Chapter 1

1. Introduction

The quest of seeing through darkness is perhaps as the old as the mankind. When human race became civilized and began to fight in an organized manner, the night fighting became an important factor of warfare. Therefore, the ability to see in darkness also became a key military requirement. The possibility of achieving this requirement with completely passive system, that is, seeing others without being seen, has always been regarded as an ultimate military objective. The development of modern thermal imaging systems has accomplished this ultimate objective. The military applications of thermal imaging systems are limited only to the imagination of the user. Thermal imagers are very versatile system and are now being very effectively used in wide variety of military roles. Its principle role can be classified into the following two major categories:

a. Reconnaissance and surveillance.
b. Automatic target tracking and weapon fire control-systems.
c. Detection, recognition and identification of target.

(1). Thermal imaging as the name suggests is a technique or a process of converting infrared radiation distribution of a scene into a corresponding two dimensional visual image [1]. The basic principle of this system is based on laws of physics that all objects with temperatures above absolute zero degree Kelvin (i.e. -273°C) emit thermal radiation. Since, this thermal radiation varies according to variations in the scene temperature; the thermal image provides a pictorial representation of temperature differences.

Thermal imaging systems perceive the very small temperature differences which exist not only between the objects and the background of a scene, but within the objects themselves. In a uniform ambient temperature environment, the differences in temperature are primarily due to emissivity characteristics of various objects. Since different objects have different emissivity characteristics, they can be easily discerned by thermal imaging techniques.

Thermal Imager Sophie is a state of the art equipment. It is a third generation IR camera and works on the principles of thermal imaging. This high tech equipment is extremely expensive. A huge amount of Foreign exchange is being expended in terms of repair and maintenance of this equipment. In the recent past, this equipment has been used intensively in different operations. During its prolonged use it was observed that power supply of battery belt causes problems which is a big hindrance during the operation.

As large no of faulty power supplies along with the battery belts started arriving in the Base workshop responsible for its repair, the situation became alarming. The matter was investigated and it was found that the multilayer main circuit card of the power supply was the acute source of failure. This is a very complicated circuit card and if it is burnt, it can not be repaired. Following problems were anaylised when the issue of the faulty power supply was raised.

1.1. Tech Problems

a. Circuit diagram of the charging card is not available; therefore, complete circuit description down to the component level is unknown.

b. Fault finding becomes difficult when there is any dry joint or print of the circuit breaks in this multi layer PCB.

c. Burnt PCB can not be repaired.

d. Different components like Chopper, FET, Coil, & relay etc are not available in the local market. Resultantly, when any of these components become faulty, the complete power supply becomes inoperative.

1.2. Problem faced by the users

a. During the operation, when the thermal sight is connected to the bty belt, the sight is turned on as the external cable of the sight is fixed in the belt. There is no turn ON/OFF button. This may cause burning of the sight when during night operation hit and trial is made by the Operator to fix male of the cable into the battery belt connections.

b. There is no charging cut off system in the power supply. Charging process continues till the time the charging is cut off manually. Over-charging causes damage to the battery cells and their life reduces.

1.3. Problems faced during procurement

a. One battery belt cost € 2302 which is equal to Rs 184107 approx. It is a very high cost in foreign currency.

b.. Procurement involving foreign exchange is a very lengthy procedure which may take several months and some times up to years. This delay in the procurement procedures is a hurdle in the supply of the equipment to the user which may effect the operational commitments.

c. International embargoes may stop the supply of the spares / accessories as it happened in the case of other sensitive equipment of military use in the past.

1.4. Theme of the study

Keeping in view the problems highlighted above, there is a need to solve this problem. The purpose of this study is to redesign the power supply of the Battery Belt of Sophie Thermal Imager so that the repair/replacement of the costly equipment may be carried out indigenously. This indigenous development will enhance the repair/maintains capability of the battery belt in particular and Sophie Sight in general. This will also save huge precious foreign exchange which is of utmost importance. This indigenous development will also be another step towards self reliance.

Chapter 2

SOPHIE THERMAL IMAGER (TI)

2.1. INTRODUCTION: - The SOPHIE Hand-Held Thermal Imager (TI) is designed for target detection, reconnaissance and identification by viewing the scene observed, both by day and night under poor climatic conditions. It is also designed for simple and fast implementation, as the imager can be used both as a portable Thermal Binocular as well as a Thermal Camera mounted on a mechanical support by a quick connection device, when installed in a system environment.

Fig 2.1

Sophie Thermal Imager is shown in fig 2.1. It is small in size, light weight and user friendly equipment. It is operated by 13.2 V NiMH battery, Battery-Belt and DC-DC Converter. Its practical reconnaissance distance for Tank size target is 3.5 Km with narrow field of view (NFOV). As shown in fig 2.2 the spectral band width of Sophie TI is 7.5 µm to 10.5 µm which covers the Far Infrared region of the Electromagnetic spectrum.[2]

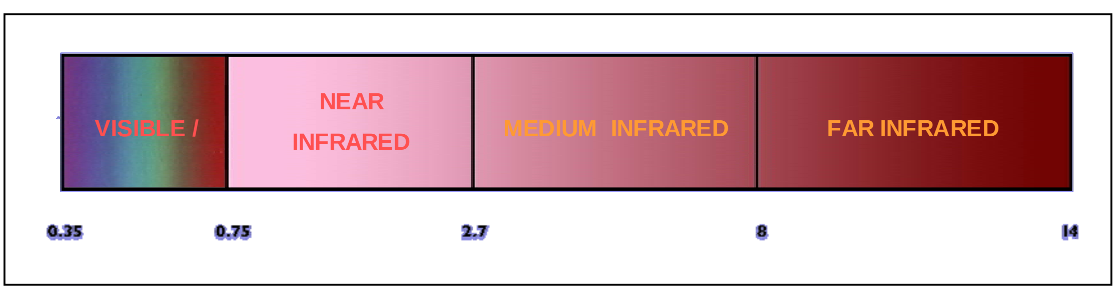

Fig 2.2

The option of changing the Fields of view from wide field of view (WFOV) to narrow field of view (NFOV) and then Electronic Magnification is incorporated to characterize the useable dimension on the object and the size of the image. Three dimensional view of the Sophie TI is shown in fig 2.3.

The whole unit is a sealed block of two different physical and functional sub assemblies which is indicated by "Body". A battery hooking strap "Battery strap" , a slot

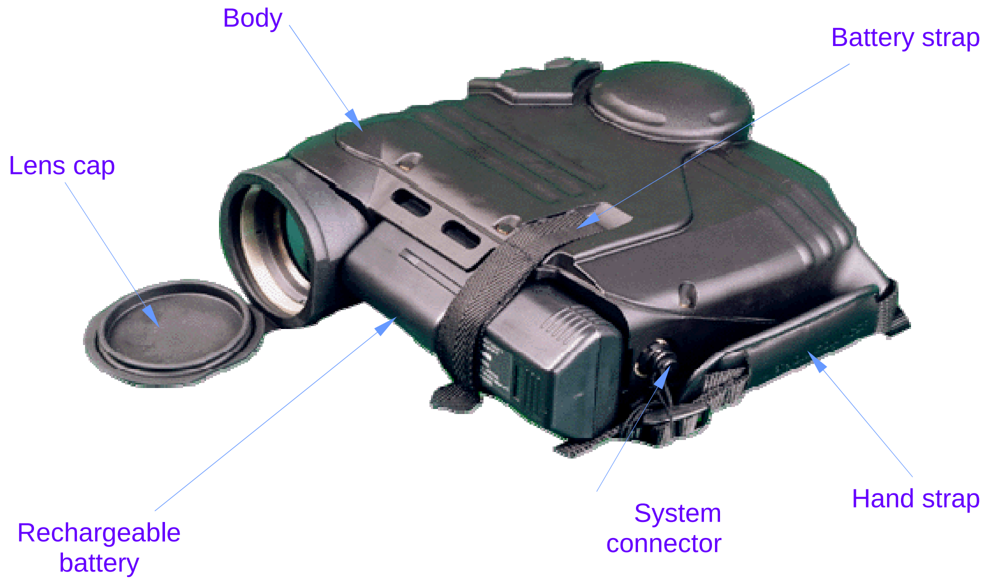

Fig 2.3

for inserting the "rechargeable battery" and a cover "Lens cap" for protecting the lens L1 are located at the front of the unit. A "system connector" protected by a plug is available on the left which is only connector in the system to communicate with external power supply e.g. Bty Belt & DC-DC converter and for video output. Two "Hand Straps" are available on left and right of the unit to hold it firmly during operation.

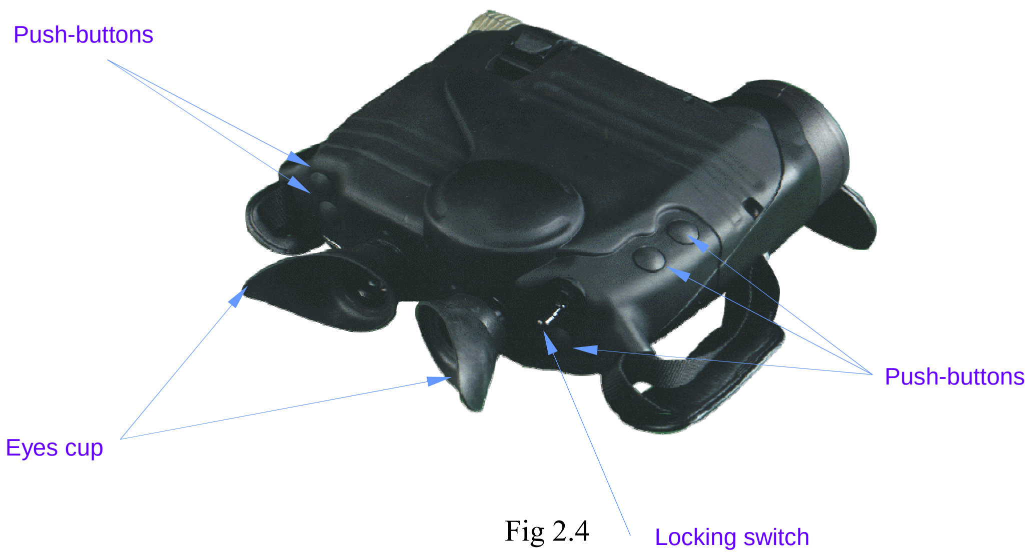

Fig 2.4

In Fig 2.4 multifunction locking switch and different pushbuttons of the Sophie TI are shown.

