SWITCHED MODE POWER SUPPLY

Dissertation submitted in partial fulfillment of the requirements for the Degree of

BACHELOR OF TECHNOLOGY

Under the Supervision of

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ABSTRACT

Considering the multiple DC voltage levels required by many electronic devices, designers need a way to convert standard power-source potentials into the voltages dictated by the load. Voltage conversion must be a versatile, efficient, reliable process. Switch-mode power supplies (SMPSs) are frequently used to provide the various levels of DC output power needed for modern applications, and are indispensable in achieving highly efficient, reliable DC-DC power-conversion systems.

In case of SMPS with input supply drawn from the ac mains, the input voltage is first rectified and filtered using a capacitor at the rectifier output. The unregulated dc voltage across the capacitor is then fed to a high frequency dc-to-dc converter. Most of the dc-to-dc converters used in SMPS circuits have an intermediate high frequency ac conversion stage to facilitate the use of a high frequency transformer for voltage scaling and isolation. In contrast, in linear power supplies with input voltage drawn from ac mains, the mains voltage is first stepped down (and isolated) to the desired magnitude using a mains frequency transformer, followed by rectification and filtering. The high frequency transformer used in a SMPS circuit is much smaller in size and weight compared to the low frequency transformer of the linear power supply circuit. The 'Switched Mode Power Supply' owes its name to the dc-to-dc switching converter for conversion from unregulated dc input voltage to regulated dc output voltage. The switch employed is turned 'ON' and 'OFF' (referred as switching) at a high frequency.

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DECLARATION

We hereby declare that the work reported in the B-Tech thesis entitled **"SWITCHED MODE POWER SUPPLY"** submitted at **Jaypee University of Information Technology, Waknaghat, India,** is an authentic record of our work carried out under the supervision of **Prof (Dr.) T.S. Lamba**. We have not submitted this work elsewhere for any other degree or diploma.

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CERTIFICATE

This is to certify that the work reported in the B-Tech. thesis entitled **"SWITCHED MODE POWER SUPPLY",** submitted by **Ashutosh Kahol (121018), Shagun Singla (121082) at Jaypee University of Information Technology, Waknaghat, India**, is a bonafide record of their original work carried out under my supervision. This work has not beensubmitted elsewhere for any other degree or diploma.

(Signature of Supervisor)

Prof (Dr.) T.S. Lamba

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26th May,2016.

LIST OF FIGURES

CHAPTER - 1

INTRODUCTION

Power supply is a broad term but this report is restricted to discussion of circuits that generate a fixed or controllable magnitude dc voltage from the available form of input voltage. A power supply is an electronic device that supplies electric energy to an electrical load. The primary function of a power supply is to convert one form of electrical energy to another and, as a result, power supplies are sometimes referred to as electric power converters.

Every power supply must obtain the energy it supplies to its load, as well as any energy it consumes while performing that task, from an energy source. Depending on its design, a power supply may obtain energy from various types of energy sources, including electrical energy transmission systems, energy storage devices such as a batteries and fuel cells, electromechanical systems such as generators and alternators, solar power converters.

1.1 Functions of a power supply

A typical power supply serves the following main functions:

(a) Changing the form of electric power. eg. electricity from the grid is transmitted in the form of AC, while electronic circuits need low-level DC.

(b) Regulation: The nominal mains voltage varies worldwide from 100 to 240VAC and is usually poorly regulated, while the circuits normally require well stabilized fixed voltages.

(c) Safety isolation: In most applications the outputs have to be isolated from the input.

1.2 Functional classification of power supplies

Power supplies are categorized in various ways, including by functional features:

(a) A regulated power supply is one that maintains constant output voltage or current despite variations in load current or input voltage.

(b) The output of an unregulated power supply can change significantly when its input voltage or load current changes.

(c) Adjustable power supplies allow the output voltage or current to be programmed by mechanical controls (e.g., knobs on the power supply front panel), or by means of a control input.

(d) An isolated power supply has a power output that is electrically independent of its power input; this is in contrast to other power supplies that share a common connection between power input and output.

1.3 Classification based on method of power conversion

Power supplies can be broadly divided into linear and switching types.

(a) Linear power converters process the input power directly, with all active power conversion components operating in their linear operating regions.

(b) In switching power converters, the input power is converted to AC or to DC pulses before processing, by components that operate predominantly in non-linear modes (e.g., transistors that spend most of their time in cutoff or saturation). Power is "lost" (converted to heat) when components operate in their linear regions and, consequently, switching converters are usually more efficient than linear converters because their components spend less time in linear operating regions.

1.4 Linear regulated power supply

This kind of unregulated dc voltage is most often derived from the utility ac source. The utility ac voltage is first stepped down using a utility frequency transformer, then it is rectified using diode rectifier and filtered by placing a capacitor across the rectifier output. The voltage across the capacitor is still fairly unregulated and is load dependent. The ripple in the capacitor voltage is not only dependent on the capacitance magnitude but also depends on load and supply voltage variations. The unregulated capacitor voltage becomes the input to the linear type power supply circuit. The filter capacitor size is chosen to optimize the overall cost and volume. However, unless the capacitor is sufficiently large the capacitor voltage may have unacceptably large ripple.

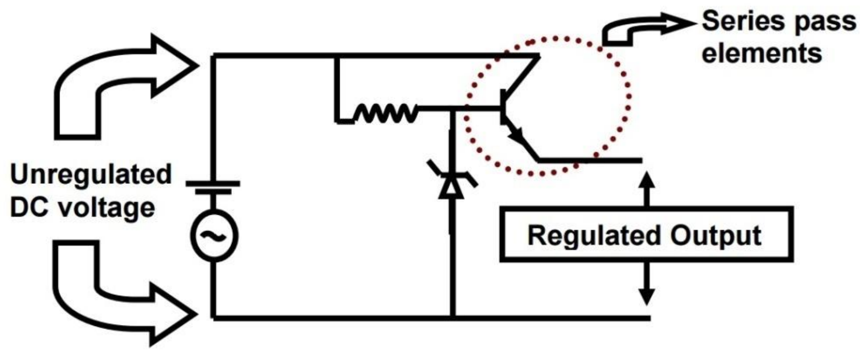

Figure 1.1: Block diagram of linearly regulated power supply

For proper operation of the voltage regulator, the instantaneous value of unregulated input voltage must always be few volts more than the desired regulated voltage at the output. Thus the ripple across the capacitor voltage (difference between the maximum and minimum instantaneous magnitudes) must not be large or else the minimum voltage level may fall below the required level for output voltage regulation. The magnitude of voltage-ripple across the input capacitor increases with increase in load connected at the output.

The step down transformer talked above should be chosen such that the peak value of rectified voltage is always larger than the sum of bare minimum voltage required at the input of the regulator and the worst-case ripple in the capacitor voltage. Thus the transformer turns ratio is chosen on the basis of minimum specified supply voltage magnitude. The end user of the power supply will like to have a regulated output voltage (with voltage ripple within some specified range) while the load and supply voltage fluctuations remain within the allowable limit. To achieve this the unregulated dc voltage is fed to a voltage regulator circuit. The circuit shows a linear regulator circuit where a transistor is placed in between the unregulated dc voltage and the desired regulated dc output. Difference between the instantaneous input voltage and the regulated output voltage is blocked across the collector - emitter terminals of the transistor. As discussed previously, in such circuits the lowest instantaneous magnitude of the unregulated dc voltage must be slightly greater than the desired output voltage (to allow some voltage for transistor biasing circuit). The power dissipation in the transistor and the useful output power will be in the ratio of voltage drops across the transistor and the load (here the control power dissipated in the base drive circuit of the transistor is assumed to be relatively small and is neglected). The worst-case series voltage drop across the transistor may be quite large if the allowed variation in supply magnitude is large. Worst-case power dissipation in the transistor will correspond to maximum supply voltage and maximum load condition (load voltage is assumed to be well regulated). Efficiency of linear voltage regulator circuits will be quite low when supply voltage is on the higher side of the nominal voltage.

1.5 Switched mode power supply

SMPS stands for switched mode PSU. In such a device, power handling electronic components are continuously switching "on" and "off" with high frequency in order to provide the transfer of electric energy via energy storage components (inductors and capacitors).

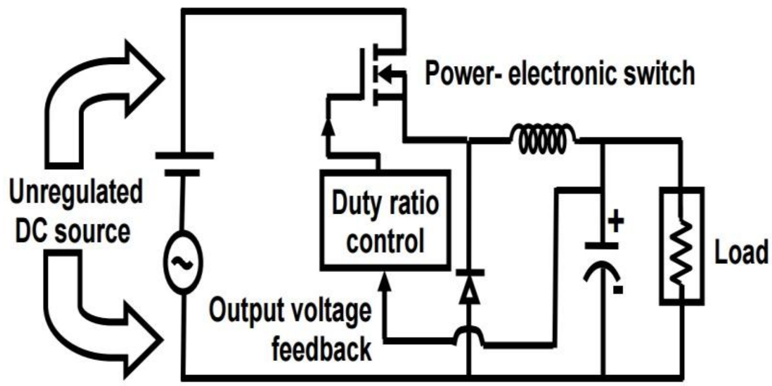

Figure 1.2: Block diagram of switched mode power supply

Switch-mode power supplies are a popular and sometimes necessary choice for DC-DC power conversion. These circuits offer distinct benefits and tradeoffs when compared to alternative methods of converting DC power.

1.6 SMPS versus linear power supply

As discussed above, in a linear regulator circuit the excess voltage from the unregulated dc input supply drops across a series element (and hence there is power loss in proportion to this voltage drop) whereas in switched mode circuit the unregulated portion of the voltage is removed by modulating the switch duty ratio.

The switching losses in modern switches (like: MOSFETs) are much less compared to the loss in the linear element. In most of the switched mode power supplies it is possible to insert a high frequency transformer to isolate the output and to scale the output voltage magnitude. In linear power supply the isolation and voltage-scaling transformer can be put only across the low frequency utility supply. The low frequency transformer is very heavy and bulky in comparison to the high frequency transformer of similar VA rating. T

The output voltage filtering circuit, in case of low frequency ripples is much bulkier than if the ripple is of high frequency. The switched mode circuit produces ripple of high frequency that can be filtered easily using smaller volume of filtering elements.

