Design & Development of Cost Effective Switched Mode Power Supply

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Design & Development of Cost Effective Switched Mode Power Supply

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IN

ELECTRICAL ENGINEERING
(Power Electronics, Machines & Drives)

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Undertaking for Originality of the Work

I **Vipsa J. Bhalani**, Roll No. **12MEEP37**, give undertaking that the Major Project entitled **"Design and Development of cost Effective Switched Mode Power Supply"** submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Power Electronics Machines** & **Drives, Electrical Engineering**, under Institute of Technology of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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CERTIFICATE

This is to certify that the Major Project Report entitled **"Design & Development of Cost Effective Switched Mode Power Supply"** submitted by **Ms.Vipsa Bhalani** (**Roll No.: 12MEEP37**) towards the partial fulfillment of the requirements for Master of Technology (Electrical Engineering) in the field of Power Electronics, Machines & Drives of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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Abstract

Efficient conversion of electrical power is becoming a primary concern to companies and to society as a whole. Switching power supplies offer not only higher efficiencies but also offer greater flexibility to the designer. Recent advances in semiconductor, magnetic and passive technologies make the switching power supply an ever more popular choice in the power conversion today. In the industries nowadays three phase supply is a prime need for their utility. Power controllers, AC Drives, DC Drives are the major devices used for different purposes. As SMPS have very efficient performance, not to keep it limited to lower voltage input range, but can be introduce it for the higher voltage inputs and enhance its versatility.

As Switch Mode Power Supply has different Topologies like Flyback, Pushpull,Half bridge, Full bridge and Forward. In this Project, by using Forward Topology and PIC controller as control scheme, size and cost of Switch Mode Power Supply can be decreased as compared to the other Topologies. The objective of this project is to fabricate the compact size and cost effective Switch Mode Power Supply by using Forward Topology. The results of Hardware are shown for all different available solutions.SMPS by using forward topology gives realiable and cost effective solution with compact design.

Abbreviation

B-B .... Buck-Boost
CM .... Circular Miles
DEFC .... Double Ended Forward Converter
EMF .... Electro Motive Force
MOS .... MOSFET
MFD .... Micro Farade
PWM .... Pulse Width Modulation
SMPS .... Switch Mode Power Supply
TI .... Texas Instruments

Nomenclature

V_{in}	Input Voltage
V_{out}	Output Voltage
I_{in}	Input Current
I_{out}	Output Current
T_{ON}	On(Conduction) Time
T_{OFF}	OFF(Delay) Time
V_{drop}	Voltage drop
I_{LOAD}	Load Current
D	Duty Cycle
S_i	i^{th}Switch
V_{dc}	DC Voltage

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Chapter 1

Introduction

1.1 Overview of SMPS

The linear regulator was the old method of creating a regulated output voltage. It operates by reducing a higher input voltage down to the lower output voltage. It can be dobe by linearly controlling the conductivity of a series pass power device in response to changes in its load. So that a large voltage being placed across the pass unit with the load current flowing through it.[10]

This type of loss ($V_{drop}*I_{load}$) causes the linear regulator to only about 30 to 50 percent efficient. That means that for each watt applied to the load, at least a watt has to be dissipated in heat. The cost of the heat sink actually makes the linear regulator uneconomical above 10 watts for small applications. Below that condition, however, they are cost effective in step-down manner.

The switching regulator operates the power devices in the full-on and cut-off states. And large currents being passed through the power devices with a low on voltage or no current flowing with high voltage across the device. This results in a much lower power being dissipated within the supply. The average switching power supply exhibits efficiency in between 70 to 90%, regardless of the input voltage. Higher levels of integration have driven the cost of switching power supplies downward that makes it an effective choice for output powers greater than 10 watts.

So the popularity of Switch Mode Power Supply has been increased due to its advantages of high power efficiency and increased design flexibilities. The Switched Mode Power Supply is essentially a dc to dc converter with control of the output voltage value. Generally in the low and medium power application a Switched Mode Power Supply provides required DC power supply with negligible AC ripples.

1.2 Block Diagram of SMPS

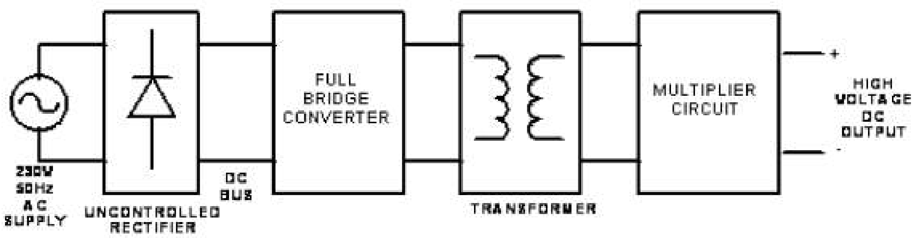

Figure 1.1: Block Diagram of SMPS

In high frequency power transformer, the ac high frequency is stepped up or stepped down depending on the ratings. Ferrite core transformer is generally used to eliminate the iron losses.In Output rectifier and filter, the AC is then again rectified and then filtered to get the required output DC voltage. The load connected to any circuit which is supplied by the SMPS. In Control and feedback, the feedback from the load is taken to make the output controllable and constant.[11]

1.3 SMPS compared with linear Power Supply

There are two main types of regulated power supplies available: SMPS and Linear. The reasons for choosing one type or the other can be summarized as follows.

a. **Size and Weight**–Linear power supplies use a transformer which operates at the mains frequency of 50/60 Hz. This component is larger and bulky by several times than the smaller transformer in an SMPS, which runs at a higher frequency (always above the highest frequency, around 20 kHz to 200kHz)

b. **Efficiency**-Linear power supplies regulate their output by using a high voltage in the initial stages and to improve the power quality. This power loss is required to the circuit, it can be reduced but never eliminated by improving the design quality. In SMPS, draw current at full voltage based on a variable duty cycle, and it can increase or decrease their power consumption to regulate the load if needed. So that a well designed SMPS will be more efficient.

c. **Heat output or Power dissipation**–An inefficient power supply must generate more heat to power the same electrical load. Therefore, a SMPS will generate less heat.

d. **Complexity**-Linear Power Supply can be designed and also it can be assembled by beginners with a relatively small part count. In contrast, SMPS are complicated and difficult to design well; they require the use of custom-made transformers and inductors. SMPS behavior may be affected by the layout of components on the circuit.

e. **Radio Frequency Interfrence**-The currents in a SMPS are switched at a high frequency . This happens due to its internal Armstrong oscillator operating at a high frequency. This high-frequency oscillator can generate unreliable electromagnetic interference. RF shielding is required to prevent disruptive interference. Linear Power Supply does not produce interference.

f. **Electronics noise at output terminal**-Uneconomical linear Power Supply with poor regulation may causes a small AC voltage ripple on the DC output at double mains frequency (100 to 120 Hz). These ripples are usually on the order of millivolts, and can be suppressed with large filter capacitors or superior voltage regulators. This small AC voltage can cause problems in some circuits. Quality linear Power Supply will suppress ripples more effectively, SMPS does not exhibit ripple at the power-line fequency, but it developes noisier outputs than linear Power Supply.

g. **Acoustic noise**-Linear Power Supply generally gives off a faint, low frequency at mains frequency, but this is audible. (The transformer is responsible.) SMPS, with its more high operating frequencies,that are not usually audible to people(unless they have a fan, and in the case of most computer SMPS). A malfunctioning SMPS may generate high peack sounds, since they generate acoustic noise at the oscillator frequency.

h. **Power Fector**-The current drawn by simple SMPS is non-sinusoidal and out-of-phase with the supply voltage waveform so that the most basic SMPS designs have a power factor of about 0.6, and their use in personal computers and small size fluorescent lamps presents a problem for power distribution.

1.4 Applications of Switch Mode Power Supply

The switched-mode power supply market is famoused within the electronics sector, with a large number of power supply manufacturers world-wide providing a wide range of units for the commercial and military. The main use of switched-mode supplies, are computers, large mainframe and small, personal and word processors also the various telecommunications systems. A typical system needs a number of output voltages from its supply and so the majority of power supplies tend to be multiple output forms. Typical supply voltages are +5V for Bipolar logic, +12V for CMOS logic,

+12V, +15V for operational amplifiers, and +24V for DC motors.

The topologies and control methods used to get the desired output voltages in a various power ranges tends to vary from manufacturer to manufacturer. The topologies reviewed previously in this section all have their more favoured applications. In general switching regulators are usually used as secondary regulators on multiple-output units, Isolated single-ended configurations are used in low power single or multiple output ac to dc converters and multiple switch topologies are used for higher output power applications. Also used as secondary regulators in some multiple output power supplies are linear regulators, mainly three terminal integrated circuits in low current outputs and magnetic amplifiers for higher current outputs.

1.5 Literature Survey

Literature survey plays a very important role in the project. Literature survey consists of high voltage dc power supply related papers that includes different power topologies, control schemes, mathematical modeling, simulations and experiments. Papers were taken from IEEE conference proceedings, journal proceedings and other standard publications. High voltage dc power supply related data were taken from manufacturer that also includes power topologies, features and advantages.

- **Paul Imbertson and Ned Mohan**

This paper is titled**"A METHOD FOR ESTIMATING SWITCH-MODE POWER SUPPLY SIZE"**A method of estimating the size of switch-mode power supplies is presented. This method includes analytical expressions for determining the physical size of inductors, capacitors, and transformers. The calculations are based on the "black box" input-output requirements of the power supply, and can be used to evaluate and compare competing design approaches or topologies which the designer may be considering. The technique is based on fundamental power supply parameters - power, energy, and electric charge - and avoids needless calculations during the initial estimation stage of a power supply design. This estimation technique is fundamental power supply parameters - power, energy, and electric charge - and avoids needless calculations during the initial estimation stage of a power supply design. This estimation technique is applied to the buck, forward flyback, and boost regulators.

