DESIGN, CONSTRUCTION AND TESTING OF A SWITCH MODE POWER SUPPLY (USING FLYBACK TOPOLOGY)

BY

AJAH CHUKWUMA

93/4089

A PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA

MARCH, 2000

DECLARATION

I hereby declare that this project was wholly and solely conducted by me under the supervision of Mr. Paul Attah of the Department of Electrical and computer Engineering. Federal university of Technology, Minna. During the 1998/1999 academic session.

Chukwuma Ajah	27-03-2,000
93/4089	*Date*

CERTIFICATION

I hereby certify that I have supervised, read and approved this project work which I deem adequate in scope and quality for the partial fulfilment of the award of a bachelor degree in Electrical and computer Engineering.

.... 24/03/2000 ....

Mr. Attah Paul
(Project Supervisor

Date

.... 6/4/2000 ....

Dr. .A. Adediran
(Head of Department

Date

Dr. J.O. ONI
(External Examiner)

6/4

Date.

DEDICATION

This project is dedicated to my beloved parents, Mr. and Mrs. Rufus Chukwu, my lovely Brothers Anthony Fredrick, Joseph, Emmanuel and my lovely Sister. Ngozi.

Also, to the Almighty God, who in his infinite mercy provided me with good health and success in my carrier, I dedicate this

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and reliable. They contributed morally and in some occasions financially to my success in the university. They are: Andrew (Dre), Kwasu (James), Chidi, Lynx, Salawudeen, Chibuike, Vivian, Alozie, Benjamin, Chika Anthony and Oluwasheun.

Lastly, I owe special thanks to the lecturers of Electrical department for their immense contributions towards making me what I am today.

ABSTRACT

Presented here in this project is a switch mode power supply using flyback opology.

The mains ac input is first rectified directly filtered and then transformed to the lesired stable output.

This is aimed at producing a power supply that is compact, high-efficiency, high veight and would supply both negative and positive voltages to electronic circuits nd devices that use dc voltage for their operations.

CHAPTER ONE :- INTROUDCTION

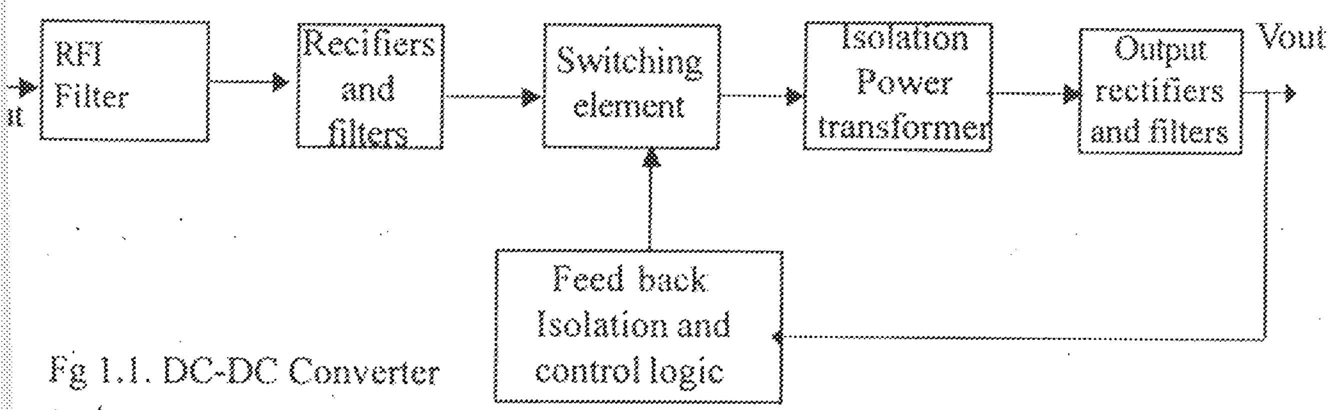
1.1 INTRODUCTION

The proliferation of LSI and VLSI technology especially the development of the microprocessor and semi-conductor memory, has spawned a generation of electronic system designs which are compact, light weight, efficient, and low-cost.

The power system based on the linear series-pass regulated design is bulky, inefficient, and obsolete for most of today's system designs. The natural trend, therefore, was toward the development of a small-size, lightweight, highly efficient power system in the form of the off-the - line switching power supply hence, the development of dc-dc power supply.

The dc-dc converters are widely used in regulated power supplies and in dc-motor drive applications.

Figure 1.1. below, shows the block diagram of dc-dc converter. Often the input to these converters is an unregulated dc voltage, which is obtained by rectifying the live voltage and therefore it will fluctuate due to changes in the line-voltage magnitude.



Fg 1.1. DC-DC Converter system

A dc-dc converter system may be of many designs, such as half-bridge, fly back, or forward, depending mainly on such deciding factors as cost, performance, and designers choice. [3] [3]

Here, the report will be centred on the 'Fly Back converter' which is the most universal among all the topologies and, also the topic of the project.

The input ac line voltage is directly rectified (hence, off - the- line switching power supply) and filtered to produce a high-voltage raw dc, which in turn is fed into a switching element, ie, transistor, where it is chopped to a high frequency (about 100 KH3 for this project), high-voltage square wave.

The resulting square wave is fed into a step-down isolation transformer, and the resulting secondary voltage is rectified and filtered to produce the low voltage out- put.

The regulation at the output is effected by feeding back a portion of the output to a comparator which compares it with a reference and adjusts the conduction period of the switching element to regulate the output. [7]

1.2 AIMS AND OBJECTIVES OF THE PROJECT

It is evident that most of today's electronic devices, such as printers, system units, television sets, compact disc player sets etc, depend on compatibility and portability of the components. In view of this, the need arises that a power supply that will stand the test of time and quality- that will provide a constant output voltage irrespective of the variations in the input voltage and the load, be produced.

I took the challenge to research into this when I discovered a rather unfortunate situation, that very few engineers are college-trained to become power supply engineers, and even the ones who get involved and make it a carrier do so either due to circumstial involvement or by demand.

My research led me into designing and improving upon a power supply that is compact, sophisticated, efficient and light weight which has a high power - to - volume density ratio with no compromise in performance. [3]

1.3 LITERATURE REVIEW

E.R Hinataketer in his book "Design of solid state and power supplies 1981" described the application of linear integrated circuit as "very popular" among people that can desire quality result. Also in his book. Engineers Handbook, Forest M. Mim III (1975) introduced the IC 723 regulator as a very versatile regulator that can be veiled on to give a stable output if any when properly connected.

Also, the work of some past students of this department (Electrical & computer Engineering) in developing a reliable power supply that will satisfy the present day demand for electronic devices are quite commendable. To start with, Adelusi Omuya (1993) and Isah Aliyu Otaru (1994), each attempted producing a power supply unit that will be able to stand the test of quality by using IC 723 as the regulator. But the economic purpose of the project was defeated coupled with the fact that, the efficiency of the unit was drastically reduced, as too many passive and active components were introduced into the circuit.

Adewumi Adenike (981902) (using the push-pull approach) in her work on switch mode power supply with multiple outputs, did quite a good job, but could not include voltage input voltage suppressor and EMI filter circuits, which reduced the reliability of the unit to a very good extent.

The most recent among them, is the work of Musa M. Mansir (981912) on switch mode unit using flyback topology. Being the first person to use the fly back approach to this, I should say that he did a good job by reducing the components

PROJECT OUTLINE

This project report is divided into four (4) main chapters, and each chapter explains part of the basic concepts of the entire work. Each chapter is linked to the next chpater so as to make the work easily comprehendable.