Linear power supply though bulkier and less efficient has some advantages too when compared with the switched mode power supply.

Generally, the control of the linear power supply circuit is much simpler than that of SMPS circuit. Since there is no high frequency switching, the switching related electro-magnetic interference (EMI) is practically absent in linear power supplies but is of some concern in SMPS circuits.

Also, as far as output voltage regulation is concerned the linear power supplies are superior to SMPS. One can more easily meet tighter specifications on output voltage ripples by using linear power supplies.

1.7 Specification

The suitability of a particular power supply for an application is determined by various attributes of the power supply, which are typically listed in the power supply's specification. Commonly specified attributes for a power supply include:

(i) Input voltage type (AC or DC) and range.

(ii) Efficiency of power conversion.

(iii) The amount of voltage and current it can supply to its load.

(iv) How stable its output voltage or current is under varying line and load conditions.

(v) How long it can supply energy without refueling or recharging (applies to power supplies that employ portable energy sources).

(vi) Operating and storage temperature ranges.

CHAPTER - 2

WORKING OF SMPS CIRCUITS

Like a linear power supply, the switched mode power supply too converts the available unregulated ac or dc input voltage to a regulated dc output voltage.

2.1 SMPS working

The basic concept behind a switch mode power supply or SMPS is the fact that the regulation is undertaken by using a switching regulator. This uses a series switching element that turns the current supply to a smoothing capacitor on an off.

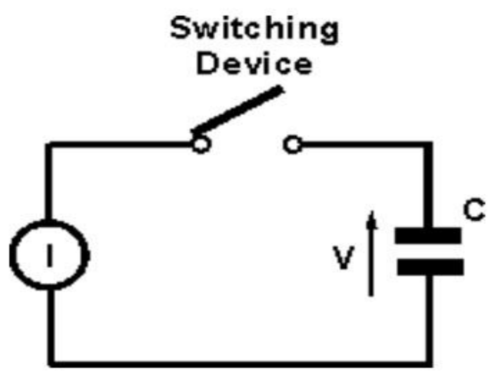

Figure 2.1: SMPS

The time the series element is turned on is controlled by the voltage on the capacitor. If it is higher than required, the series switching element is turned off, if it is lower than required, it is turned on. In this way the voltage on the smoothing or reservoir capacitor is maintained at the required level.

In a SMPS, the output current flow depends on the input power signal, the storage elements and circuit topologies used, and also on the pattern used to drive the switching elements. The spectral density of these switching waveforms has energy concentrated atrelatively high frequencies. As such, switching transients and ripple introduced onto the output waveforms can be filtered with a small LC filter.

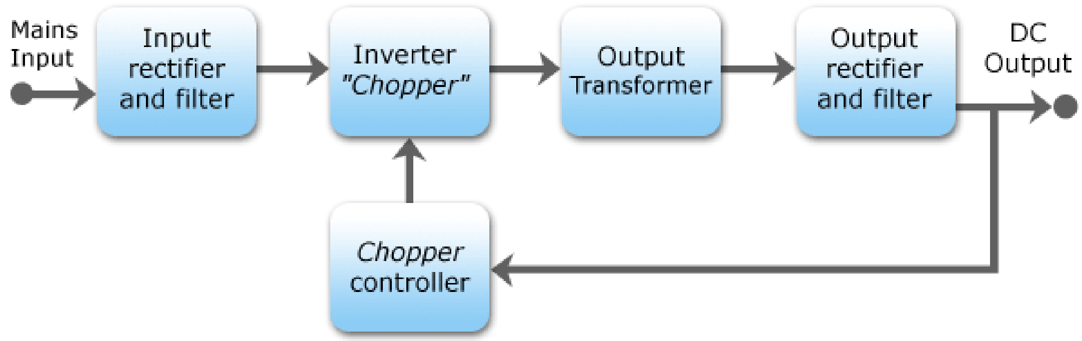

Figure 2.2: Block diagram of SMPScircuit.

(a) Input rectifier stage: If the SMPS has an AC input, then the first stage is to convert the input to DC. This is called rectification. This feature permits operation from power sources that are normally at 115 V or at 230 V. The rectifier produces an unregulated DC voltage which is then sent to a large filter capacitor.

(b) Inverter stage: The inverter stage converts DC from the rectifier stage described above, to AC by running it through a power oscillator, whose output transformer is very small with few windings at a frequency of tens or hundreds of kilohertz. The frequency is usually chosen to be above 20 kHz, to make it inaudible to humans. The switching is implemented as a multistage MOSFET amplifier. MOSFETs are a type of transistor with a low on-resistance and a high current-handling capacity.

(c) Voltage converter and output rectifier: If the output is required to be isolated from the input, as is usually the case in mains power supplies, the inverted AC is used to drive the primary winding of a high-frequency transformer. This converts the voltage up or down to the required output level on its secondary winding. The output transformer in the block diagram serves this purpose.

If a DC output is required, the AC output from the transformer is rectified. The rectified output is then smoothed by a filter consisting of inductors and capacitors.

Simpler, non-isolated power supplies contain an inductor instead of a transformer. This type includes boost converters, buck converters, and the buck-boost converters. These belong to the simplest class of single input, single output converters which use one inductor and one active switch. The buck converter reduces the input voltage. The output voltage of a boost converter is always greater than the input voltage and the buck-boost output voltage is inverted but can be greater than, equal to, or less than the magnitude of its input voltage.

(d) Regulation: A feedback circuit monitors the output voltage and compares it with a reference voltage.

(e) Transformer design: Any switched-mode power supply that gets its power from an AC power line requires a transformer. The terminal voltage of a transformer is proportional to the product of the core area, magnetic flux, and frequency. By using a much higher frequency, the core area can be greatly reduced. However, core losses increase at higher frequencies.

(f) Power factor: Switched mode power supplies incorporate a simple full-wave rectifier connected to a large energy storing capacitor. Such SMPSs draw current from the AC line in short pulses when the mains instantaneous voltage exceeds the voltage across this capacitor. During the remaining portion of the AC cycle the capacitor provides energy to the power supply.
As a result, the input current of such basic switched mode power supplies has high harmonic content and relatively low power factor. This creates extra load on utility lines, increases heating of building wiring, the utility transformers, and standard AC electric motors, and may cause stability problems in some applications such as in emergency generator systems or aircraft generators. Harmonics can be removed by filtering, but the filters are expensive. Unlike displacement power factor created by linear inductive or capacitive loads, this distortion cannot be corrected by addition of a single linear component. Additional circuits are required to counteract the effect of the brief current pulses. Putting a current regulated boost chopper stage after the off-line rectifier can correct the power factor, but increases the complexity and cost.

A switched-mode power supply (switching-mode power supply, switch-mode power supply, switched power supply, SMPS, or switcher) is an electronic power supply that incorporates a switching regulator to convert electrical power efficiently. Like other power supplies, an SMPS transfers power from a source, like mains power, to a load, such as a personal computer, while converting voltage and current characteristics. Unlike a linear power supply, the pass transistor of a switching-mode supply continually switches between low-dissipation, full-on and full-off states, and spends very little time in the high dissipation transitions, which minimizes wasted energy. Ideally, a switched-mode power supply dissipates no power. Voltage regulation is achieved by varying the ratio of on-to-off time. In contrast, a linear power supply regulates the output voltage by continually dissipating power in the pass transistor. This higher power conversion efficiency is an important advantage of a switched-mode power supply. Switched-mode power supplies may also be substantially smaller and lighter than a linear supply due to the smaller transformer size and weight.

Switching regulators are used as replacements for linear regulators when higher efficiency, smaller size or lighter weight are required. They are, however, more complicated; their switching currents can cause electrical noise problems if not carefully suppressed, and simple designs may have a poor power factor.

2.2 Types of Switched Mode Power Supply

Switched-mode power supplies can be classified according to the circuit topology. The most important distinction is between isolated converters and non-isolated ones.

2.2.1 Non-Isolated topology

(a) Buck: A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

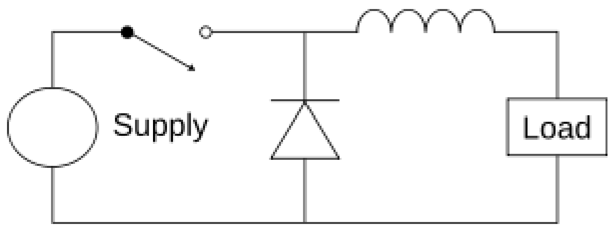

Figure 2.3: Buck converter circuit diagram

Theory of operation: The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a transistor and a diode). In the idealized converter, all the components are considered to be perfect.

Specifically, the switch and the diode have zero voltage drop when on and zero current flow when off and the inductor has zero series resistance. Further, it is assumed that the input and output voltages do not change over the course of a cycle (this would imply the output capacitance as being infinite).

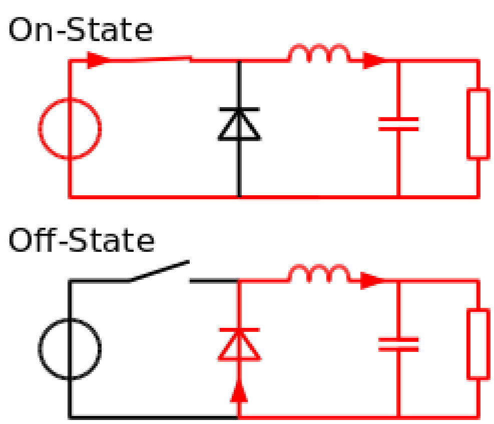

Figure 2.4: The two circuit configurations of a buck converter

(b) Boost: A boost converter (step-up converter) is a DC-to-DC power converter steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination.