- **D.K. W. Cheng and F.H. Leung**

This paper is titled**"DESIGN OF A SWITCHING MODE POWER SUPPLY WITH UPS FEATURES"**presented circuit integratcs a flyback converter and a buck converter to provide a Switch-Mode Power Supply (SMPS) with uninterruptible power supply (UPS) features. It can accept a high voltage of main power input and a low voltage of backup battery input. It uses ONE PWM ICcontroller for the normal and backup modes of operation so that it does not require a synchronization and a detection circuit for power failure. Therefore, the cost and circuit size will be reduced together. High efficiency can be obtained due to the use of a single DC-DC conversion topology from input to output over the conventional UPS. It can also provide full isolation among the high voltage main power input, the low voltage backup battery input and the voltage output. The prototype circuit was built, and the circuit operation and the experimental results of this converter are presented.

- **D. H. Liu J. G. Jiang**

This paper is titled**"High Frequency Characteristic Analysis of EMI Filter in Switch Mode Power Supply (SMPS)"**In switch mode power supply (SMPS), EMI filter plays an important role in suppressing common mode (CM) and differential mode (DM) conducted emissions. In this paper, the high frequency characteristic of an input filter is analyzed. Its frequency characteristic measured by a network analyzer is compared with simulation results based on models with/without parasitic parameters respectively. The effect of the parasitic parameters of capacitors and CM inductors is analyzed and discussed using the parameter sensitivity analysis, which gives a reference to design EMI filter and to deal with high frequency problems of filters.

- **P.Miller**

This paper is titled**"SWITCH MODE POWER SUPPLY TEACHING EXPERIMENT"**Switch mode power supplies are widely used in electronic equipment today. Our students needed to be able to study such power supplies in a laboratory environment. Commercial switch mode power supplies were ruled out because of the high voltages used and the ease with which they are damaged in unskilled hands. A number of teaching equipment suppliers were approached, however no suitable equipment was available for purchase, so our own teaching experiment was made at

The University of Glasgow for student use. The equipment devised demonstrates the operation of buck, boost, inverting and flyback switch mode power supplies. The student is able to safely observe the currents and voltages around the major components and verify the basic operating equations relating input voltage and current to output voltage and current as the operating duty cycle is changed. The power supply under observation is unaffected by the connection of test equipment and is sufficiently robust for student use.

- **Mohamed Miloudi, Abdelber Bendaoud, Houcine Miloudi, Said Nemmich, Helima Slimani**

This paper is titled**"Analysis and Reduction of Common-Mode and Differential-Mode EMI Noise in a Flyback Switch-Mode Power Supply (SMPS)"**In the design of power electronics systems, electromagnetic compatibility (EMC) should be well attended. This paper provides a characterization approach for conducted electromagnetic interference (EMI) in a Flyback switch-mode power supplies. However, when such equipment is poorly designed and/or constructed then considerable levels of EMI are generated, and problems are caused both within the network and to the other electronic equipment nearby. Advances in computer aided design software and device models have enabled the waveforms within a switchmode power supply to be accurately simulated. As a result of this, simulation techniques can be used to predict conducted interference levels generated by a Flyback. This paper introduces an efficient method to predict by simulation the conducted EMI of Flyback, accordingly mitigation is incorporated to reduce these electromagnetic emissions and susceptibility of SMPS.

Chapter 2

Different Topologies for SMPS

2.1 Introduction

Power supplies which are used extensively in industrial applications are often required to meet all or most of the following specifications.

a. Isolation between the source and the load.

b. Controlled direction of power flow.

c. High power density for reduction of size and weight.

d. High conversion effciency.

Depending upon the output voltage, the power supplies can be categorized into two , types.
(a) DC Power Supply
(b) AC Power Supply
Controlled DC supply can be obtained from the phase controlled rectifiers, but there are certain disadvantages, which led to the switched mode power supplies. An AC to DC rectifier operates at supply frequency of 50 Hz. In order to obtain almost negligible ripple in the DC output voltage, physical size of the filter circuits required is large. This makes the DC power supply ineffcient, bulky and weighty.

In the other hand, SMPS works like a DC chopper. By operating the on-off switch very rapidly, ripples can be easily altered by the L and C filter circuits, which are small in size and less weighty. It may therefore be inferred that it is the requirement of small physical size and weight that has led to the wide spread use of SMPS. Varying the duty cycle of the switching device by PWM techniques controls the output DC voltage.

The switching mode supplies have high effciency and can supply a high load current at a low voltage. There are six common confgurations for switched mode power supply.

(1) Flyback Converter

(2) Push Pull Converter

(3) Half bridge Converter

(4) Full bridge Converter

(5) Double Ended Forward Converter

(6) Forward Converter

2.2 Flyback Converter

All above converters looked at so far have virtually no electrical isolation between the input and output circuits; in fact they share a common connection. This is fine for many applications, but it can make these converters quite unsuitable for other applications where the output needs to be completely isolated from the input. Here is where a different type of topology tends to be used -the isolating type. The flyback converter can be developed as an extension of the Buck-Boost converter. Above Figure 2.1 shows the basic converter; in the B-B Fig replaces the inductor by a transformer. The buck-boost converter works by storing energy in the inductor during the ON phase and releasing it to the output during the OFF phase. With the transformer the energy storage is in the magnetisation of the transformer core. To increase the stored energy a gapped core is often used.

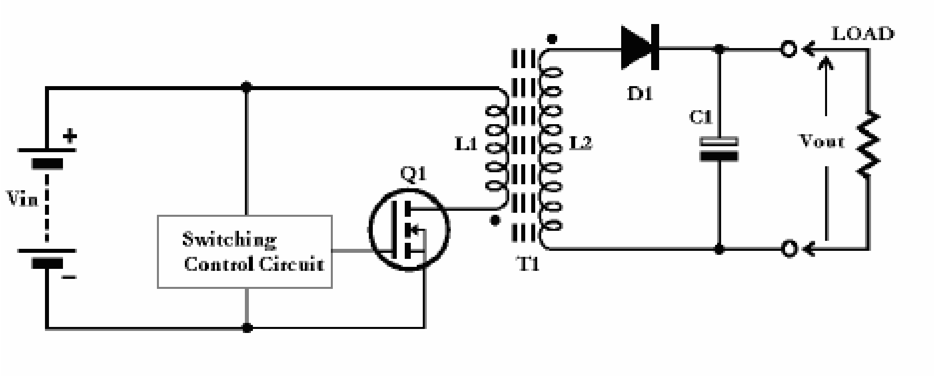

Figure 2.1: Flyback Converter

When MOSFET Q1 is switched on, current flows from the source through primary winding L1 and energy is stored in the transformers magnetic field. Then when Q1 is turned off, the transformer tries to maintain the current flow through L1 by suddenly reversing the voltage across it and generating a Flyback pulse of back-EMF.

In the case of transformer design main attention is to be paid for flyback converter. The ratio between output and input voltage of a flyback converter is not simply a matter of the turns ratio between L2 and L1, because the back-EMF voltage in both windings is determined by the amount of energy stored in the magnetic field, and hence depends on the winding inductance, the length of time that Q1 is turned on, etc. However the ratio between L2 and L1 certainly plays an important role, and most Flyback converters have a fairly high turns ratio to allow a high voltage step-up ratio.

Because of the way the Flyback converter works, the magnetic flux in its transformer core never reverses in polarity. As a result the core needs to be fairly large for a given power level, to avoid magnetic saturation. Because of this Flyback converters tend to be used for relatively low power applications-like generating high voltages for insulation testers, Geiger counter tubes, cathode ray tubes and similar devices drawing relatively low current.

If third small winding is added in the transformer secondary, that can be allowed to sense Flyback pulse amplitude (should be reasonably close to output voltage V_{out}).This voltage can be allowed to fed to MOSFET switching control circuit to allow it to automatically adjust the switching and regulate the output voltage.

Advantages

• The action of the fly-back means that the secondary inductance is in series with the output diode when current is delivered to the load; i.e. driven from a current source. This means that no filter inductor is needed in the output circuit. Hence, each output requires only one diode and output filter capacitor. This means the fly-back is the ideal choice for generating low cost, multiple output supplies.

Disadvantages

• The output capacitor is only supplied during the transistor on time. This means that the capacitor has to smooth a pulsating output current which has higher peak values than the continuous output current that would be produced in a forward converter.

• This, together with the higher peak currents, large capacitors and transformers, limits the fly-back to lower output power applications in the 20 to 200W range.

Applications

• Lowest cost, multiple output supplies in the 20 to 200W range. e.g. main input T.V. supplies, small computer supplies, E.H.T. supplies.

2.3 The Push-Pull Converter

To utilize the transformer flux swing fully, it is necessary to operate the core symmetrically as described earlier. This permits much smaller transformer sizes and provides higher output powers than possible with the single ended types. The symmetrical types always require an even number of transistor switches. One of the best known of the symmetrical types is the push-pull converter shown in Fig.2.2

The primary is a centre-tapped arrangement and each transistor switch is driven alternately, driving the transformer in both directions. The push-pull transformer is

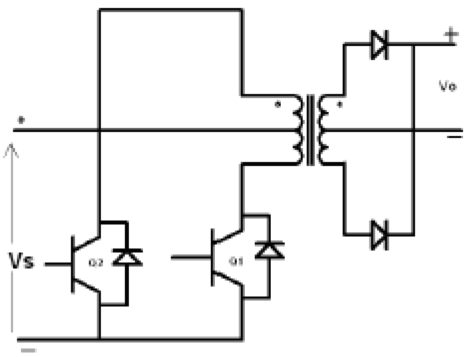

Figure 2.2: The Push-Pull Converter

typically half the size of that for the single ended types, resulting in a more compact design. This push-pull action produces natural core resetting during each half cycle; hence no clamp winding is required. Power is transferred to the buck type output circuit during each transistor conduction period. The duty ratio of each switch is usually less than 0.45. This provides enough dead time to avoid transistor cross conduction.The push-pull configuration is normally used for output powers in the 100 to 500W range. The bipolar switching action also means that the output circuit is actually operated at twice the switching frequency of the power transistors. Therefore, the output inductor and capacitor can be even smaller for similar output ripple levels. Push-pull converters are thus excellent for high power density, low ripple outputs.