2.2. <u>Accessories</u>:

The composition of the system is as follows:-

- One Thermal Imager
- Three rechargeable batteries
- One carrying bag
- One mechanical interface composed of:
  a. One Sophie adapter
  b. One BKS adapter
  c. A set of shims (3, 3.5, 4, 4.5 & 5 mm)
  d. Three screws, washers and spring washers.
- One power supply DC-DC converter
- One rechargeable batteries interface belt.
- One cable no. 18
- One battery charger including:
  a. One battery charger
  b. One specific battery adapter for charging of two batteries simultaneously
  c. One 24 V DC cable
  d. One AC power supply cable

2.3. <u>Battery Belt</u>

The battery belt is another source of supply for Sophie TI. As shown in fig 2.5 it includes 11x NiCd 1.2V 10Ah cells assembled in four packs (3+3+3+2). This belt has an integral charger. This charger accepts a vide range input supply from 100 VAC to 250 VAC, 50/60 Hz. All the battery packs and charger are placed in a deep moulded leather case. It is used to provide extended running time. The belt provides 13.2 V to the system. Its endurance time is 7 hrs and charging time is 12 to 14 hrs. If the voltage of a battery pack falls below 75% of its nominal voltage, cells may be damaged by voltage reversal, thus shortening the life of the battery. To guard against this an over discharge protection (ODP) is incorporated. This ODP cuts off power to the output sockets when the belt has reached its maximum discharge state. The maximum discharge state is 9.5V to 10.5 V.

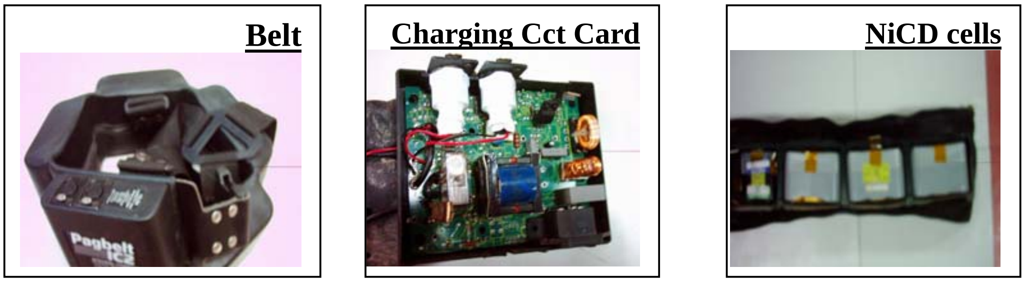

Fig 2.5

The output socket becomes isolated if cell temperature exceeds 70°C and can be reset by pressing thermal protection reset button when the temperature falls. The battery belt is protected against short circuit and excessive currents by means of a self re-setting protection device. Its rated max current is 10 A. The protection device will allow current surges up to 15 amps, but will trip if a continuous current in excess of 12 is drawn.

Our main concern is the battery belt used with the Sophie sight. This accessory of the sight holds very high importance for the user. Because the operating time of the sight is 2 hrs with detachable battery where as the operating time enhances almost 5 times when the bty belt is used. The operating time of this belt is 7 hrs when used in operation mode [3]. Where as, the operation time may be enhanced up to 8 hrs in standby mode.

Beside over discharge protection ,there is another protection in this battery belt circuit. This protection is against over heating. If the temperature of the battery cells exceeds by 70 ˚C during charging, the charging circuit stops functioning. The circuit is also protected against excessive current. This circuit allows current up to 10 A to pass. The protection device can bear a surge up to 15 Amp, but will trip if continuous current in excess of 12 Amp is drawn.

2.3.1. <u>Limitation With the Circuit</u>

As already mentioned in the chapter 1, there is no over voltage protection available in this power supply. The charging of battery belt does not stop even after cells of the battery belt are fully charged. Due to this drawback of the circuit, the life of the cells is reduced.

When this battery belt is used in the operational area special attention is paid to this aspect. One individual is detailed who keeps the record of the charging time. Due to the shortage of the manpower, the user units face problems in sparing the individual for this job.

2.3.2. Block diagram of the circuit

The OEM has not supplied any technical manuals or any circuit description of this power supply. However the charging circuit of the supply has been analyzed and has been decoded to a large extent. Problems were faced to analyses this multilayer circuit but these problems have been overcome and the circuit card has been decoded as shown in fig 2.6.

Block Diagram

Existing Power Supply

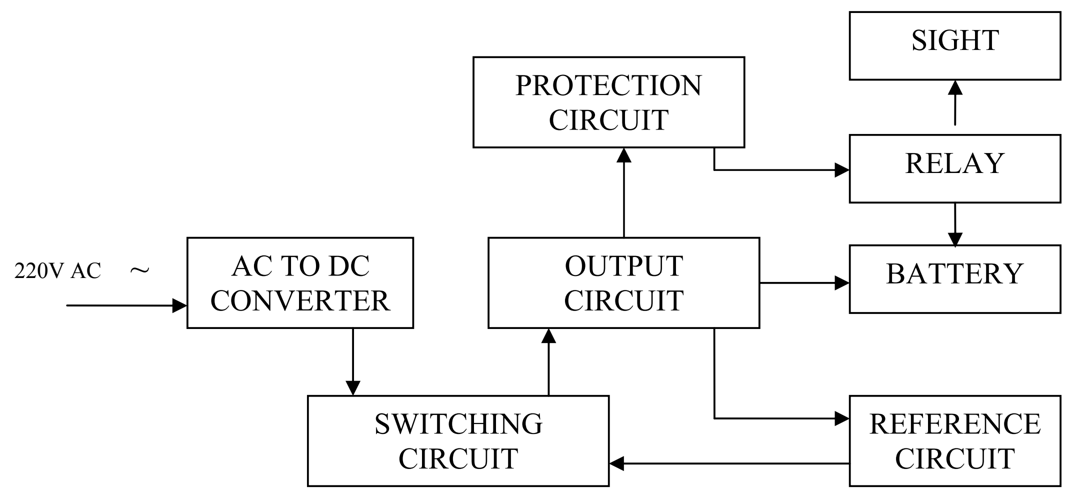

Fig 2.6

2.3.3. AC to DC Converter

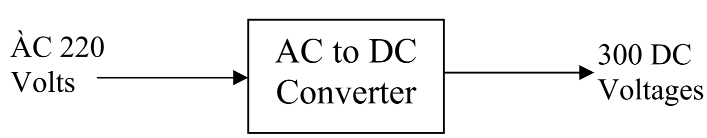

Fig 2.7

As shown in fig 2.7, 220 volt AC is supplied at the input. This AC is converted into the DC voltage by a Bridge rectifier.

2.3.4. Switching Block

Switching circuit is shown in the fig 2.8, attached in the end of this chapter, that FET BC 40 is used for the switching operation. When power is turned ON, positive voltage is developed at the drain of the FET. Self oscillator IC, UC 3844 also gets started as power is turned ON. The IC can be located in fig 2.8 in the power supply block. This IC receives voltage at its Vcc and it gives its output at the gate of FET. When FET receives pulse at its gate, it starts operating. Voltage appears at the primary of the transformer and the induction in the transformer starts.

2.3.5. Transformer

Referring to fig 2.8 at the end of this chapter, technical data of the transformer used is as follows:

- Material Used Ferrite
- No. of primary turns 97
- No. of secondary turns 19
- Output voltage 20 volt
- Working frequency 20 KHz.

From the fig-2.8, it can be seen that one end of the primary winding is connected with the FET BC-40 and the other end of the primary winding is grounded. Due to switching action alternate voltage appears at the primary windings. Due to effect of this varying voltage, emf is induced in the secondary windings. The output of this transformer is 20 volt AC.

2.3.6. Reference Circuit

As shown in circuit diagram fig 2.8, LM 358 is used as a comparator IC. The pin description of the IC is as under:-

Pin no. 8	Vcc
Pin no. 4	Ground
Pin no. 3	Sample Voltage is received
Pin no. 1	Output
Pin no. 2	Fix voltage are received.

Sample voltage from the output of transformer is applied at the pin no. 3 of the comparator IC. Fix reference voltage is applied at Pin no. 2 of the comparator IC. Comparator IC, compares the two applied voltages and generates error signal. This signal is applied to the oscillator, UC 3844. Location of UC 3844 can be seen in fig 2.8 in the power block. The oscillator IC changes the turn ON and turn OFF time of the FET. Through this procedure, the correction in output voltage of the transformer is carried out.

2.3.7. Output Block

Fig 2.8 shows that rectifier diode BYTO 3400 is connected with the secondary winding L4 of the transformer. This diode converts AC voltage into DC voltage. 20 volts DC is supplied to the charging circuit directly through this diode.

2.3.8. Protection Circuit

a. Low Battery Protection Circuit

In fig 2.8, portion marked as blue is the protection circuit. From the output of the diode TO 3400, through an inductor, the output is provided to the relay. This is low battery protection circuit. Point A and Point B of the relay are closed when the required voltage is achieved. Voltage at that moment appears at output of the sockets C and D where the thermal imager is connected. At that time a reference from the relay goes to the IC TLC 556 CN. This IC is meant to sense the low voltage level of the battery.