To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

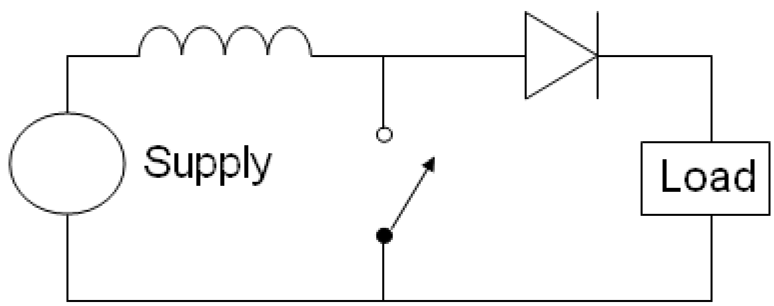

Figure 2.5: Boost converter circuit diagram

Theory of operation: The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage.

When the switch is closed, electrons flow through the inductor in counter-clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

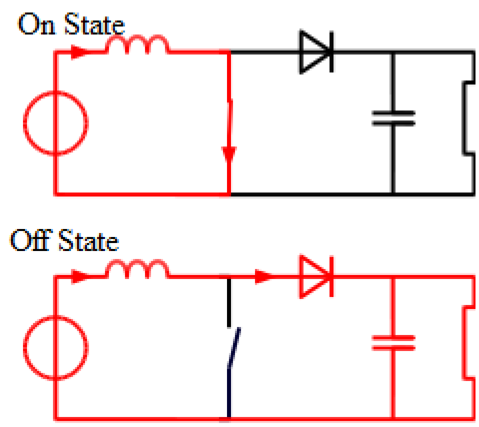

Figure 2.6: The two circuit configurations of a boost converter

(c) Buck-Boost: The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer.

The inverting topology

The output voltage is of the opposite polarity than the input. This is a SMPS supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. Another drawback is of any consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. The switch can be on either the ground side or the supply side.

A buck converter combined with a boost converter The output voltage is typically of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor and the boost inductor, sometimes called a "four-switch buck-boost converter", it may use multiple inductors but only a single switch as in the SEPIC and Cuk topologies.

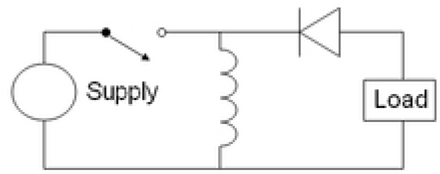

Figure 2.7: Buck-boost converter circuit diagram

Theory of operation: The basic principle of the buck–boost converter is fairly simple.

While in the On-state, the input voltage source is directly connected to the inductor (L). This results in accumulating energy in L. In this stage, the capacitor supplies energy to the output load.

While in the Off-state, the inductor is connected to the output load and capacitor, so energy is transferred from L to C and R.

Like the buck and boost converters, the operation of the buck-boost is best understood in terms of the inductor's "reluctance" to allow rapid change in current. From the initial state in which nothing is charged and the switch is open, the current through the inductor is zero. When the switch is first closed, the blocking diode prevents current from flowing into the right hand side of the circuit, so it must all flow through the inductor. However, since the inductor doesn't like rapid current change, it will initially keep the current low by dropping most of the voltage provided by the source. Over time, the inductor will allow the current to slowly increase by decreasing its voltage drop. Also during this time, the inductor will store energy in the form of a magnetic field.

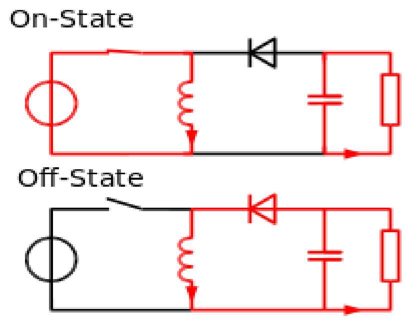

Figure 2.8: The two circuit configuration of buck-boost converter

(d) Split-pi:A split-pi topology is a pattern of component interconnections used in a kind of power converter that can theoretically produce an arbitrary output voltage, either higher or lower than the input voltage. In practice the upper voltage output is limited to the voltage rating of components used. It is essentially a boost (step-up) converter followed by a buck (step-down) converter. The topology and use of MOSFETs make it inherently bi-directional which lends itself to applications requiring regenerative braking.

The split-pi converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is a switched-mode power supply with a similar circuit topology to a boost converter followed by a buck converter. Split-pi gets its name from the pi circuit due to the use of two pi filters in series and split with the switching MOSFET bridges.

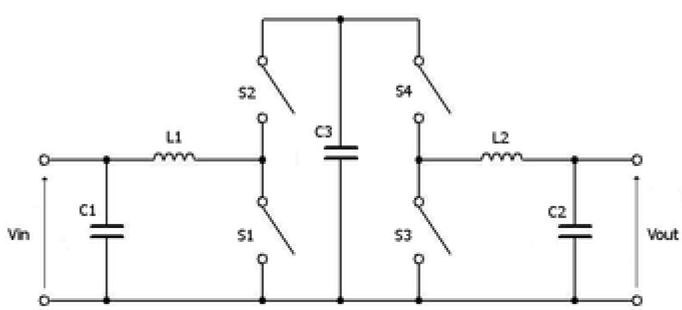

Figure 2.9: Schematic of split-pi converter

Theory of operation: In typical operation where a source voltage is located at the left-hand side input terminals, the left-hand bridge operates as a boost converter and the right-hand bridge operates as a buck converter. In regenerative mode, the reverse is true with the left-hand bridge operating as a buck converter and the right as the boost converter.

Only one bridge switches at any time to provide voltage conversion, with the unswitched bridge's top switch always switched on. A straight through 1:1 voltage output is achieved with the top switch of each bridge switch on and the bottom switches off. The output voltage is adjustable based on the duty cycle of the switching MOSFET bridge.

(e) Cuk: The Ćuk converter (pronounced *Chook*; sometimes incorrectly spelled Cuk, Čuk or Cúk) is a type of DC/DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is essentially a boost converter followed by a buck converter with a capacitor to couple the energy.

The non-isolated Ćuk converter can only have opposite polarity between input and output. It uses a capacitor as its main energy-storage component, unlike most other types of converters which use an inductor. It is named after Slobodan Ćuk of the California Institute of Technology, who first presented the design.

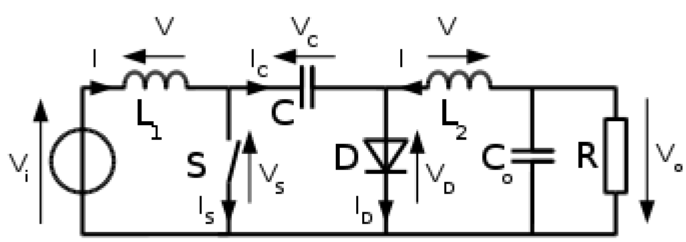

Figure 2.10: Circuit diagram of cuk converter

Theory of operation:A non-isolated Ćuk converter comprises two inductors, two capacitors, a switch (usually a transistor), and a diode. Its schematic can be seen in figure 2.10. It is an inverting converter, so the output voltage is negative with respect to the input voltage.

The capacitor C is used to transfer energy and is connected alternately to the input and to the output of the converter via the commutation of the transistor and the diode.

The two inductors L_1 and L_2 are used to convert respectively the input voltage source (V_i) and the output voltage source (C_o) into current sources. At a short time scale an inductor can be considered as a current source as it maintains a constant current. This conversion is necessary because if the capacitor were connected directly to the voltage source, the current would be limited only by the parasitic resistance, resulting in high energy loss. Charging a capacitor with a current source (the inductor) prevents resistive current limiting and its associated energy loss.

As with other converters (buck converter, boost converter, buck-boost converter) the Ćuk converter can either operate in continuous or discontinuous current mode. However, unlike theseconverters, it can alsooperate in discontinuous voltage mode (the voltage across the capacitor drops to zero during the commutation cycle).

(f) Single ended primary-inductor converter (SEPIC): The single-ended primary-inductor converter (SEPIC) is a type of DC/DC converter allowing the electrical potential (voltage) at its output to be greater than, less than, or equal to that at its input. The output of the SEPIC is controlled by the duty cycle of the control transistor.

A SEPIC is essentially a boost converter followed by a buck-boost converter, therefore it is similar to a traditional buck-boost converter, but has advantages of having non-inverted output (the output has the same voltage polarity as the input), using a series capacitor to couple energy from the input to the output (and thus can respond more gracefully to a short-circuit output), and being capable of true shutdown: when the switch is turned off, its output drops to 0 V, following a fairly hefty transient dump of charge.

SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output. For example, a single lithium ion battery typically discharges from 4.2 volts to 3 volts; if other components require 3.3 volts, then the SEPIC would be effective.

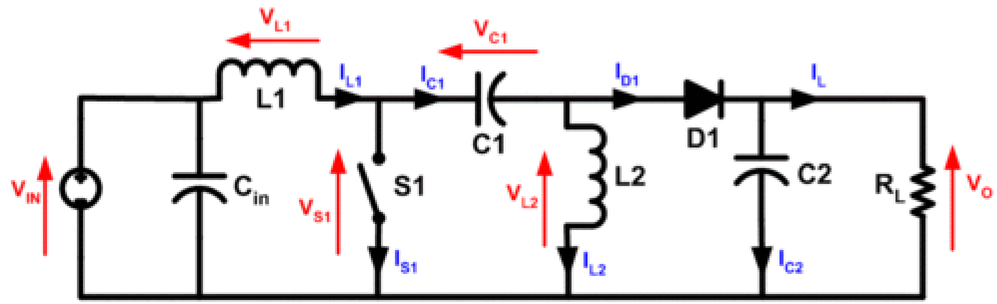

Figure 2.11: Schematic of SEPIC

2.2.2 Isolated Topology

(a) Flyback: The flyback converter is used in both AC/DC and DC/DC conversion with galvanic isolation between the input and any outputs. The flyback converter is a buck-boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation. When driving for example a plasma lamp or a voltage multiplier the rectifying diode of the boost converter is left out and the device is called a flyback transformer.