Advantages

• As stated, the push-pull offers very compact design of the transformer and output filter, while producing very low output ripple. So if space is a premium issue, the push-pull could be suitable.

• Clamp diodes are fitted across the transistors, as shown. This allows leakage and magnetization energy to be simply channeled back to the supply, reducing stress on the switches and slightly improving effciency.

Disadvantages

• One of the main drawbacks of the push-pull converter is the fact that each transistor

must block twice the input voltage due to the doubling effect of the centre-tapped primary, even though two transistors are used. This occurs when one transistor is off and the other is conducting. When both are off, each then blocks the supply voltage.
• A further major problem with the push-pull is that it is prone to flux symmetry imbalance. If the flux swing in each half cycle is not exactly symmetrical, the volt-sec will not balance and this will result in transformer saturation, particularly for high input voltages. Symmetry imbalance can be caused by different characteristics in the two transistors such as storage time in bipolar and different on-state losses.
• The centre-tap arrangement also means that extra copper is needed for the primary, and very good coupling between the two halves is necessary to minimize possible leakage spikes.

Applications

• Compact design, very low output ripple supplies in the 100 to 500W range. More suited to low input applications. e.g. Telecommunication supplies.

2.4 The Half Bridge Conterter

Of all the symmetrical high power converters, the half-bridge converter shown in Fig.2.3 It is also referred to as the single ended push-pull, and in principle is a balanced version of the forward converter. The Half-Bridge has some key advantages over the push-pull, which usually makes it first choice for higher power applications in the 500 to 1000W range. The two mains bulk capacitors C1 and C2 are connected in series and an artificial input voltage mid-point is provided, shown as point A in the diagram. The two transistor switches are driven alternately, and this connects each capacitor across the single primary winding each half cycle.$V_{in}/2$ is superimposed symmetrically across the primary in a push-pull.

Advantages

• Since both transistors are effectively in series, they never see greater than the supply voltage, V_{in}. When both are off, their voltages reach an equillibrium point of $V_{in}/2$.

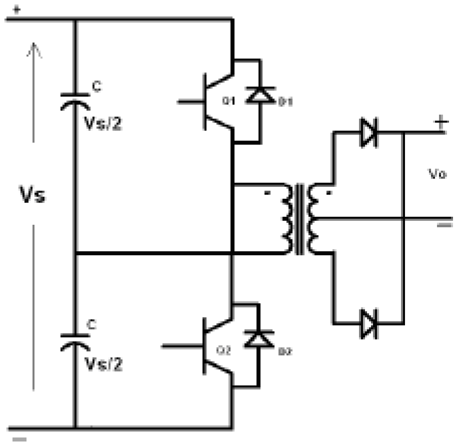

Figure 2.3: The Half Bridgel Converter

This is half the voltage rating of the push-pull (although double the current). This means that the half-bridge is particularly suited to high voltage inputs, such as off-line applications.

• Another major advantage over the push-pull is that the transformer saturation problems due to flux symmetry imbalance are not a problem. By using a small capacitor (less than 10mF) any dc build-up of flux in the transformer is blocked, and only symmetrical ac is drawn from the input.

• The leakage inductance and magnetization energies are dumped straight back into the two input capacitors, protecting the transistors from dangerous transients and improving overall effciency.

• The bridge circuits also have the same advantages over the single-ended types that the push-pull possesses, including excellent transformer utilization, very low output ripple, and high output power capabilities.

Disadvantages

• The need for two 50/60 Hz input capacitors is a drawback because of their large size. The top transistor must also have isolated drive, since the gate/base is at a floating potential.

• The circuit cost and complexity have clearly increased, and this must be weighted up against the advantages gained. In many cases, this normally excludes the use of the half bridge at output lower levels below 500W.

Applications

• High power up to 1000W. High current, very low output ripple. Well suited for high input voltage applications. e.g. large computer supplies, Lab equipment Supplies.

2.5 The Full-Bridge Converter

The Full-Bridge converter shown in Fig.2.4 is a higher power version of the Half Bridge, and provides the highest output power level of any of the converters discussed.The maximum current ratings of the power transistors will eventually determine the upper limit of the output power of the half-bridge. These levels can be doubled by using the Full-Bridge, which is obtained by adding another two transistors and clamp diodes to the Half-Bridge arrangement. The transistors are driven alternately in pairs, Q1 and Q2, then Q3 and Q4. The transformer primary is now subjected to the full input voltage. The current levels flowing are halved compared to the half-bridge for a given power level. Hence, the Full-Bridge will double the output power than the Half-Bridge using the same transistor types.

Advantages

• As stated, the Full-Bridge is ideal for the generation of very high output power levels. The increased circuit complexity normally means that the Full-Bridge is reserved for applications with power output levels of 1000W and above.

• The Full-Bridge also has the advantage of only requiring one main smoothing capacitor compared to two for the Half-Bridge, hence, saving space.

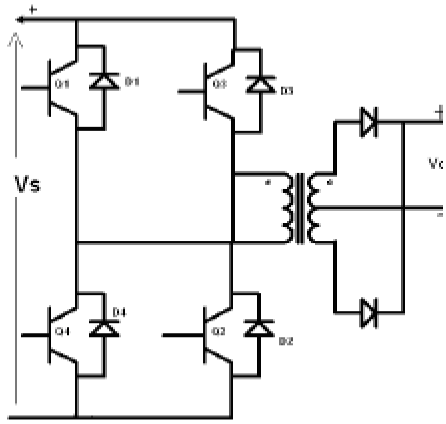

Figure 2.4: The Full Bridge Converter

• Its other major advantages are the same as for the Half-Bridge.

Disadvantages

• Four transistors and clamp diodes are needed instead of two for the other symmetrical types.

• Isolated drive for two floating potential transistors is now required.

• The Full-Bridge has the most complex and costly design of any of the converters discussed, and should only be used where other types do not meet the requirements.

Applications

• Very high power, normally above 1000W. Very high current, very low ripple outputs. Well suited for high input voltage applications. e.g. Computer Mainframe supplies, large lab equipment supplies.

2.6 Double Ended Forward Converter

The double ended forward converter topology is the member of Push Pull Class. The push pull converter provides isolated output feature, which was not there in Buck, Boost converters. Means its output returns are DC-isolated from input returns. But it has the leakage inductance effect in its transformer windings, so due to it the leakage inductance spike is present extra in the measure of break down voltage calculation. That is the criterion of selecting the switching Device. So the rating require be higher and higher and the same way the cost of the Switching device too. And that topology was using the transistor it had the problem of flux imbalance and due to which transistor was failing.

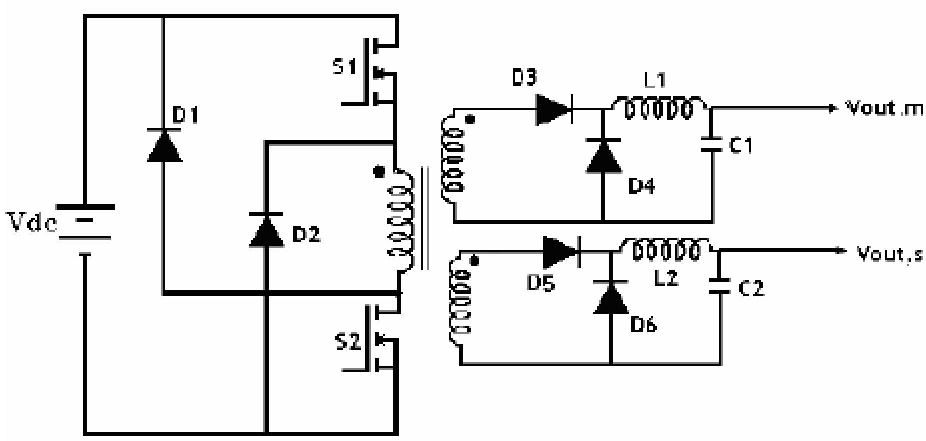

Figure 2.5: Double ended Forward Converter

These two problems are overcome in new topology, Double Ended Forward Converter. The very basic diagram is as shown in Figure 2.5 Although it has two switching devices rather than one compared with the forward converter, it has very significant advantage. In the off stage, both the switches are subjected to only DC input voltage rather than twice that as in the single ended forward converter. Further, at turnoff, there is no leakage inductance spike. Although there are two switches with break down voltage rating 1000V which can take that stress, it is a far more reliable design to use the double ended forward converter with half the off voltage stress. Reliability is of overriding importance in the power supply design.

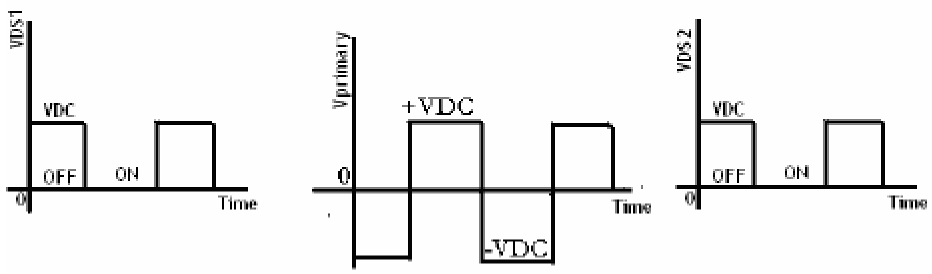

Figure 2.6: Double ended Forward Converter

The first two figure of fig 2.6 are the waveform across the Switch, and the voltage waveform across the primary of transformer. From these waveforms it is very clear that with this topology OFF State voltage across the switch is just the same as the DC supply source voltage. So this can lead to the economic choice of the Switching Device. So for our purpose all requirements are met here. So Topology can be followed.