When the level of the battery drops down from the specified minimum level due to continuous use of the sight, the IC senses this low voltage level and the relay cuts off the main circuit from the battery. This protection prevents the sight from operating at the low level voltage.

b. Heat sensor

Heat sensor is also installed in this power supply as a protection; the sensor is shown in fig 2.8. This sensor senses the temperature of the cells and gives its output to IC TLC 556CN. When the temperature of the cells rises above 70 ˚C, the sensor is activated and disconnects the sight through relay thus saving it against getting burnt-out.

2.3.9. <u>Charging Circuit</u>

Output is received against L4, the secondary winding of the chopper transformer. AC voltage received at the output is rectified into DC by the diode BYTO 3400. This diode gives output directly at the positive terminal of the load i.e the charging battery. The negative terminal is grounded. The charging cycle is completed and the charging starts.

2.3.10. <u>Reset Switch</u>

The relay as shown in fig 2.8 cuts of the sight form the power supply when protection circuits are activated. Reset available in the circuit (shown in fig, marked as SW) has to be pressed manually to reset the circuit.

Chapter 3

Selection of suitable topology

3.1. Introduction

Selection of suitable topology is the most important step in designing of a power supply. Many significant technological changes in power supply design may result in improved performance. It is important to mention here that output voltage and load current always depend on the application. The power supply designs are often tailored to specific applications. No simple procedure exists to select 100% right topology. In order to achieve the desired results two or more topologies may be used in the regulator for better performance.[4]

For the designed power supply, back to back forward converter topology which is also known as half bridge was selected. The complete selected topology is a combination of half bridge and buck converter. Before describing half bridge converter a brief description of forward converter is given in the following paragraphs.

3.2 Forward converter

It is the most widely used topology for output power less than 150W to 200 W, when maximum input voltage is in the range of 60 volts to 200 volts. If the forward converter are used when the input voltage is less than 60 volts, the primary input current of the converter becomes uncomfortably large. Similarly when forward converters are used when input voltage is above 250 volts, the maximum stress on the transistors becomes too large. These two factors are the major reasons due to which forward converters are considered suitable for the input voltage range between 60 volts to 250 volts.

Isolated single switch forward converter is shown in the figure 3.1, on next page[5].

Forward Converter

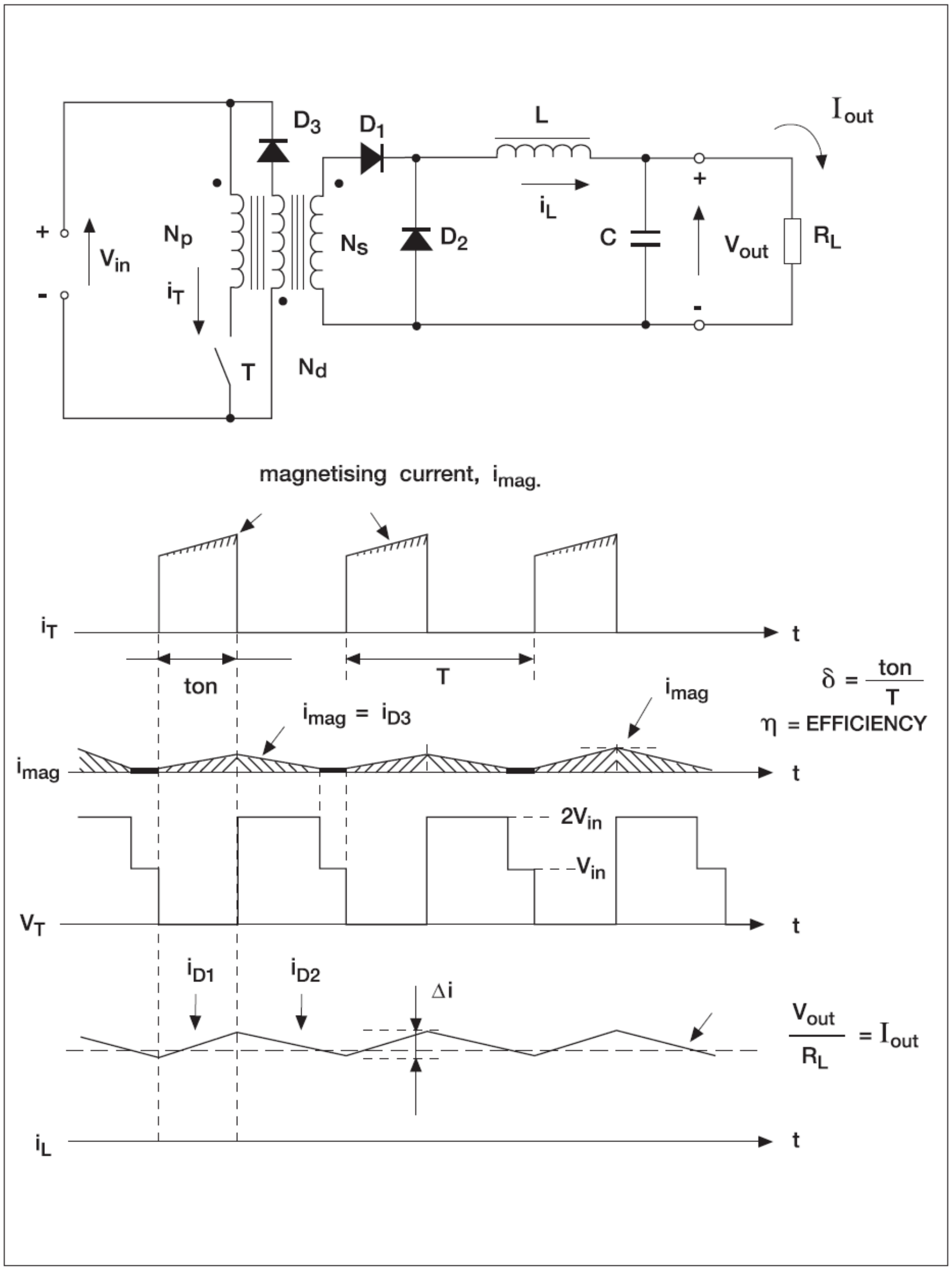

Fig 3.1

Referring fig 3.1, the forward converter transfers energy directly from the input source to the load during the ON-time of the power switch T. During OFF-time of the power switch, the energy is delivered through the output inductor L, and the rectifier diode D2. The secondary current is reflected into the primary as

$$I_p = \frac{N_s}{N_p} \times I_s$$

There are two modes of operation of this forward converter. Both modes are discussed briefly in the following paragraphs.

Mode 1

Mode 1 begins when switch 'T' (as shown in fig 3.1) is closed. The voltage across the primary winding of the transformer develops and due to effect of the primary voltage, emf is induced in the secondary winding of the transformer. Primary current starts to build up and transfers energy from primary winding to the secondary winding. The energy is then transferred to LC circuit through rectifier diode D1, which is forward biased. From inductor L the energy is transferred to the load RL.

Mode 2

This mode begins when switch T in fig 3.1 is opened. The polarity of the transformer voltage reverses. This causes diode D1 to turn off and diode D2 and diode D3 to turn on . Diode D2 becomes forward biased and delivers energy to Load RL through inductor L. Diode D3 and the tertiary windings 'Nd' provide a path for magnetic current returning to the input. The relationship between output voltage and input voltage of the forward converter is as follows:-

$$V_{out} = \left(\frac{N_s}{N_p}\right) V_{in} \times D$$

Where

D = Duty cycle

Ns = Number of secondary turns

Np = Number of Primary turns

Vin = Supplied Voltage

Vout = Output Voltage

The voltage relationship shows that by changing the value of duty cycle or the ratio between the primary and the secondary turns, the output voltage can be varied.

In the wave form shown in fig 3.1, IT is the current through the switch T, when it is in closed position. ID3 is the magnetizing current through Diode D3. VT is the voltage across the switch. IL is the output current through inductor L.

3.2.1. LC filter on the output

Referring fig 3.1, LC filter can be seen at output of the secondary windings Ns. To provide a steady DC output and reduce the ripples and noise, LC low pass filters are normally used on the output of the switched mode power supply. In forward converters, these filters carry out two main functions. Their prime function is to store energy, so as to maintain a nearly steady DC output voltage throughout the power switching cycle. The second function is to reduce noise and the ripples of output current and voltage.

3.2.2. Forward converter with double switch

Principle of operation of the forward converter using double switch i.e. two transistors, is same as discussed earlier for the forward converter using single switch. Forward converter with double switch was used for the design of the power supply. A few reasons for this choice are discussed as follows.

a. Stress on the switch, which is NPN transistor, was reduced to half when two switches were used.

b. To give reliability to the system.

