.4] Photographs of the Project

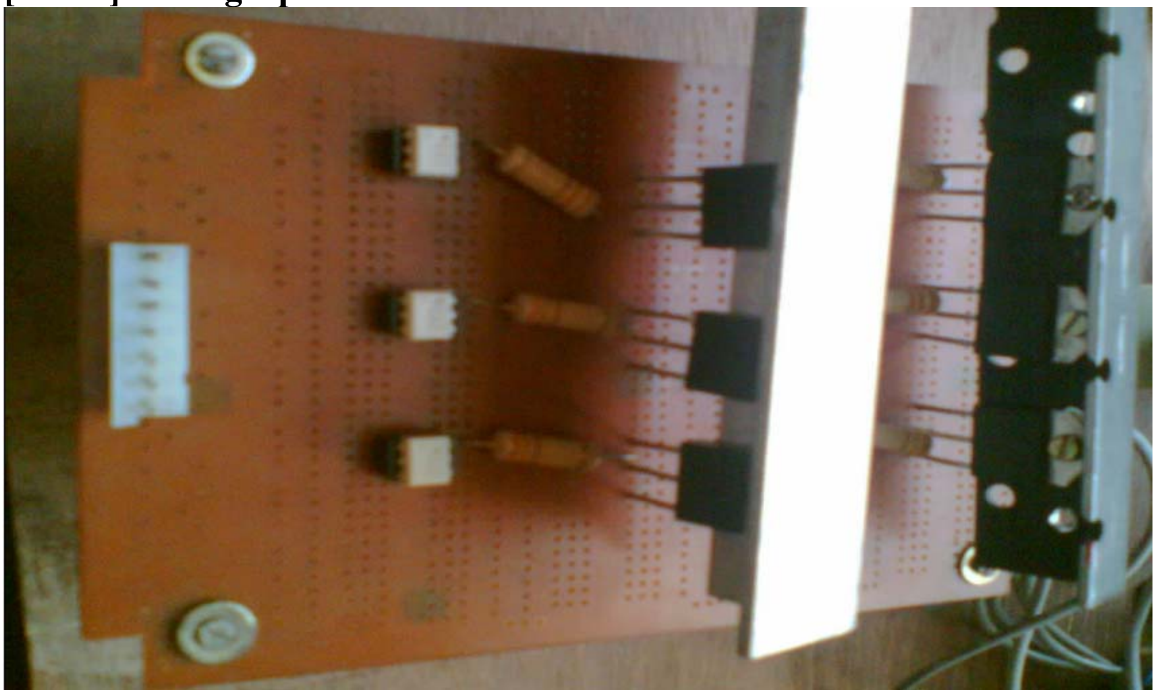
[11.4.1] Power supply and zero crossing detector circuits:



[11.4.2] Photograph of control circuit:

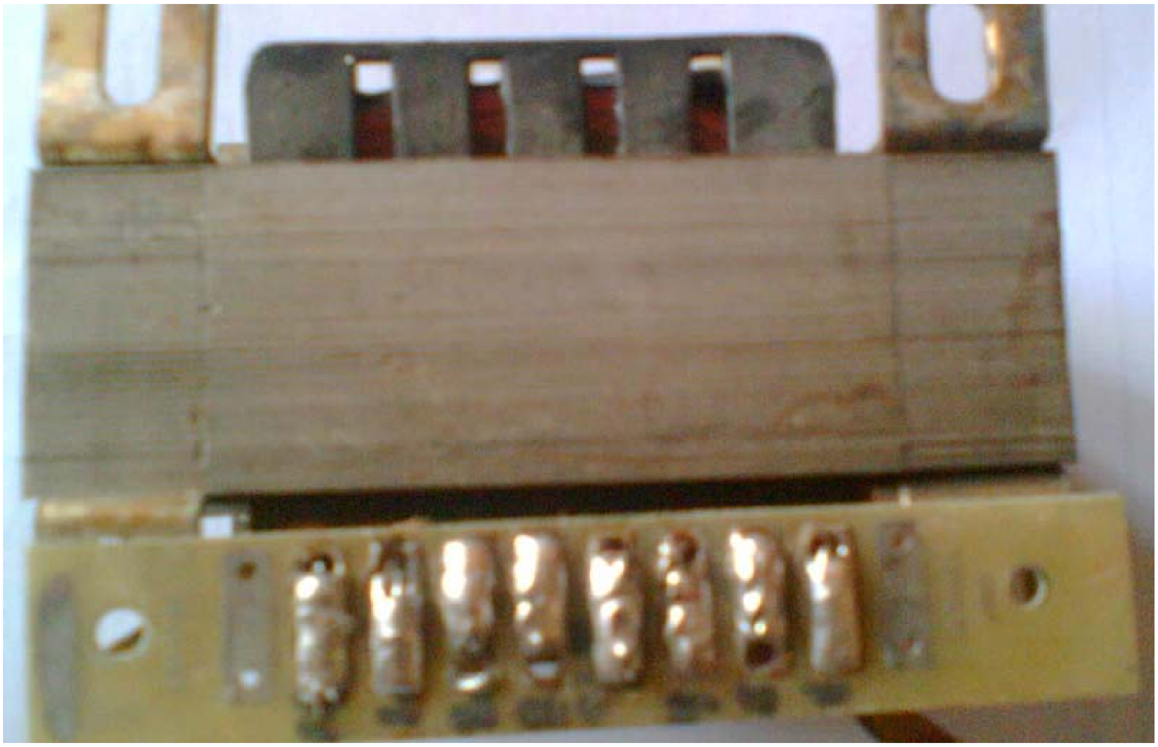


[11.4.3] Photograph of driver card:



[11.10] Photograph of auto transformer:

[11.11] Tapings of auto transformer:



Chapter 12

Conclusion and Future Scope

[12.1] Conclusion:

The microcontroller based constant power purifier is a new concept for a solid state voltage stabilizer. The present stabilizers are either slow in response or have distortion in the output voltage waveform. Constant power purifier does not suffer from this problem. The high voltage correction speed, pure sine wave output, high efficiency and high power factor makes it best in the presently available stabilizers.

The concept of constant power purifier is based on solid state on load tap changing transformer. This concept has been experimentally verified by fabricating and testing 1.5 KVA system. The output voltage remains in the band of 230V $\pm$5 %, which is the supply requirement of most types of electronics load. The input voltage range is from 175V to 285V. The efficiency is about 95% which is comparable with available stabilizers. For practical purpose 6 tapings transformer is taken. For getting higher resolution in the output voltage higher taping can be taken.

[12.2] Advantages and limitations:

Advantages:

[1] Zero crossing switching technology

[2] High transient and dynamic response

[3] Pure sine wave output with ultra fast correction rate

[4] Over voltage and under voltage protection

[5] no EM/RF interference

Limitations:

[1] Resolution is less than servo voltage stabilizer.

[2] For getting higher resolution no of triac required are high.

[3] Cost is high but performance is better than relay based and resonant stabilizers.

[12.3] Areas of applications:

[1] LAN/ File servers

[2] Computer installation

[3] Intercoms/ photo copiers/ FAX & Xerox

[4] process control instruments

[5] CNC based machines

[6] Video, cable TV, communication systems

Other Area of Application:

By increasing the ratings of the device we can replace mechanical on load tap changer with solid state on load tap changer. Today research is going on in these methods. The only draw back is higher cost of thyristor of higher ratings.

[12.4] Future Scope:

This project works as per planning and to make it more efficient following modification can be done.

[1] In this project triac is used as static switch. For higher rating back to back SCRs can be used. SCRs have higher dv/dt capabilities than triac.

[2] in this project triac is working on line commutation method. So correction speed is 10ms. Though this is the highest speed of presently available stabilizers, to increase correction speed further GTO can be used. During tap changes GTO can be tuned off by giving negative pulse to gate. So in this way voltage correction speed can be increased.

[3] Back to back IGBT with PWM control can be used.

References:

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APPENDIX