2.6.1 Operation

Double Ended Forward Converter works as follows. The Switches S1 and S2 are series with the top and bottom of the transformer primary. Both of these MOSFETs are turned on simultaneously and turned off simultaneously. When they are on, primary and secondary dots are positive and power is delivered to the loads. When they turn off, current stored in the magnetizing inductance reverses the polarity of all windings. The dot end of primary winding tries to go far negative but is caught at ground by the Diode D2. The no dot end of primary tries to go far positive but caught at Vdc by Diode D1. The drain of S1 can never be more than Vdc below its source, and the source of the S2 can never be more than Vdc above its drain. Leakage voltage spikes are clamped so that the maximum voltage stress on either Switch can never be more than the Maximum DC input voltage.

2.7 Forward Converter

The forward converter topology is shown in FIG 2.7 It is the most widely used topology in its range of 150-200W power output with maximum DC input voltage ranges 60-200V. The forward topology is the member of Push-pull family. In Push-pull there are two transistors, here it is having only one and hence the problem of flux imbalance is shorted out.

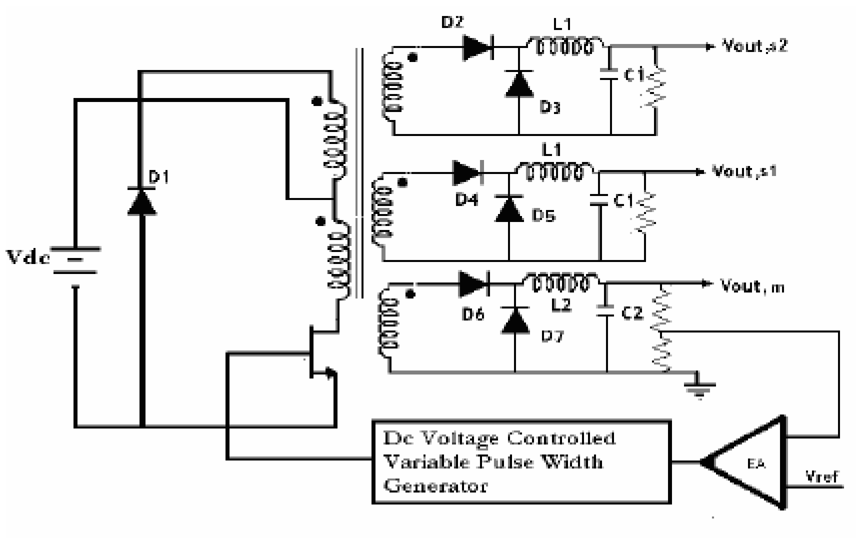

Figure 2.7: Forward Converter

Here with forward converter we can have multiple output-via transformers. One Master followed by two slaves. The output of master is fed back to switching control circuit in order to obtain constant regulated output at master and slave secondary. Master output is used to regulate the switching of Electronic-switching device and slave outputs are dependent upon the switching of the device.

The power flows to the loads when the power transistor Q is turned on. Thus converter is termed as Forward Converter.

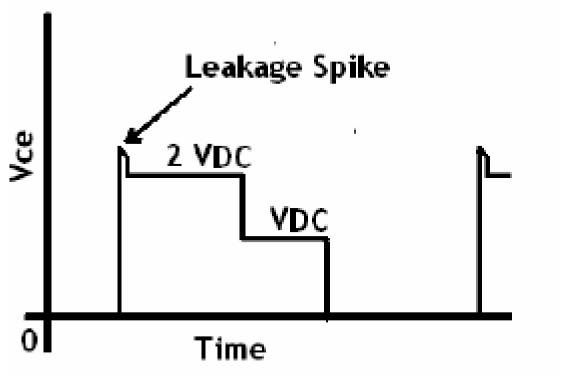

Figure 2.8: Waveform acros Transister V_{ce}

For the purpose of High Voltage input, if we use this topology, magnetic point of view it has no problem. Here short coming of flux imbalance is no present. But the FIG 2.8 shows there will be more than 2 times DC voltage will come across the Power Transistor Q, when it would be OFF.

Advantages

• Since the transformer in this topology transfers energy directly there is negligible stored energy in the core compared to the fly-back. However, there is a small magnetization energy required to excite the core, allowing it to become an energy transfer medium. This energy is very small and only a very small primary magnetization current is needed. This means that a high primary inductance is usually suitable, with no need for the core air gap required in the fly-back.

• Negligible energy storage means that the forward converter transformer is considerably smaller than the fly-back, and core loss is also much smaller for the same through-out power. However, the transformer is still operated asymmetrically, which means that power is only transferred during the switch on-time,and this poor utilization means the transformer is still far bigger than in the symmetrical types.

• This, coupled with the smaller transformer and output filter capacitor requirements means that the forward converter is suitable for use at higher output powers than the fly-back can attain, and is normally designed to operate in the 100 to 400W range.

Disadvantages

• Because of the unipolar switching action of the forward converter, there is a major problem in how to remove the core magnetization energy by the end of each switching cycle. If this did not happen, there would be a net dc flux build-up, leading to core saturation, and possible transistor destruction. This magnetization energy is removed automatically by the push-pull action of the symmetrical types. In the fly-back this energy is dumped into the load at transistor turn-off. However, there is no such path in the forward circuit. This path is provided by adding an additional reset winding of opposite polarity to the primary. A clamp diode is added, such that the magnetization energy is returned to the input supply during the transistor off time. The reset winding is wound bifilar with the primary to ensure good coupling, and is normally made to have the same number of turns as the primary. (The reset winding wire gauge can be very small, since it only has to conduct the small magnetization current.) The time for the magnetization energy to fall to zero is thus the same duration as the transistor on-time. This means that the maximum theoretical duty ratio of the forward converter is 0.5 and after taking into account switching delays, this falls to 0.45. This limited control range is one of the drawbacks of using the forward converter.

Application

• Low cost, low output ripple, multiple output supplies in the 50 to 400W range. e.g Small computer supplies, DC/DC converters.

In this project, SMPS has been made by forward topology with the rating of 0-100V DC Output Voltage and maximum 1A current. By using forward topology, SMPS can become compact and cost-effective.

Chapter 3

Overview of Circuit Diagram

3.1 Diagram of SMPS

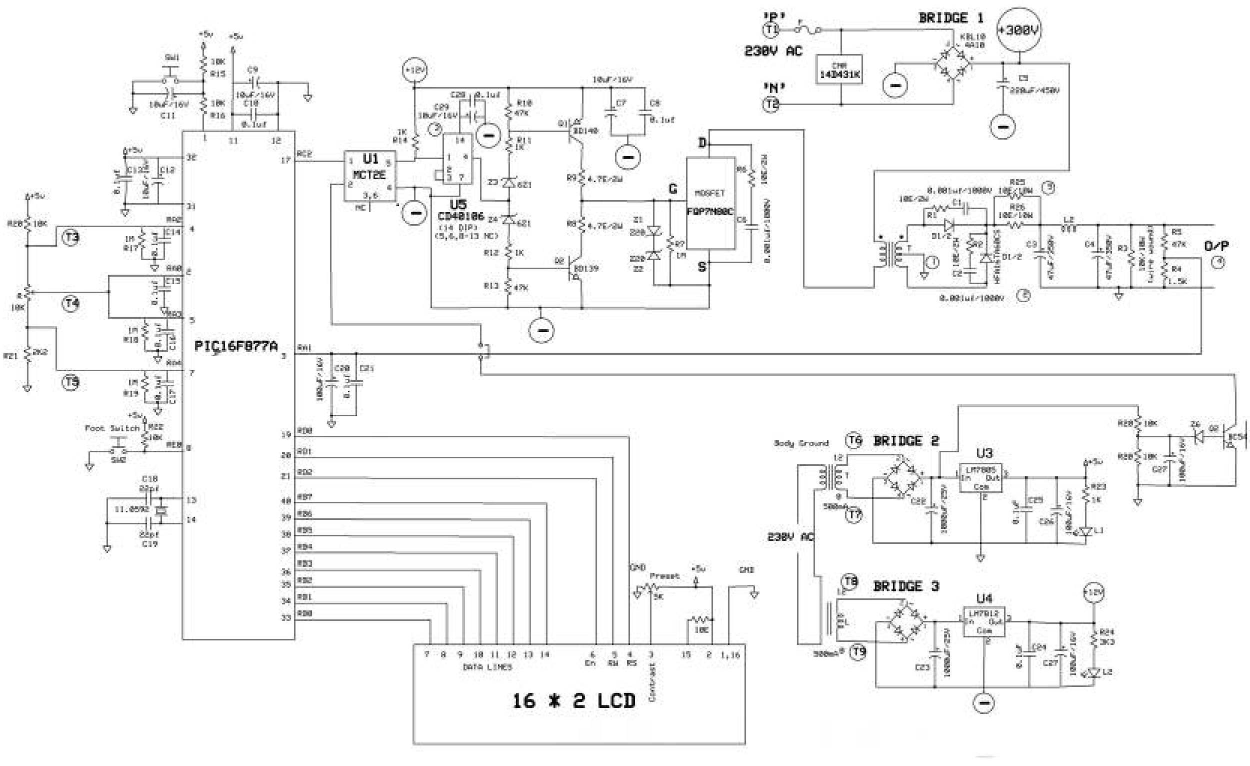

Figure 3.1: Schematic of SMPS

3.2 General Discription about circuit diagram

In this circuit diagram Switch Mode Power Supply has been designed for 0-100V Dc output voltage that can be used in many applications as per desired manner.

