Switched Mode Power Supply

Project Work

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Submitted by

S. Chinnusamy Jaikumar
V. Sathish
A. Vijayakumari

Under the Guidance of

Dr. K. A. Palaniswamy, B.E., M.Sc.(Engg), Ph.D.,
M.I.S.T.E., C.Eng(I), F.I.E.

Department of Electrical and Electronics Engineering

Kumaraguru College of Technology

Coimbatore-641 006

Department of Electrical and Electronics Engineering

Kumaraguru College of Technology

Coimbatore-641 006

Certificate

This is to certify that the report entitled

Switched Mode Power Supply

has been submitted by

Mr. / Ms. S. CHINNUSWAMY JAI KUMAR

In partial fulfilment for the award of
Bachelor of Engineering in Electrical and Electronics Engineering
Branch of Bharathiar University, Coimbatore-641 046
during the academic year 1990-91

Guide

Dr. K. PALANI
Head of the Department
Department of Ele

Certified that the candidate was Examined by us in the project work Viva-Voce Examination held on .... and the University Register Number was ....

Internal Examiner

External Examiner

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SYNOPSIS

A power supply with high regulation is essential to achieve a steady regulated 5V level for TTL family of ICs.

A **SWITCHED MODE POWER SUPPLY** can be used to get high quality power supply from varying supply voltages.

In this project a detailed study of switched mode power supply is made. A 5V, 5A SMPS unit is designed and fabricated using pulse width modulator ICs, switching transistors, diodes etc. Two auxillary supplies +12V, 1A and -12V, 1A can also be obtained from the unit.

The experimental observations on the unit are presented in this report. The regulation is found to be well within the requirements of power supplies to TTL family of ICs.

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CHAPTER I

INTRODUCTION

Electronic equipments require power supplies producing low voltages at large currents, upto 5A. The electric supply is obtained at 220V, 50 Hz Ac. This has to be converted into low voltage DC using step down transformer and rectifiers, and ripples are filtered with capacitors and inductors.

1.1 NEED FOR REGULATING POWER SUPPLIES

For Integrated Circuits, these DC supplies are to be regulated against mains voltage or load current variations.

The degree to which a power supply provides a constant output voltage under the above conditions is the basic figure of merit of the power supply.

Accordingly, regulation is defined as given below

$$\text{Line Regulation } (\%) = \frac{Eo - Ein}{Eo} \times 100$$

Where Eo = Change in output voltage

Ein = Change in input voltage.

Eo = Nominal output voltage.

$$\text{Load Regulation (\%)} = \frac{(E_{nl} - E_{fl})}{Eo} \times 100$$

Where E_{nl} = Output voltage with no load.

E_{fl} = Output voltage with full load.

1.2 CLASSIFICATION OF REGULATING POWER SUPPLIES

The power supplies employ different approches to process the power and to convert it from one form to other. They can be mainly classified as

(i) Dissipative (Linear) Power Systems and

(ii) Nondissipative (Switch-Mode) Power Systems.

1.2.1 DISSIPATIVE POWER SYSTEMS

As the name indicates, this supplies keep the output voltage constant by obtaining a higher rectified voltage from the transformer and distipating the excess power as heat. It means more power loss and low power efficiency.

1.2.2 NONDISSIPATIVE POWER SYSTEMS

The nondissipative power systems operate in the switched mode resulting in high efficiencies. The rectified ac input is chopped at a high frequency rate to result in a square wave. This square wave voltage can be levelled-up or levelled down by using transformers. The output can be rectified and filtered to get dc at a different voltage level than the input. The output voltage of the SMPS is controlled by varying either the duty cycle or frequency, or both, of the signal that turns the switching transistor 'ON' or 'OFF'. By varying the duty cycle or frequency of the switching, one can vary the stored energy in each cycle, and thus control the output voltage. As a switch can only be 'ON' or 'OFF', it either allows energy to pass through or stops it, but does not dissipate energy in itself. Since, only the energy required to maintain the output voltage at a load current is drawn, there is no dissipation and hence a higher efficiency is obtained. Energy is pumped in discrete lumps, but the output voltage is kept steady by capacitor storage.

1.3 SMPS

A SMPS is an off-line system which works directly on mains (180V to 250V Ac). The Block diagram of an SMPS is given in fig 1.1. The mains voltage is rectified and filtered by high voltage rectifiers and capacitors. The unregulated DC voltage obtained is chopped at high frequency (> 15 KHZ) by switching transistor and control circuit. The chopped DC is applied to primary of the transformer and voltage at secondary is rectified using fast recovery power diode and smoothered using inductance and capacitors, to give the required DC output. The transformer used is very small in size as it works on very high frequency. The DC output voltage obtained is fed back via sense amplifier to the control circuit, which adjusts the duty cycle of the switching transistor via the isolated driver transformer to keep the output voltage constant, even for any voltage or current change.

1.4. Types of SMPS

1.4.1 BUCK REGULATOR

In a buck regulator, the output voltage is always less than the input voltage. This means that a switching regulator can be used as a dc step-down transformer with highest efficiency. Fig (1.2) shows a simple buck converter power stage. The output voltage is compared with a stable reference voltage and the amplifier error signal is used to generate a pulse width modulated waveform, which controls the switch ON/OFF periods. When the switch is turned ON, current flows through the inductor and into output capacitor and load. When the output voltage exceeds the ref voltage, the switch is turned OFF. At this instant, the stored energy in the inductor reverses its polarity, takes the path through the diode and sends the current into the load while the voltage is maintained by the capacitor. When all the stored energy in the inductor is used up, the capacitor discharges and the output voltage decreases. At this step, the switch is turned ON and the process continues such that the output voltage is maintained very close to the reference voltage.

1.4.2 BOOST REGULATOR

In a boost regulator, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Fig 1.3. When the switch is turned ON, the current flows through the inductor and energy is stored in it. When the switch is turned OFF, the stored energy in the inductor tends to collapse and its polarity changes such that it adds to the input voltage. Thus, the voltage across the inductor and the input voltage are in series and together charge the output capacitor to a voltage higher than the input voltage.

1.4.3 BUCKBOOST REGULATOR

This regulator operates on the principle of both buck and boost. A schematic of this is given in Fig 1.6. When the switch is ON, the inductor charges and stores energy. When the switch is OFF, the stored energy tries to collapse reversing its polarity, thus sending current into the output capacitor and load. This takes output voltage to an opposite polarity to that of the input voltage. The output voltage is determined by the rate of discharge of the inductor. Rapid discharge results in a lower voltage and vice versa.

The above three are the basic fundamental converters. There are a few other converters which are derived from these basic converters. They are

a) Flyback converter

b) Forward converter

c) Push-Pull converter.

1.4.4 FLYBACK CONVERTER

The flyback convertor is a buck-boost converter. The basic circuit of a flyback converter is given in Fig 1.5. In this circuit the current flows in the choke when the transister is switched on. The diode is unable to pass current to load at this time because it is short circuited by the transister. When the transistor opens, a high voltage is induced in the choke, which passes current into the output load. Since the transistor is in parallel with the supply voltage, it is referred to as the shunt type circuit. Diode D_1 also prevents the output from discharging into the transistor during its on period. This is a flyback circuit because no current flows from supply to the output during the ON period.

The flyback converter can be modified into a flyback transformer type converter as shown in Fig 1.6 by having to windings in the choke coil-one in series with the switching transister, another with the output diode. The primary winding carries current during the forward conduction period of the switching transister, while the secondary can carry current only during the OFF period (Flyback period). The energy in the magnetic field is coupled to the secondary winding.

The transformer winding is denoted by dots which show the starting end of the winding around the magnetic core. The dot convention is such that when current is rising into the dot of one winding, a positive voltage is induced in the second winding at its dotted end.

During switch-on period of the transister, the voltage induced in the secondary does not pass any current to the output because the diode is reverse biased.

A well developed flyback circuit is shown in Fig 1.7. In this, to limit the maximum voltage arross the transister to twice the supply voltage, a demagnetising winding is used. To keep the transister voltage to twice the supply voltage, the turns ratio between the primary and the demagnetising winding should be 1:1. The demagnetising winding feedsback the energy stored, if there is no load on the secondary.

To keep the transistor in the safe operating area, the collector current should be very low when transistor turns OFF, and V_{CE} voltage of transistor should be twice that of $V_{IN\ MAX}$ (at 250V Ac).

To control the voltage and currents of power transistor, a network comprising resister, capaciter and diode is required. When transistor turns OFF, the primary current passes through the capacitor and diode, slowing down the voltage rise in the collector. When transistor turns on, the capacitor discharges through the transistor, but its current is limited by the resistor.

1.4.5 FORWARD CONVERTER

This is a buck converter. The basic circuit is given in Fig 1.8. In this, the choke carries current both when the transistor is conducting as well as when it is not. The diode carries the current during the off period of the transistor. Energy, therefore, flows into load during both periods. The output voltage can only be less than the input voltage in this circuit. The choke stores energy during the on period and also passes some energy into the output load. The diode serves two functions:

(a) it provides a discharge path for the choke so that when the transistor switch opens, there is no arcing due to induced high voltages; and

(b) it provides a path for the current in the coil to decay.

Fig 1.9 shows a developed circuit for use as a forward converter. When transistor conducts, diode D_1 conducts and energy is stored in the output choke Lo and supplied to load. During this time the current through choke rises, as shows in the waveform. When transistor turns off, voltage has reverse polarity and energy to the load is supplied by choke Lo via diode D_2. During this period the choke current I_L decreases. Demagnetising winding is used to feed back energy stored in primary when transistor turns off, and it limits the maximum collector voltage to twice the input voltage. Care should be taken to ensure that the duty cycle is less than 0.5. Otherwise, transformer will saturate and the power transistor will get damaged.

1.4.6 PUSH - PULL CONVERTER

Push-pull converter shown in Fig 1.10 basically comprises two single ended systems (say, forward converters). There are two switching transistors (represented in this circuit by S_1 & S_2) instead of one, and both trun on and off alternately. voltage across the transistor is equal to supply voltage V_{IN} when it turns off. The amount of energy supplied by the choke is lesser as most of the time, energy to the load is supplied by the primary side. In push-pull converter the magnetisation is in both directions, so transformer does not saturate.

The above discussed are just bare-bone circuits of simple switched mode power supplies. They merely describe the essential principles of energy conversion through storage of energy in the magnetic field of a choke coil.

Energy is stored only during the conduction period of the switching transistor. The amount of energy decides the power capacity of an SMPS. In order to increase energy, large current must be pumped into high inductance. The inductance L is a measure of the flux per ampere of current in the coil. So, the energy stored in a coil is given by

$$\tfrac{1}{2} LI^2 = \tfrac{1}{2} (\phi/I)I^2$$
$$= \tfrac{1}{2} \phi \, I.$$

Where

L = Inductance of the coil in Henries.

ϕ = Flux linking the coil in webers &

I = Current in amps.

1.5 COMPARISON OF THE DIFFERENT TYPES OF SMPS

Each of the above discussed circuits has its own advantage over one another. Flyback converter is the cheapest but its regulation is poor and output ripple is greater. Normally these circuits are not used when output power required in beyond 100 watts. But where multiple outputs are required, and output power is less than 100 watts, this is the obvious choice as it does not require any output choke and so the cost is reduced. Only the main winding, which requires a tight regulation, is sensed and the rest are partially regulated.

Flyback converter is useful where high voltage is a requirement, because it is not possible to have large inductive chokes at the output, which is a requirement for high voltage regulation.

When output power is high, and tight regulation with low ripple is the requirement, then push-pull converter is used. Generally, push-pull SMPS is used where output power is beyond 200 watts. But push-pull SMPS is the most complex of these power supplies, as it requires two power transistors. So the driving circuit becomes more complex.

Where tight regulation is required and output power is 100 to 200 watts, but with low voltage output, the forward converter is most useful. The circuit is not very complex as compared to push-pull type, and regulation is also good as it uses the output choke at the secondary side.

For a particular through power at a fixed high frequency, the size of the transformer decreases from flyback SMPS to forward SMPS and to the push-pull SMPS respectively.