Below are the respective chapters and the their summaries:

- Chapter one, gives the general introduction of the project. Here an insight on the whole research is discussed, and this includes introduction, Aims and objectives of the project, literature review and project outline.
- Chapter 2, deals with the system design. Discussed here, is the procedures taken in designing the various stages and modules of the project as, the input section of the converter, the input transient voltage protection. AC input live filters for RFI suppression, Rectification, operation of the bridge rectifier, capacitor filters, the switching transistor, the transforner and its theory of operation, the optical coupler, the 555 timer as astable and as monostable multivitrator, the Op-Amp and the output filter.
- In Chapter Three, discussions are made on the construction and testing of the project, and also the result obtained are discussed.
- In chapter four are conclusion, recommendations, and also references of text books consulted.

CHAPTER TWO
SYSTEM DESIGN

2.0 INPUT SECTION

As aforementioned in the past chapter, an off-the - line switching power supply rectifies the ac line directly without requiring a low-frequency, line isolation transformer between the ac main and the rectifier. Since in most of todays electronic equipment the manufacturer is generally addressing an international market, the power supply designer must use an input circuit capable of accepting all world voltages, normally 90 to 130v ac or 180v to 260v ac. Below are different design stages underwent to make the project realisable.

2.1 THE INPUT TRANSIENT VOLTAGE PROTECTION

Although the ac mains are normally rated at 115v ac or 230v ac, it is common for high-voltage spikes to be induced, caused by nearby inductive switching or natural causes, such as electrical storms or lighting. During severe thunder storm activity, voltage spikes in the order of 5kv are not uncommon.

On the other hand, inductive switching voltage spikes may have an energy content.

$$W = \frac{1}{2} L I^2$$

Where L is the leakage inductance of the inductor, and I is the current flowing through the winding.

Although, these voltage spikes may be short in duration, they may prove fatal for the input ratifiers and the switching transistors, unless they are successfully suppressed.

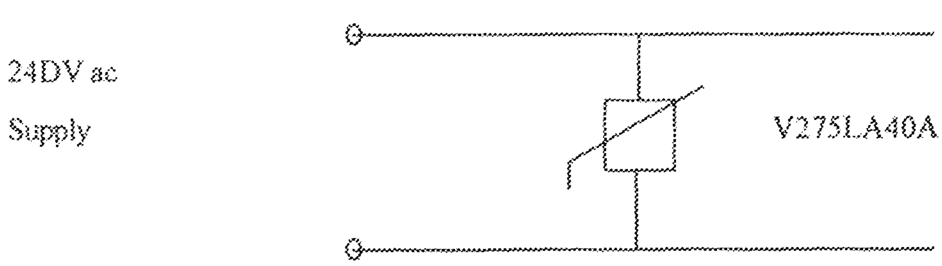


Fig 2.1. Zinc oxide varistor.

The figure above depicts a zinc oxide varistor used as a transient voltage suppressor. It acts as a variable impedance, that is when a voltage transient appears across the varistor, its impedance sharply decreases to a low value, clamping the input voltage to a safe level. The energy in the transient is dissipated in the varistor. For the purpose of this project V275LA404 rated at 275V rms and can dissipate a 140J transient, is used. [9]

2.2. AC INPUT LINE FILTERS FOR RFI SUPPRESSION

Utilization of an LC filter for differential-and common-mode RFI suppression at switching power supply ac mains is the most common method of noise suppression. Normally a coupled inductor is inserted in series with each ac line, while capalitors are placed between lines (called x capacitors) and between each line and the ground conductor (called Y capacitors)

The capacitance and inductance of the components may be within the following values.

CX: 0.1 to 2F

CY: 2200PF to 0.033PF

L: 1.8mH at 25A to 47 mH at 0.3A

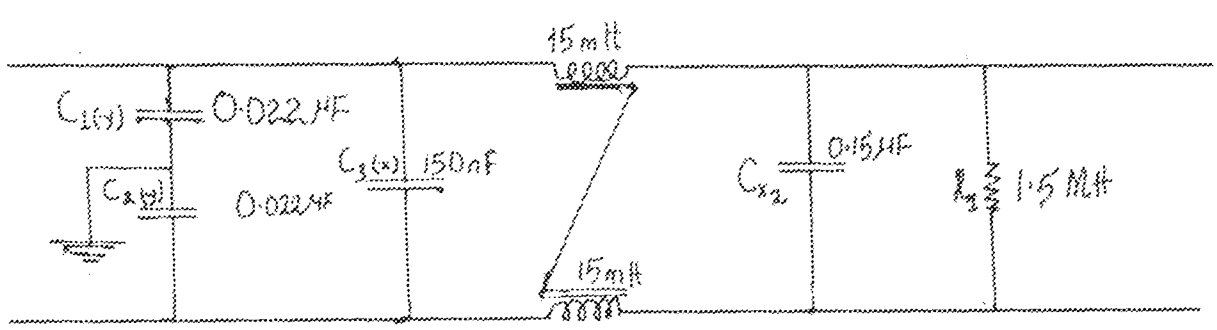


Fig. 2.2. A switching Power supply input line filter for Ac mains RFI noise suppression.

Vs = Source Voltage

Vd = Average output voltage

Vr = r.m.s Value of load voltage

V max = Maximum load voltage.

$$vd = \frac{1}{\Pi}\int_{0}^{\pi}\sqrt{2}\ Vs\ Sin\ wt\ d(wt) \text{ ------------ } 2.1$$

Integrating equation 2.1. gives

$$Vd = \frac{\sqrt{2}\ Vs}{\Pi}\ [-\ Coswt\ ]$$

Note: Vrms = Vs

$$\Rightarrow Vd = \frac{\sqrt{2}\ Vs}{\Pi} \times 2$$

$$= \frac{2\sqrt{2}\ Vs}{\Pi}$$

But $Vmax = \sqrt{2}\ Vrms$

Vrms = 240V

Therefore $Vmax = \sqrt{2} \times 240$

$= \underline{\underline{339.411v}}$ [8]

PIV rating for the bridge rectifier = 2 x Vmax

= 2 x 339.411 = 678.82v

2.31. OPERATION OF THE BRIDGE RECTIFIER.

During the positive input half-cycle, terminal M of the secondary is positive and N is negative. Diodes D_1 and D_3 become forward biased (ON) whereas D_2 and D_4 are reverse biased (OFF). During the negative input half - cycle, terminal N becomes positive and M negative. Diodes D2 and D4 conduct while diodes D_1 and D_3 remain reverse biased.

2.4. CAPACITOR FILTER

As stated in the last chapter, the dc output of the rectifier is the pulsating type. Consequently, a capacitor is applied across the output of the rectifier to filter off the ripples, thereby leaving the dc as ripple free as possible.

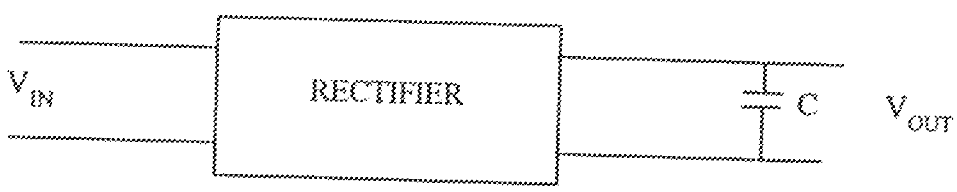


Fig. 2.4. Shunt capacitor filter

Another good function of the capacitor filter is the prevention of noise from being impressed on the ac line. [2]

2.41 OPERATION OF A CAPACITOR

During the positive half cycle of the ac input to the bridge rectifier (fig 2.3.) whereby diodes D_1 and D_3 conduct, the capacitor charges up to the peak value of the input voltage, Vm (point 2 in fig 2.5b), and holds the charge till input ac supply to the rectifier goes negative.