As shown in diagram two linear power Supply has been used.One of 5V power supply is used for supply of PIC controller and othe of 12V supply is used for driving circuit for MOSFET.

In PIC controller, PWM mode is utilized to set the duty cycle in close loop circuit.and such a way MOSFET can be triggerd by adjusting PWM mode.Similarly ADC, LCD display and foot swich configuration have been used in SMPS. 17th pin of PIC is for PWM mode that is applied to the optocoupler IC and the close loop of the PIC power supply is also given to the second pin of the optocoupler IC. So the driving circuit can only operated if PIC controller will be in an operation.Then output of the optocoupler is given to Schimitt trigger IC so that singnal can become strong. Rest of the driving circuit has designed in such a way that MOSFET will turn on when upper transistor will turn on.and MOSFET will turn off when lower transistor will turn on.

Main supply is of 230V AC which is fed to bridge and it converts into DC. Then DC voltage is applied to primary of transformer and AC secondary voltage is again rectified into DC as shown in figure.Voltage Divider has provided at the output to set the duty cycle in a close loop system. Foot switch has provided at PIC IC for the safty purpose.Without pushing foot switch whole system can not be operated.If any damage will creat in the system then first fuse will get off which is nearer to main supply as shown in figure 3.1.

3.3 Flow chart of PIC Programming

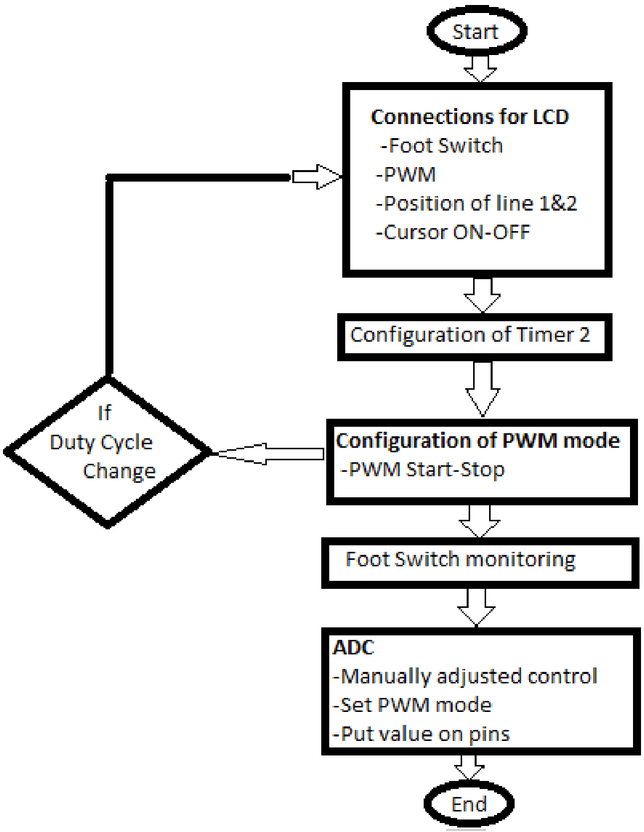

Figure 3.2: Flow Chart for PIC Programming

3.4 Voltage Divider and Potentiometer

Voltage dividers and potentiometers are passive circuit components that provide a simple way to convert a DC voltage level to another, lower, DC voltage level. Figure shows the electrical circuit of a voltage divider on the left, and a potentiometer on the right. A voltage divider consists of two resistors in series with a voltage tap between

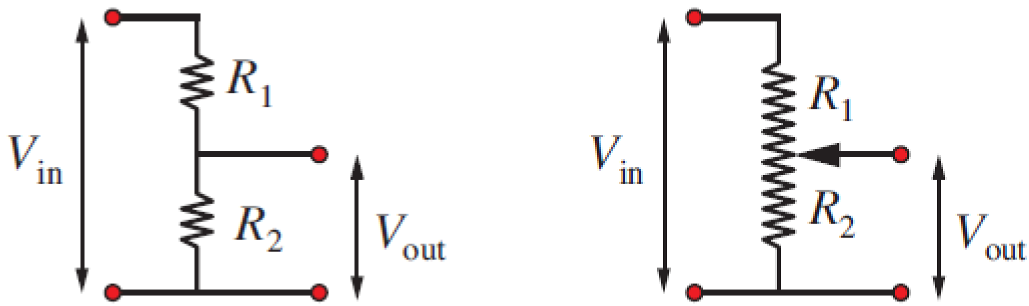

Figure 3.3: Voltage Multiplier and Potentiometer

the two resistors. In the left side of Figure the input voltage, V_{in}, is applied across R_1 and R_2. The output voltage, V_{out}, is the voltage drop across R_2. Vout is less than Vin because the total voltage across R_1 and R_2 must add up to V_{in}. A potentiometer is a voltage divider that allows adjustment of V_{out}. Typical potentiometers have sliders or rotary knobs that move a contact called a wiper along the surface of a resistor. As depicted in the right side of Figure the wiper divides a single, fixed resistor into R_1 and R_2. By sliding the wiper along the fixed resistor, the value of R_2 is changed, which allows the output voltage to be adjusted from 0 to V_{in}. Voltage dividers and potentiometers are passive in the sense that they transform V_{in} to V_{out} without a separate source of power. Any power consumed during the transformation comes from the source of the input voltage. In contrast, an active component requires an external source of power to operate. Because voltage dividers and potentiometers are passive, these devices can only decrease the voltage, i.e., V_{out} is always less than Vin.

Chapter 4

Flowchart of Transformer Design

4.1 Rating of designed center tap Transformer

(a) Turns of Primary windings=360T & Secondary winding=120T

(b) Gauge of Primary winding=33G & Secondary winding=24G

4.2 Steps for designing the Transformer

Step 1:

Calculate the apparent power Pt

Step 2:

Calculate the area product.

Step 3:

Select the E-core from the table with a value close to the calculated one.

Step 4:

Calculate the core losses in mw/g from the graph of flux density, frequency and core losses for the ferrite core.

Step 5:

Calculate the primary and secondary turns.

Step 6:

Find the wire gauge and calculate the resistance of the windings.

Step 7:

Calculate the copper losses and the total losses.

Step 8:

Check whether the turns fit into the effective window area.