Because of the simplicity in construction and the exact match with the power output, Flyback converter principle is followed in this power supply.

1.6 COMPARISON BETWEEN LINEAR POWER SUPPLY AND SMPS

Table 1.1 shows the comparison between the linear power supply and switched mode power supply. It may be observed that the SMPS is cheaper, more efficient than the linear power supply.

Table 1.1 COMPARISON BETWEEN LINEAR POWER SUPPLY AND SMPS

PARAMETER	LINEAR SUPPLY	SMPS
1. Efficiency	Less than 50% (25%- 50%)	More than 50% (65%- 75%)
2. Temperature rise	50 to 100°C	20 to 40°C
3. Ripple	Less	More
4. Stalic regulation	Quick regulation	Low to regulation
5. Isolation from mains	Not so good	Quite good
6. RF interference	None	can be a problem unless properly shielded
7. Circuit complexity	Less complex	More complex
8. Size & Weight	More	Less
9. Cost	More	Less
10. Reliability	More reliable	Depends upon availability of suitable transistors

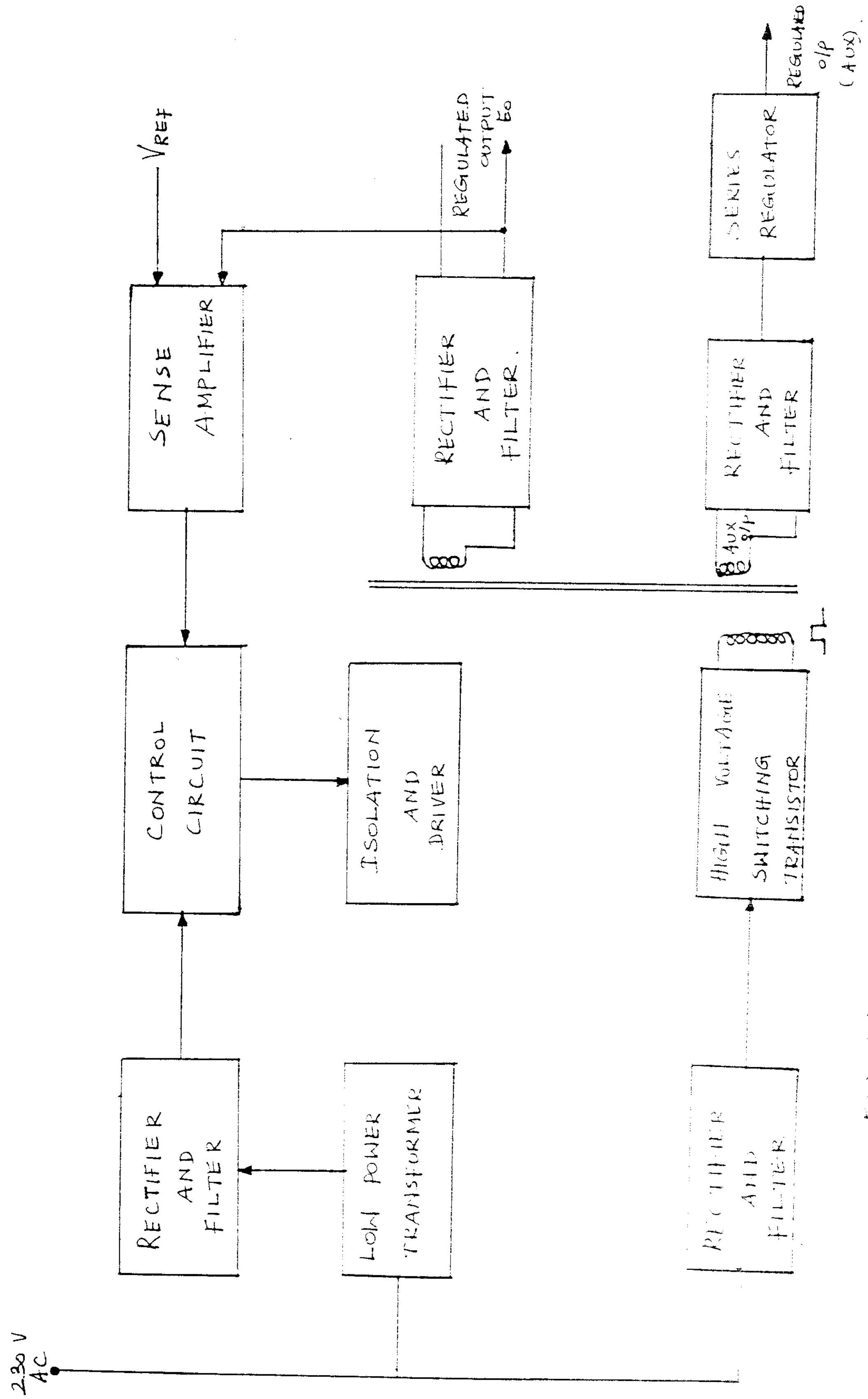


FIG 1.1 SMPS BLOCK DIAGRAM.

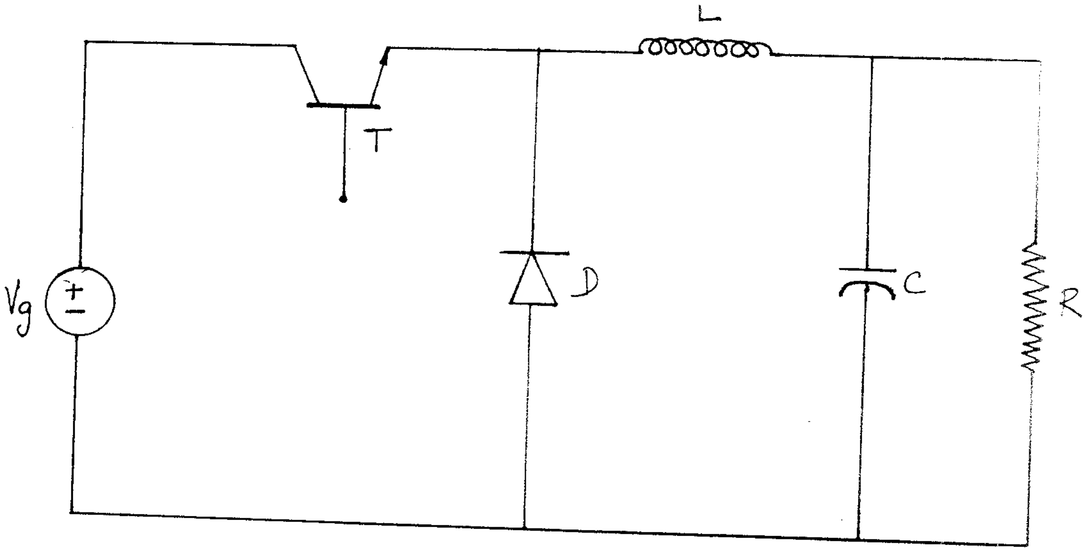


FIG 1.2 BUCK CONVERTER

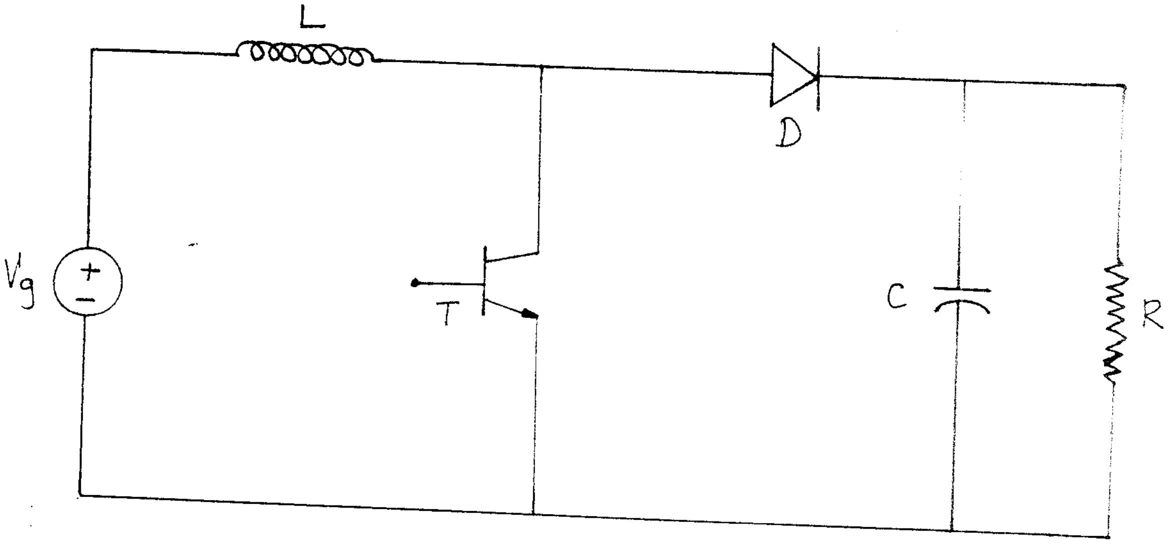


FIG 1.3 BOOST CONVERTER.

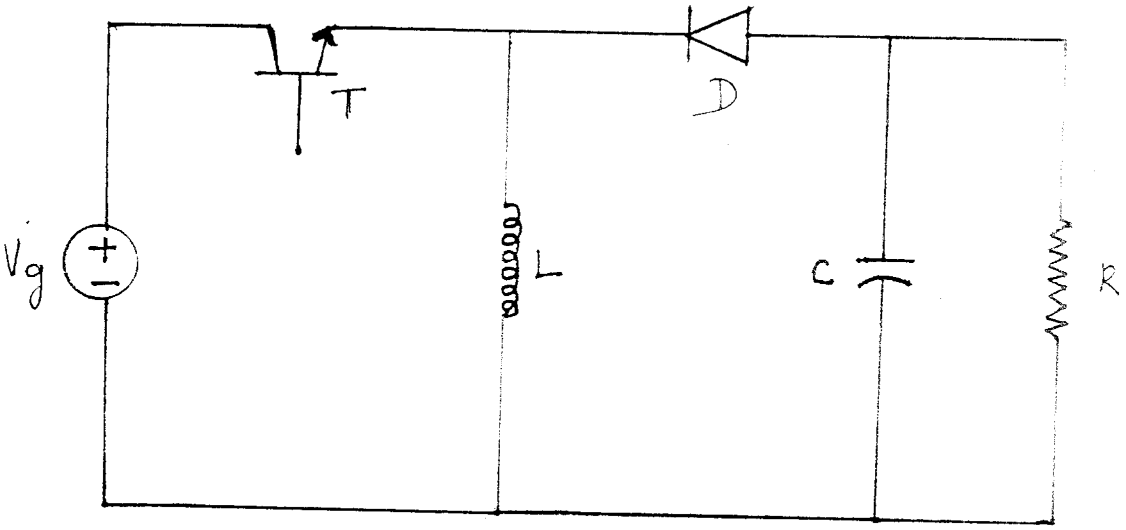


FIG 1.4 BUCK BOOST CONVERTER

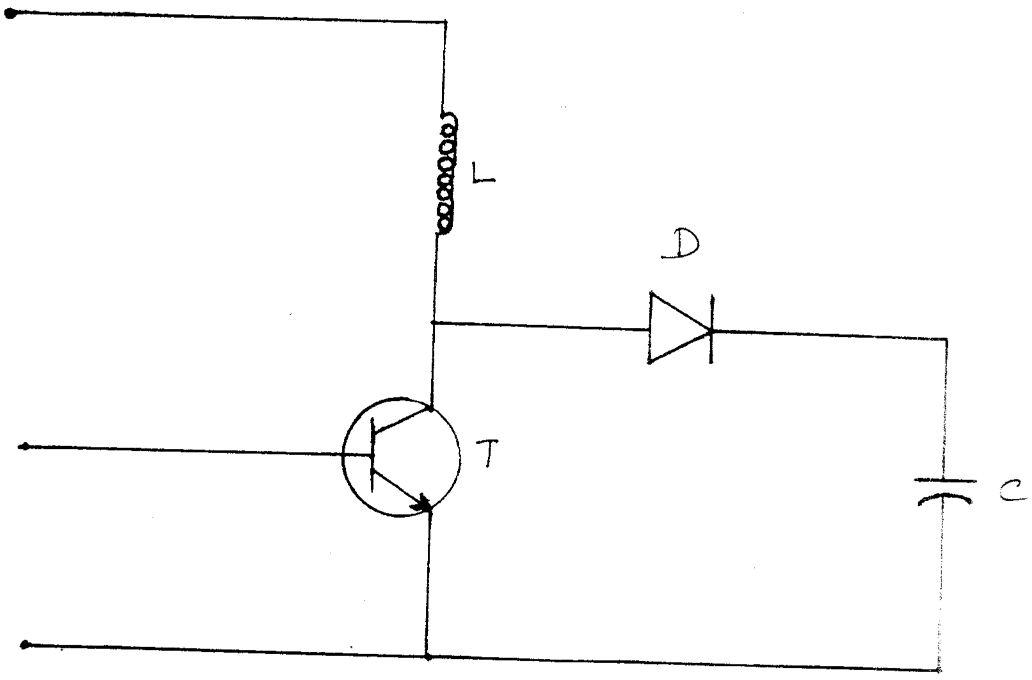


FIG 1.5 BASIC FLYBACK CONVERTER.