During the positive half cycle, the capacitor attempts to discharge through D_1 and D_3 but cannot because they are reverse biased, and hence it is forced to discharge through the load from point 2 to 3 in fig 2.5c and its voltage decreases.

RC which is the discharging time constant is always about 100 times more than the charging time. The process of charging and discharging of the capacitor is a continuous one. [2]

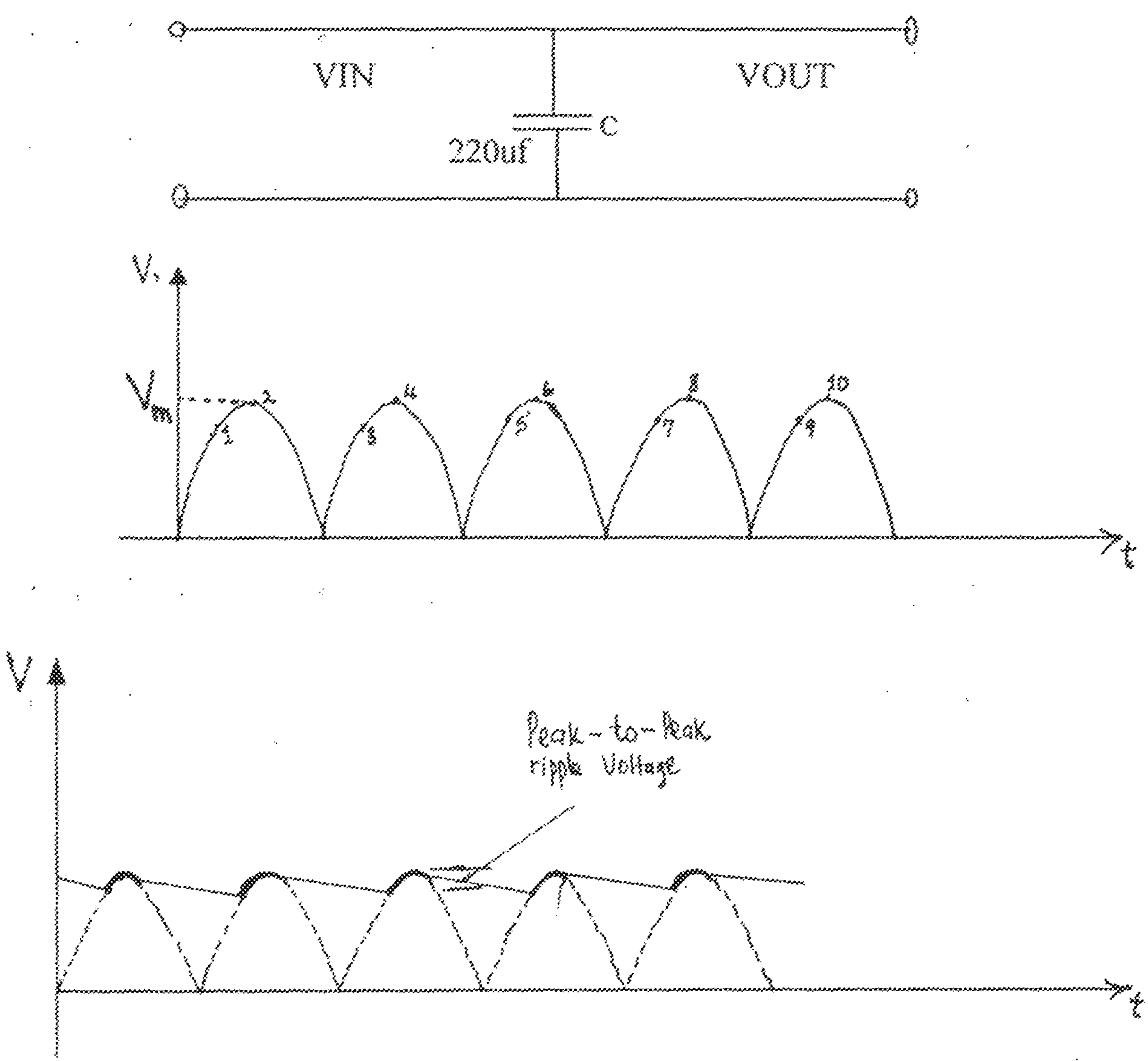


Fig 2.5. Filtering action of a capacitor
(a) Circuit (b) Without filter (c) With filter.

FILTER SPECIFICATIONS.

The ripple factor for the bridge rectifier is as below:

Ripple Factor $rf = \frac{Vac}{Vdc} = \frac{\sqrt{V^2rms - V^2dc}}{Vdc}$

$$Vrms = \frac{Vmax}{\sqrt{2}}, \quad Vdc = \frac{2}{\Pi} Vmax.$$

$$\Rightarrow r_f = \frac{\sqrt{\frac{(Vmax)^2}{\sqrt{2}} - \frac{(2\,Vmax)^2}{\Pi}}}{\frac{2}{\Pi}\,Vmax}$$

$$\frac{\sqrt{\frac{v^2max}{2} \quad \frac{4vmax}{\Pi^2}}}{\frac{2Vmax}{\Pi}} \qquad \frac{\sqrt{V^2 max\,(\,1/2 - 4/\Pi^2)}}{\frac{2Vmax}{\Pi}}$$

$$= \frac{Vmax\,(0.5 - 0.405)}{Vmax\ \ 2/\Pi} = 0.4841$$

Therefore, r_f = 0.4841 ------------------------ (1)

Now, the capacitor filter that would reduce the ripple above to a considerable value is designed as below:

$$C = \frac{It}{\Delta V}$$

C = Capacitance, (UF)

I = Load Current, (A)

t = Time the capacitor must supply current (ms)

ΔV = allowable peak to peak ripple, V

Assuming a minimum efficiency of 80% for a 100w output power:

$$\text{Input power } P_{in} = \frac{Pout}{efficiency} = \frac{100}{0.8} = \underline{125W}$$

dc output = 350v

load current I = P/V = 125/350 = 0.36. A

For t = 0.3ms for a $50H_z$ac line frequency

then,

$$C = \frac{It}{\Delta V} = \frac{0.36 \times 0.3 \times 10^{-3}}{0.4841} = 220\ UF$$

Therefore

C = 220 UF.

From the above calculation, a capacitor with capacitance of 220UF was employed and its working voltage is 450V. [4]

2.5 THE SWITCHING TRANSISTOR

The selection of the switching transistor from this project is done by considering:-

* the maximum collector voltage at turn off and the maximum collector current at turn on.