Chapter 4

Design Methodology of Power Supply

Block diagram of 20 watt power supply for Sophie thermal imager is shown as follows

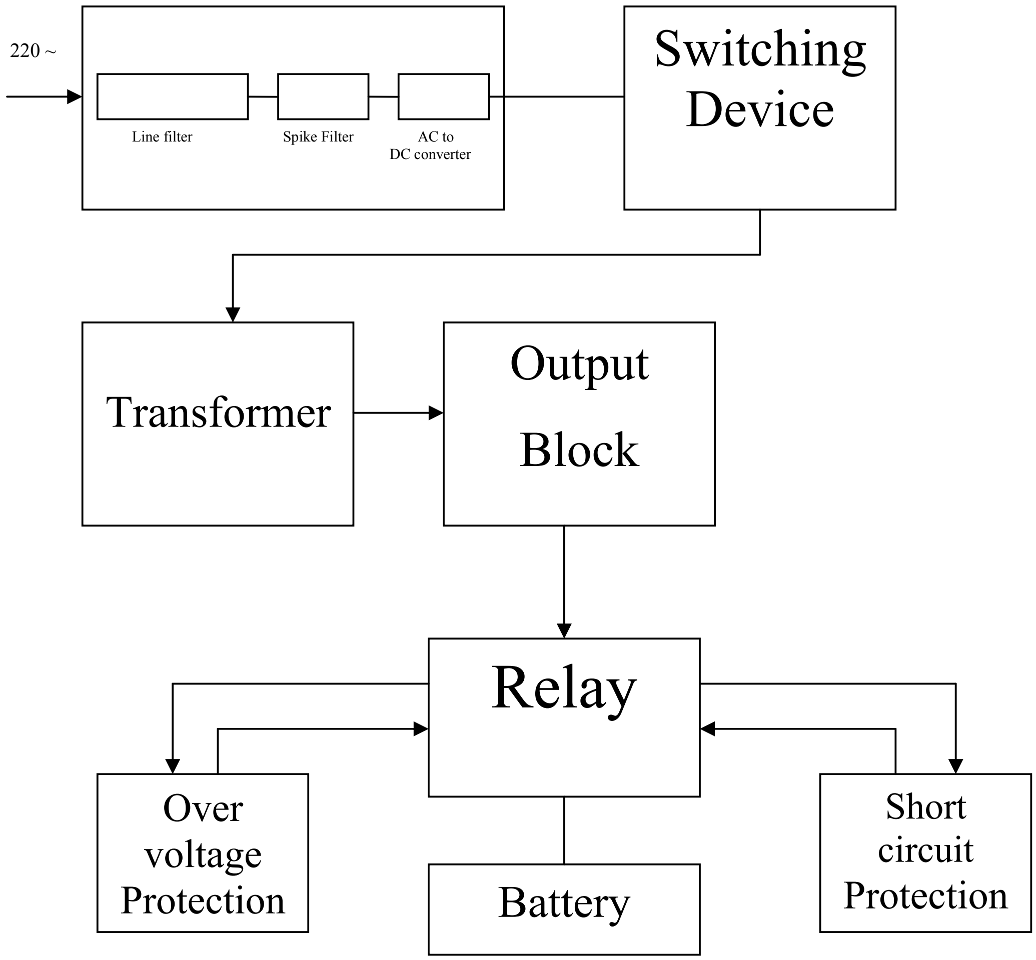

Fig 4.1

A brief description of these blocks is given in the following paragraphs.

4.1 **AC to DC converter**

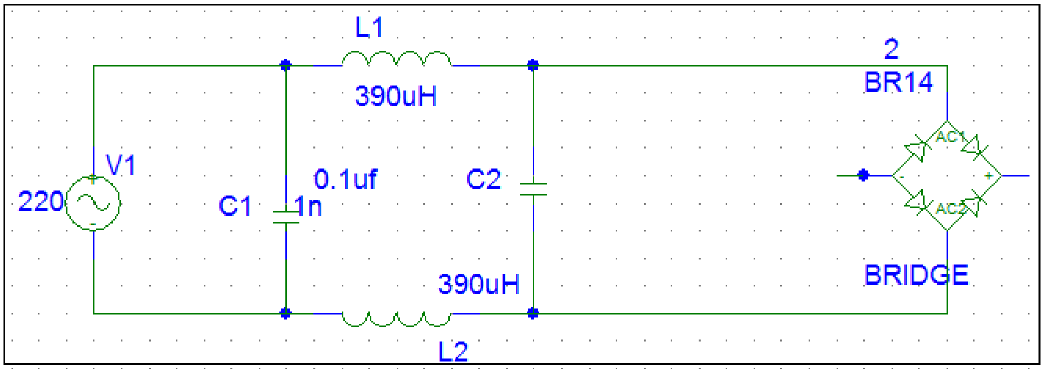

Fig 4.2

This portion of the power supply was designed to convert 220 volts AC into 300 volts DC. In fig 4.1, it is seen that a combination of line and spike filters is used to reduce the noise and the peak voltages. The extra noise and the voltage spikes produced by generator are reduced by using two filter capacitors C1,C2 and two inductors L1,L2. Filtered AC voltage is then passed through bridge rectifier which converts 220 volt AC voltage into 300 volt DC. This power supply is designed to be used in the operational area. In the field area, the direct power line is not available, therefore, generator is used as an alternative source. Due to the use of generator, extra noise and voltage spikes are produced. As already discussed, this noise and voltage spikes are reduced by using two filter capacitors, C1 and C2 and two inductors and 2.

4.2 Switching device

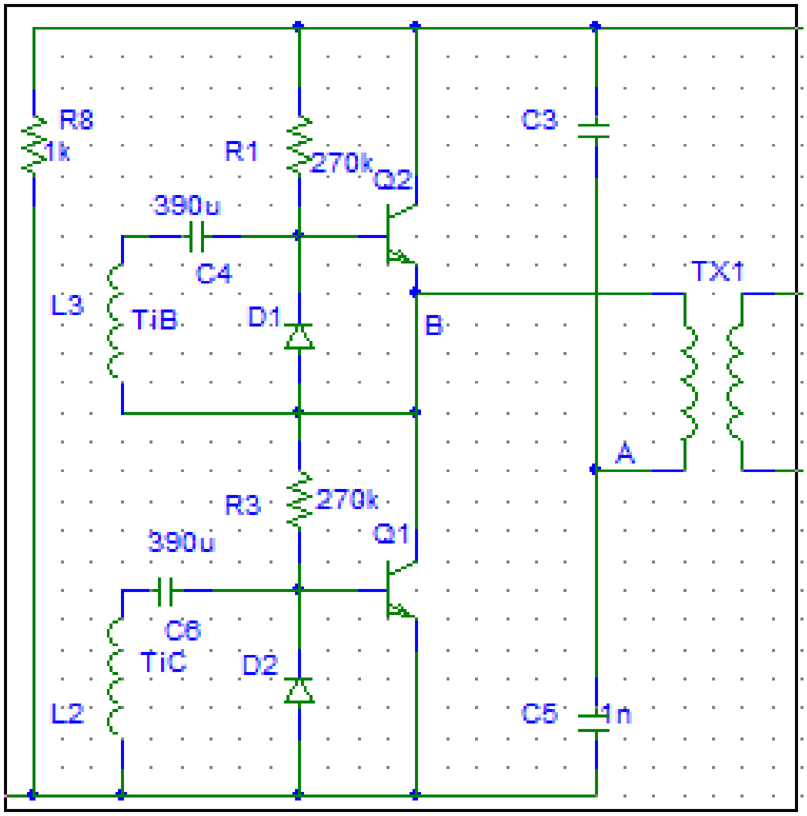

Fig 4.3

4.2.1 Circuit Description

Referring to fig 4.3 two NPN transistors Q1 and Q2 were used. Emitter of Q2 is connected with the collector of Q1. Auxiliary coil TiB is connected with the base of Q2 and the coil TiC is connected with the base of Q1. Two resistors R1 and R3 are connected with the base of transistor Q2 and Q1 respectively. Both auxiliary coils TiB and TiC are out of phase with each other. TiB is out of phase with the primary windings of the transformer and TiC is in phase with the primary windings of the transformer.

4.2.2 Principal Operation

The power supply was designed to operate within the frequency range of 20 KHz. The time period was calculated as 50 µ sec. It is the time period that is required by the transistors to operate between turn ON and turn OFF state. The maximum turn ON period was calculated as

0.8 T/2 of the total period of operation [6]. The turn ON period for Q1 and Q2 was calculated as 20 μ sec.

Since switching action can not be made clear unless operation of the transformer is discussed, therefore, operation of the transformer TX1, as shown in fig 4.2, is also discussed simultaneously along switching operation.

Initially, Q2 turns on as a result of base drive in resistor R1. When Q2 is in the ON state, collector and emitter of the transistor Q2 are short circuited. Positive voltage appears at point B. At point B, one terminal of primary winding of transformer is connected. Due to positive pulse at point B, the primary of the transformer starts induction. emf is induced in the secondary windings of the transformer. Primary voltage of the transformer induces voltage in the secondary winding of the transformer. As discussed earlier coil TiB is out of phase with the primary windings of the transformer, Emf with opposite polarity is induced in the coil TiB. This opposite polarity reverse biases the base of the transistor Q2. Resultantly transistor Q2 stops its operation.

When positive voltage appears at point B, Q1 receives pulse through resistor R3. Q1 comes into the active region and its collector and emitter are short circuited. Negative voltage appears at point B as the result of induction of Q1.

At point B. the primary windings of the transformer receive its second pulse. Emf is induced in the primary windings of the transformer. As discussed earlier TiB is out of phase with the primary windings of the transformer, the induced Emf in TiB will produce positive pulse at the base of Q2. Q2 will turn on and due to the action of induced Emf in the coil TiC, Q1 will stop operating.

The transformer operates due to the supply of alternate pulses produced by the switching action of Q1 and Q2 at point B.

4.3 **Transformer Designing**

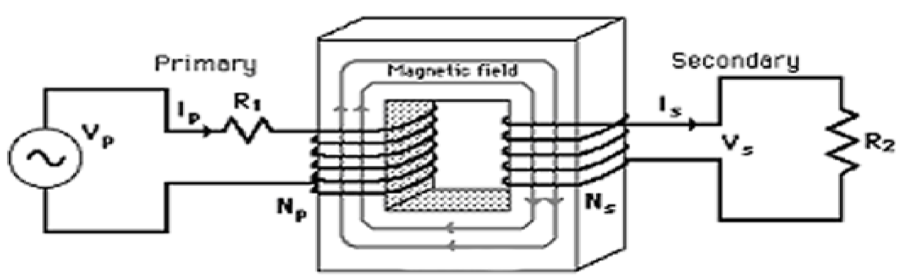

Fig 4.4

The pictorial representation of the transformer can be seen in the fig 4.4.The transformer was design on 155 volts 20 KHz frequency range. The designed parameters are discussed in the following paragraphs.

4.3.1 **Input voltage of transformer**

The transformer was designed at 155 volts.