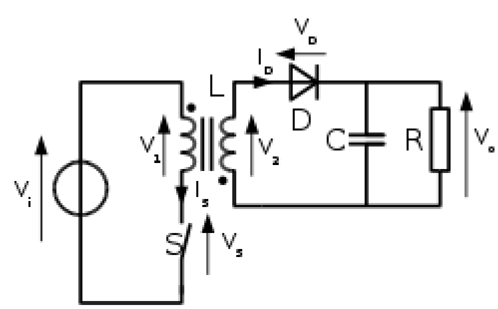

Figure 2.12: Schematic of flyback converter

Theory of operation: The flyback converter is an isolated power converter. The two prevailing control schemes are voltage mode control and current mode control (in the majority of cases current mode control needs to be dominant for stability during operation). Both require a signal related to the output voltage. There are three common ways to generate this voltage. The first is to use an optocoupler on the secondary circuitry to send a signal to the controller. The second is to wind a separate winding on the coil and rely on the cross regulation of the design. The third consists on sampling the voltage amplitude on the primary side, during the discharge, referenced to the standing primary DC voltage.

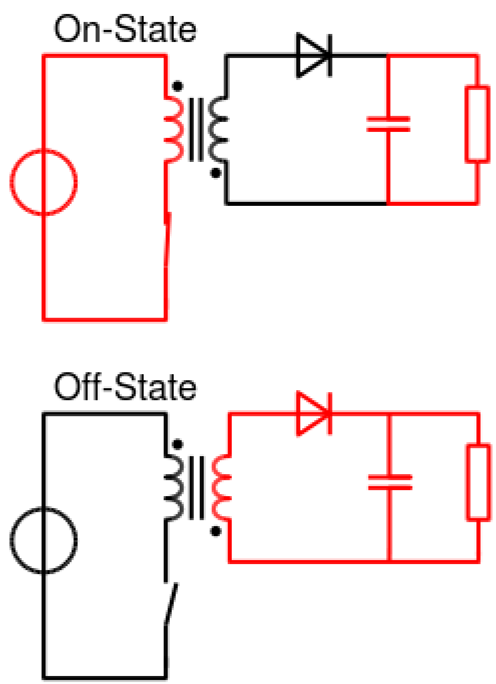

Figure 2.13: The two configurations of flyback converter

(b) Forward: The forward converter is a DC/DC converter that uses a transformer to increase or decrease the output voltage (depending on the transformer ratio) and provide galvanic isolation forthe load. With multiple output windings, it is possible to provide both higher and lower voltage outputs simultaneously.

While it looks superficially like a flyback converter, it operates in a fundamentally different way, and is generally more energy efficient. A flyback converter stores energy in the magnetic field in the inductor air gap during the time the converter switching element (transistor) is conducting. When the switch turns off, the stored magnetic field collapses and the energy is transferred to the output of the flyback converter as electric current. The flyback converter can be viewed as two inductors sharing a common core with opposite polarity windings.

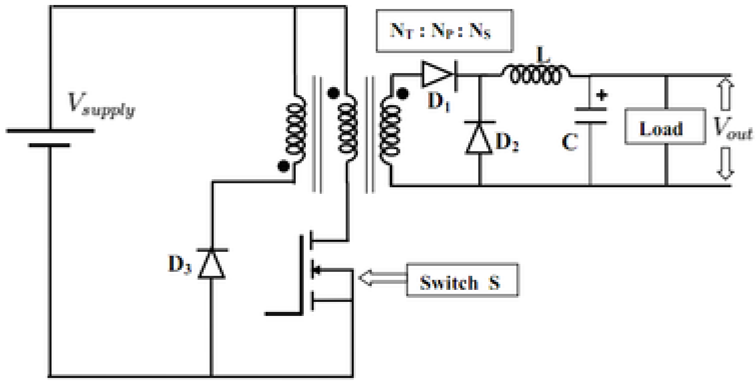

Figure 2.14: Basic schematic of forward converter

(c) Push-Pull: A push–pull converter is a type of DC-to-DC converter, a switching converter that uses a transformer to change the voltage of a DC power supply. The distinguishing feature of a push-pull converter is that the transformer primary is supplied with current from the input line by pairs of transistors in a symmetrical push-pull circuit. The transistors are alternately switched on and off, periodically reversing the current in the transformer. Therefore, current is drawn from the line during both halves of the switching cycle. This contrasts with buck-boost converters, in which the input current is supplied by a single transistor which is switched on and off, so current is only drawn from the line during half the switching cycle. During the other half the output power is supplied by energy stored in inductors or capacitors in the power supply. Push–pull converters have steadier input current, create less noise on the input line, and are more efficient in higher power applications.

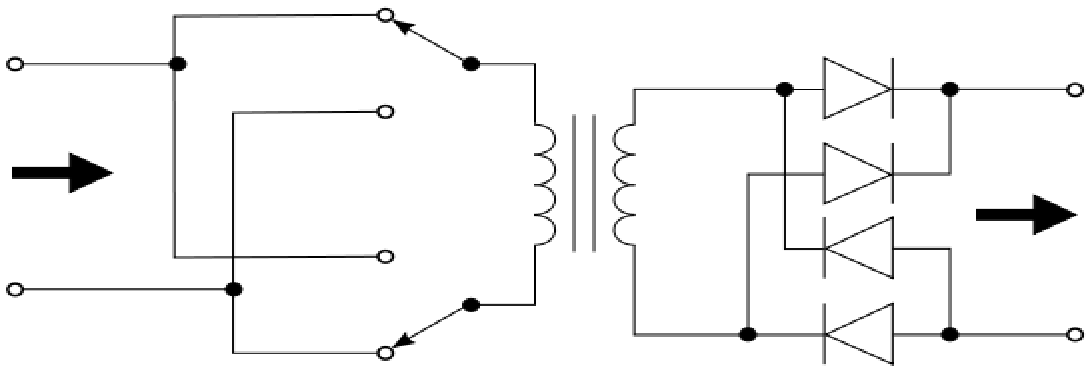

Figure 2.15: Circuit of push-pull converter

2.3 Switched mode power supply specifications

Power supplies may have several specifications to be met, including their voltage and current ratings. There may be short time ratings of higher magnitudes of current and continuous ratings of somewhat lower magnitudes. One needs to specify the tolerable limits on the ripple voltages, short-circuit protection level of current (if any) and the nature of output volt-current curve during over-current or short circuit (the output voltage magnitude should reduce or fold back towards zero, gradually, depending on the severity of over-current).

The fuse requirement (if any) on the input and the output side may need to be specified. One needs to specify the type of input supply (whether ac or dc) or whether the power supply can work both from ac or dc input voltages. Acceptable range of variation in input voltage magnitude, supply frequency (in case of ac input) are also to be specified. Efficiency, weight and volume are some other important specifications. Some applications require the electro-magnetic compatibility standards to be met. By electromagnetic compatibility it is meant that the level of EMI generation by power supply should be within tolerable limits and at the same time the power supply should have the ability to work satisfactorily in a limited noisy environment.

It is quite common to have output voltage isolation and it is specified in terms of isolation breakdown voltage. In case of multiple power supplies it needs to be specified whether all the outputs need to be isolated or not and what should be the acceptable ripple voltage range for each. In majority of the cases the available source of input power is the alternating type utility voltage of 50 or 60 Hz. The voltage levels commonly used are 115V (common in countries like, USA) and 230 volts (common in India and many of the European countries). Most utility (mains) power supplies are expected to have ± 10% voltage regulation but for additional precaution the SMPS circuits must work even if input voltages have ± 20% variation.

Now-a-days universal power supplies that work satisfactorily and efficiently both on 115 V and 230 V input are quite popular. These power supplies are very convenient for international travelers who can simply plug-on their equipment, like laptop computer and shaving machine, without having to pay much attention on the exact voltage and frequency levels of the utility supply. In contrast some of the other power supplies have a selector switch and the user is required to adjust the switch position to match the utility voltage. In case user forgets to keep the selector switch at correct position, the equipment attached may get damaged.

2.4 Advantages & disadvantages of SMPS circuits

Switch mode power supplies are widely used because of the advantages they offer in terms of size, weight, cost, efficiency and overall performance. The majority of electronic DC loads are supplied from standard power sources. Unfortunately, standard source voltages may not match the levels required by microprocessors, motors, LEDs, or other loads, especially when the source voltage is not regulated. The other advantages of SMPS circuits are as follows:

(a) Versatility

Fortunately, the versatility of SMPSs solves the problem of converting a standard source voltage into a usable, specified output voltage. There are numerous SMPS topologies, which are classified into fundamental categories - these power supplies step up, step down, invert, or even step up and down the input voltage. Unlike linear regulators, which can only step down an input, SMPS are attractive because a topology can be selected to fit nearly any output voltage.

(b) Efficiency

For instance, it is often required to step down an input voltage to achieve a lower output voltage. A simple solution implements a linear regulator, as this device requires only a few capacitors and adequate thermal management. However, where such simplicity ends, inefficiency begins—even to unacceptable levels if the voltage differential is large. The efficiency of a linear regulator is directly related to the power dropped across its pass transistor.

A well-designed SMPS can achieve 90% efficiency or more, depending on load and voltage levels.

Although high efficiency is the principal advantage with SMPS designs, other benefits naturally occur as a direct result of minimizing power loss. For example, a reduced thermal footprint is observed in the SMPS when compared to its less efficient counterparts. This benefit equates to reduced thermal-management requirements. Also, more importantly, lifetime increases due to improved reliability, because components are not subjected to excessive heat, as they would be in a less efficient system.

(c) Flexible technology

Switch mode power supply technology can be sued to provide high efficiency voltage conversions in voltage step up or "Boost" applications or step down "Buck" applications.

Disadvantages and Trade-offs of SMPSs

Of course, the high efficiency afforded by SMPSs is not without its penalties. Perhaps the most often cited issue regarding switch-mode converters is their propensity to radiate electromagnetic interference (EMI) and conduct noise. Electromagnetic radiation is caused by the fast transitions of current- and voltage-switching waveforms that exist in SMPS circuits. Rapidly changing voltages at the inductor node cause radiated electric fields, while fast-switching currents of the charge/discharge loops produce magnetic fields.

SMPSs also can be quite complex and require additional external components, both of which can equate to an increase in overall cost of the power supply.