The maximum collector voltage at turn - off is given as

$$Vcemax = \frac{V_{in}}{1 - max.}$$

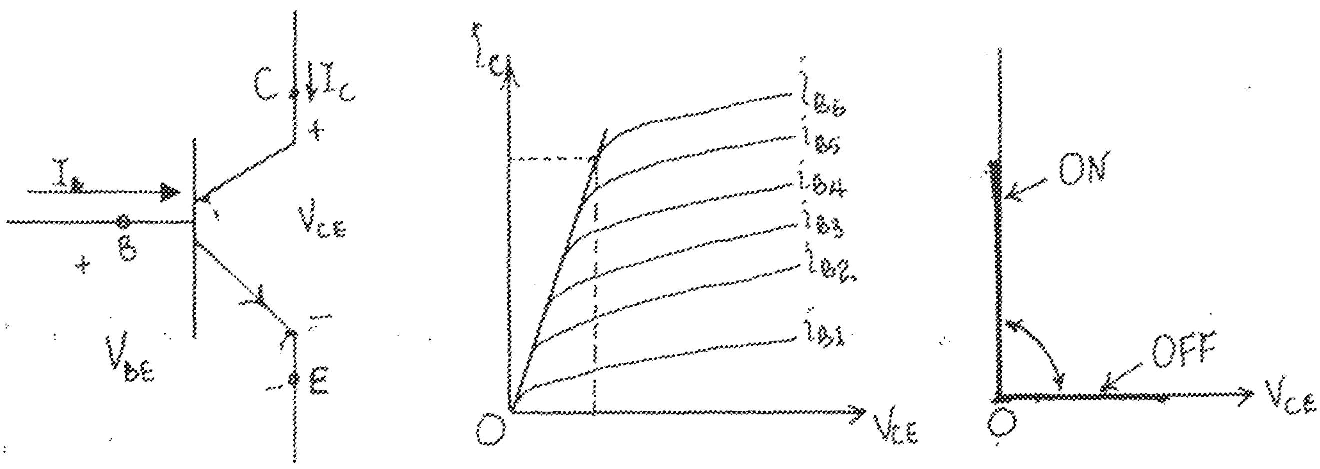
In this project, an N-P-N bipolar transistor is used for the switching.

2.51 BIPOLAR JUNCTION TRANSISTORS (BJTs)

The circuit symbol for an NPN bipolar Junction transistor, its steady-state I - v characteristics and the idealized characteristics are shown in fig 2.6. a, b and c respectively. It can be seen from the i - v characteristics, that a sufficiently large base current is needed for the device to be fully on, requiring that the control circuit provides a base current that is sufficiently large so that [1]

$$I_B > \frac{I_C}{B}$$

Where B is the dc current gain of the device.



(a) (b) (c)

Figure 2.6.: Bipolar junction transistor: (a) Symbol, (b) i - v Characteristics, (c) Idealized characteristics.

For the power transistor, the on - state voltage Vce (sat) is usually in the 1 - 2V range, making the conduction power loss in BJT quite small. Fig. 2.6. (c) shows the idealized BJT operating as a switch - that is in its saturation mode.

BJTs are current - controlled devices and base current must be supplied continuously to keep them in the on - state. High - power transistors are usually of low dc current gain B range of 5 - 10. For the design of this project, a high power transistor of dc current gain of 6 is chosen. [1]

TRANSISTOR CALCULATIONS:

$$V_{ce\,max} = \frac{V_m}{1 - max}$$

$$V_m = 350V$$

$$max = 0.4$$

$$V_{ce\,max} = \frac{350}{1 - 0.1} = \frac{350}{0.6} = 583V$$

From the calculation above, a suitable transistor of Vce = 700V was used in the project construction.

$$I_c = \frac{6.2\,P_{out}}{V_{in}}$$

$$P_{out} = 100W$$

$$V_{in} = 350V$$

$$I_c = \frac{6.2 \times 100}{350} = 1.8\,A$$

Therefore the collector current IC is 1.8 A

2.6 TRANSFORMER

A transformer is simply defined as a machine that changes an alternating voltage from one value to another. A transformer can be step - up or step - down type. Step -down:- If it receives energy at higher voltage and delivers it at lower voltage. Step - up :- If it receives energy at lower voltage and delivers it at higher voltage. But for the purpose of their project, the step down transformers are used.

A simple transformer consists of two coils wound on a closed Iron core as represented in fig 2.7. The coils are insulated from each other and from the core. Energy is supplied to one winding, called the primary winding, and is delivered to the secondary winding. [5]

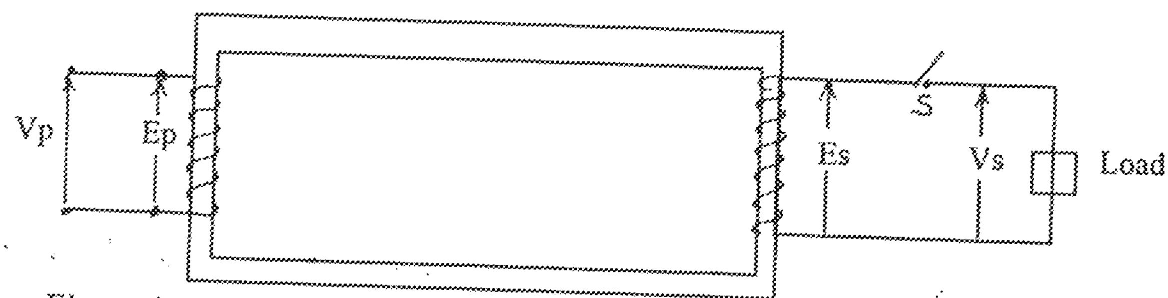


Figure 2.7 : Transformer circuit Diagram

2.61 THEORY OF OPERATION

A small current called the exciting current flows when an alternating voltage V_p is applied to the primary winding of the transformer represented in figure 2.7 above, with load switch 5 open.

The exciting current causes an alternating flux to be set up in the core. The alternating flux so set up cuts across the turns of both the primary and the secondary windings as it increases and decreases in alternate directions, thereby inducing an e.m.f in both windings. The e.m.f. induced in the primary winding opposes the applied voltage Vp. Since the turn of both windings are cut by the same flux, the e.m.f. induced in each turn of both windings are the same. If Ep is the e.m.f. induced in the primary winding and Es is the e.m.f. induced in the secondary winding, then the voltage per turn in the two winding, is Ep/Tp and Es/Ts respectively and Ep/Tp = Es/Ts.

If the resistance of the primary winding is small, as is usually the case, Ep will be almost equal to the applied voltage, Vp Neglecting this small difference and noting that the secondary terminal voltage Vs will be equal to Es then.

$$Vp/_{Vs} = Np/_{Ns}$$

This equation shows that the voltage of each winding of a transformer are directly proportional to the number of turns in each winding.

The main transformer used in this design is T, which is high frequency power transformer. The transformer core is made of ferrite material. Ferrites do not have very high operating flux density but they offer low core losses at high frequencies, good willing coupling and ease of assembly. [5]

2.62. THE FLYBACK, CONVERTER TRANSFORMER CHOKE

In the flyback converter two modes of operation are possible for the transformer choke Viz:-

(i) Complete energy transfer where all the energy stored in the inductor - transformer is transferred to the secondary before the switch is turned on and

(2) In complete energy transfer, where not all the energy stored in the transformer - inductor is transferred to the secondary before the transistor switch is turned on.

For the purpose of this project, complete energy transfer is used. [3]

2.63 **DESIGN PROCEDURE**

The steps as stated below were taken to design a flyback converter transformer - choke for a complete energy transfer mode:

(1) The core geometry and ferrite material were chosen. For the purpose of this design, a ferroxcube pot-core ferrite of 3C8 material was chosen.

(2) A working Bmax chosen. From the Ferroxcube catalog specifications for the 3C8 material, the flux density at 100°c is Bmax = 3300G. Half of Bsat is used therefore Bmax is given to be 1660G

(3) The maximum working primary current was found using the equation below.

$$IP = \frac{3\ Pout}{Vin} = \frac{3 \times 100}{350} = 0.85\ A$$

4. The core bobbin and size were determined. A working current density of 400 cm/A was chosen and the equation below was used to calculate the Ae Ac product.