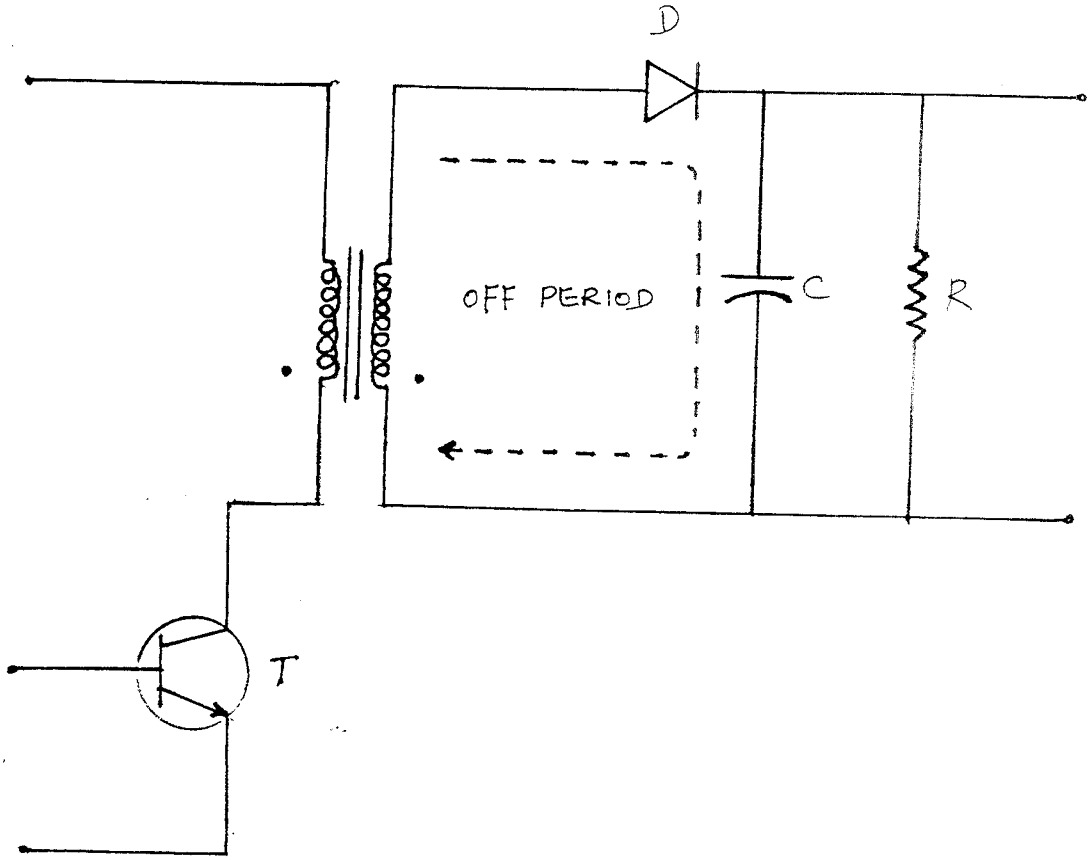


FIG 1·6 FLYBACK TRANSFORMER TYPE CONVERTER.

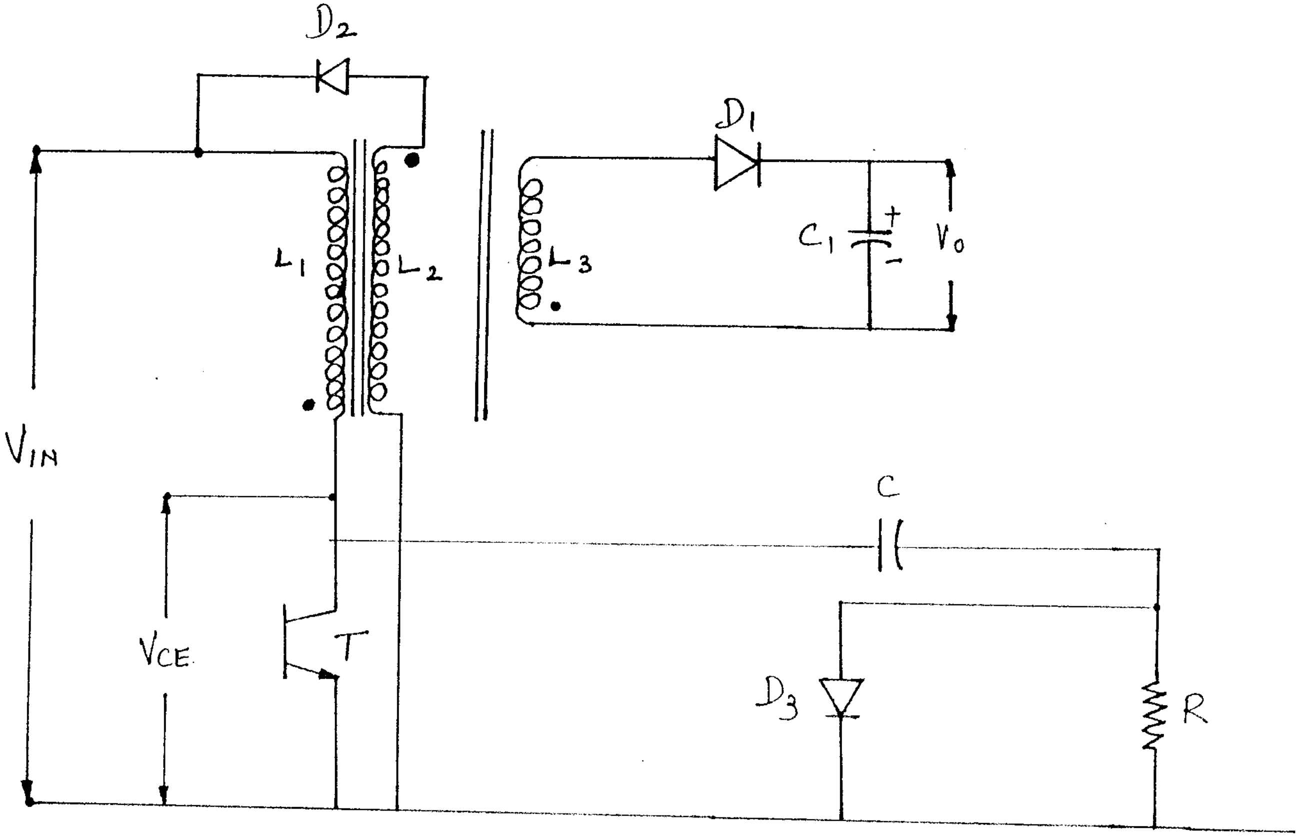


FIG 1.7 DEVELOPED CIRCUIT FOR FLYBACK CONVERTER

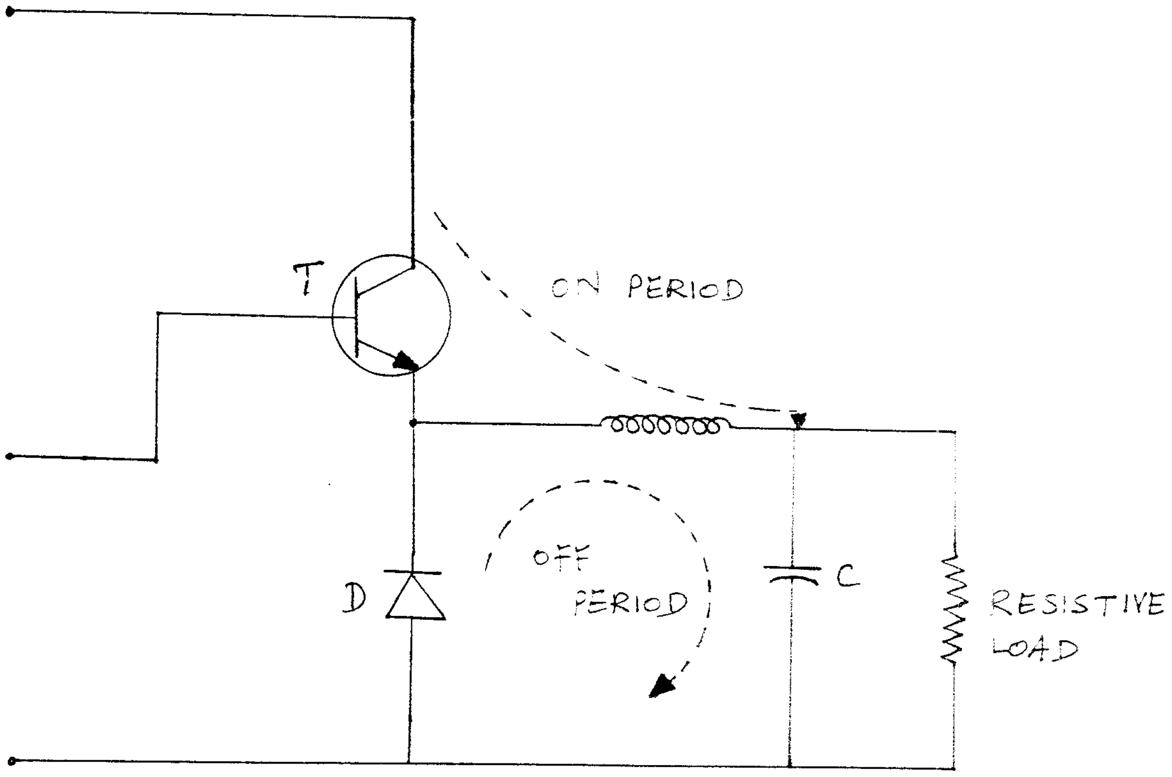


FIG 1·8 BASIC FORWARD CONVERTER.