Noise: The transient spikes that occur from the switching action on switch mode power supplies are one of the largest problems. The spikes can migrate into all areas of the circuits that the SMPSs power if the spikes are not properly filtered. Additionally, the spikes or transients can cause electromagnetic or RF interference which can affect other nearby items of electronic equipment, particularly if they receive radio signals.

CHAPTER - 3

HARDWARE IMPLEMENTATION

One of the major problems that is to be solved in an electronic circuit design is the production of low voltage DC power supply from Mains to power the circuit. The conventional method is the use of a step-down transformer to reduce the 230 V AC to a desired level of low voltage AC. The simplest, space saving and low cost method is the use of a Voltage Dropping Capacitor in series with the phase line.

An ordinary capacitor will not do the job since the device will be destroyed by the rushing current from the mains. Mains spikes will create holes in the dielectric and the capacitor will fail to work. X-rated capacitor specified for the use in AC mains is required for reducing AC voltage.

3.1 Capacitive power supply

A capacitive power supply is a type of power supply that uses the capacitive reactance of a capacitor to reduce the mains voltage to a lower voltage.

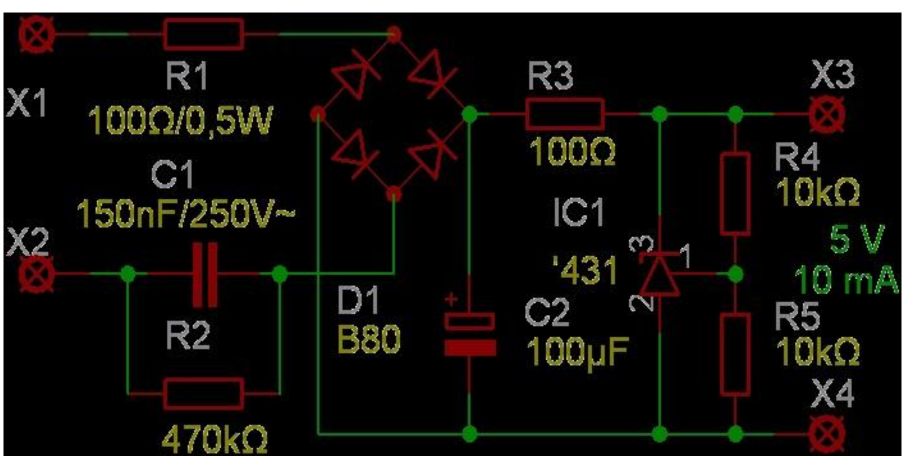

Figure 3.1: Schematic of capacitive power **supply**

3.1.1 Components used in capacitive power supply

(a) X-rated capacitor

Usually X Capacitors are connected across the line i.e., line to line connection or line to neural connection. So the X rated capacitor checks and reduces symmetrical interference. In Capacitor Power Supplies it is connected in series with the line (line to line connection) to drop voltage. Safety Standards classify X and Y rated capacitors to different classes according to their rated voltage and peak impulse voltage that can safely withstand. Peak Impulse voltage refers to sudden rise in voltage that may cause due to lightning or other power surges. We usually use the safety capacitors with voltage rating more than double the expected voltage in our filtering applications.

(b) Bleeder resistor

A bleeder resistor is a resistor connected in parallel with the output of a high-voltage power supply circuit for the purpose of discharging the electric charge stored in the power supply's filter capacitors when the equipment is turned off, for safety reasons. It eliminates the possibility of a leftover charge causing electric shock if personnel handle or service the equipment in the off state, believing it is safe.

The power supply circuits in electronic equipment that produce direct current (DC) needed by the device from the alternating current (AC) supplied by mains use filter capacitors to smooth the DC current. A large electric charge can remain in these capacitors after the unit is turned off, constituting a shock hazard. For example switching mode power supplies use a bridge rectifier to convert mains AC power into DC at 320 V (for 220 V mains), before the voltage is reduced by the chopper. These incorporate one or more filter capacitors to smooth the pulsing output voltage from the rectifier. These must typically store enough energy at this high voltage to power the load during the zero crossings of the AC input. In addition, the capacitors in many supplies are made large enough to supply the load during AC outages lasting for a significant fraction of a second. This stored charge is often enough to deliver a lethal shock.

This stored charge can remain in the capacitors for a long time after the unit has been turned off. Therefore, to discharge the capacitor after the supply has been turned off, a large-value resistor is connected across its terminals. After it is switched off, the charge on the capacitor will drain off through this "bleeder resistor", causing the voltage to decay quickly to safe levels.

(c) Diode bridge

A diode bridge is an arrangement of four (or more) diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input.

When used in its most common application, for conversion of an alternating current (AC) input into a direct current (DC) output, it is known as a bridge rectifier. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a rectifier with a 3-wire input from a transformer with a center-tapped secondary winding.

(d) Filter capacitors

They are capacitors used for filtering of undesirable frequencies. They are common in electrical and electronic equipment, and cover a number of applications, such as glitch removal on direct current (DC) power rails, used after a voltage regulator to further smooth dc power supplies.