4.3.2. **Selection of Flux Density**

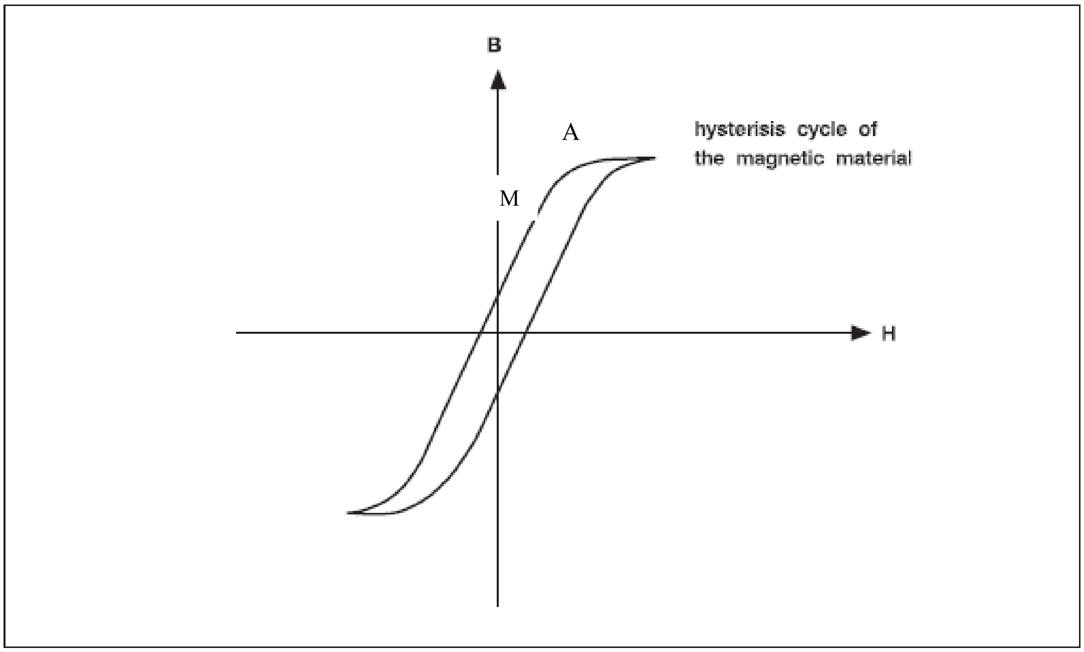

Fig 4.5

In fig 4.5 it is seen that the relationship between magnetic field (H) and magnetic flux density (B) is not linear. If the relationship between the two is plotted for increasing levels of field strength, it will follow a curve up to a point where further increases in magnetic field strength will result in no further change in flux density. This condition is called magnetic saturation.

Fig 4.5 shows that the core saturates at point A. The selection of flux density is a compromise. For typical forward converter transformer for up to 30 KHz frequency ranges , the medium range of flux density appropriate [7]. To avoid saturation of the core, the value for the flux density was selected well before the saturation point. The selected value of flux density was 225 mT which lies close to point M on the B-H curve.

4.3.3. Calculation of Primary number of Turns

Calculation of primary turns was carried out using volt second approach. The applied voltage to the transformer is square wave, therefore, the primary turns were calculated for single turn 'ON' period.

$$Np = \frac{Vin \times ton}{\Delta\ Bcc.Ac.}$$

Where

Np	=	primary turns		
V	=	Applied voltage	=>	155 volts
ton	=	on time in µs	=>	$\frac{.8\ T}{2}$
			=>	20 µsec

Δ Bac = Maximum Flux Density => 250 mT

=> 0.25 T

Ae = Cross sectional Area = 1.81 cm^2

=> 181mm^2

$$Np = \frac{141 \times 20}{.225 \times 181}$$

⇨ 68.50 turns.

For simplicity 69 turns were incorporated in the design parameters.

4.3.4 **Calculation of Secondary number of Turns**

The secondary turns were calculated for the lowest output voltage.

Secondary voltage, Vs was calculated as

$$Vs = 1.20 \times Vout$$

$$Vs = 1.20 \times 20 \text{ volts} = 24 \text{ volts}$$

Allowing for 1 volt drop due to inductor and diode, Vs comes to 25 volts. This must be available at the minimum input voltage and maximum on period. Secondary turns were calculated as

$$Ns = \frac{Vs}{Vp\ /turn}$$

Vp/turn = primary volts per turn

With 69 primary turns, volt/turn is

$$Vpt = \frac{V\ in}{Np}$$

$$= \frac{155}{69}$$

$$= 2.24 \text{ v/turn}$$

Minimum secondary turns were calculated as

$$\frac{Vs}{Vpt} = \frac{24}{2.24} = 10.90 \text{ turns}$$

For simplicity 11 turns were selected.

The primary turns were re-adjusted at that point as follows.

$$\frac{Vin}{Np} = \frac{Vs}{Ns}$$

$$Np = \frac{155 \times 11}{24} = 71.04$$

$$= 72 \text{ turns}$$

Therefore efficiency of the transformer was calculated as.

$$\eta = \frac{Po}{Pin} = \frac{Vout \times Iout}{Vin \times Iin} = \frac{24}{24.025} = 99\ \%$$

4.3.5. **Calculation of Auxiliary Number of Turns**

For biasing of transistors in switching mode, auxiliary coils are used .These coils behave as secondary coils when transformer operates in the induction mode. One fourth of total numbers of secondary turns were selected as auxiliary number of turns.[8]

Number of turns selected for the auxiliary coils was '4'.

4.3.6. **Calculation of Losses**

There are two major losses for the transformer operation.

a. CU losses

b. Core losses

CU losses for both primary and secondary windings were calculated in the following steps.

a. **CU losses for primary windings**

Size of wire used for primary winding of the transformer was 26 AWG.

Length / turn = 38.6 mm

Total no of turns = 71

Resistance of the wire used = .001789 Ω / cm

Total length of the wire used for primary side of transformer

= 38.6 x 71

=. 2740.6 mm

= 274.06 cm

Total Resistance for 71 turns = .001789 x 274.06 => .490 Ω

Primary current was calculated as.

$$\frac{Ns}{Np} = \frac{Ip}{Is}$$

$$\frac{11}{71} = \frac{Ip}{1}$$

$$I_p = \frac{11}{71} = .1549 \text{ Amp}$$

$$= .155 \text{ Amp}$$

CU Losses = $I^2 R$= $(.155)^2 (.490)$

= .0117 w

a.a. **Secondary CU losses**

No of secondary turns = 11

Max secondary current = 1 Amp

Resistance / Cm = .000708 Ω/cm

Wire size used = 22 AWG

Length / turn = 41.7 mm

Total length of secondary wire = $\left(\frac{41.7 \text{ cm}}{10}\right) \times 11 = 45.87$ cm

Total Resistance of secondary wire = .000708 x 45.87

= .0324 Ω

Total loss = $I^2 R$

= $(1)^2 (.0324)$

= .0324

Total CU losses due to primary and secondary windings are

= > .490 + .0324 W

= ..5224 Watts

b. **Core Losses**

Types of material used was Ferrite

Core Model selected was 812 E 250

Total weight of the core was calculated as 81 g

Loss mwatt/gm for ferrite core = 29 mw

Core loss = 81 x 29 (x 10^{-3})

=> 2.349 watts

Hence total losses of the transformer were calculated as

Total losses = CU losses + core losses

=> .5224 + 2.439

=> 2.9614w

4.3.7. **Primary current**

$$\frac{NP}{Ns} = \frac{IS}{IP}$$

Ip = .155 Amp

4.3.8. **Power Output**

The out put power of the transformer was calculated as

$P_o = VI$

= 21.5x1 = 21.5 watts

Input power was calculated as

Pin =VI

=155X.155

=24.025 Watt

Efficiency was calculated as

$$\eta = \frac{P_0}{Pin} \times 100 \Rightarrow \frac{21.5}{24.05} \times 100 \Rightarrow 90\%$$

4.4 **Output block**

As already discussed in chapter 3, the selected topology for designed power supply was forward converter .The output block is discussed in the following paragraphs keeping in view the topology of the forward converters.

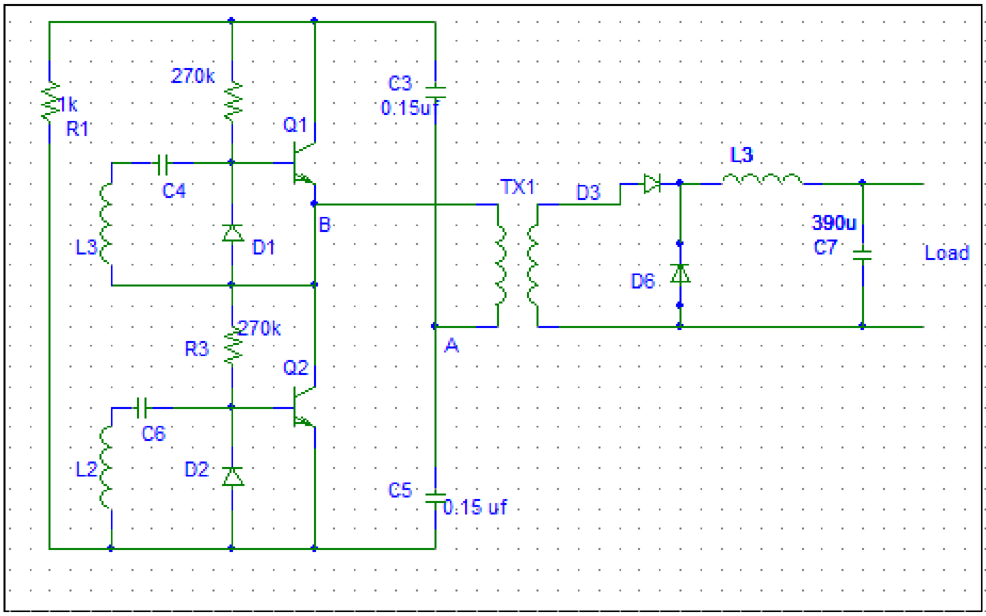

Fig 4.6

4.4.1 **Circuit description**

Referring fig 4.5, rectifier diode D3 of 5 Amp rating is connected with the secondary of the transformer. Diode, D6 and D4 are also incorporated in the circuit. Inductor L3 and capacitor C7 form a closed loop with the Diode D6. Power is supplied to the load through inductor L3.