Where

Ae = core effective area, cm^2

Ac = Bobbin winding area, cm^2

$$Ae\ Ac = \frac{0.68 \times 100 \times 400 \times 10^{3}}{20 \times 10^{3} \times 16000}$$

$$= 0.850\ cm^{4}$$

A core size close to the calculated AeAc product of 0.8 cm4 was chosen. From the data sheet, 151-512A femore cube put core was chosen. Also from the manufacturer's data we get Ae = $2.02cm^2$ and Ac = 0.748 yielding AeAc = $1.5cm^4$.

Taking the worst-case operating condition of 90Vac, Vin, Min = 90 x 1.4 - 20V dc ripple and rectifier drop = 107Vdc.

Now, for the number of turns in the primary:

$$N_p = \frac{350 \times 10^8}{4 \times 1600 \times 20 \times 10^3 \times 2.02}$$

= 124.73 turns

= 125 turns

6. The transformer secondary turns is then calculated using the equation below.

$$N_s = N_p \; V_s/V_p$$

$$= \frac{125 \times 25}{350} = 9.76 = 10 \text{ turns}$$

2.7. THE OPTICAL COUPLER (OR OPTOISORATOR)

The optocoupler is used primarily to provide isolation between the input and output of the power supply, while at the same time providing a signal path for regulation control.

The optocoupler consists of two main components: the light source, which could be an incandescent lamp or a light-emitting diode (LED), and the detector, which could be a photovoltaic cell, photodiode, phototransistor, or light-sensitive SCR. Figure 2.8 below shows the internal circuiting of an optoisolator

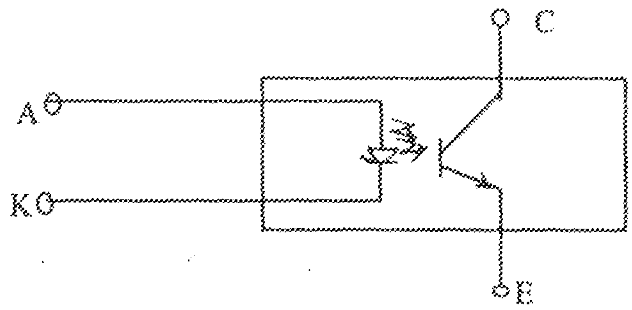


Figure 2.8 A **TYPICAL OPTOCOUPLER CIRCUIT.**

2.27 OPTOCOUPLE CIRCUIT DESIGN

Optocoupler when used in an off-the-line switching power supply for the purpose of providing input - to - output isolation, the following design criteria must be kept in mind.

(1) The optocoupler must sustain an isolation break down voltage as dictated by local and/or international safety standards.

(2) The amplifier circuitry driving the coupler must be well designed to compen sate for the coupler's thermal instability and drift.

(3) An optocoupler with a good coupling efficiency is preferred.

Every necessary observation was made before choosing a very suitable optocoupler (PC11.3) from the data book, and was connected as below. [3]

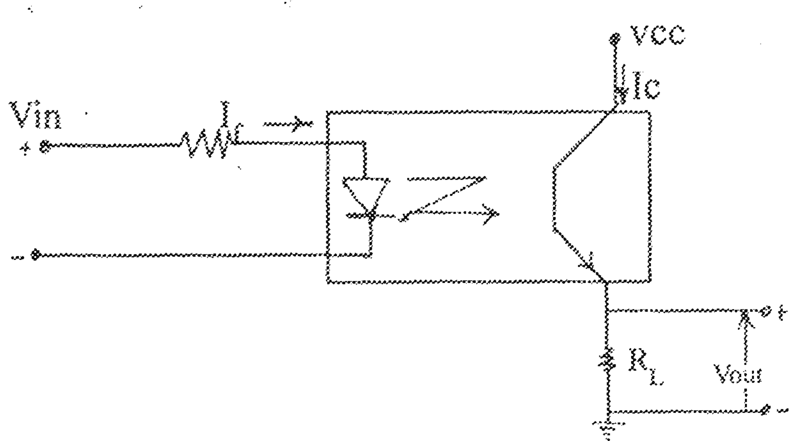


Figure 2: 9 An Optocouple in a basic

Linear mode.

As in figure 2.11, resistors R_A, R_B and Capacitor fix the time during which the capacitor alternately charges and discharges to provide an output signal oscillating between levels near OV and Vcc.

Capacitor C charges toward + Vcc with time constant $(R_A + R_B)$ C. When this capacitor voltage reaches the threshold level of (2/3) Vcc, the output switches low and the discharge transistor turns on during the discharge output low. Capacitor C then discharges through resistor R_B at a time constant R`C until it reaches the trigger input level, (1/3) Vcc. The flip - flop is triggered, with output then going high, the discharge transistor is turned off, and the capacitor begins to charge again. [9]