4.3 Flowchart of Transformer

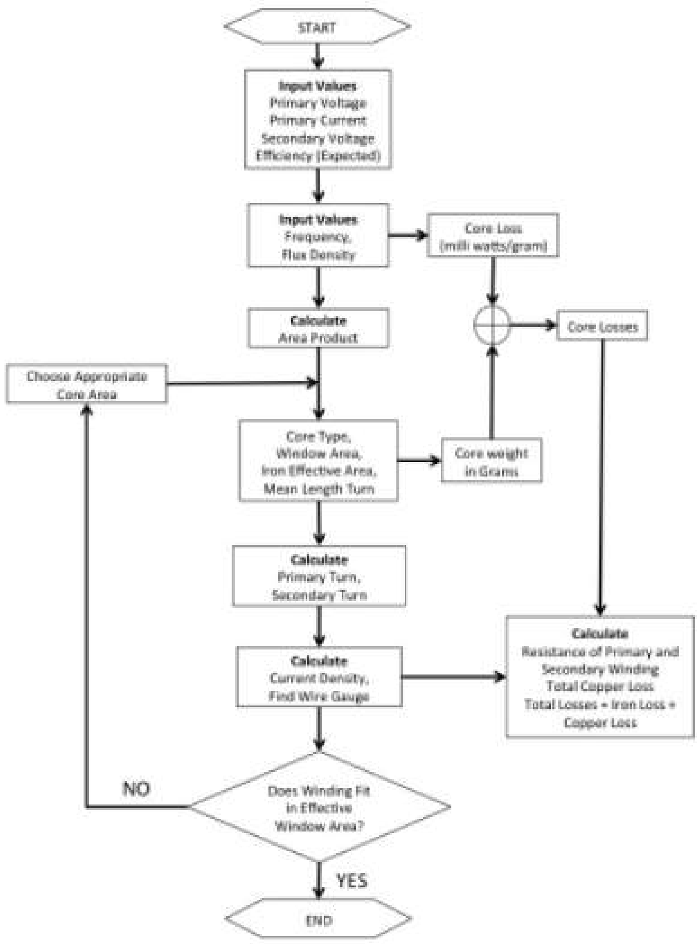

Figure 4.1: Flowchart of Transformer

Chapter 5

Hardware results & Images

5.1 Hardware results

5.1.1 Output Voltage waveforms

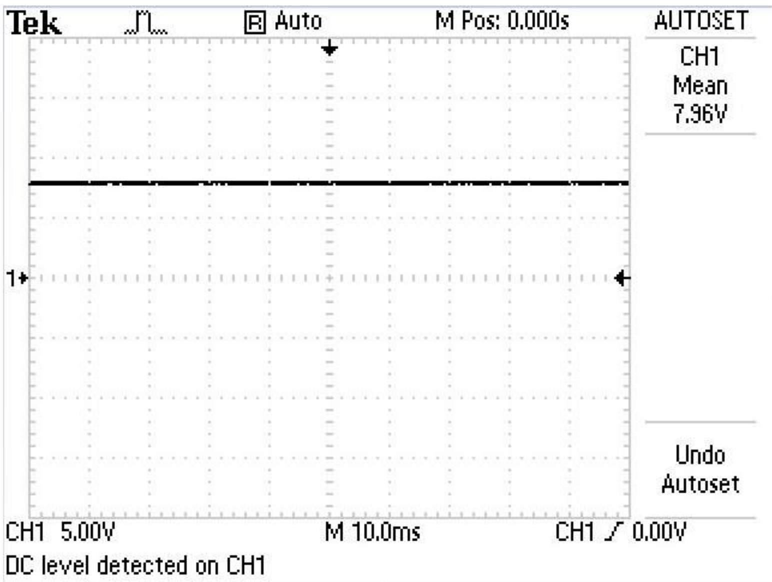

Figure 5.1: Input Voltage=8V & Output Voltage=7.9V DC at 40W load

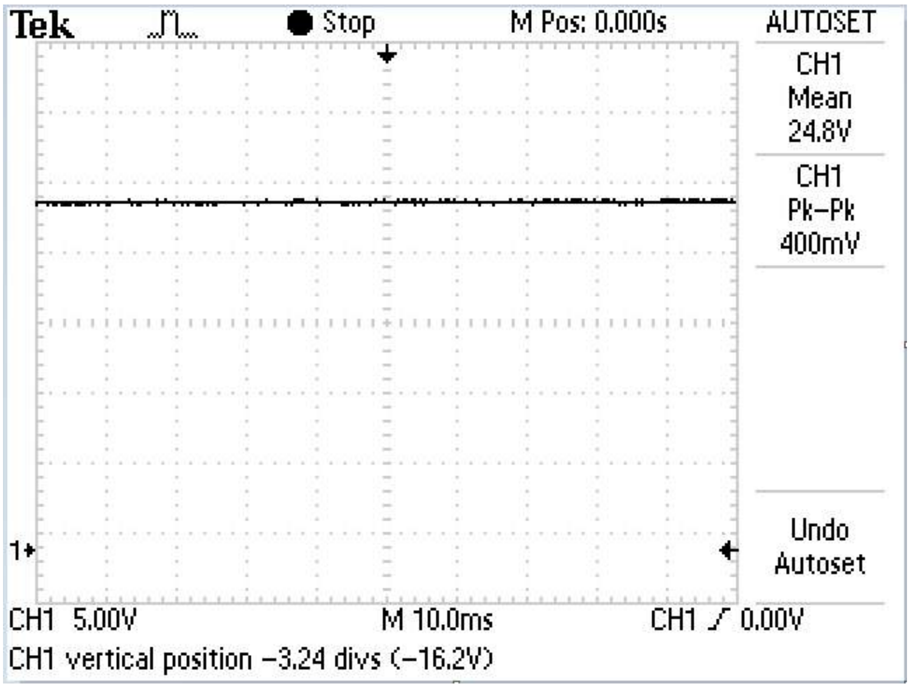

Figure 5.2: Input Voltage=24V & Output Voltage=24.8V DC at 60W load

5.1.2 Tested Hardware results

As shown in Table I, Input voltages have been selected in between 0-100V DC range at different load situation. so that we get output voltage with less that 5% regulation. In no load condition output voltage regulation is more which is shown in results of table.Also Figure 23 shows that by adjusting 8V Input voltage from 0-100V variable on variac, we get 7.9V DC output voltage.This defines that the regulation in closeloop situation is quite less as compared to openloop.Also in figure 24, by adjusting 24V as input voltage we get 24.8V DC output voltage at 60W load. In figure 25, fluctuation is showing in no load condition. and Figure 26 shows the switching voltage waveform of MOSFET at 18V DC output voltage in ON-OFF state. Also Table I defines that regulation is very much less after 25V in variable load condition.So that the efficiency remains maintain at higher voltage in this system.But in no load condition, regulation has not bee maintain either in variable load or no load condition.

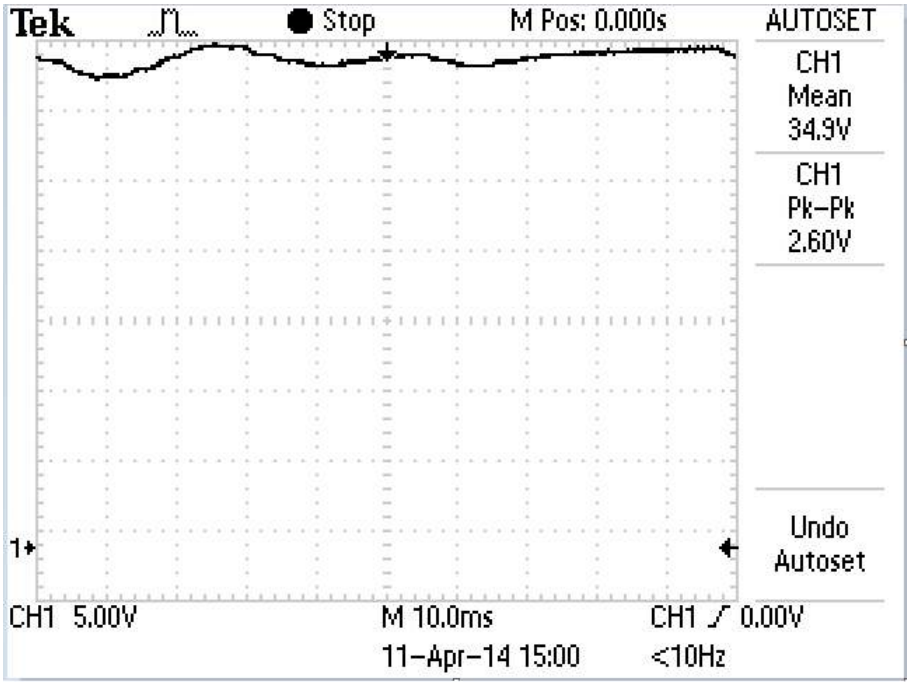

Figure 5.3: Input Voltage=35V & Output Voltage=34.9V DC No load

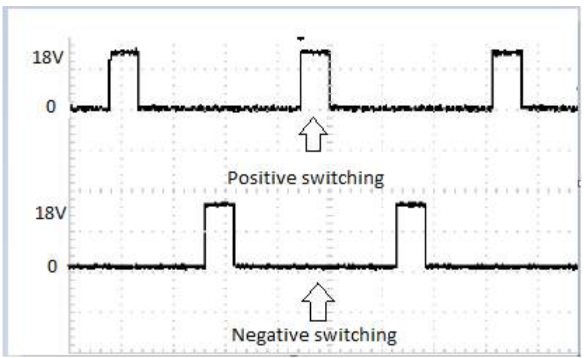

Figure 5.4: Switching Waveforms at 18V DC

Table I: Hardware Results

Input Voltage(0-100V DC)	**Output Voltage**	**Load**
8V	7.9V	40W
15V	15.1V	40W
20V	20.7V	40W
25V	24.8V	60W
28V	28V	60W
34V	34.9V	60W
56V	56.2V	60W
70V	70V	60W
92V	92V	100W
66V	66V	100W
20V	19.1V	No Load
56V	57.1V	No Load