4.4.2. **Principle of operation**

Due to switching operation as discussed earlier, voltage develops in the primary windings of the transformer . Due to the voltage developed in the primary windings, emf is induced in the secondary windings of the transformer. Due to this induced voltage, current flows in the secondary windings. Forward converter does not store energy in the primary windings of the transformer, all the energy is transferred to the secondary windings, when transistors Q1 and Q2, as discussed in the switching block , are in the ON state. AC current produced at the output of transformer, TX1 is converted into DC through diode D3. It is then passed through the inductor

L3. The inductor reduces the spikes produced in the output current and then supply it to output load. During the switch OFF period of transistor Q1 and Q2, the diode D3 is reverse biased and diode D6 is forward biased. Also capacitor C7 is charged during this operation.

During this interval the power stored in the capacitor is discharged and this power will be delivered to the load through the diode D6 and inductor L3.

4.4.3 **Output inductor**

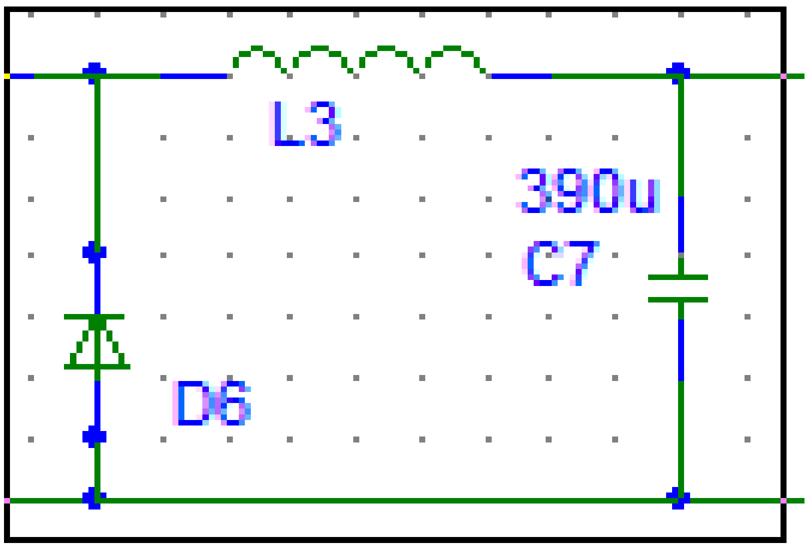

Fig 4.7

The output inductor L3 is shown in fig 4.6. Output inductor L3 was designed as follows[9]

$$L = \frac{V_{out} \times T_{ON}}{.25 \times I_{out}}$$

The value of the inductor comes out as 500 μH. As discussed earlier this output inductor reduces the spikes of output current.

4.5. **Protection Circuits in the Power supply**

Two protection circuits have been incorporated in the new power supply.

a. Over voltage protection circuit.

b. Short circuit protection circuit.

4.5.1. **Over voltage Protection Circuit**

The circuit diagram of over voltage protection is shown in the fig 4.8

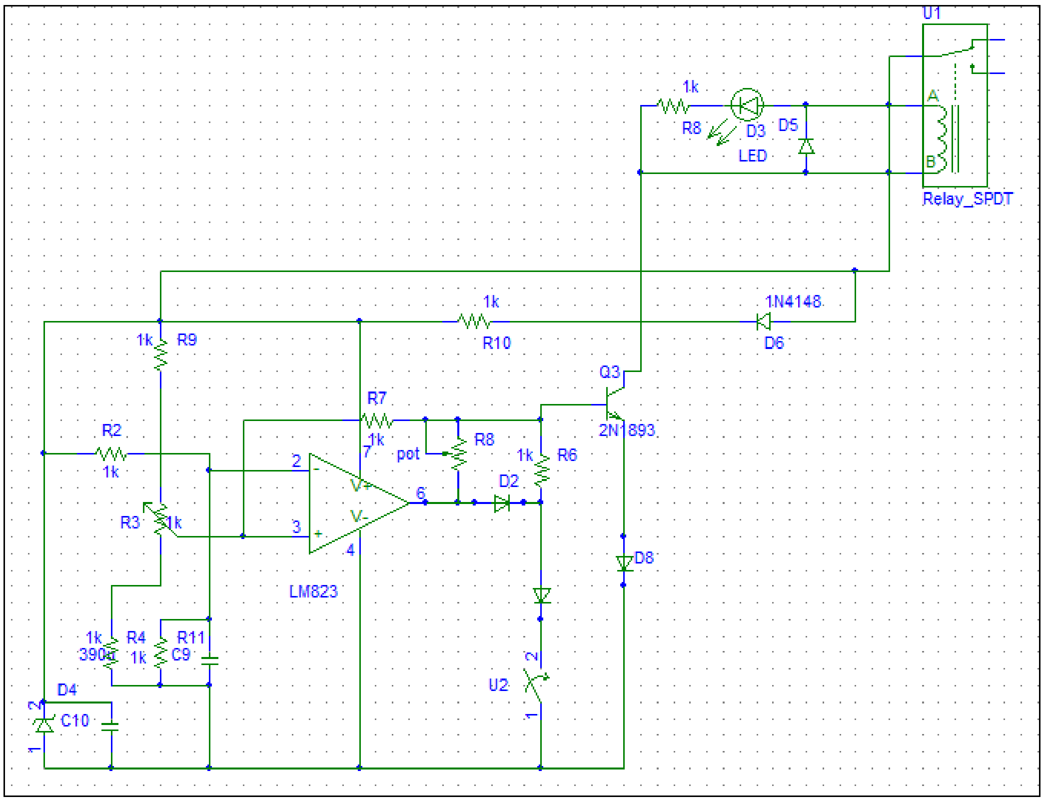

Fig 4.8

4.5.2. **Circuit Description**

Referring fig 4.8, comparator IC LM 823 was used in this circuit. Pin no .5 of the IC is non Inverting end and Pin no 6 is the inverting end of the IC.

Pin no 8 is used as input of the IC and pin no 1 is used as the output. Pin no 4 is grounded. Non inverting end is connected with the relay through a series of resistors. DC voltages 6.2 V are supplied to the inverting end as a reference voltage. A zener diode of 9 volts rating is connected in series with the pin no. 8, of the converter. This zener diode is the protection for the comparator IC LM 823 and it does not allow more than 9 volts DC to pass through its input. A positive feed back loop is connected between the output of the converter and the non inverting end of the comparator IC. Feed back loop is shown in fig 4.9.

4.5.3. **Principle of operation**

Voltage supplied at the inverting end of the comparator IC LM 823 was 6.2 V DC. The non inverting end is connected through a series of resistors with one terminal of relay. Once the voltage of the charging battery reaches the value equal to 16.5 volts, the IC LM 823 receives 6.2 volts at its inverting end. The output of the comparator becomes low and it stops its operation. At this stage, 0 volt appear at the output of comparator. The output of this comparator IC is connected with the base of the transistor Q3. Due to low output of comparator, the transistor Q3 turns off. The collector of the transistor is connected to the relay which disconnects the power supply, when transistor Q3 is not conducting. In this way the battery is saved from getting over charged.

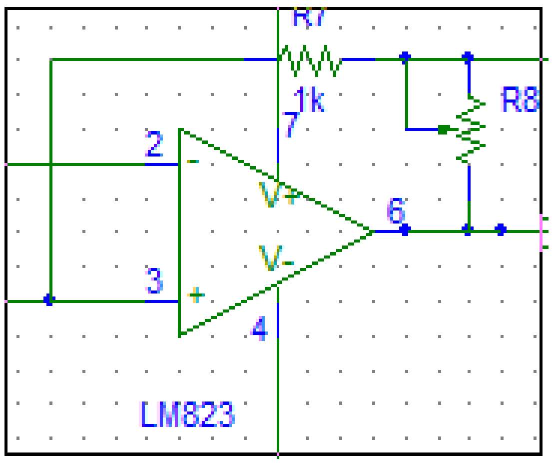

Fig 4.9

As discussed earlier, a feed back loop as shown in fig 4.9 is also incorporated in the circuit. The design parameters of this feed back loop are such that the comparator IC does not operate till the voltage of the battery falls below the value equal to two volts. Once the voltage of the charging battery falls below 14.5 volts, the comparator starts operating. If this loop is not incorporated in the circuit the comparator will immediately turn on when voltage of the battery drops from 16.5 volts. In such a situation, the comparator will hang up between the ON/OFF state and relay will continue to jitter between open and close position. This positive feed back loop maintains 6.2 V DC at non inverting end till the time the voltage of the battery falls from 16.5 V DC to 14.5 V DC. When the voltage of the charging battery falls below the desired voltage the comparator gives high output, Q3 gets positive voltage at its base and it starts its operation. The relay operates and its contacts are closed. In this situation the charging of the Ni Cad battery will continue till the time the voltage level of the charging cells exceeds 16.5 volts barrier.