3.1.2 PSPICE IMPLEMENTATION

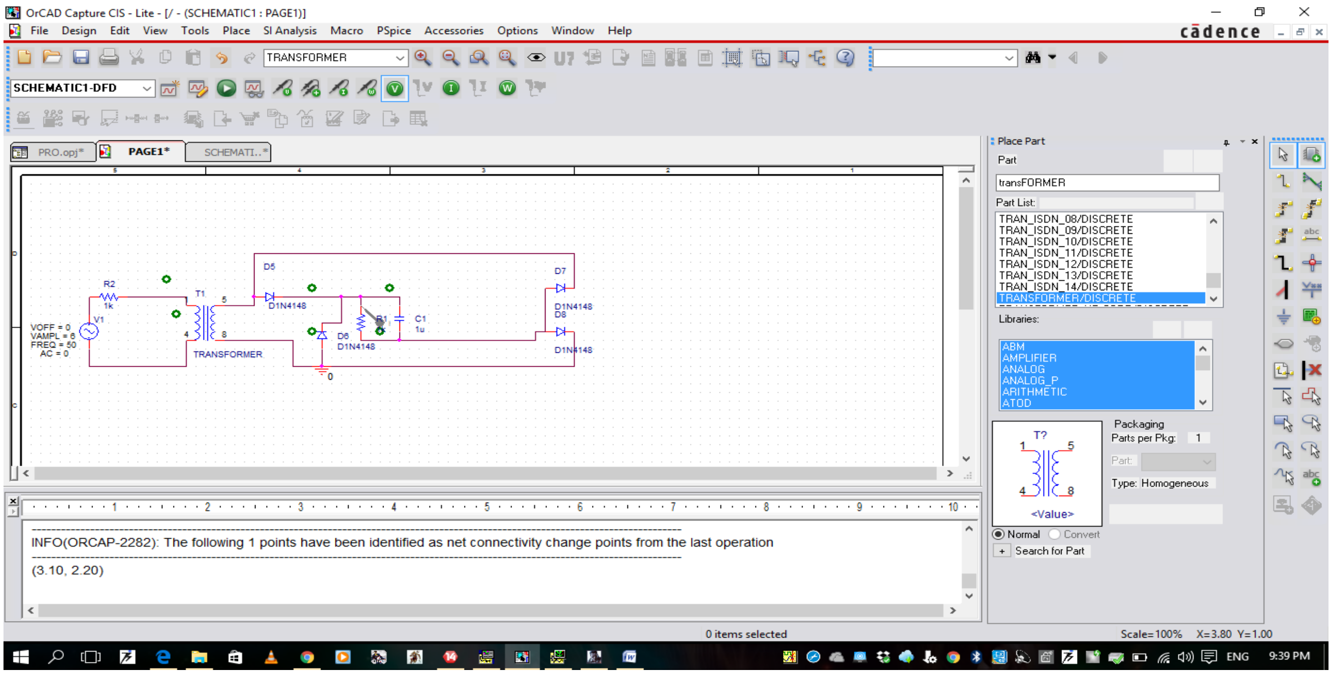

Figure 3.2:PSPICE implementation of circuit

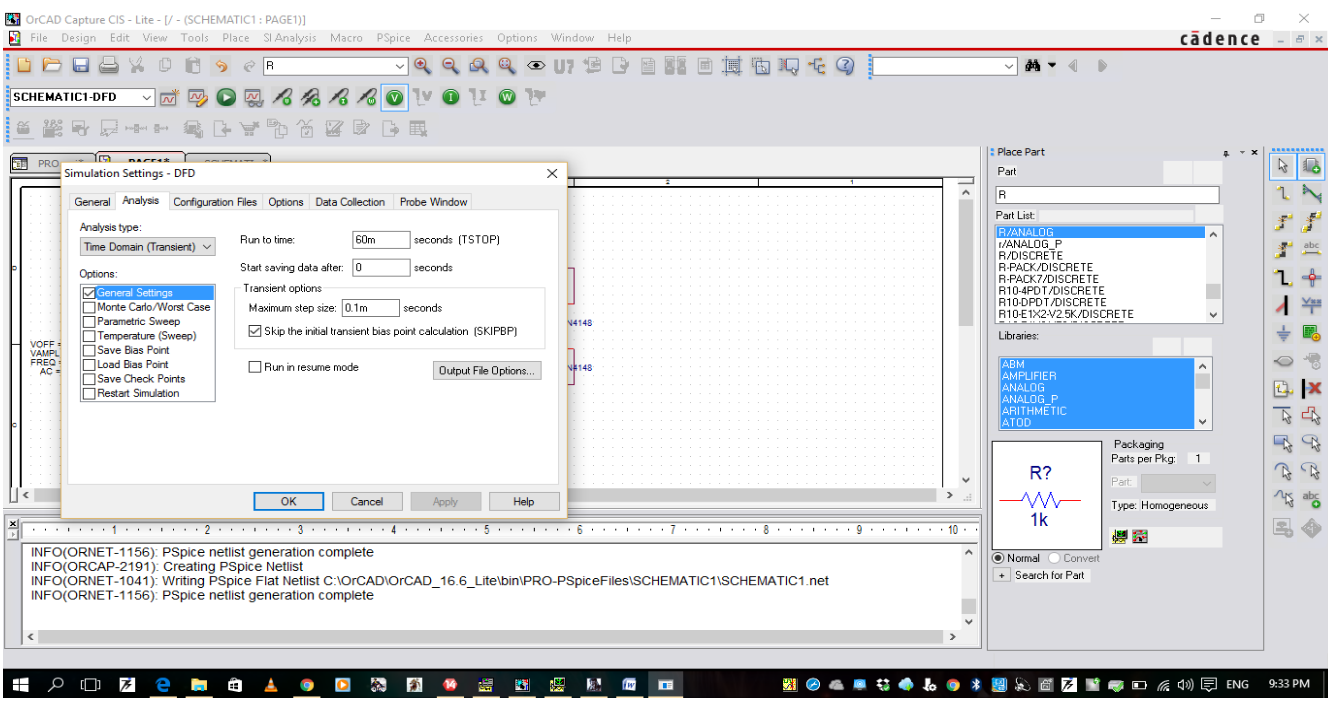

Figure 3.3: Simulation settings

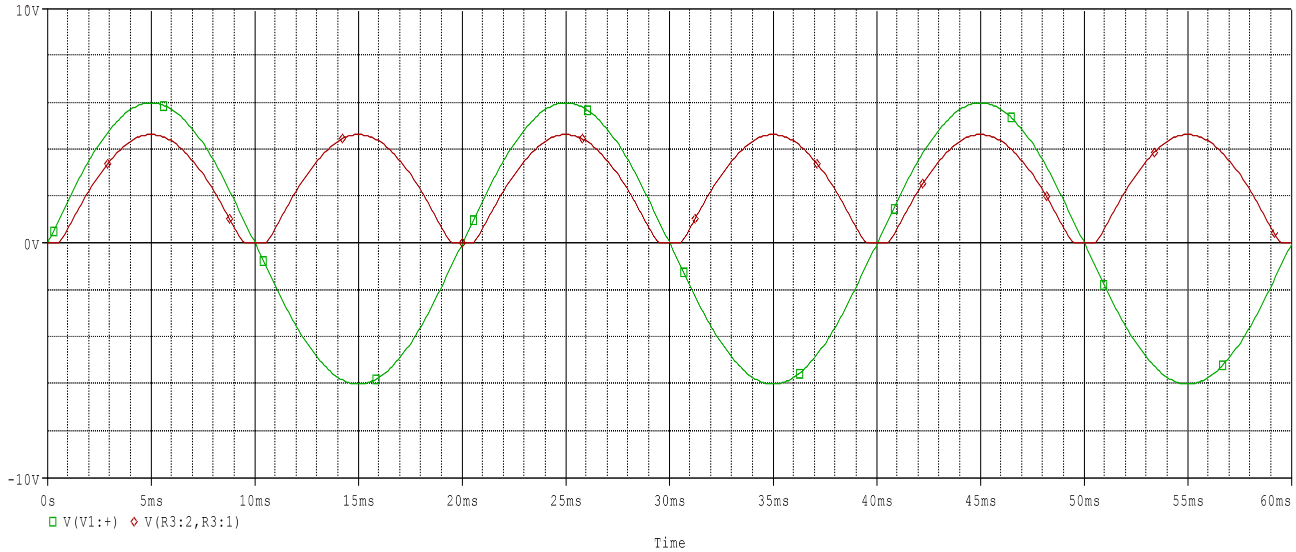

Figure 3.4: Output waveform

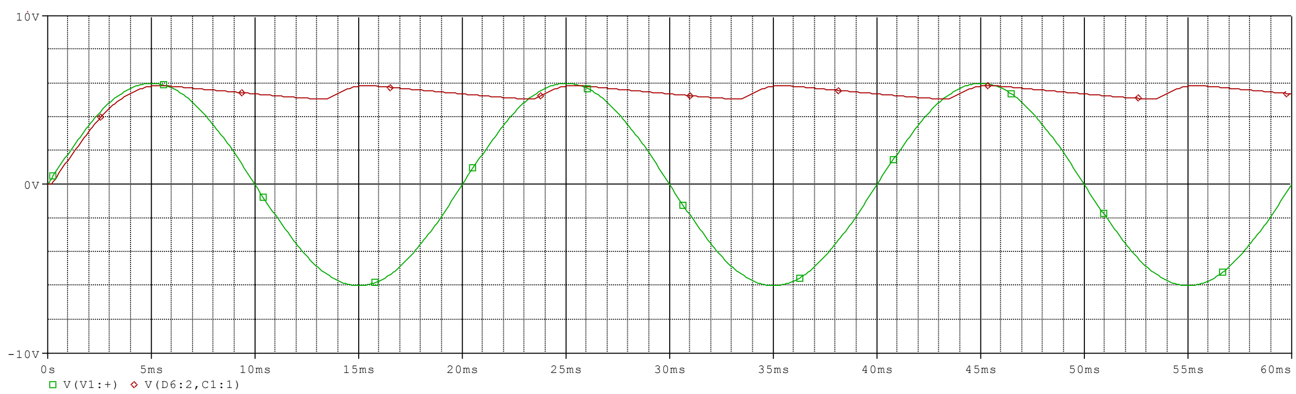

Figure 3.5: Ripples reduced using a low pass filter (C=0.9nf , R=1k)

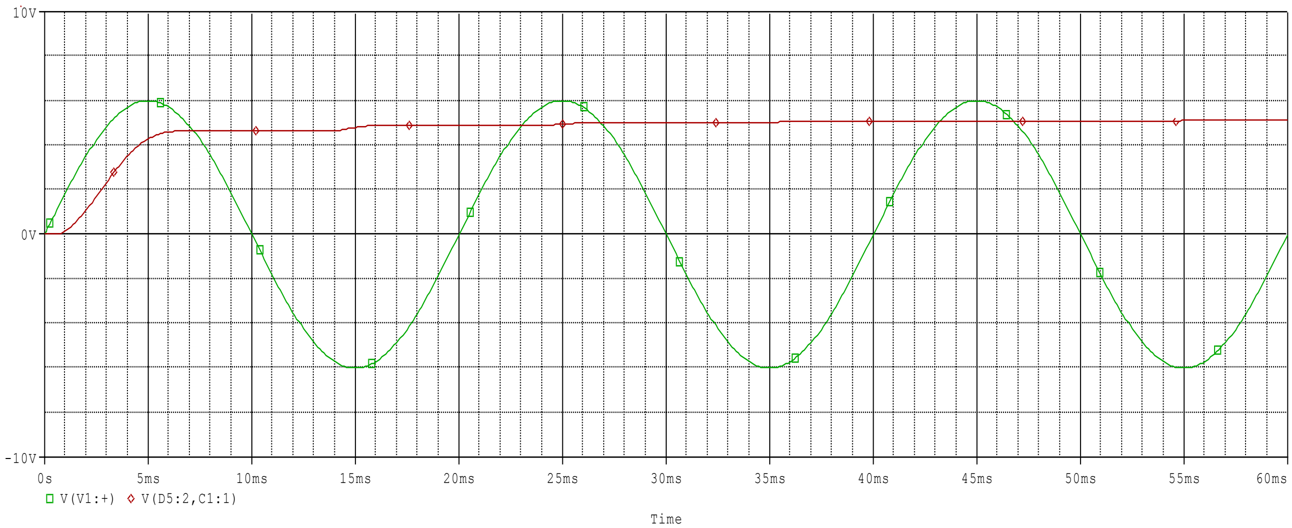

Figure 3.6: Ripples reduced further (C=1uf, R=10k)