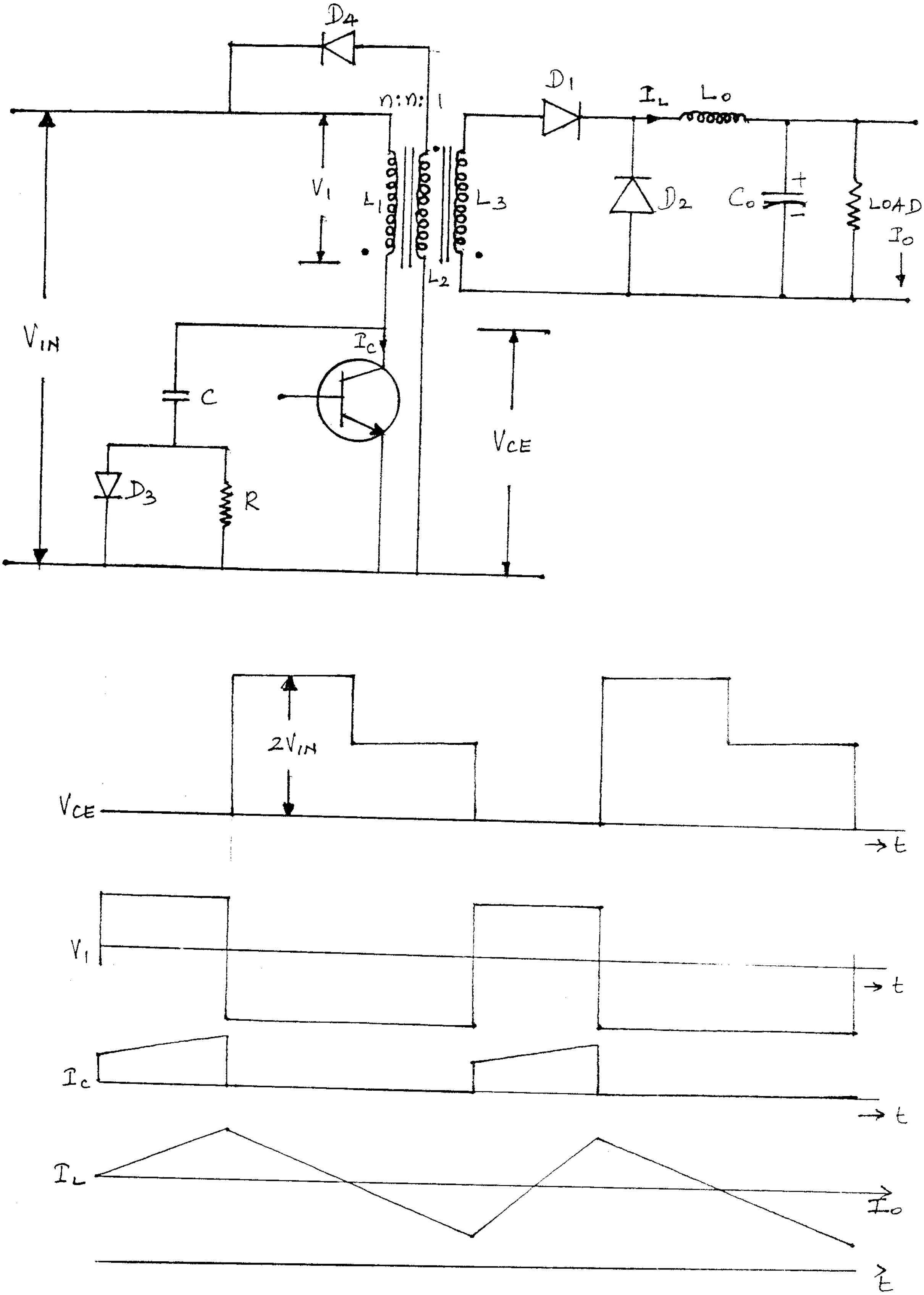


FIG 1.9 MODIFIED FORWARD CONVERTER WITH ASSOCIATED WAVEFORMS.

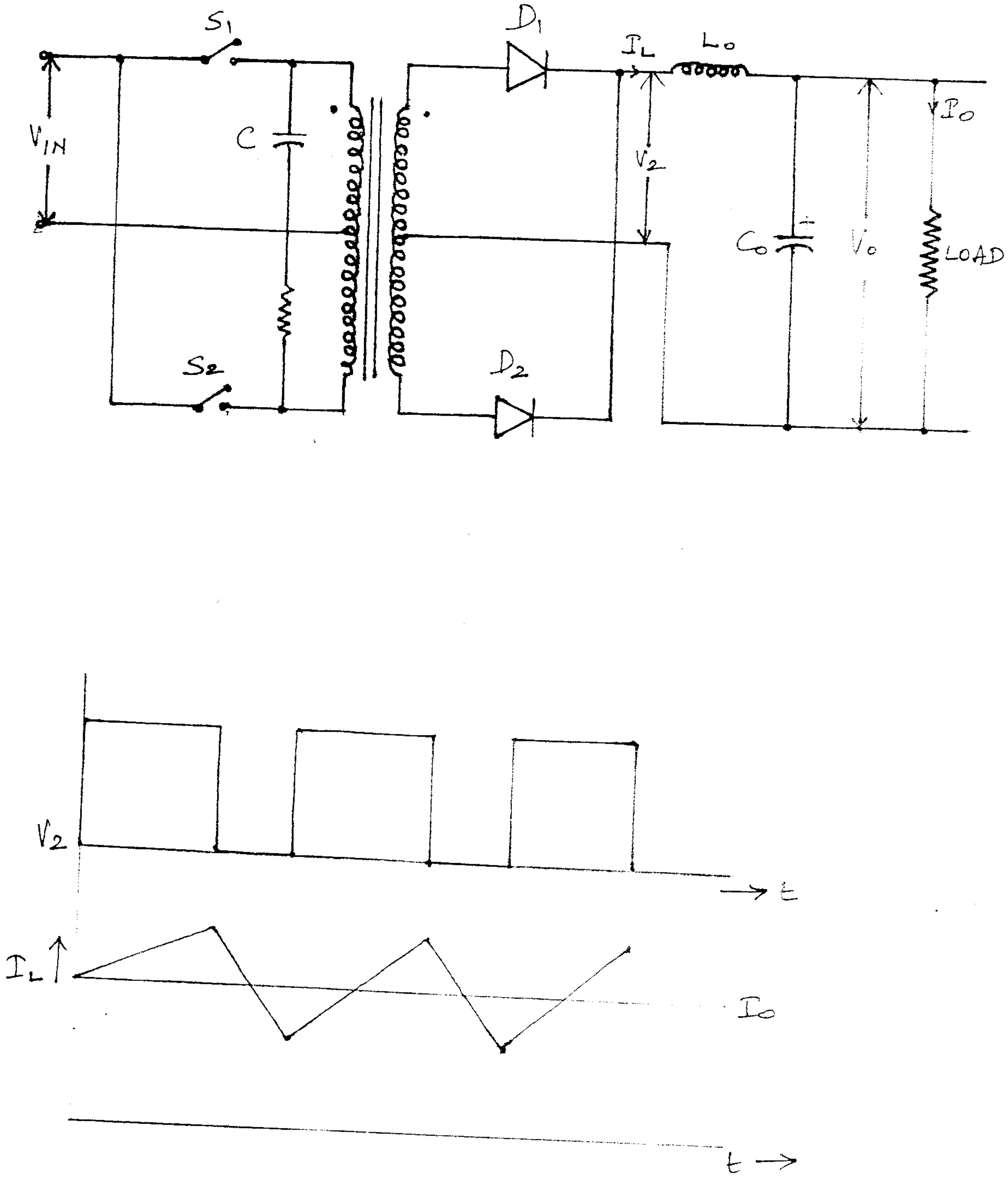


FIG 1.10 BASIC CIRCUIT OF PUSH-PULL SMPS WITH ASSOCIATED WAVEFORMS.

CHAPTER II

DESIGN OF SMPS

An SMPS can be designed for any output required using a control IC, one or two switching transistors of adequate voltage and current, a few fast recovery switching diodes, a good collection of electrolytic capacitors, some other components and lastly a ferrite core of ample size to provide the power, wound with a number of turns as needed to handle the currents/voltages. While the design is simple, the unavilability of a few parts in our country makes it difficult to construct.

In this projectm a SMPS unit is designed for a main output of (5V, 5A) and two auxillary outputs of +12V & -12V (of 1 Amps each).

2.1 AVAILABILITY OF PRIME COMPONENTS

The locally available E-E core, when wound, behaves almost similar to an air core transformer. Ferrite core is the suitable one for the purpose. But Indian ferrite cores are of iron dust. Fortunately the Line output Transformer (LOT) used in TV receiver satisfies the requirements. It is a 2-limb U-I core and is of good quality ferrite.

However it has got a disadvantage over E-I or other available cores. It has high radiation field which requires shielding the unit with a wrap around the copper foil.

Designing the power supply involves the choice of a suitable circuit configuration both for the switching part and the controlling part. In the switching part, the transformer along with transistor as a switch and suitably rated fast recovery diodes are used.

Since the switching transistor is generally quite expensive for large currents and voltages, the design here is based only on the economical and freely available BU208 transistor used in Television sets.

The following list gives the building blocks of this circuit.

1. An LOT (Line Output Transformer) Core
2. A BU208 transistor and
3. A LM or SG3524 regulating pulse width modulator IC.

The functional requirements of the supply are:

1. A 5V, 5A power suitable for digital and computer applications.
2. A ±12V, 1A for linear and RS232 circuits.
3. Complete isolation of outputs from mains.

2.2 ISOLATION OF OUTPUTS FROM MAINS

The requirement of isolation is easily taken care of by having several windings on the ferrite transformer.

In some SMPS, even optoisolators are employed because the control circuit is at hot mains potential (230V) This is given in Fig 2.1.

It is the control circuit that provides the proper switching pulses and also senses the output voltage. This sense signal is fed through an LED and a transistor type of isolator.

Such optoisolator supplies are used in colour TV recivers and in the Apple computer power supply.

Since the available devices in our country are not suitable for linear control applications, the optoisolator is not feasible for this design. Instead, the circuit has been designed with an isolated control circuit, feeding the pulse through a separate driver transformer. The configuration is shown in Fig 2.2.

2.3 POWER SUPPLY TO REGULATOR IC

The control signal from 5V output is used to modulate the pulses of IC 3524. In order to provide power for this IC, there are two methods.

1. Using the output of the SMPS itself.
2. Using a separate miniature 200 ma mains transformer of 18V rating.

The first method leads to problems in start-up phase. The second method needs extra components like 200 MA, 18V (9V-0-9V) transformer plus a bridge rectifier unit and capacitor filter. This method is reliable.

2.4 SWITCHING ACTION

The pulses and details of switching circuit are shown in Fig 2.3. In the switching part shown in the Fig 2.3 the coil must have high inductance and low resistance. A current must be passed trhogh it by the switching transistor for each pulse drive. Peak current is a function of the input volts, switch voltage, the inductance of the coil and the time for which the switching transistor is turned on.

When the supply voltage is turned on, the current rises exponentially in an R-L circuit. When supply is switched off, a high voltage is induced, which turns on the secondary diode, and current drops quickly to zero.

The capacitor and resistor are provided to pass the decaying current after switching off. Without these, the voltage across the transistor collector would rise to a very high value when it is switched off. A VDR is also added to prevent this.

The energy per cycle is given by

$$E = \frac{1}{2} LI_{max}^2$$

Where 'L' is the inductance of primary.

One way to increase energy is to make L large. As the supply voltage E is

$$E = L \frac{dI}{dt} + RI$$

Making L large would decrease the value of dI/dt for a given supply. During the on-time of the pulse, current I would not be able to rise sufficiently. So I_{max} would be low. If L is very small, I rises to E/R, the ultimate value, very rapidly, but the energy would be very small& R has to be low, consisten with surge current of the switching transistor.

In order to make I_{max} large, we have to reduce winding and other resistances, switch from a high mains voltage and use as fast a transistor as available. Reducing the resistance will increase the peak voltage. This damping resistor should have resistance of 50-ohms to 100-ohms.

Another important factor is the drive current for the switching transistor. Switching transistor BU208 does not have a high current gain (hFE about 4). Hence to switch large currents, adequate base current drive has to be provided. The rise time of the collector current of the transistor improves with increased base current. If the collector should be switched to a current of 100 mA, the base drive must be around 25 mA. If the collector has to switch a current of 1A, the drive has to be 250 mA. If the same 25 mA drive is given, the transistor will not switch to full conduction in the later case and will dissipate power due to linear operation. Normally the transistor does not get hot at all in any SMPS, it just becomes warm. If it heats up, the base drive current has to be increased.

2.5 REGULATION

An SMPS is regulated essentially by changing either the switch-on period or repetition rate of switching or both. When the power is switched on, current is pumped into the coil and energy is stored into it. This energy is released to the output via a fast recovery diode into a reservoir electrolytic capacitor. The output voltage across the capacitor is smooth and can drive the DC load. As the load varies, the output voltage drops.