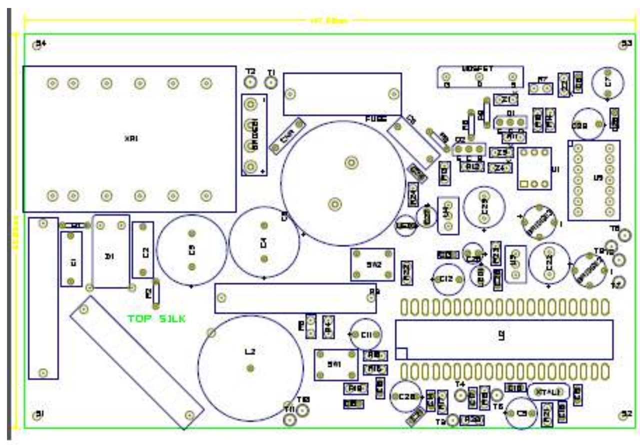

Figure 5.5: Layout of Top side

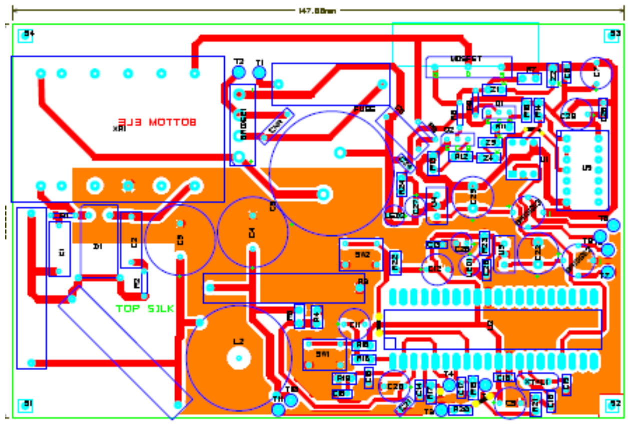

Figure 5.6: Layot of Bottom side

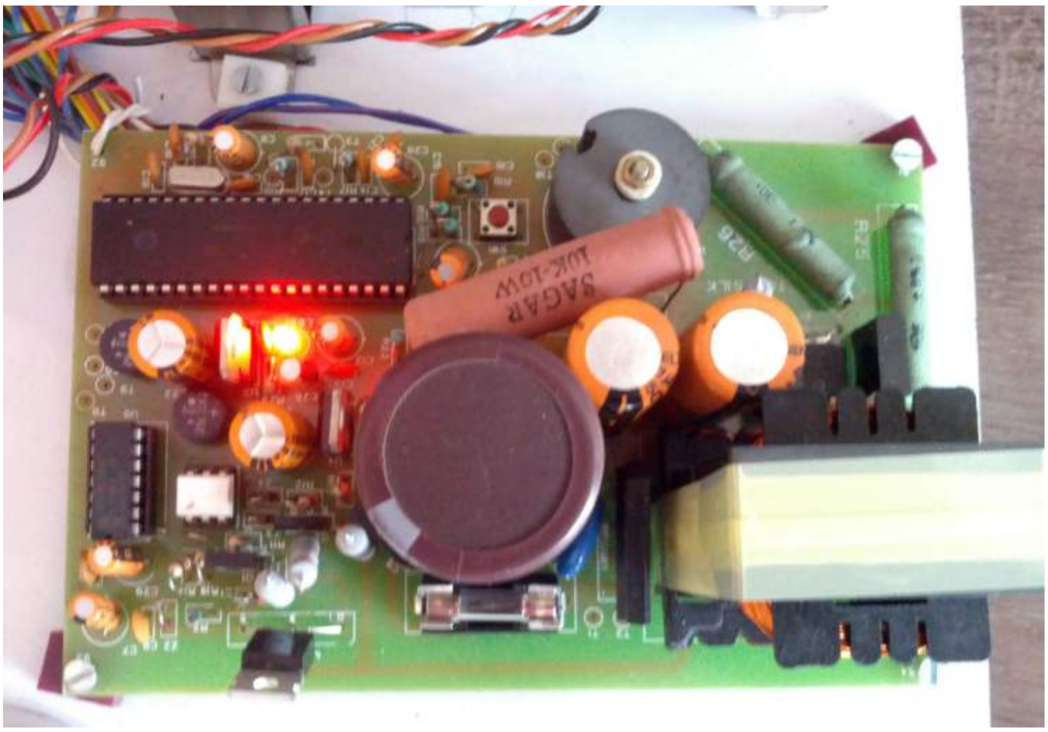

Figure 5.7: Hardware setup

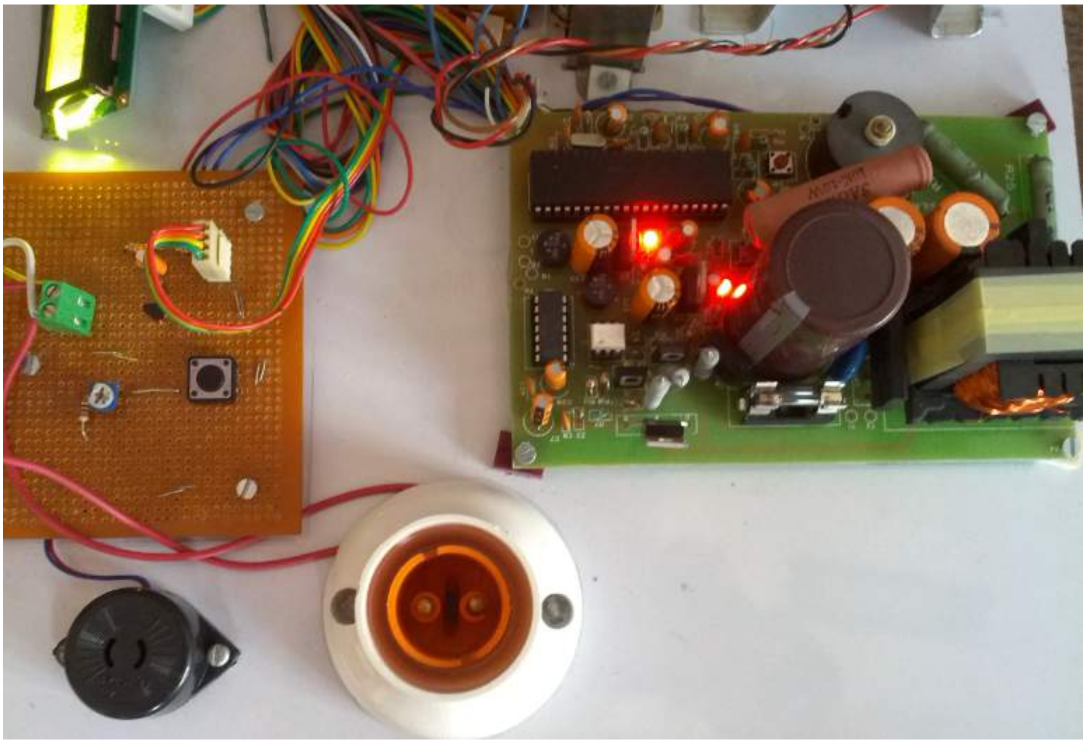

Figure 5.8: Hardware setup

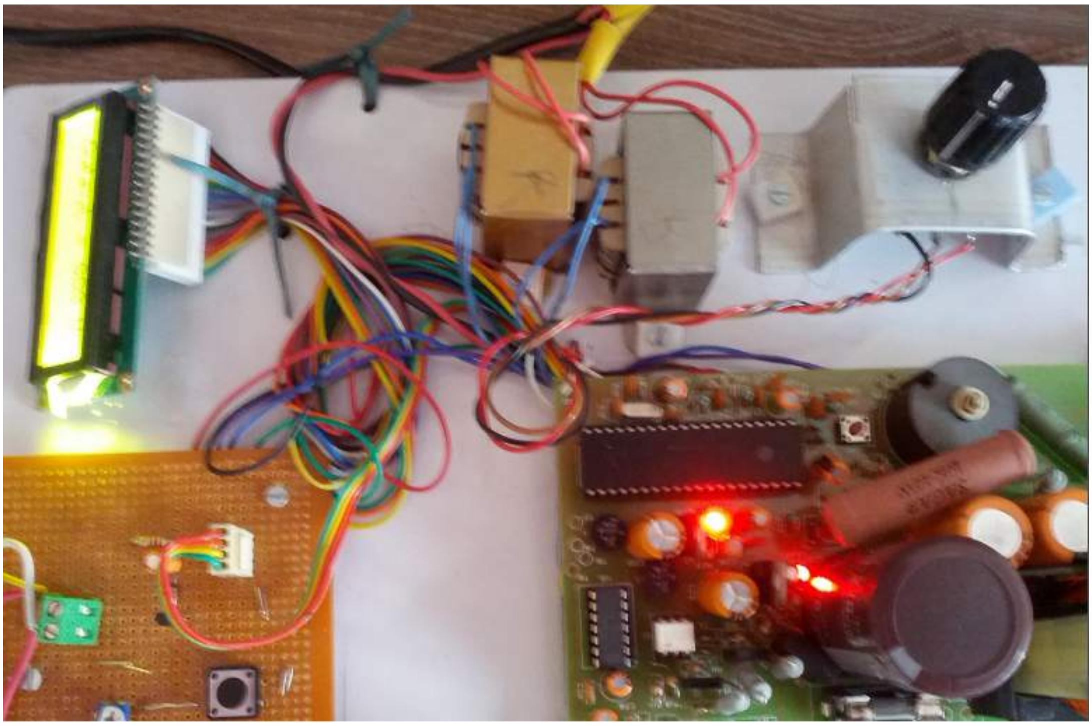

Figure 5.9: Hardware setup

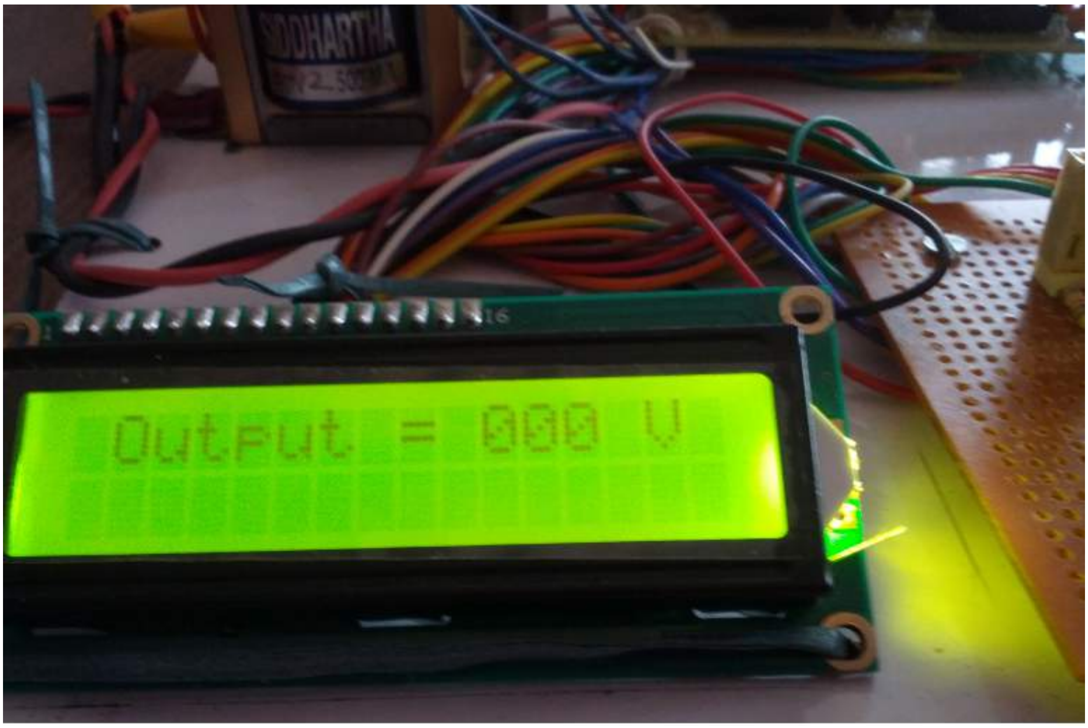

Figure 5.10: Hardware setup

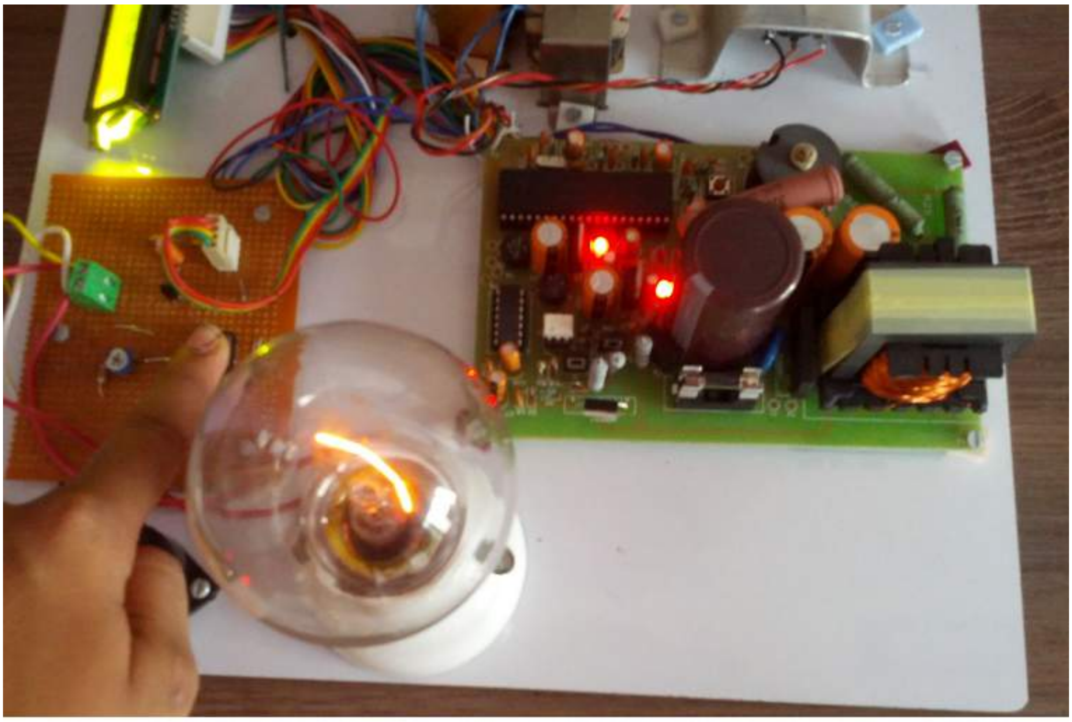

Figure 5.11: Hardware setup

Chapter 6

Conclusion & Future Scope

6.1 Conclusion

In proposed work, Forward Topolgy with fix PWM Technique has been implemented and verify with various load condition.It has been observed that at output side the voltage ripple is maintain less than 5% during all transient and steady state load condition.It has been concluded that proposed SMPS is cost-effective solution with reliable output voltage regulation and efficiency from no-load to full load.

6.2 Future Scope

In the said proposed work the future implement can be done with Switch Power Supply in a high power range in both closeloop and openloop system.Also this project can be extended by changing the control scheme to get better efficiency. Also Uniniterruptible Power Supply feature can be added with this system so that it can be used in many sensitive application like medical equipments where requirement of power is necessary in any wrost condition.

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Appendix A

Datasheet

A.1 ICs used in SMPS

A.1.1 Optocoupler IC MCT2E

Apllication

• General Purpose Switching Circuits

• Interfacing and coupling systems of different potentials and impedances

• I/O Interfacing

• Solid State Relays

• Monitor and Detection Circuits

Maximum Ratings

Table I: Input LED maximum rating

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	3	Volt
Forward Current-Continous	I_F	60	mA
LED Power dissipation at T_A=25 C	P_D	120	mW

Table II: Output Transistor maximum ratings

collector-Emiter Voltage	V_{CEO}	30	volt
Emiter-Collector Voltage	V_{ECO}	7	voit
Collector-Base Voltage	V_{CBO}	70	volt
Collector Current-continous	I_C	150	mA
Detector power Dissipation at T_A=25 C	P_D	150	mA

Table III: Total Device

Isolation Surge Voltage	V_{ISO}	7500	volt
Total Device Power Dissipation at T_A=25 C	P_D	250	mW
Ambient operating Temperature range at T_A=25 C	T_A	-55 to 100	C
Storage Temperature range	T_{stg}	-55 to 150	C

A.1.2 LCD 2×16

Product Overview

Innovatis LCD 2×16 A Module provides versatile display functions. Through its simple connections, it can be controlled by Innovatis BASIC Commander for a wide range of LCD applications. In this module, two display lines, each with 16 characters on each line can be displayed. By using the cursor control command, the position of the character to be displayed on the screen can be arbitrarily changed. In this module, the backlight function can be used to change the backlight to allow the message to be read easily. In addition, it can be configured to display user defined characters to display any specially required characters. Please use LCD2×16 as the module

Applications

•Together with an RTC Module, it can be used to display a real time clock or a simple electronic clock.

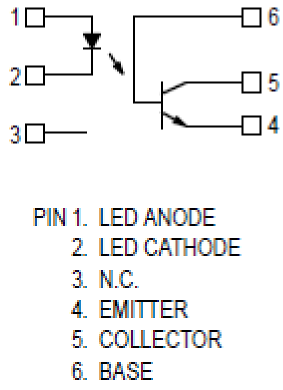

Figure A.1: Schematic

- It can be used to display the operating status at any time for various applications.
- It can display status or error messages directly on the screen without using the PC.
- With the user-defined characters, special patterns can be created to produce creative messages.

Product Features

•It can be used to display corresponding characters in ASCII code.