3.1.3 Laboratory results

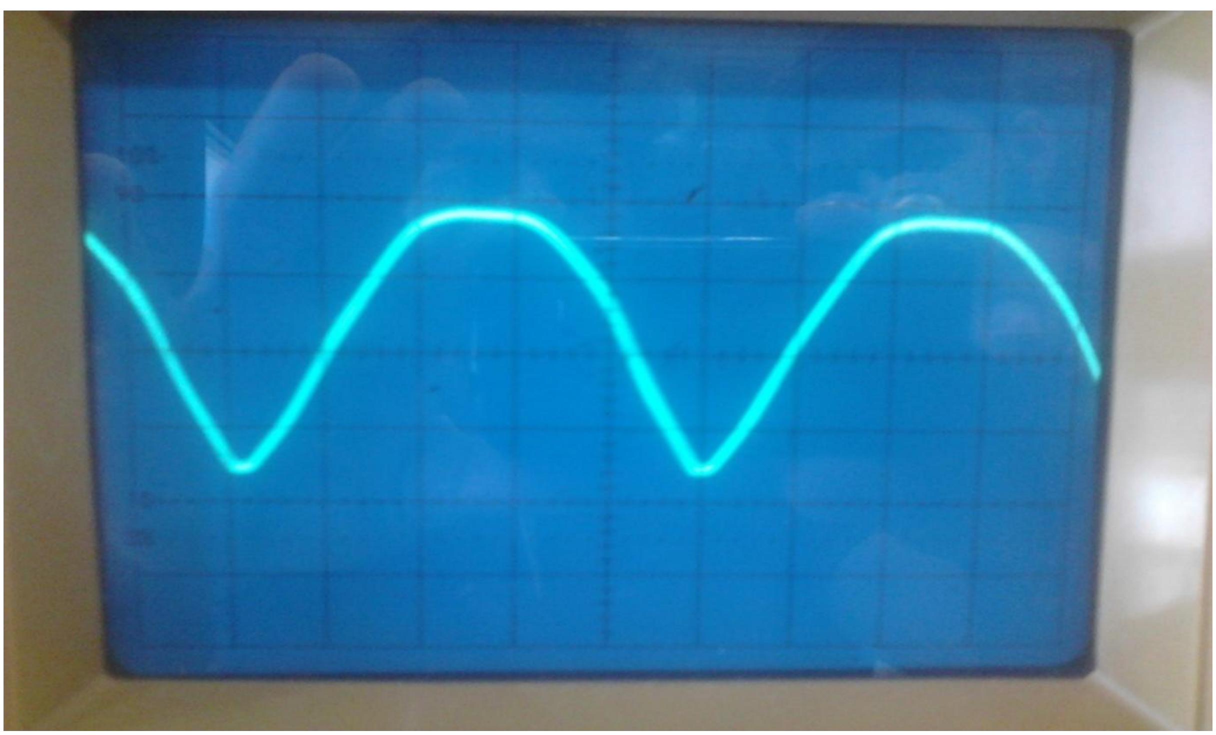

Figure 3.7: Output waveform in laboratory

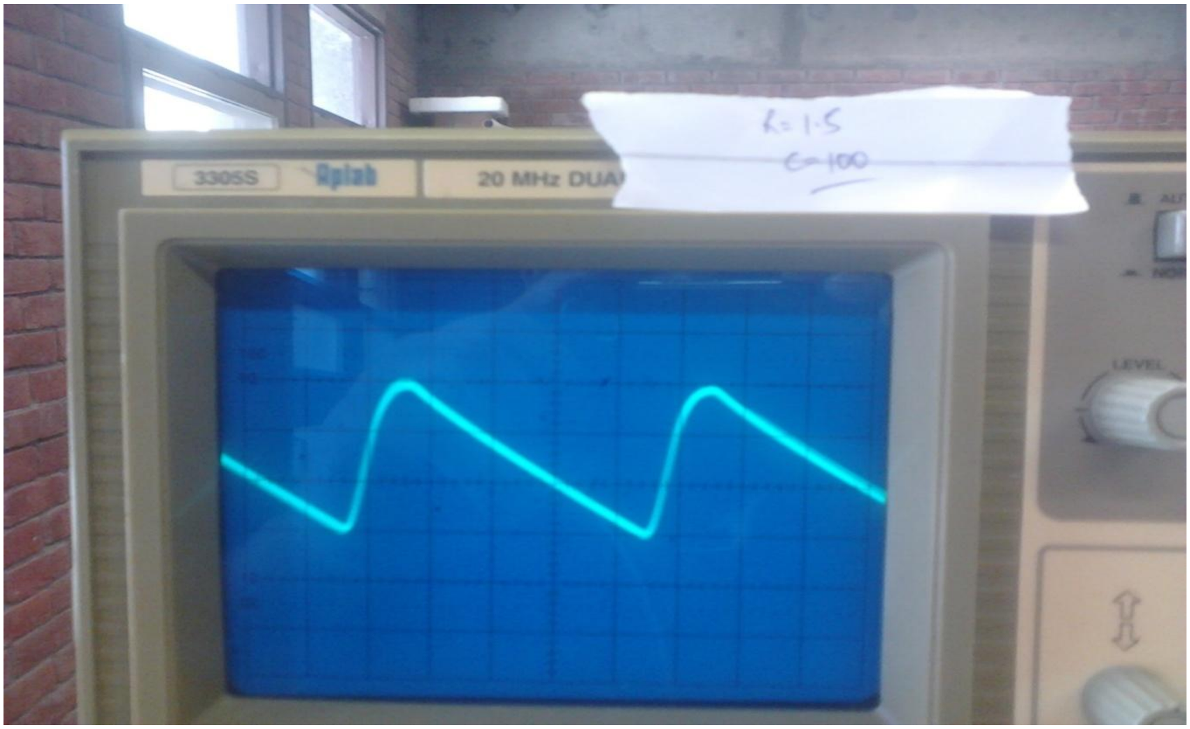

Figure 3.8: Ripples with R=1.5k and C=100uf

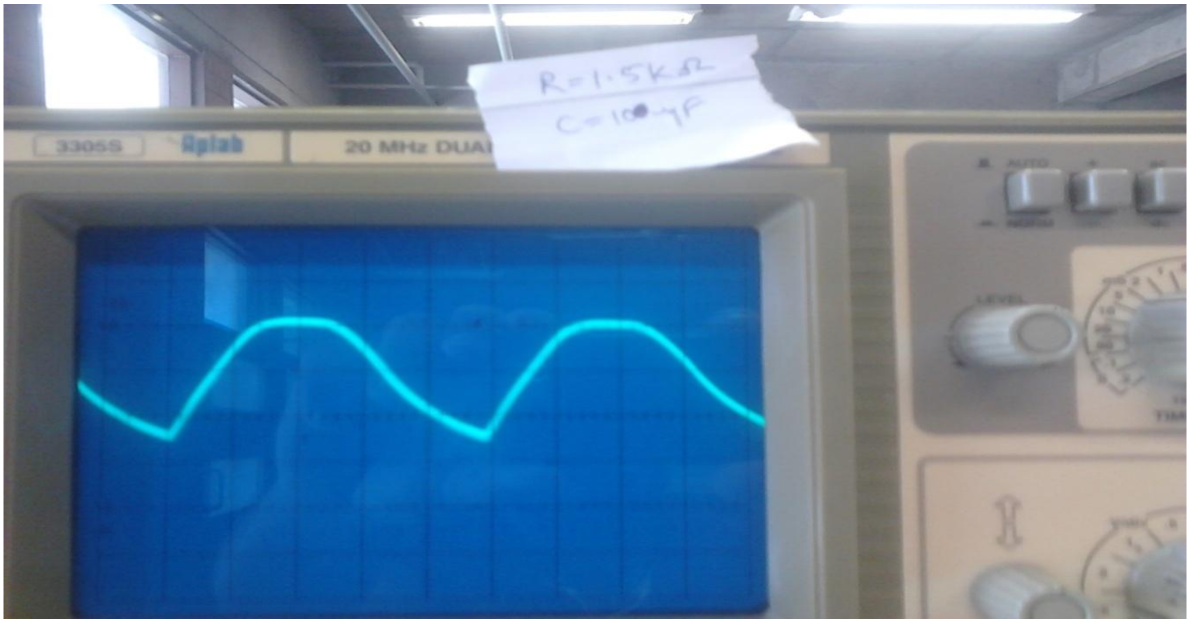

Figure 3.9: Ripples with R=1.5k and C=10uf

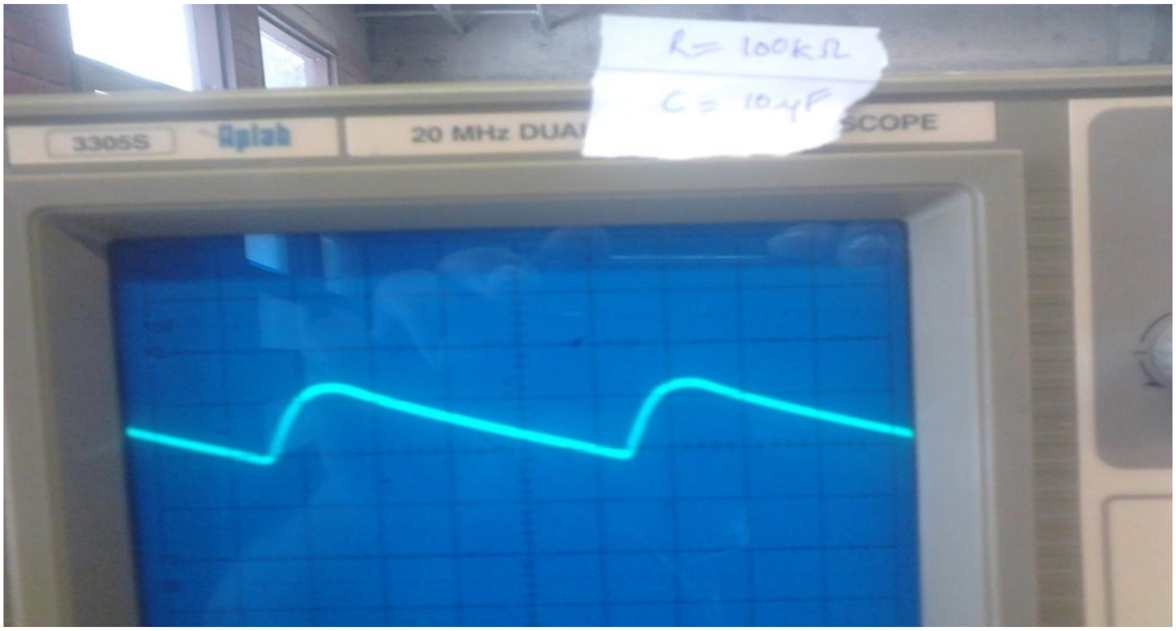

Figure 3.10: Ripples with R=100k and C=10uf

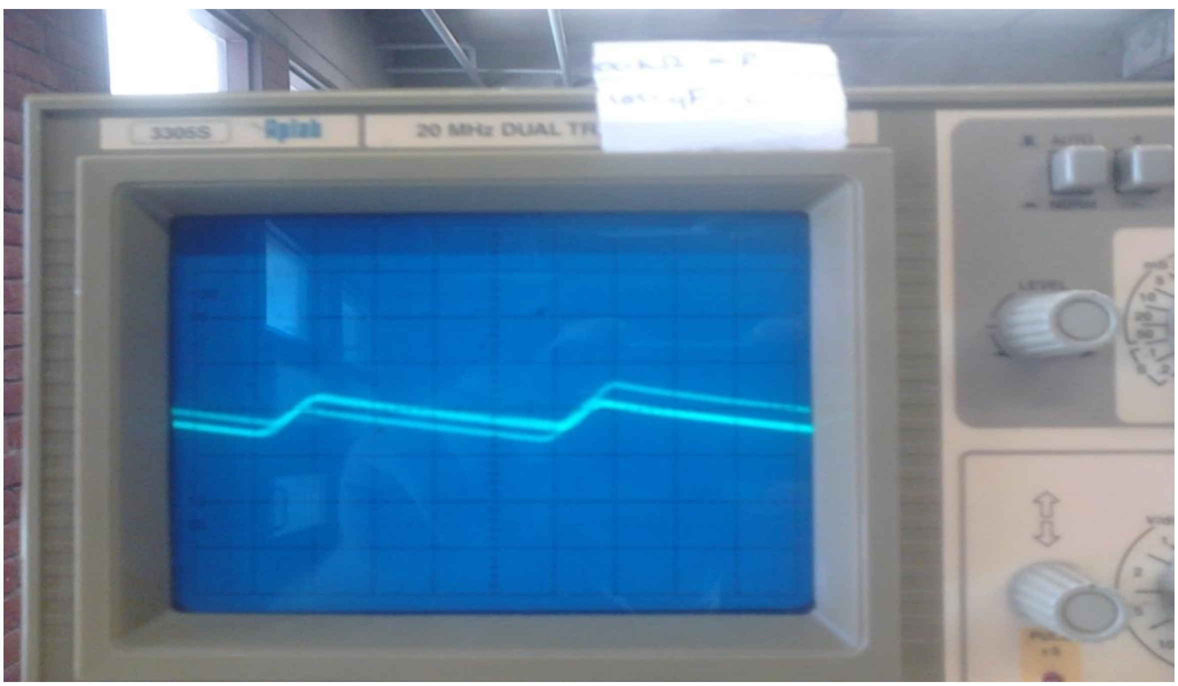

Figure 3.11: Ripples with R=100k and C=100uf

3.2 7W Circuit design (7W, 90-130 Vac, 500mA)

3.2.1 Topology used: Buck and Boost Converter

3.2.2 Components used

(a) Resistance: The electrical resistance of an electrical conductor is a measure of the difficulty to pass an electric current through that conductor.