The drop in voltage is compensated by increasing the pulse width during which the current increases in the coil. More width means more time for the current to rise to a greater value, causing an increased storage of magnetic energy in each cycle.

If the output voltage becomes higher than the desired value, it could be decreased quickly by either fully cutting off the switching pulses for a little while or reducing the pulse width, depending upon the amount of output voltage to be reduced.

The above process is possible by using the IC SG or LM 3524. This can work with 10V to 40V supply and can send current output upto 100 mA in pulses to switch a transistor to pass current in a ferrite core transformer.

The internal functions of the IC are shown in Fig2.4. As stated earlier, the pulse width modulator is a circuit that varies the duty cycle of a pulse train at a fixed frequency.

The IC has built-in PWM to vary the on time of the series pass transistor. The internal oscillator drives a flip-flop which in turn drives two gates. There gates are driven out of phase by the Q and $\bar{Q}$ outputs of the flip-flop. The IC's output is therefore disabled by the comparator whenever the output goes high. This happens when the error amplifier determines that the internal reference voltage equals or exceeds the sampled portion of the output voltage. It also takes place if the current limit amplifier senses an overload condition.

LM3524 has a built-in 5V reference regulator capable of supplying 50 mA at its pin 16.

The frequency of its internal oscillator is determined by the external resistor and capacitor at pins 6 & 7 which are rated as 1K Ω and 0.02 μF respectively. Normally the resistor at pin 6 should have a value between 1K Ω and 100 K Ω and the capacitor should have a value between 0.001 μF and 0.1 μF.

The error amplifier is a transconductance type differential input one with a high gain of 80 dB. the gain may be set by feed back.

The output of the amplifier which is also the input to the pulse width modulator, has an impedance of 5 megohms which enable it to be overridden by a DC voltage, thereby forcing a desired duty cycle to appear at the output.

The amplifier's inputs have a common mode range of 1.8V to 3.4V. The IC's internal regulator biases these inputs suitably.

The output stage of the IC consists of two npn transistors driven 180° out of phase with each other by the flip-flop. Each transistor is capable of supplying upto 100 mA.

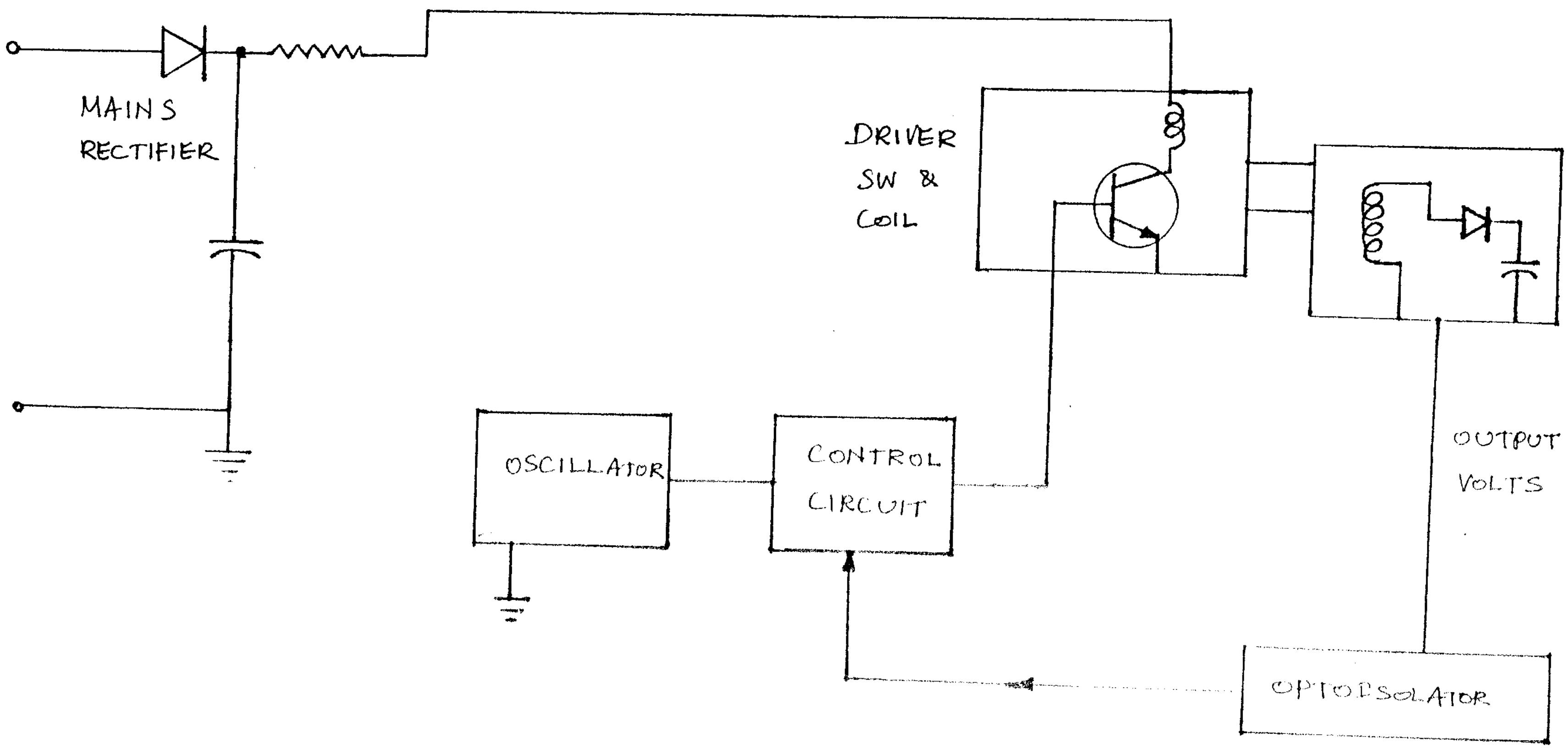


FIG 2.1 BLOCK DIAGRAM OF AN SMPS USING OPTOISOLATOR

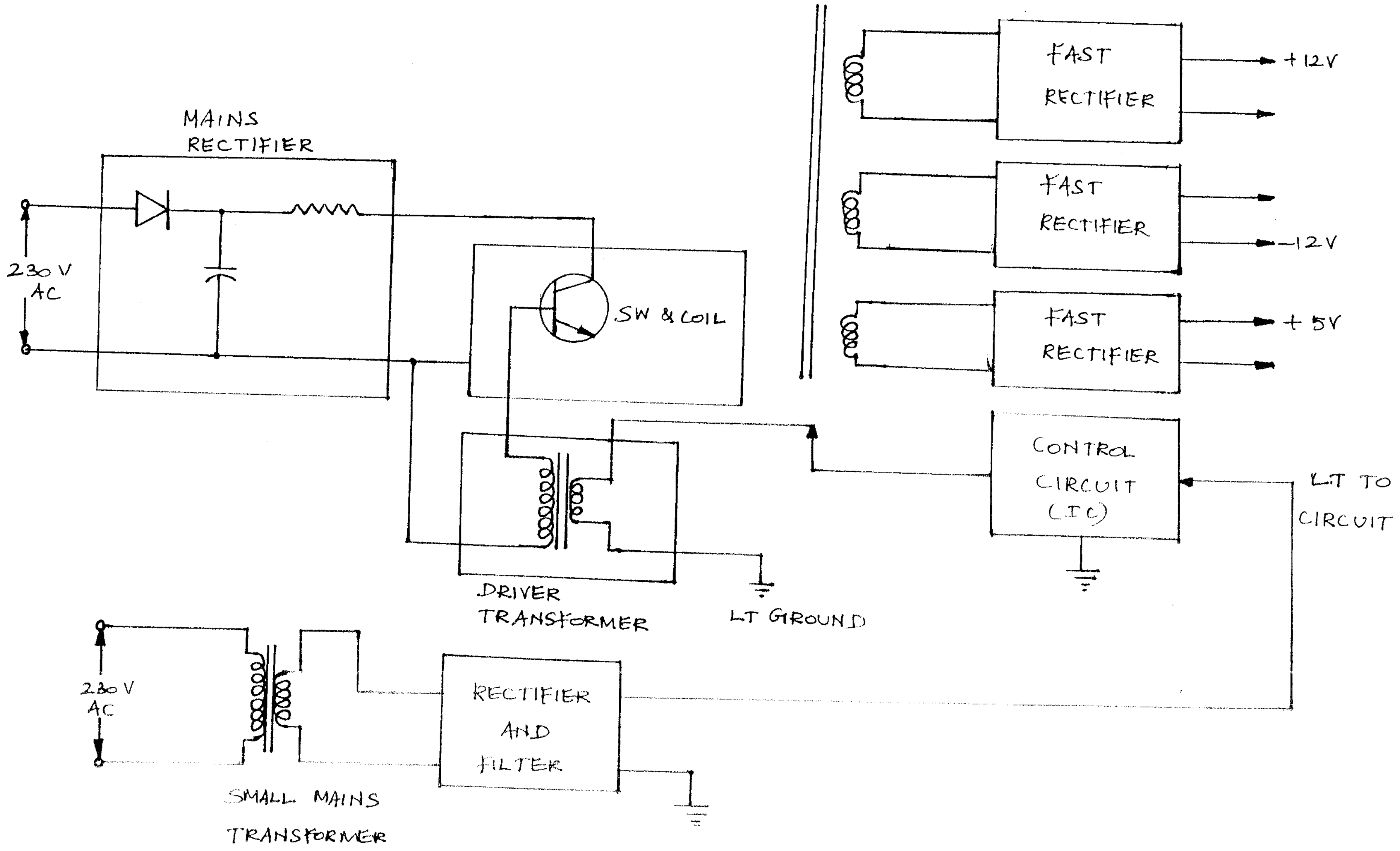


FIG 2.2 ISOLATED OUTPUTS IN SMPS USING ISOLATED CONTROL SUPPLY.

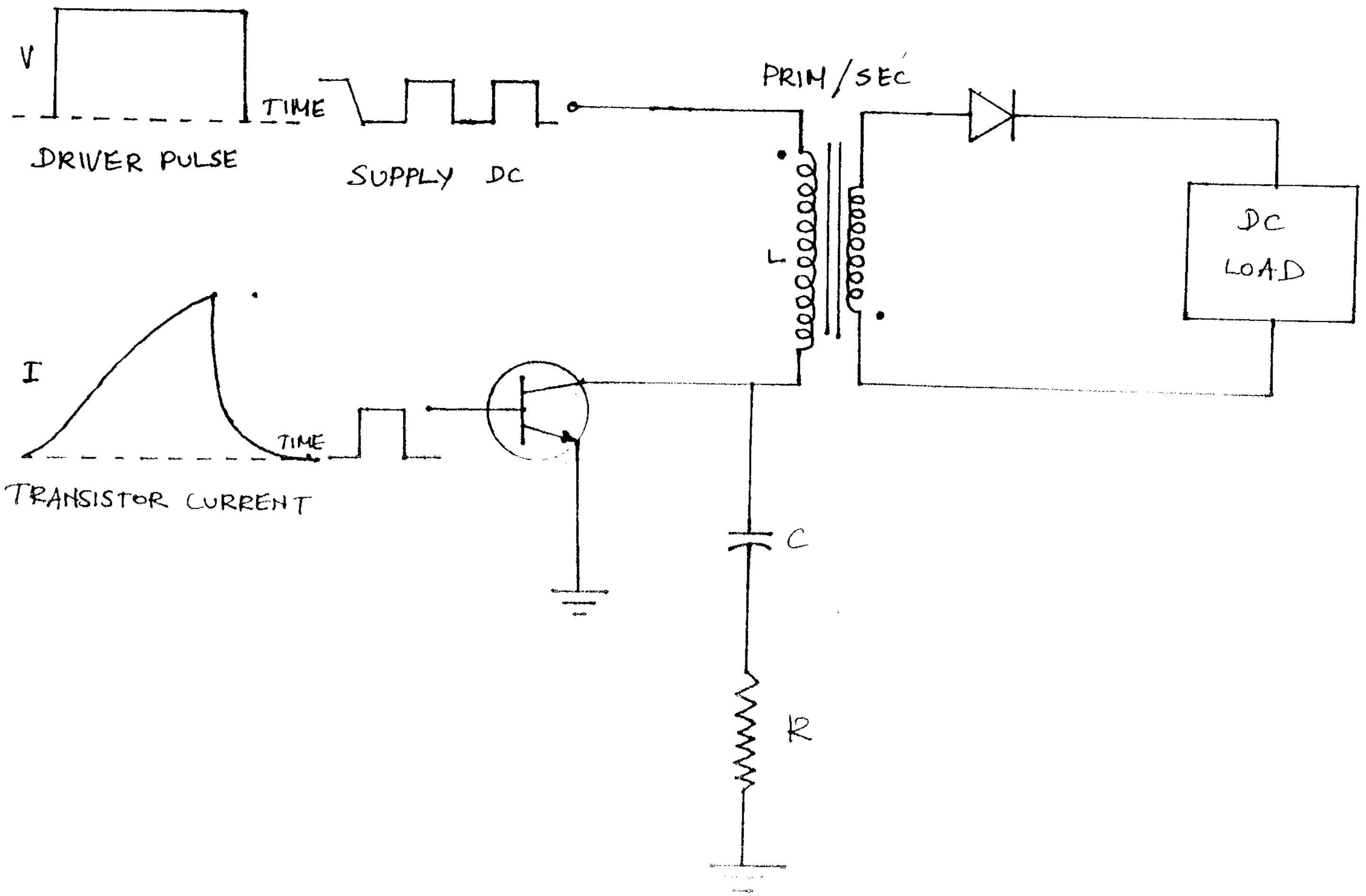


FIG 2.3 SWITCHIN CIRCUIT AND PULSES.