4.6. **Short Circuit Protection**

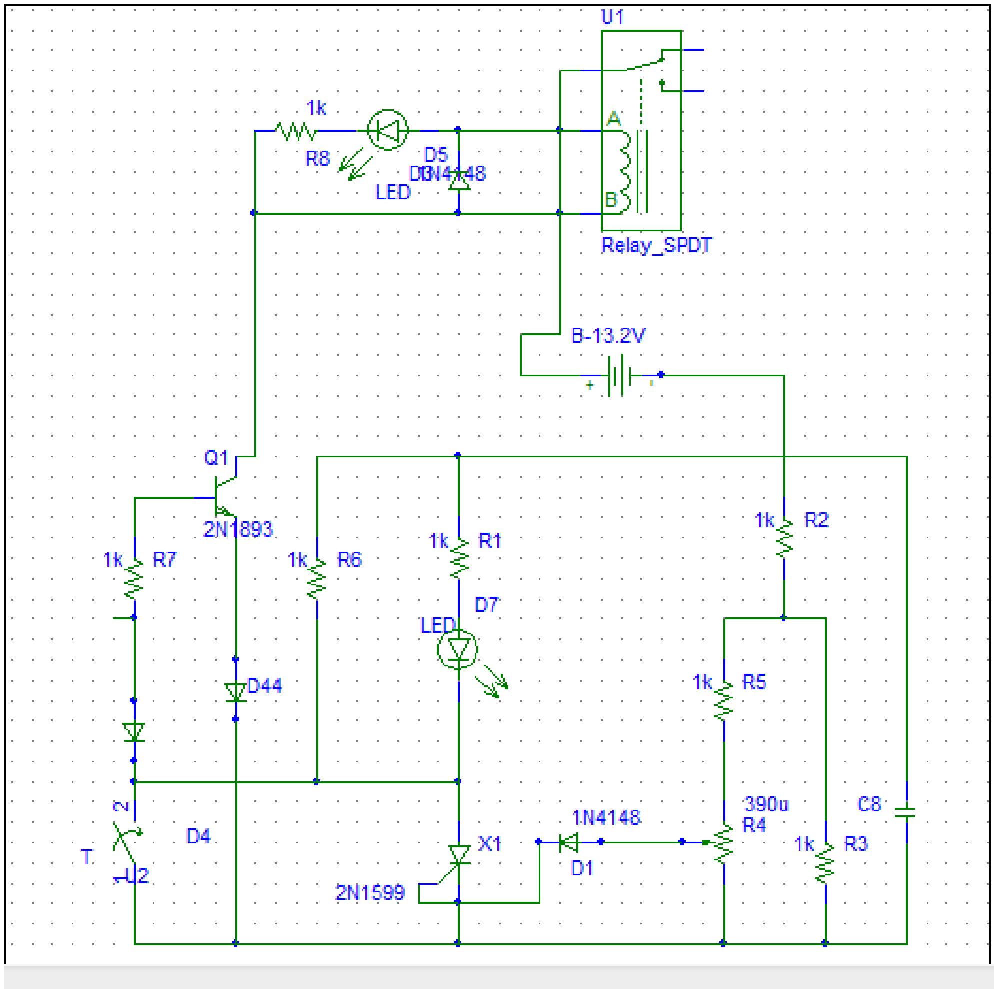

Fig 4.10

4.6.1. **Circuit Description**

The complete circuit description of short circuit protection is shown in fig 4.10. If accidentally battery terminals are short circuited, this circuit operates and isolates the main equipment and charging circuit from the main supply. An LED D7 as shown in fig 4.10, is present in the circuit which glows during the charging.

4.6.2. **Principle of Operation**

This is the most effective over load protection method for low power and low cost devices. It operates in such a way that if the load power exceeds a predetermined maximum limit for a value beyond the defined level, the power supply will turn off. The design of the circuit is such that when the load resistance decreases, the output voltage falls and the current rises. If this current exceeds the predetermined limits, the over load short circuit protection circuit will start functioning and power supply will be cut off. When the battery connected in the circuit, as shown in fig 4.10 and marked as B-13.2 V, is short circuited accidentally, heavy current flows through the resistors R_{19} and R_{34}. Due to the arrangement of voltage divider, diode D_{40} is forward biased. Diode D_{40} gives pulse at the base of SCR, X2, as shown in fig 4.10. SCR is short circuited and makes diode D_{44} reverse biased. This causes negative voltage to appear at the base of the Q3 and resultantly it stops operating. This effect cause the terminals of the relay to open up and the complete circuit and the equipments are saved from costly damage.

4.7. **Circuit diagram of newly designed power supply**

After carrying out detailed analysis of the circuit, limitation of size and circuit protection which could be incorporated in the power supply, were determined. The circuit diagram of the power supply is shown in fig 4.11.

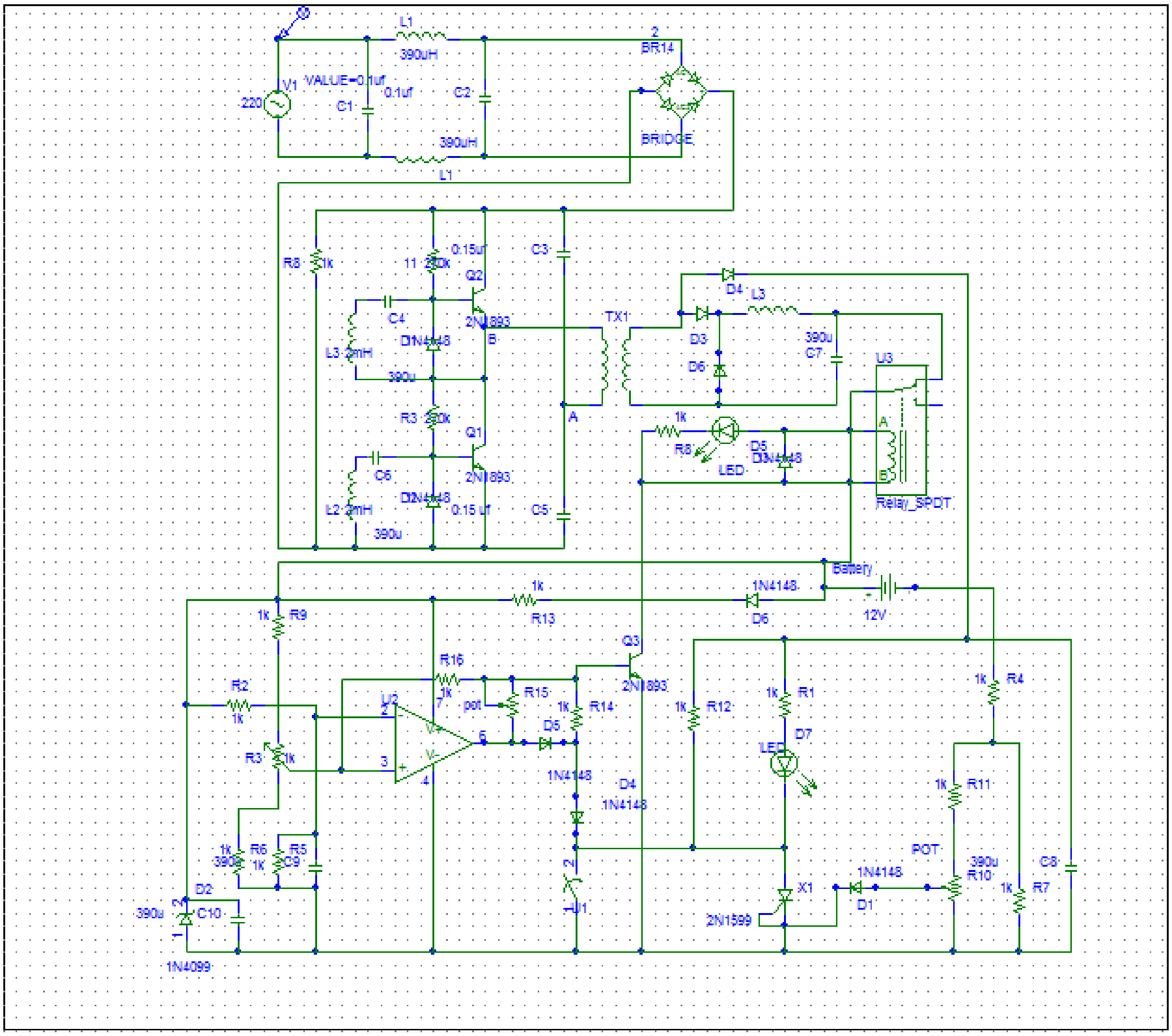

Fig 4.11

4.8. **Fabricated model of the designed power supply**

After complete technical analysis of the circuit diagram of new power supply as shown in fig 4.11, the fabrication process of the power supply was carried out. The same was completed in two stages. Both stages with their photographs are shown in the following paragraph.

Stage 1

The designed power supply was first developed on the project board as shown in fig 4.12 below.

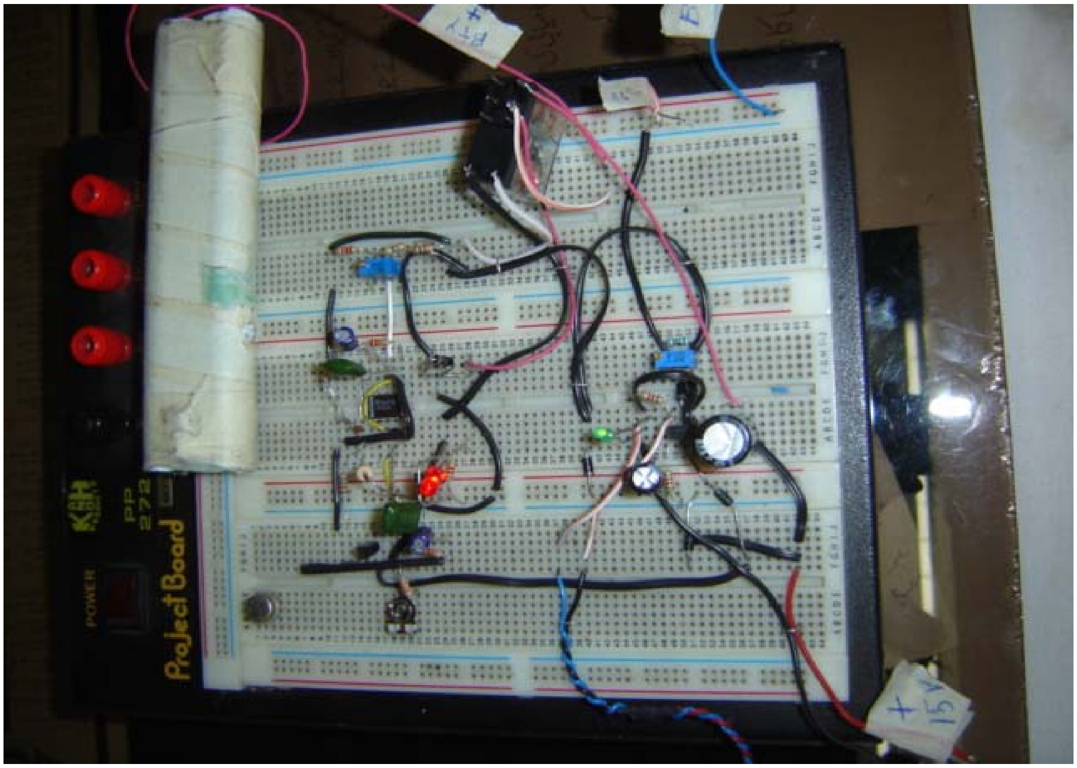

Fig 4.12

Both protection circuits, i.e. short circuit protection and over voltage protection were tested by installing a portable battery, as shown in fig 4.12 in the project board. After successful trials, the power supply was fabricated on the print board as discussed ahead.