• The module will automatically convert and display the data according to its data type.

• 255 steps backlight control.

• For continuous inputs, the module will carriage return automatically

• Cursor position assignment and Tab function with configurable Tab steps and HOME function.

• Destructive backspace, clear to end of line or end of screen from the cursor position.

• Set the user defined characters to display various creative characters.

• Display off command to reduce power consumption.

A.1.3 PIC16F877A

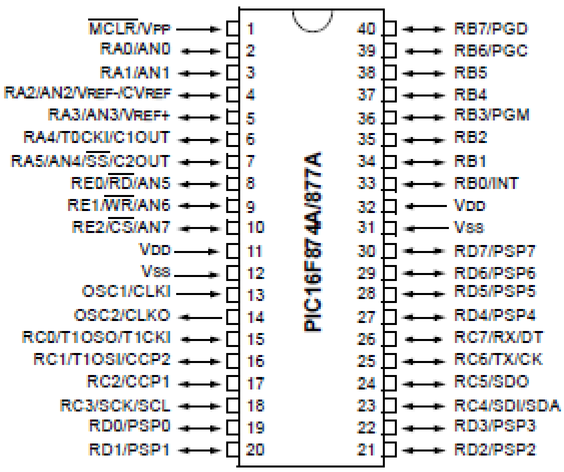

Figure A.2: Pin diagram of PIC16F877A

Peripheral Features

• Timer0: 8-bit timer/counter with 8-bit prescaler

• Timer1: 16-bit timer/counter with prescaler, can be incremented during Sleep via external

• crystal/clock

• Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler

• Two Capture, Compare, PWM modules - Capture is 16-bit, max. resolution is 12.5 ns - Compare is 16-bit, max. resolution is 200 ns - PWM max. resolution is 10-bit

• Synchronous Serial Port (SSP) with SPI^{TM} (Master mode) and I2C (Master/Slave)

• Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection

• Parallel Slave Port (PSP) 8 bits wide with external RD, WR and CS controls (40/44-pin only)

• Brown-out detection circuitry for Brown-out Reset (BOR)

Analog Features

•10-bit, up to 8-channel Analog-to-Digital Converter (A/D)

• Brown-out Reset (BOR)

• Analog Comparator module with: - Two analog comparators - Programmable on-chip voltage reference (V_{REF}) module - Programmable input multiplexing from device inputs and internal voltage reference - Comparator outputs are externally accessible

Special Microcontroller Feateures

• 100,000 erase/write cycle Enhanced Flash program memory typical

•1,000,000 erase/write cycle Data EEPROM memory typical

• Data EEPROM Retention greater than 40 years

• Self-reprogrammable under software control

• In-Circuit Serial$Programming^{TM}$ ($ICSP^{TM}$) via two pins

• Single-supply 5V In-Circuit Serial Programming

• Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation

- Programmable code protection
- Power saving Sleep mode
- Selectable oscillator options
- In-Circuit Debug (ICD) via two pins

CMOS Technology

- Low-power, high-speed Flash/EEPROM technology
- Fully static design
- Wide operating voltage range (2.0V to 5.5V)
- Commercial and Industrial temperature ranges
- Low-power consumption

A.1.4 MOSFET FQP7N80C

General Description These N-Channel enhancement mode power field effect transistors are produced using Fairchilds proprietary, planar stripe, DMOS technology. This advanced technology has been especially tailored to minimize on-state resistance, provide superior switching performance, and withstand high energy pulse in the avalanche and commutation mode. These devices are well suited for high efficiency switch mode power supplies.

Features

•6.6A, 800V, RDS(on) = 1.9 @VGS = 10 V

- Low gate charge (typical 27 nC)
- Low Crss (typical 10 pF)
- Fast switching
- 100
- Improved dv/dt capability

Abolute Maximum Ratings

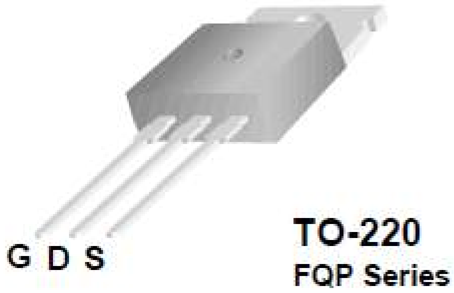

Figure A.3: MOSFET IC

Table IV: Table of ratings

Symbol	Parameter	FQP7N80C	Units
V_{DSS}	Drain-Source Voltage	6.6	V
I_D	Drain Current T_C=25	6.6	A
I_D	Drain Current T_C=100	4.2	A
I_{DM}	Pulsed Drain Current	26.4	A
V_{GSS}	Gate-Sourse Voltage	$\pm$30	V
E_{AS}	Single Pulse Avalanch Energy	580	mJ
I_{AR}	Avalanch Current	6.6	A
E_{AR}	Repetitive Avalanch Energy	16.7	mJ
dV/dt	Peak Diode Recovery	4.5	V/nS
P_D	Power Dissipation at T_C=25	167	W
T_J,T_{STG}	Storage Temperature	-55to150	C
T_L	Lead Temperature	300	C