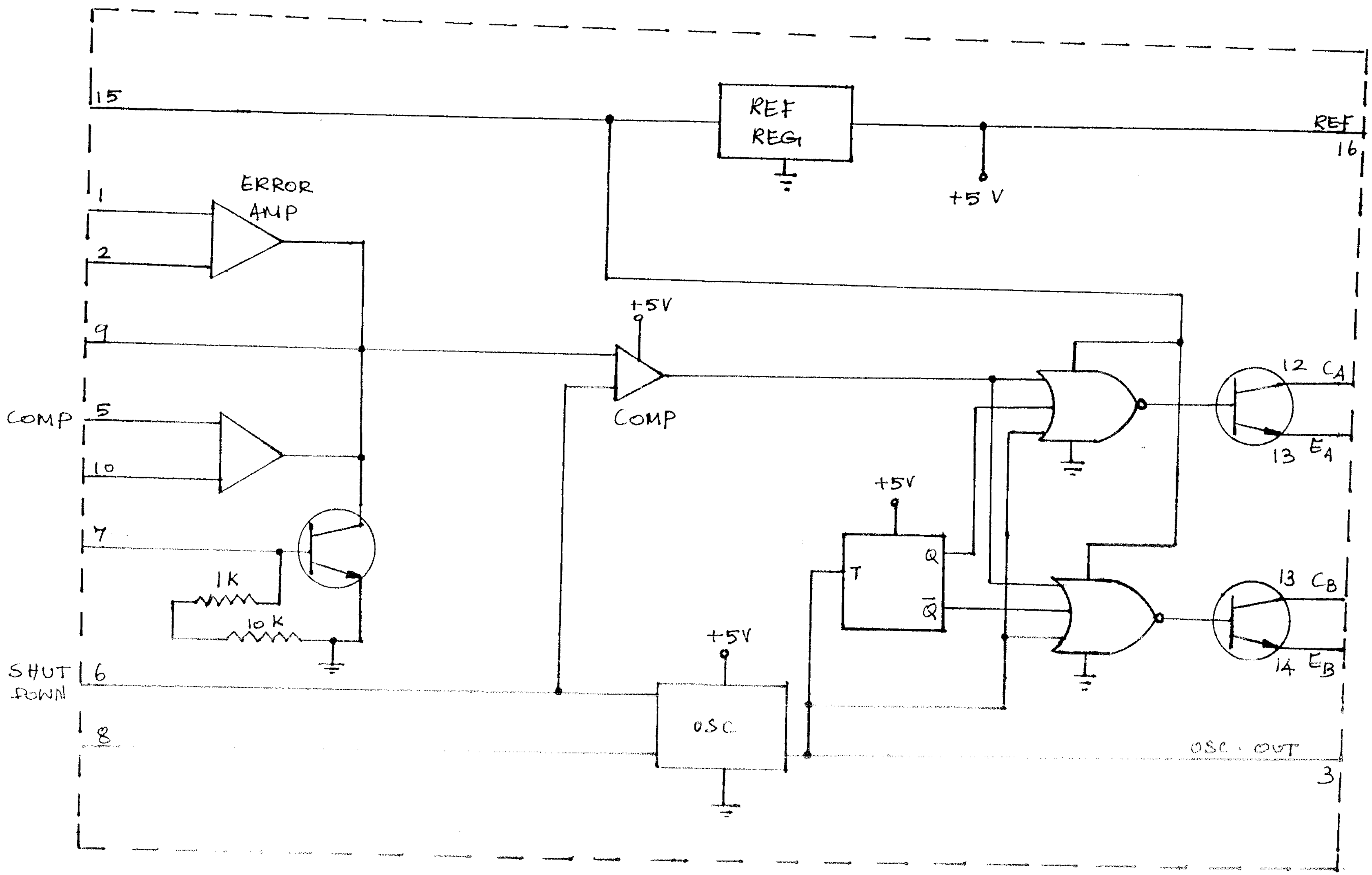


FIG 2.4 INTERNAL CONFIGURATION OF I.C.

CHAPTER III

CONSTRUCTION OF SMPS

The complete circuit diagram of the SMPS designed is shown in Fig 3.1.

3.1 POWER SUPPLY TO REGULATOR IC

A 200 MA mains transformer of 9V-0-9V is used to power SG3524. Four diodes are used to rectify 18V supply and generate low DC voltage supply. It may drop to 15V with load, but does not have much effect on the supply.

The IC is operated at about 18 KHz. Timing resistor R_2 and capacitor C_3 are of 1K and 0.02 ratings respectively.

3.2 SWITCHING SECTION

One output to this IC is further amplified by pnp transistor EC P055 (or 2N6107 BEL). This drives the switching transistor through driver transformer X3. A driver transformer of a TV receiver similar to the BEL TV circuit is used. Turns are wound on this core as given in the parts list. The direction of secondary must be proper, as shown by the dots, while connecting it to the circuit. The dot shows the starting end of the winding.

Both the driver transformer and transistor ECP055 work on a low voltage of 18V. One end of this 18V is at ground, along with the ground potential of 5V, 5A and the 12V output supplies.

The reference input for the error voltage amplifier within the IC is obtained from its internal 5V reference, with a divider of two 4.7K resistors, thus keeping pin 1 at 2.5V. A 10K preset is used at 5V output of the SMPS. A tapped voltage is fed to pin 1 of this IC, which adjusts the output pulses accordingly.

3.3 HIGH FREQUENCY TRANSFORMER

Transformer X_2 is made up of any TV LOT core; using its bobbin, four windings are wound, starting from the inside to the outside. Only one limb of the core has all these windings and the other limb is free. The innermost primary winding has 250 turns, wound with 27 SWG wire. The windings are as below

N_1 250 turns primary 27SWG enamelled copper wire.
N_2 40 turns secondary 27SWG enamelled copper wire.
N_3 40 turns secondary 27SWG enamelled copper wire.
N_4 12 turns secondary 19SWG enamelled copper wire.

N_2 and N_3 are in series with a centre tap. These provide +12V and -12V supplies. N_4 is for 5V, 5A supply.

The LOT of a TV set is used. The metal plates at top and bottom are carefully unclamped. The bobbin carrying the EHT coil and inner coils is removed. The bobbin has pins fixed for PCB mounting. The windings are stripped off, keeping only the bobbin for use. Then the four coils are wound, their ends marked N_1 to N_4. The beginning and end of each coil is made as shown in the circuit diagram.

3.4 DRIVER TRANSFORMER

The driver transformer is wound with 27SWG wire with primary of 150 turns and secondary of 100 turns. The core of a TV driver transformer is used here. The same bobbin is used after stripping the winding.

3.5 MAIN SUPPLY (5V, 5A)

The 5V at N_4 is rectified by diode IN3880 and filtered by a capacitor, an inductor (choke) and another large 1000 μF capacitor. The output of D_6 is sampled and used to control the IC via the 10K preset. By adjusting this preset, the 5V output voltage can be increased or decreased.

The ripple is not reduced since the capacitor C_8 has a lower value of 220 μF. However, by feedback the IC controls the output ripples fast. The inductor and capacitor C_9 filter out any residual ripples to a level of about 30mV. The ripple is not reduced if C_8 is of higher value.

0.1 μF capacitor connected between the 5V sampling point and the centre point of the 10K preset enables to filter the ripples, by passing all the ripples to pin 1 of the IC. Eventhough the output voltages are 5V and 12V, 35V capacitiors are used because 16V and 25V types become hot and they burst.

The filter inductor for 5V uses any (24 x 16)mm pot core wound with 22SWG wire for as many turns as it would contain.

3.6 AUXILLARY SUPPLIES (±12V)

The 12V auxillary supply is rectified by BY396 diodes with a current rating of 3A. BY396 diodes are fast recovery rectifiers. After filtering, the 12V supplies are obtained by using monolithic voltage regulator ICs 7812 and 7912. These ICs provide stabilised outputs of +12V and -12V, each for 1A rating. Heatsinks are required for these ICs. Other ICs can be used if greater outputs are needed.

The diodes used for rectifying voltages at N_2 and N_3 windings are in opposite direction so as to get +12V and -12V outputs. No feedback is given from these to the IC. Only the 5V line is regulated by it, since it gives greater output current.

A light load of 20 ohms is permanently connected across the 5V output. In its absence, if the 5V line is left open (not drawing any current), then the +12V and -12V supplies will not be able to supply any load. This is because the switching output pulses cease without any load on the 5V line, since feedback is taken from the 5V point to pin1 of the IC.

The use of a separate miniature transformer for the 18V DC supply for the IC provides isolation between 220V mains, and the 5V and ±12V outputs.

3.7 OUTPUT FILTER

The 5V output filter inductor is preferably of the pot core type, but even small iron core type used for audio output transformer could also be employed. In case of pot core, two halves have to be tightened after the coil is fitted.

3.8 OVERVOLTAGE PROTECTION

Overvoltage shut down is provided by connecting the 5V output via a 5.6V zener diode to pin 10 of IC 3524. This prevents any voltage rise above 5.6V causing the IC to shut down the drive.

3.9 FABRICATION DETAILS

This SMPS design has been adopted for a single PCB construction enclosed by a box. The SMPS is constructed inside a sheet metal box. The components are housed inside carefully and all the transistors along with diodes are mounted on mica washers on the back plate of the box and wired.

The PCB layout for all the components is shown in Fig 3.2. As per the layout diagram, the winding ends of the turns N_1 to N_4 on the LOT core are brought out to pins of its former. The LOT is fixed firmly to the PCB by the pins.

While fitting on the PCB, the driver transformer winding ends 1 to 4 are matched with the circuit diagram.

The BU208 switching transistor is mounted on a suitable heatsink. The ECP055 driver transistor needs no heatsink and is inserted directly on to the holes. Two bolts and nuts are used for BU208 transistor for collector to metal case contact while mounting on the PCB.

IC SG3524 is directly soldered on the board, without any socket. This is because any loose contact at the socket may give rise to either over voltage, or failure of parts.

The 200mA, 9V-0-9V transformer is also mounted on the PCB. the centre tap is left unconnected. Therefore, the 18V outlet leads are taken down to the PCB holes. The four rectifier diodes are arranged in the form of a bridge in order to provide full wave rectification. The DC supply is filtered with a 1000μF can type, 25V DC electrolytic capacitor. The positive and negative leads are inserted properly.