DESIGN CALCULATIONS

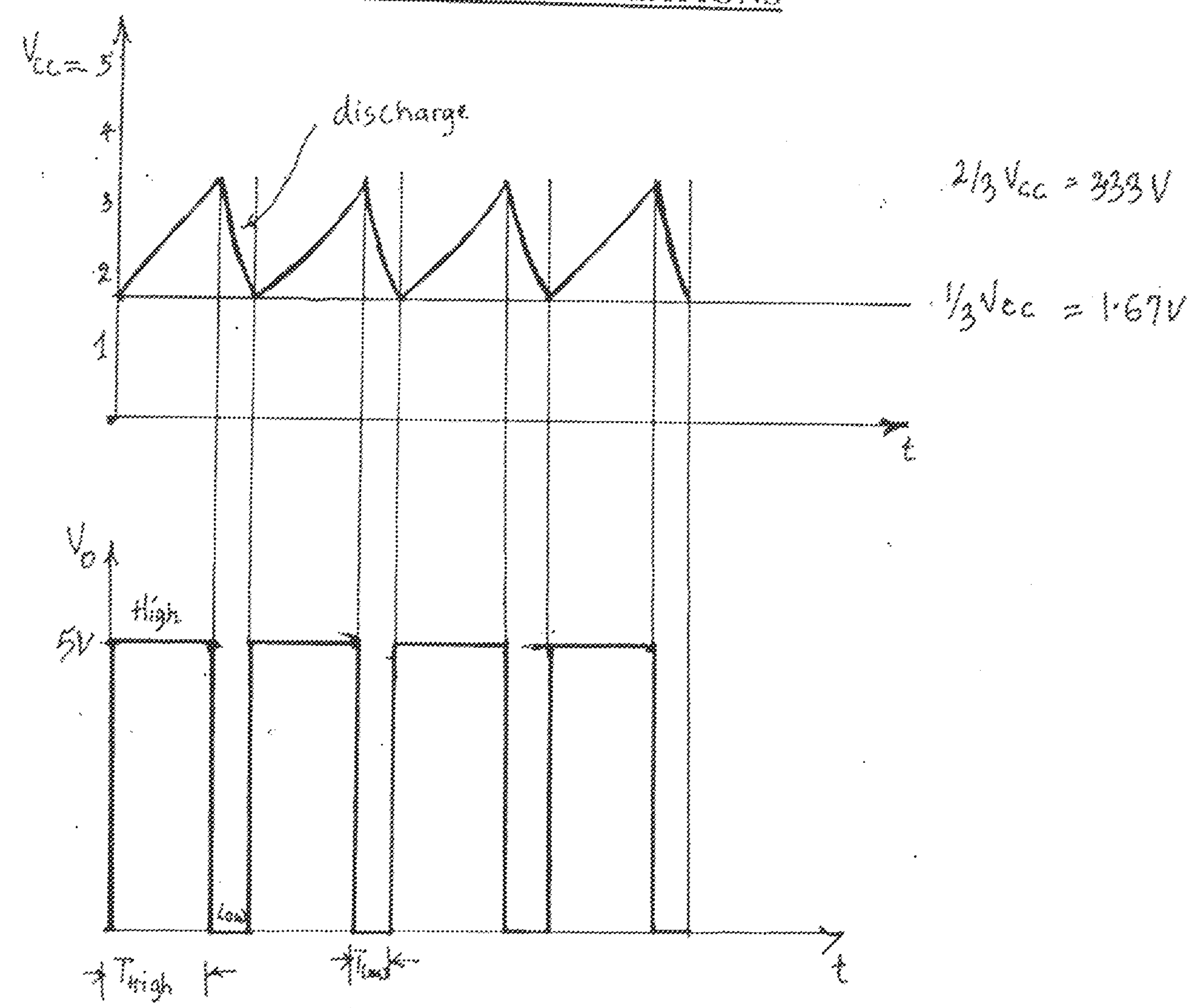


Figure 2.12 Wave form for 555 astable multivibrator.

Period $= T = T_{HIGH} + T_{LOW} = 0.7\ (R_A + R_B)\,C + 0.7R_BC$

$= 0.7\ (R_A\ T\ 2R_B)C$

$= 0.7\ (1.8 \times 10^3 + 2\ (2.4 \times 10^3))\ (0.0022 \times 10^{-6})$

$T = 10.2$ Usec

The frequency of operation, f, is

$$f = \frac{1}{T} \qquad \frac{1.43}{(R_A + 2R_B)C}$$

$$= \frac{1}{10.2 \times 10^{-6}}$$

$= 100KH_z$

The duty cycle of the output can be expressed as duty cycle, $D = \frac{T_{LOW}}{T} \times 100\%$

representing the percentage of time the output is low

$$D = \frac{T_{LOW}}{T} \times 100\%$$

$$= \frac{0.7R_BC}{T} = \frac{0.7 \times 2.4 \times 10^3 \times 0.0022 \times 10^{-6} \times 100}{10.2 \times 10^{-6}}$$

$= 0.36 \times 100\%$

$= \underline{36\%}$

Therefore the Duty cycle $= 36\%$

2.82 PULSE WIDTH MODULATION (PWM)

Although many switching techniques can be employed to implement a switched - mode power supply the fixed frequency PWM technique is by far the most popular choice. In this system (PWM) a square wave pulse is normally generated to drive the switching transistor on or off. The conduction time of the transistor is accordingly increased or decreased, by varying the pulse width, thereby, regulating the output voltage.

Here, the switch control signal is generated by comparing a signal level control voltage $V_{control}$ with a repetitive wave form as shown in fig 2.13a and fig 2.13b. The control voltage signal is generated by amplifying the error, or the difference between the actual output and the desired value. As shown below, the sawtooth repetitive waveform with a constant peak, establishes the switching frequency. [4]

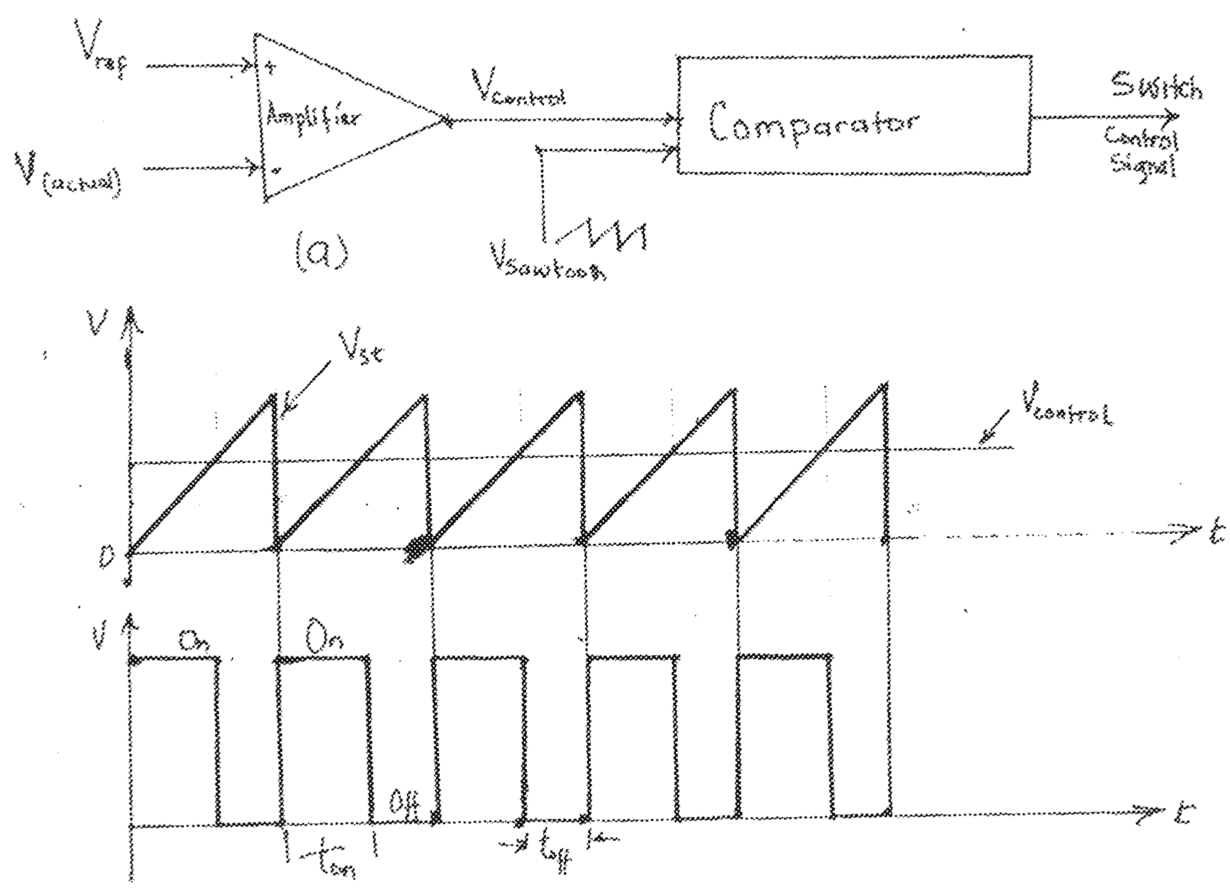
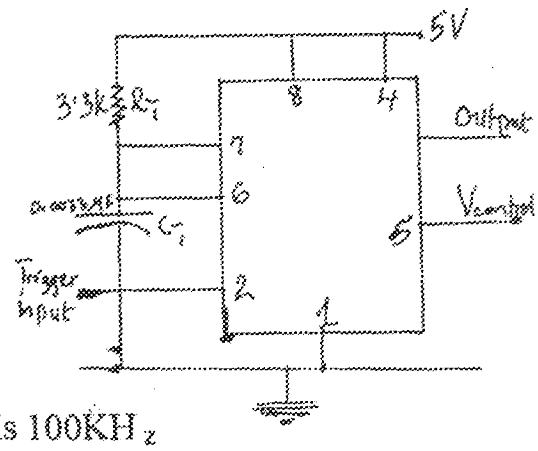


Figure 2-13 Pulse Width Modulator (PWM): (a) block diagram (b) Comparator signals

To effect the comparison, a 555 timer IC operating in its monostable state was used. The figure 2.14 below, shows the circuit connection of the 555 timer.