Stage 2

After carrying out successful trials on the project board, the power supply was fabricated on the print board, as shown in fig 4.13

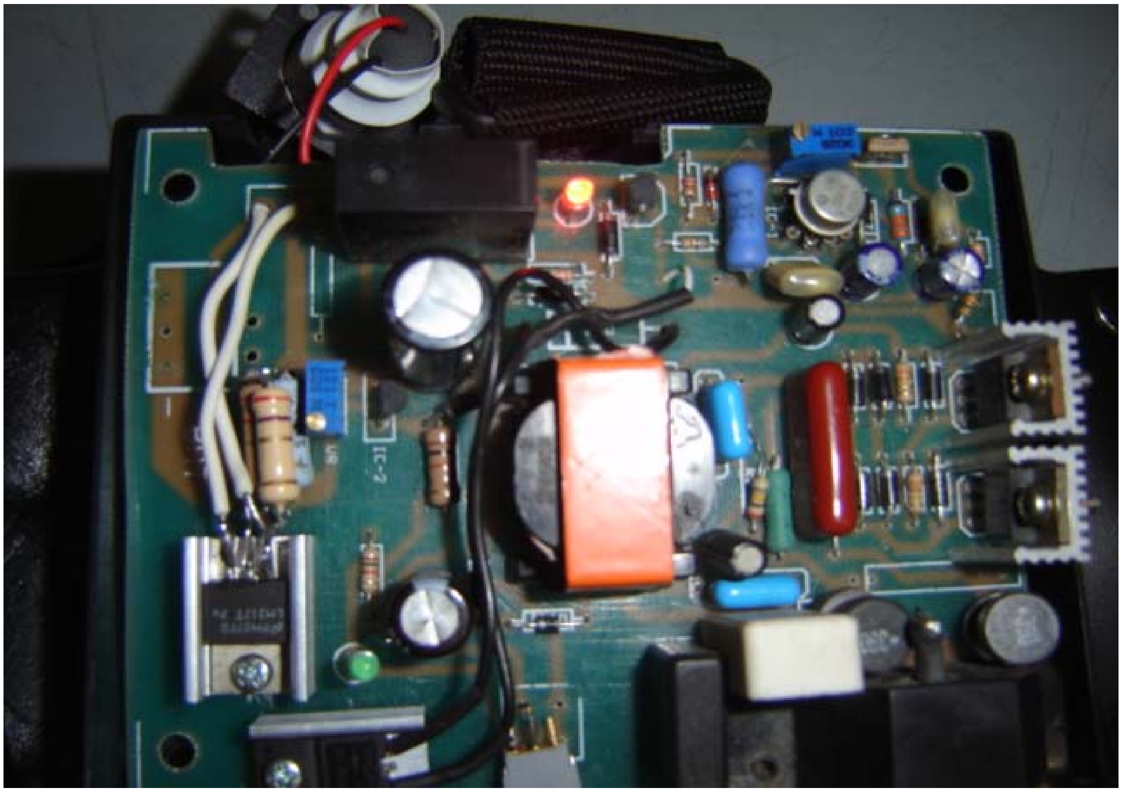

Fig 4.13

The developed power supply, as shown in fig 4.13 was first tested by connecting a portable battery with it, (The ampere rating of the portable battery and the actual battery being the same). The protection circuits were also tested by applying load through external power source. After successful trials, the designed power supply was connected with battery belt of Sophie Thermal Imager as illustrated in fig 4.14.

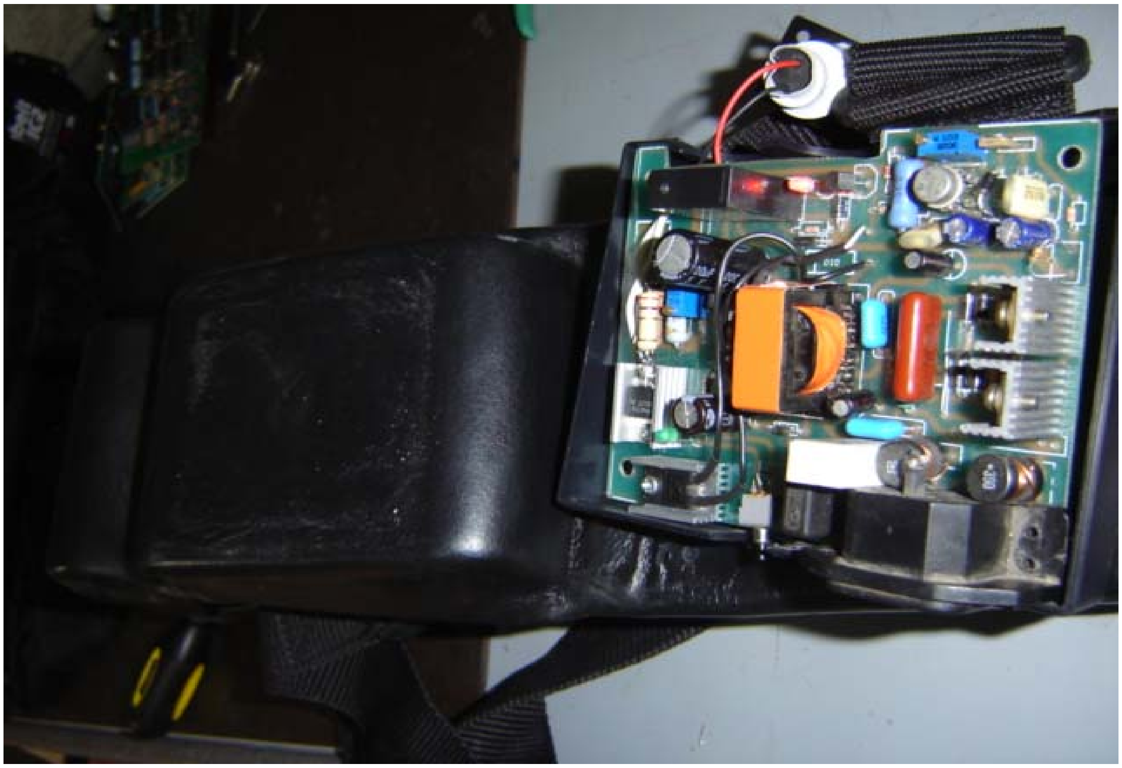

Fig 4.14

The designed power supply proved to be an excellent supply source, when it was connected with the battery belt.

4.9. Merits of the project

A few advantages of newly designed power supply are highlighted below:-

a. The new power supply is more cost effective and efficient than the original one.

b. Over voltage protection and short circuit protection have been integrated in the new system

c. Circuit of the new power supply is simple and easy to repair.

d. All components of the newly designed power supply are easily available in the local market.

e. Indigenous development is a step forward towards the overall objective of self reliance.

4.10. Cost analysis

Newly designed power supply has same parameters but with simple circuitry, besides being cost effective. Cost comparison of both power supplies is as under:-

a. Cost of original power supply = Rs 120000.00

b. Cost of newly designed power supply= Rs 15000/

c. Net saving per power supply = Rs 105000.00

Chapter 5

Conclusion And Future Work

5.1. Conclusion

Switched mode power supply designed for the PAG belt Sophie Thermal Imager has been given extensive testing for several charging cycles. Performance of the newly designed power supply was also compared with the existing one, yielding excellent results. Over the course of development, procurement source of the electronic component did become a problem. However by putting in concerted efforts the source was located and required component obtained. Resultantly for any future large scale development procurement of the required component will not be a glitch. Indigenous development of new power supply will contribute significantly towards the increased availability of equipment to the end users besides saving millions of rupees in the precious foreign exchange. The indigenous development therefore, is a step forward towards the overall objective of self reliance in the field of defense.

5.2. Future work

Presently, there are 11x NiCd battery cells connected in series, in both original as well as newly developed power supply. For any future work on this subject, it will be a good idea to have a heat sensor in the battery cell in order to constantly monitor the temperature. In case of excessive temperature, a cut off relay could be used to automatically disconnect the supply preventing costly damage to the main equipment.

<u>Formula</u>

<u>Core Area</u>

1. $$Ae\,Ac = \frac{0.68 P_{out\,D} \times 10^{3}}{f\,B_{max}}$$

2. Wire Size = Current Density x Primary I (or sec)

3. Primary Turns.

$$N_p = \frac{V_p \times 10_8}{Icf\,B_{max} Ae}$$

$$Ns = \frac{Np}{Vp} \times Vs$$

<u>Primary current</u>

$$I_p = \frac{3.2\,P_{out}}{V_{in}}$$

Inductor

$$L = \frac{5\,V_o T}{I_{dc}}$$

Secondary Voltage

$$Vs = 1.25\,V_o$$