The mains supply is rectified by a diode of atleast 2A current rating. This is mounted with its leads bent so as to fit in a raised position above the board, without touching the laminate. A small fuseholder is mounted next to the diode to carry a 1.5A glass fuse. The electrolytic capacitor is a can type with 100+100μF, 350V rating. After fiting these, the rectified DC voltages for both HT and LT are measured and checked. The capacitor should be discharged before touching, even after switching off.

Finally, the IC and its associated components are soldered. Pin 16 of the IC has to give a voltage of 5V, which is its internal zener reference. Square pulses are observed at pins 12 and 13. The positive supply is between 18V and 20V.

ECP055 is then fitted, its collector bolts contacting the PCB tracks. After the driver transformer is fitted, pulses are observed on the secondary of the transformer.

BU 208, rectifier diodes and other capacitors are fitted now. The 5V output is connected to the 10K Ω preset and a jumper is provided to connect this to pin 1 of the IC. Also, the 5.6V zener diode is connected from the 5V supply to pin 10 of the IC.

A light load of 20 Ω , 5W is permanently connected across the 5V. The 12V regulator ICs are fitted later.

Now upon applying the mains supply, the LOT makes a mild hissing sound and the voltages are obtained at the 5V points. The 5 volt line is adjusted to 5.2V by the 10KΩ preset.

A load of 1 ohm resistor obtained by a small bit of a broken heater coil wire used in opentype househld heaters is connected to the 5V supply and the current is measured along with the voltage. The voltage drop is within 0.3V from no load to full load of 5A. This meets all requirements for TTL ICs to be powered from the SMPS.

The 12V IC regulators are iserted at this stage. The IC 7912 has its centre pin as the input voltage pin. These supplies are loaded and tested upto 1A (using 10 Ω , 10W resistors).

If the voltage of these supplies happens to drop on full load (with the 5V output kept unloaded), then the dummy 5V load has to be increased. The load resistor of 20 ohms must be decreased yo 15 ohms.

As a precaution against failure of BU208, a low rating fuse (normally 1A) is fitted initially. Also resistor R_1 is increased to 100 Ω, 10w in the beginning. After ensuring that the 5V output is generated (by adujsting preset R_{11}), this is reduced.

To minimise the line RF interference, a 0.1 μF, 1000V capacitor is connected across the Ac line on the board. This filters some of the outgoing switching noise.

Finally the LOT core is wrapped around with copper foil to shield it well. Then the entire board is covered by the enclosure.

CHAPTER IV

EXPERIMENTAL OBSERVATIONS

To appreciate the function of each and every component of the SMPS. The whole circuit is Tested stagewise.

4.1 POWER SUPPLY TO REGULATOR IC

This stage consists of a transformer (200mA, 9-0-9V) for stepping down the input ac supply (230v). This stepped down voltage is rectified by using a bridge rectifier and filtered by a capacitor.

This stage along with the output waveform is shown in Fig (4.1). This provides power supply to the IC.

4.2 MAINS RECTIFICATION

This stage is the main stage of SMPS. The mains voltage is directly rectified without stepping down.

This stage along with the output characteristics is shown in Fig (4.2). Dual capacitor is used for filtering. The output voltage is found to vary linearly with increase in load.

4.3 TESTING OF IC

This stage is the testing of IC. The components are connected as shown in Fig (4.3).

The nature of waveform at collector and output pin12 of the IC are shown in Fig 4.4 and Fig 4.5.

4.4 TESTING OF SPECIAL COMPONENTS

4.4.1 DIODES

When used at frequencies of 15khz and above, diodoes generally behave in a different manner as compared to diffused junction types used at mains frequency. Switching diodes with either gold doped junction or the schottky barrier diodes are employed in SMPS. There is not much charge storage in the junction in such switching diodes. The difference between the ordinary diodes and special diodes is shown in Fig (4.6).

4.4.2 CAPACITORS

Since the frequency of switching is very high in SMPS, electrolytic capacitors invariably affect at such frequencies. The equivalent series resistance of a capacitor is about 0.05 to 0.1 ohms. It grows with frequencies above 10KHz. The impedence of a capacitor becomes minimum at about 20KHz, whereupon it increases further as shown in Fig (4.7).

4.5 TESTING OF THE UNIT

After testing stagewise, an overall circuit connection is made, and following waveforms are obtained on testing.

1. Pulse at secondary of driver transformer point 3.
2. Induced voltage at point 4 of LOT.

The above waveforms are shown in Fig (4.8) & (4.9).

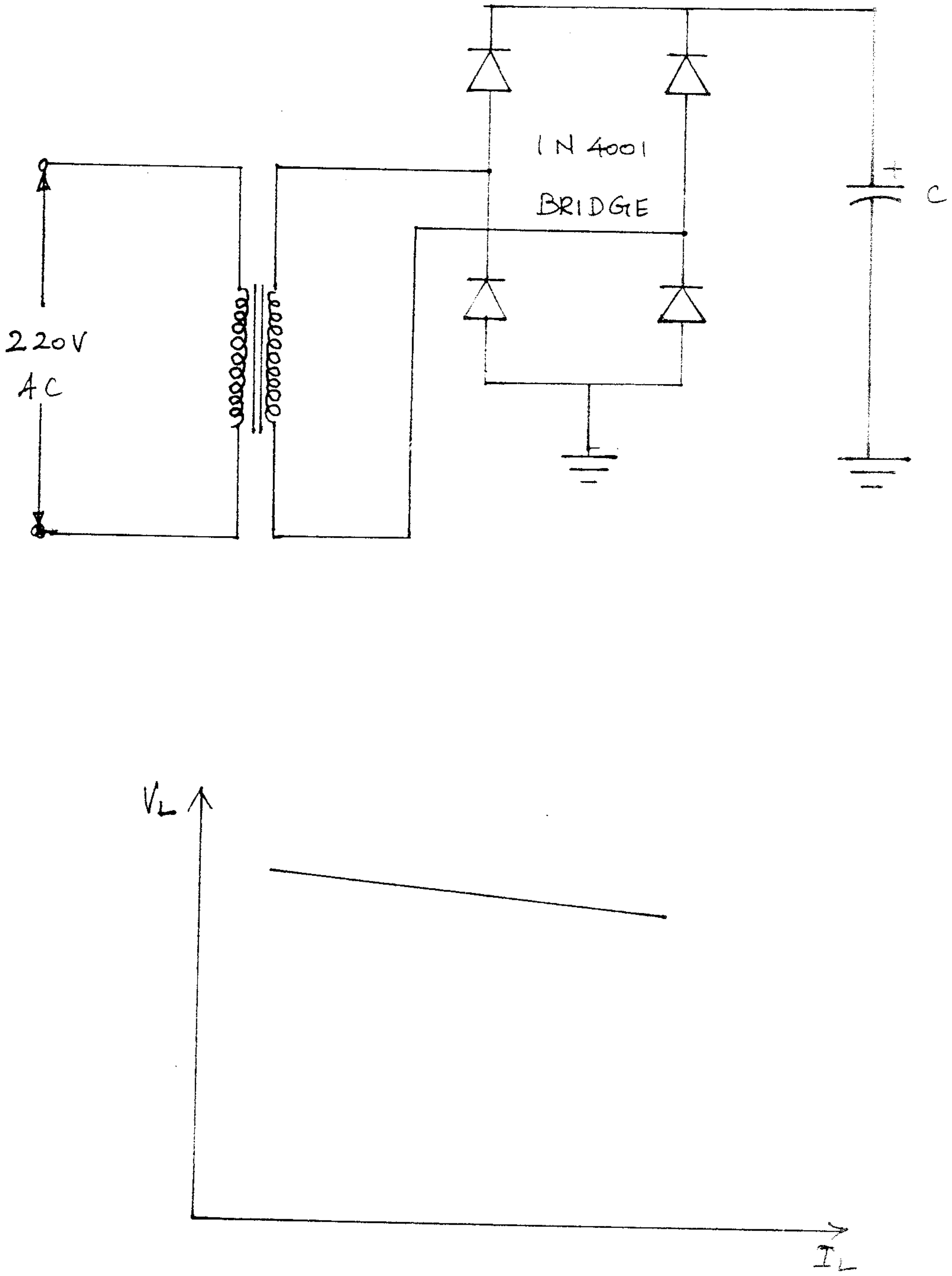
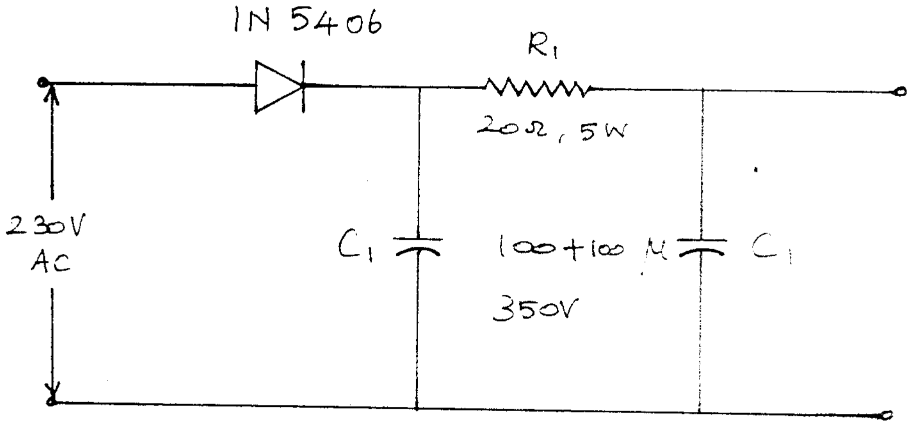


FIG 4.1 POWER SUPPLY TO REGULATOR IC.



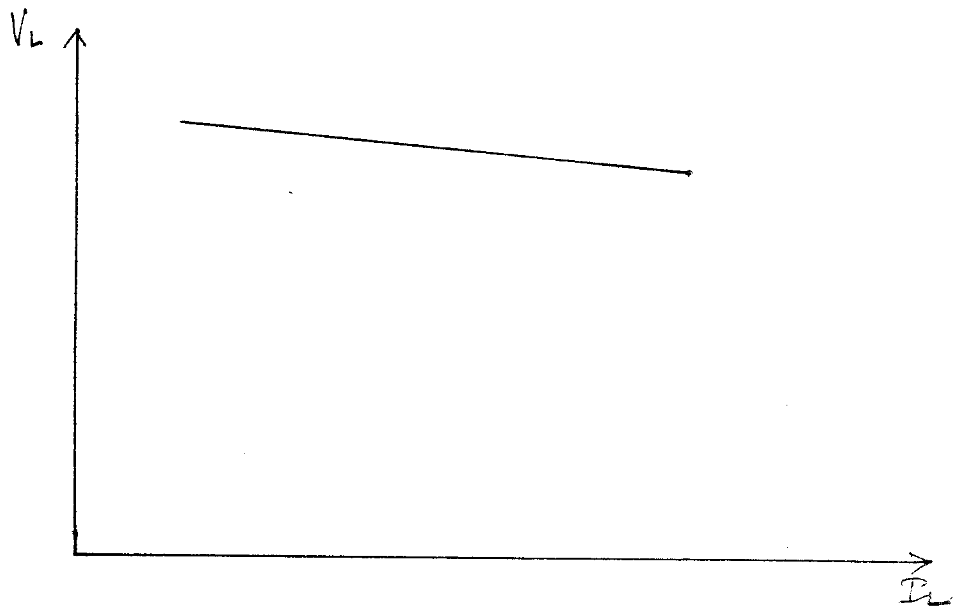


FIG 4.2 MAINS RECTIFICATION.