Fig 2-14 Monostable Multivibrator using 555 timer



The oscillator frequency is determined by

$$F_{osc} = \frac{1.1}{R_1C_1} = \frac{1.1}{3.3 \times 10^3 \times 0.0033 \times 10^{-6}} = 100KH_z$$

Hence, the frequency of oscillation of the 555 timer is 100KH z

It can be rightly seen from the above diagram that the Vcontrol (ie the amplified error) is fed into pin 5. This (Vcontrol) is used to modulate the sawtooth pulses that are fed into pin 6, to get a square wave at the output of the timer (pin 3), which drives the power transistor from on to off. [7]

2.9 THE OPERATIONAL AMPLIFIER

An Operational amplifier is a very high gain, high input resistance r_{in} directly-coupled negative-feedback amplifier which can amplify signals having frequency ranging from OH z to a little beyond IMH z They are made with different internal configurations in linear ICs. Figure 2-15 below shows the symbol: [2]

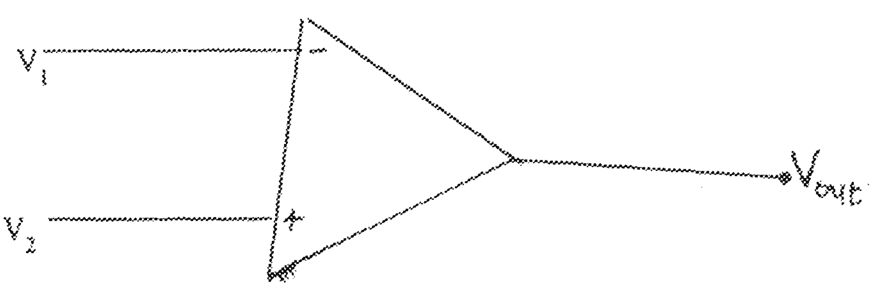


Figure 2. 15 OP-AMP SYMBOL

The OP - AMP's input can be single-ended or double-ended (or differential input) depending on whether the input voltage is applied to one input terminal only or to both.

2.91 OP-AMP APPLICATIONS

The applications of OP-AMP are as listed below:

(a) Phase Inventer

(b) Scale Charger

(c) Voltage follower

(d) Summoning Amplifier

(e) Difference Amplifier

(f) Integrator

(g) Differentiator

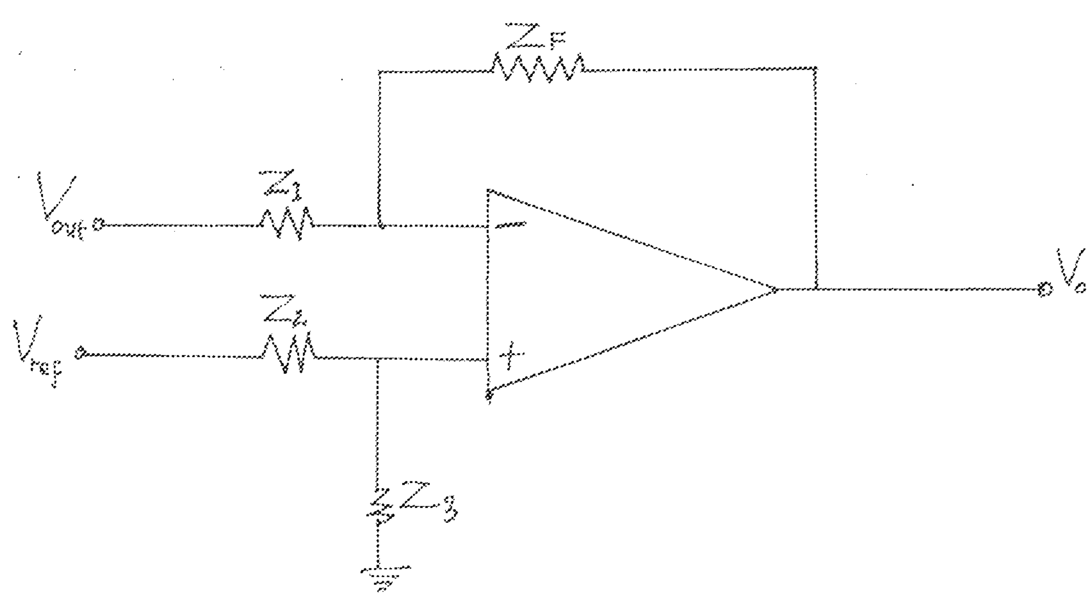
(h) Summing integrator

(i) Summing Differentiator

(j) Logarithmic Amplifier and

(k) Exponential. (Amplifier

For the purpose of this project, the differential amplifier application is employed.



Differential Amplifier Circuit

The Calculations below are used to obtain the output voltage (amplified error) Vo, of the above Circuit

let Vo [I] be the output voltage due to Vout only, and Vo[II] be the output voltage due to Vref only.

Now, with V_1, $V_o^{I} = \frac{-Z_f V_1}{Z_1}$

With V_2, $V_o^{II} = \frac{V_2 \times Z_3}{Z_3 + Z_2} \quad \frac{(1 + Zf)}{Z_1}$

But $Vo = Vo^{I} + Vo^{II}$ = Vcontrol

Therefore $Vo = \frac{-ZfV_1}{Z_1} + \frac{Z_3}{Z_2 + Z_3} \quad \frac{(Z_1 + Z_f) V_2}{Z_1}$

$$Vo = \frac{Z_f (V_2 - V_1)}{Z_1}$$

Zf = 4.7k

Z1 = 10k

Vout = V1 5v

Vref = V2 = 12V

$$Vo = \frac{4.7}{10} (12 - 5)$$

= 2.35V

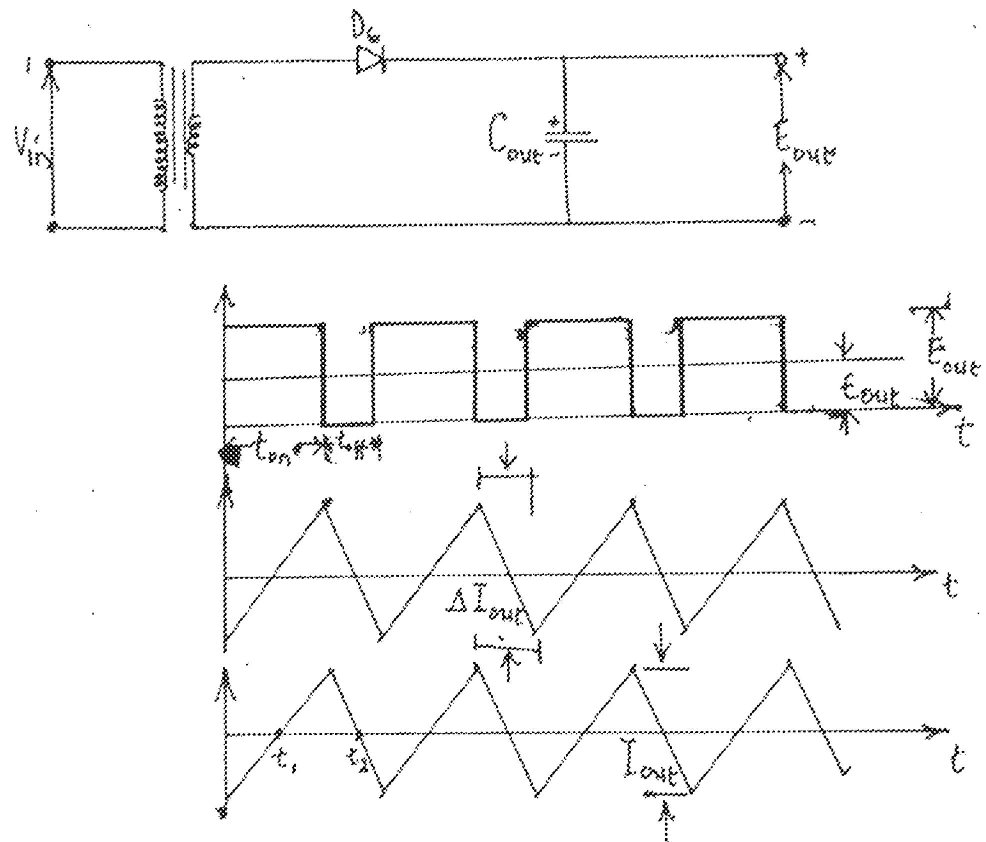
Therefore the Vcontrol used for the pulse width modulation is 2.35V.