(b) Capacitor: A capacitor (originally known as a condenser) is a passive two-terminal electrical component used to store electrical energy temporarily in an electric field.

(c) Inductor: An inductor, also called a coil or reactor, is a passive two-terminal electrical component which resists changes in electric current passing through it. It consists of a conductor such as a wire, usually wound into a coil. Energy is stored in a magnetic field in the coil as long as current flows.

(d) Diode:A diode is a specialized electronic component with two electrodes called the anode and the cathode. Most diodes are made with semiconductor materials such as silicon, germanium, or selenium.

(e) NCP 1216: NCP-1216 represents an enhanced version of NCP1200-based controllers. Due to its high drive capability, NCP1216 drives large gate-charge MOSFETs, together with internal ramp compensation and built-in frequency jittering.

With an internal structure operating at a fixed 40 kHz, 60 kHz or 100 kHz, the controller drives low gate−charge switching devices like an IGBT or a MOSFET thus requiring a very small operating power.

Due to current−mode control, the NCP1200 drastically simplifies the design of reliable and cheap offline converters with extremely low acoustic generation and inherent pulse−by−pulse control.

Internal Ramp compensation easily prevents sub harmonic oscillations from taking place from taking place in continuous conduction mode.
When the current set point falls below a given value, e.g. the output power demand diminishes, the IC automatically enters the so called skip cycle mode and provides excellent efficiency at light loads.

Because this occurs at a user adjustable low peak current, no acoustic noise takes place.
The NCP1216 features an efficient protective circuitry, which in presence of an overcurrent condition disables the output pulses while the device enters a safe burst mode, trying to restart. Once the default has gone, the device auto-recovers.

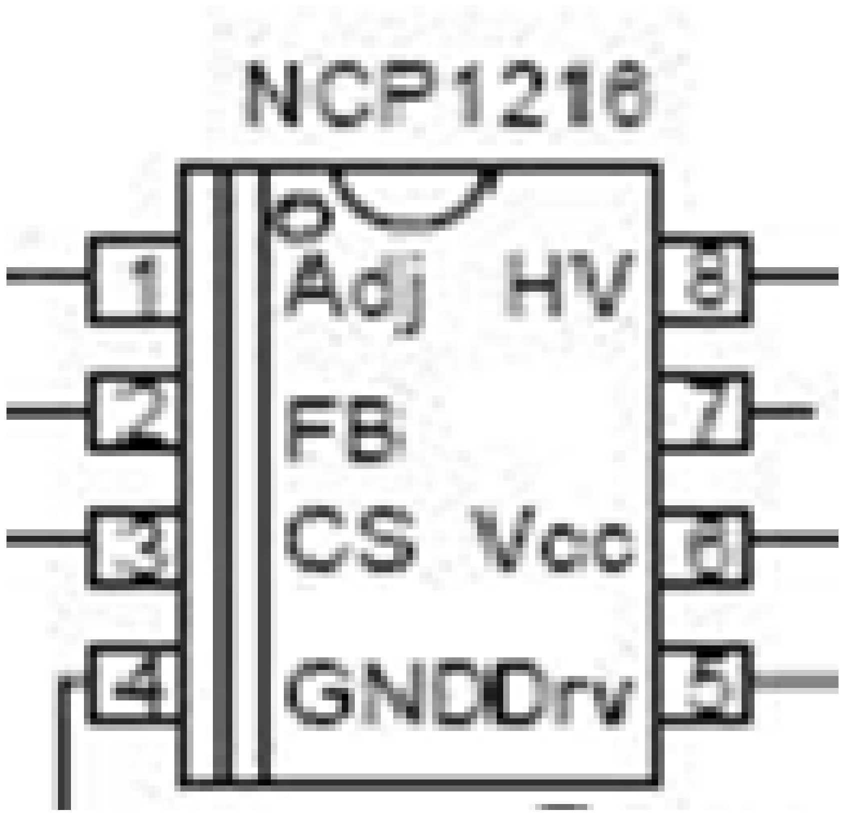

Figure 3.12: NCP 1216

Features of NCP 1216

- No auxiliary winding operation
- Current-mode control with adjustable skip-cycle capability
- Internal ramp compensation
- Built-in frequency jittering for better EMI signature
- Auto-recovery internal output short circuit protection
- Extremely low no-load standby power
- 500mA peak current capability
- Fixed frequency versions at 65 kHz, 100 kHz, 133 kHz
- Internal temperature shutdown
- Direct optocoupler connection
- SPICE models available for TRANsient and AC analysis
- Pin-to-pin compatible with NCP1200 series
- Internal 1ms Soft Start (A version Only)
- Limited Duty Cycle to 50% (A Version Only)

PIN Description:

Pin no.1	Adj.	Adjust the skipping peak current	This pin lets you adjust the level at which cycle skipping process takes place
Pin no. 2	FB	Sets the peak current set point	By connecting an optocoupler to this pin, the peak current setpoint is adjusted accordingly
Pin no. 3	CS	Current sense input	This pin senses the primary current and routes it to the internal comparator
Pin no. 4	GND	The IC ground	
Pin no. 5	Drv	Driving pulses	The drivers' output to external MOSFET
Pin no. 6	Vcc	Supplies the IC	This pin is connected to external bulk capacitor
Pin no. 7	NC	No connection	This un-connected pin ensures adequate creepage distance
Pin no. 8	HV	Generates Vcc	This pin injects constant current into Vcc bulk capacitor

Table 3.1:NCP 1216 pin description

Circuit schematic:

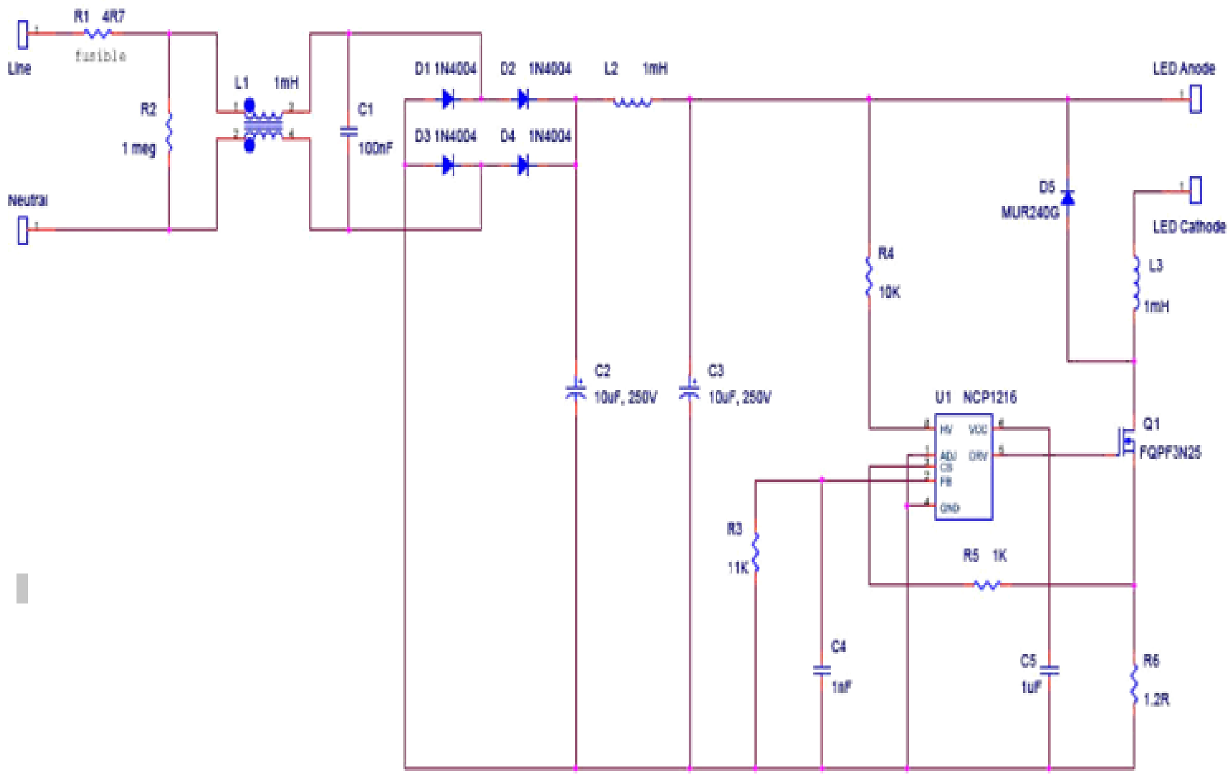

Figure 3.13: Schematic of 7W circuit

CONCLUSION

A 3W capacitive power supply was successfully implemented using a X-rated capacitor, diodes, filter capacitor and bleeder resistor. The output voltage came out to be 12V and the output current ranged from 225mA to 260mA. The glitches in the rectified voltage waveform were removed using a higher value of filter capacitor. The bleeder resistor managed to remove the excess charge stored in the capacitor. The LED load illuminated at the full potential giving out 280 lumens.

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