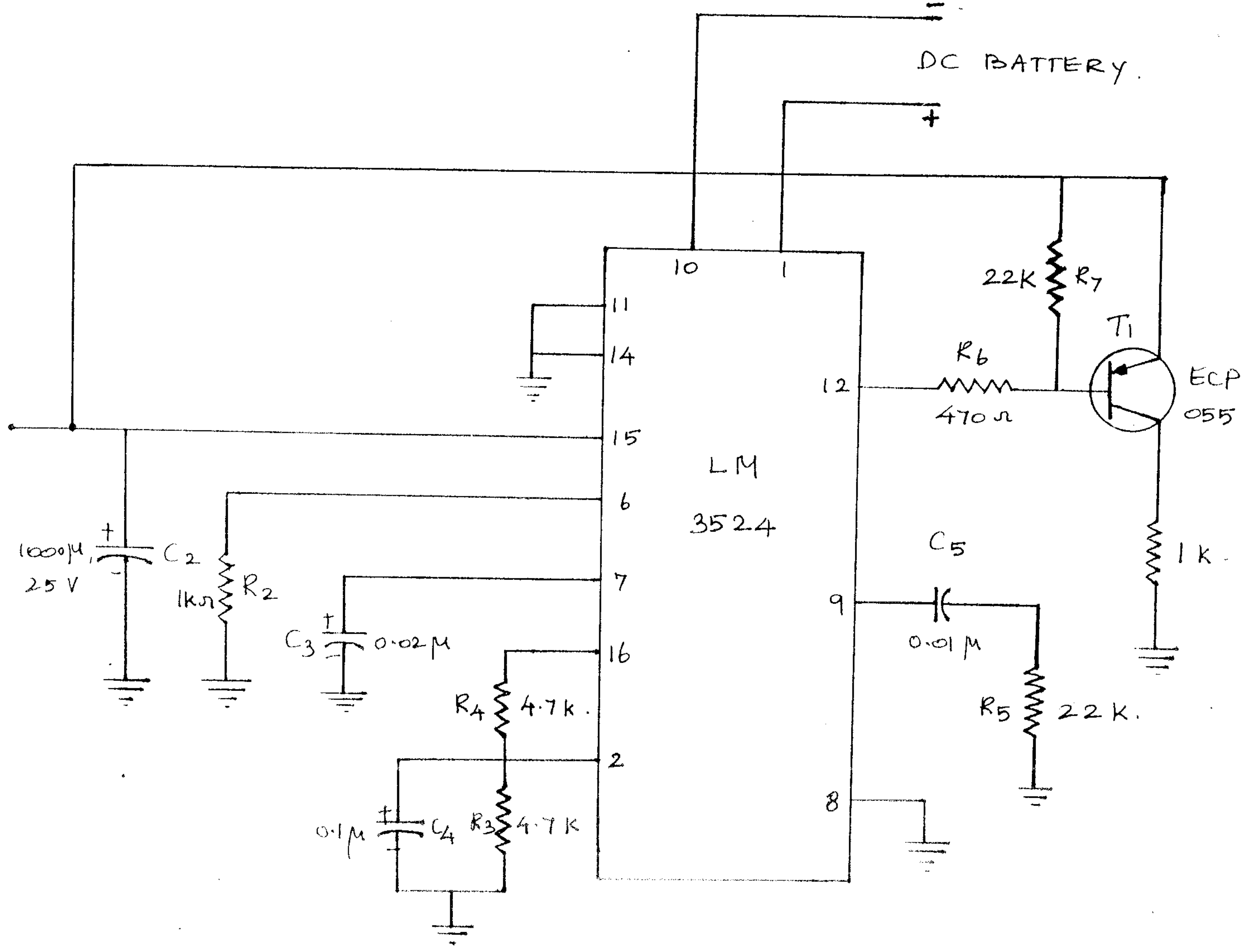


FIG 4.3 FUNCTIONING OF REGULATOR IC.

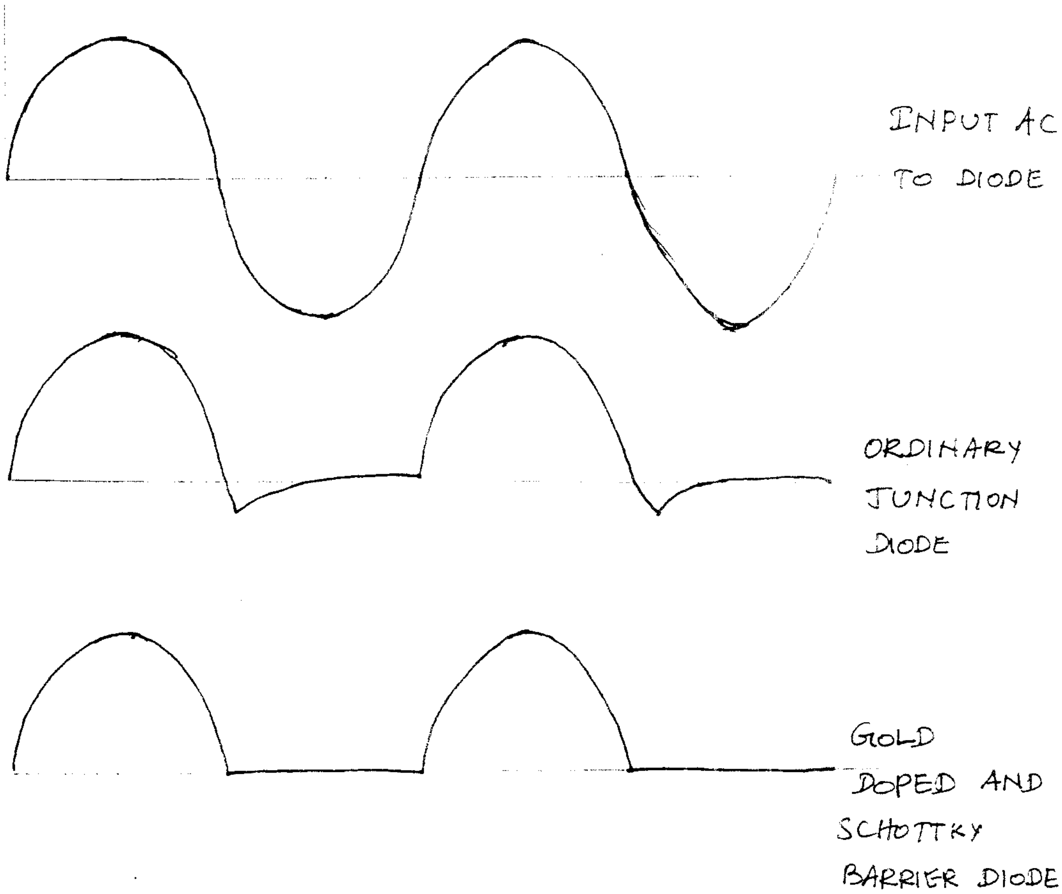


FIG 4.6 RECTIFICATION NATURE

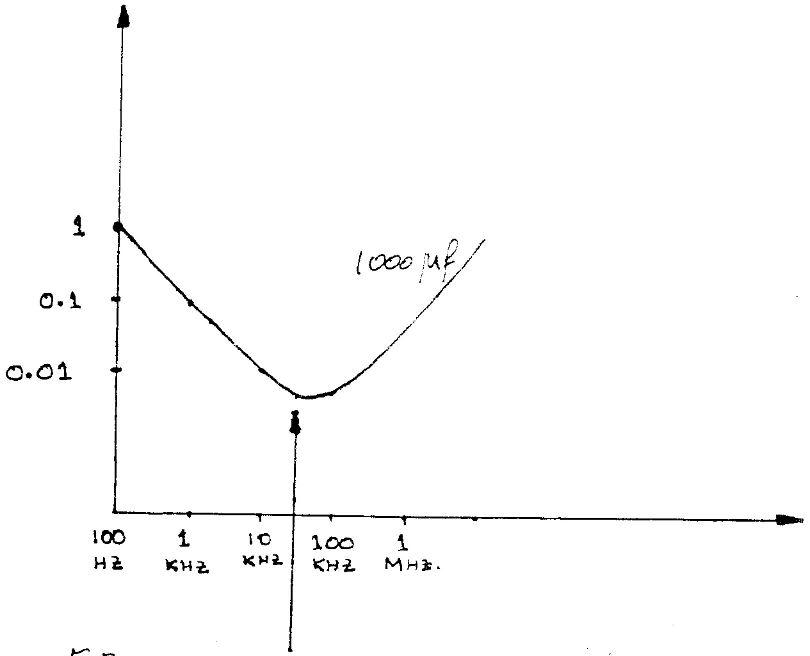


FIG 4.7 VARIATION OF RESISTANCE OF A CAPACITOR WITH RESPECT TO FREQUENCY.

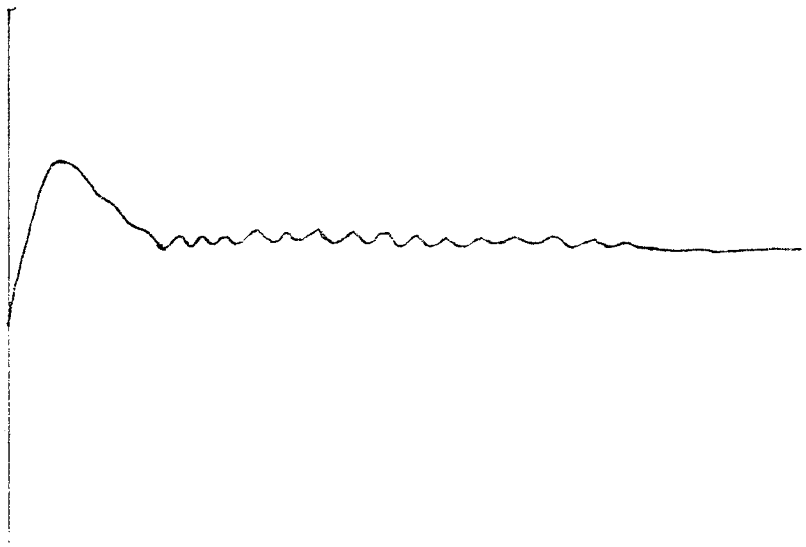


FIG 4.8. PULSE AT SECONDARY OF DRIVER TRANSFORMER POINT 3.

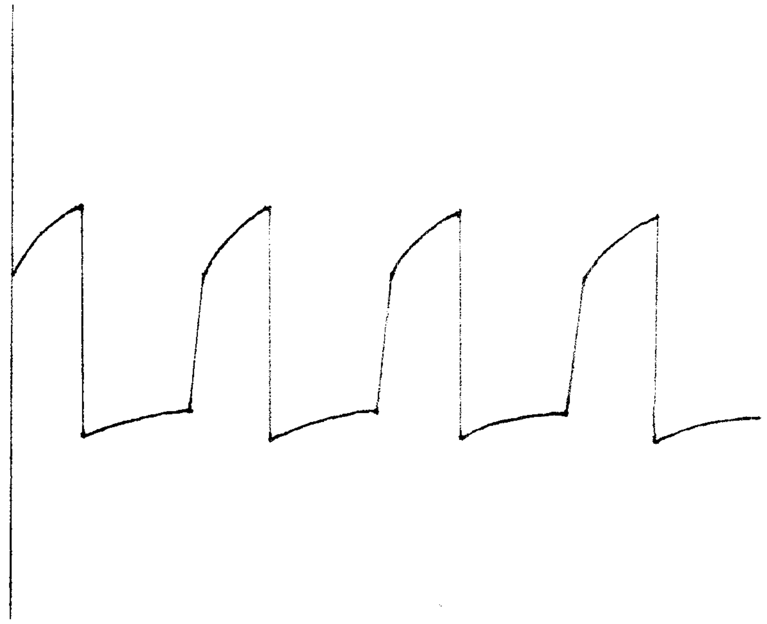


FIG 4.9. INDUCED VOLTAGE AT POINT 4 OF LOT.

CHAPTER V

CONCLUSION

A 5V, 5A switched mode power supply unit has been designed and fabricated successfully. It is highly efficient, smaller in size, more economical and light in weight.

We feel that this type of power supply will replace the existing linear power supplies in the very near future.

This circuit can be further improved by using a Bridge Rectifier Circuit instead of a Half wave Rectifier Circuit.

The output current ratings of the SMPS can be changed to any required value by slight modifications in the windings of the transformers and by using suitable switching transistors and fast recovery rectifiers.

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