Note: Vcontrol above is not a steady value, as it fluctuates alongside vout.

2.10 OUTPUT FILTER CAPACITOR

The choice of the output filter capacitor depends upon the type of converter being used as well as maximum operating current and switching frequency. Most of today's applications use electrolytic capacitors, preferably of the low ESR has a direct effect on the output ripple and also on the life of the capacitor itself. A majority of capacitor manufacturers offer low ESR electrolytic capacitors with guaranteed performance at 100KH.

Regardless of the type of capacitor used for the output filtering, the analysis below pertains to the calculation of its value. [6]



Fi.* (a) The output section of a PWM flyback converter (b/c) its associated voltage and current wave forms.

Referring to the figure above, the current wave form in the output capacitor C_{out} is centred about zero and has an amplitude of DI. Notice that the current waveform crosses the zero reference in the positive direction at T1, which is the middle of the ON time, while at t2, which is the middle of the OFF time, it crosses the zero reference in the negative direction. Thus the current will produce a ripple voltage ΔV which is given by

$$V_{out} = 1/C_{out} \int_{t_1}^{t_2} i\,dt \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

But the average during the time interval t_1 and t_2 is ($\Delta I_{out}/2)/2$ or $\Delta I_{out}/4$. Therefore, integrating eq. I above gives

$$V_{out} = \frac{I_{out}}{4\,c_{out}} \cdot \frac{T}{2} = \frac{(\Delta I_{out})\,T}{8\,c_{out}} = \frac{\Delta\ I_{out}}{8 f_{out} C}$$

Where T is the total period of On time t_1 and OFF time t_2.

Rearranging terms, the minimum output capacitor is

$$C_{out} = \frac{\Delta I_{out}}{8f\ \Delta V_{out}}$$

Where $I_{out} = 0.25\ I_L$; I_L = Specified output current

Δv_{out} = allowable peak - to - peak output voltage ripple

f = Operating frequency

For the purpose of this project, an electrolytic capacitor of the value as calculated below was used ;

given that

$$C_{out} = \frac{\Delta I_{out}}{8 \times f \times \Delta v_{out}}$$

Where $\Delta I_{out} = \frac{I_{out}}{4}$

But $I_{out} = 8A$

Therefore $\Delta I_{out} = 8/4 = 2A$

f (frequency of operation) = 100KH$_3$

Ripple voltage $\Delta V = 0.1$

Therefore

$$C_{out} = \frac{2}{8 \times 100 \times 10^3 \times 0.1}$$

$$= 2.5 \times 10^{-5} F$$

$$= 250nF$$

Hence the capacitance of the output capacitor is 250nF

CHAPTER THREE

CONSTRUCTION, TESTING AND RESULTS

3.1 CONSTRUCTION

To enhance the construction of this project, the components as specified by the design were all brought and carefully assembled together in line with the design circuitry. This was done in modules as underlisted:

The input state

The Switching and feedback stage and

The output stage.

To allow for modifications, necessary corrections and to eliminate unnecessary waste of time and the project was initially constructed on a bread board, tested and observed working in conformity with the design goal. After which it was transferred to some vero Boards where permanent soldering was effected.

To ensure that the project was a success, instruments like wire cutter and stripper, soldering lead, soldering iron, digital multimeter, solder sucker, connecting wire, screw-driver, long nose plier, vero board and Bread board were used. To construct the design on the vero boards, the following steps were taken.

(i) The layout design plan of the components position on the vero board was made making sure that unnecessary distance between, components were avoided to reduce the length of wire used components were also not placed too close to each other to avoid shorts.

(ii) IC sockets were soldered onto the vero board in places allocated to them in the layout.

(iii) The switching transistor was then mounted on its heat sink and soldered to the board.

(iv) The discrete components:- resistors, capacitors and diodes were soldered directly to the board.

(v) Installed components were then connected to one another using the connecting wires

(vi) The transformers were mounted as shown in the circuit diagram.

(vii) After each connection made, the digital multimeter was used to check for continuity and shorts.

(viii) The ICs were then plugged into the circuit, and the circuit was then ready to be tested.

Also in constructing the casing appropriate measurements were taken to suit the shape and size of the hardware components of the project. Some perforations were also made to allow for cooling of the components. A well polished white painting was used to give it a state-of -th-art look, and also aimed at reducing the EMI from external bodies

3.2 TESTING

The testing of this project started from the construction stage, as each of the modules on completion was tested before moving on to the next one. The circuit was in each case checked for continuity using a digital multimeter. Also, the required behaviour of each component after soldering was tested.

The output of the transformers were also tested then, on completion of the entire construction, the output was tested to confirm its proper functioning.

In testing, all measurements were taken with reference to the ground.

3.3. DISCUSSION OF RESULTS

The output was measured with reference to ground and an output voltage Vout of 12.3V was obtained which is in conformity with the desired 12V output voltage. From the above, I can really say that the aim of the project has been achieved as the little difference in value is practically considered negligible.

The reason for this difference in value could not be far fetched from the very low input resistance observed on the primary winding of the high frequency transformer choke.

CHAPTER FOUR

CONCLUSION, RECOMMENDATION AND REFERENCE

4.1 CONCLUSION

I would like to say that the result of this project has proved it a success as the output obtained is practically considered the same as the desired output.

The major obstacle encountered in making this project a success was the provision of the high frequency transformer choke used in the construction, as it is not easy to come-by in the market.

Also, the soldering exercise was not so easy a task, but it was skilfully done and progress was made.

4.2. RECOMMENDATION

It is apparent that the dream of most students undertaking a final year project is to produce a project that will stand the test of quality, but it is rather unfortunate that this dream rarely comes true, due mainly to improper funding.

In-view of this, I would recommend that:

1. The school authority sponsors about 80% of the total financial requirement of the project.
2. Many students be grouped together and given a substantial project to execute, as it is said that two good heads are better than one.
3. The projects to be executed in the departmental laboratory by the concerned students under the strict supervision of their supervisors.

The above recommendations if hearkened to, I believe would go a long way in boosting the department's, the school's and the entire institution's ego.

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CIRCUIT DIAGRAM OF A SWITCH MODE POWER SUPPLY, USING FLYBACK TOPOLOGY.