

Sepic-Cuk Boost Based SIMO Converter Using dsPIC Microcontroller

*A Project report submitted in partial fulfilment
of the requirements for the degree of B. Tech in Electrical Engineering*

By

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CERTIFICATE
To whom it may concern

This is to certify that the project work entitled **Sepic-Cuk Boost Based SIMO Converter Using dsPIC Microcontroller** is the bonafide work carried out by **Rahita Majumder(11701615034) and Adriraj Barua(11701615003)**, students of B.Tech in the Dept. of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India, during the academic year **2018-19**, in partial fulfillment of the requirements for the degree of Bachelor of Technology in Electrical Engineering and that this project has not submitted previously for the award of any other degree, diploma and fellowship.

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Full Signature of the Students

Place:

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ABSTRACT

In recent years, different techniques for multiple dc outputs and different voltage levels have been studied and developed. This research has focused on isolated dc–dc converter configurations, such as those for flyback, forward, pushpull, halfbridge, and fullbridge (Hbridge; this term is derived from the typical graphical representation of such a circuit) converters, as well as nonisolated dc–dc converters. Several applications have also been studied, such as integrated dual output converters, integrated multipleoutput converters, and single inductor multipleoutput converters . In addition, emerging power architectures oriented toward renewable energy sources (such as wind turbine, solar array, and fuel cells), batteries, and distributedgeneration utility grids have proliferated in important ways. The concept of multiport converters applies to a static power electronic converter, which is capable of interfacing with different sources and storage systems and with loads having different voltage levels. Multiport converters are particularly interesting for sustainable energygeneration systems that must integrate various lowpower sources and storage elements. A first classification of the multiport converters can be performed as a function of the input and output number; these include configurations for multipleinput, multipleoutput (MIMO) multipleinput, singleoutput (MISO) , and 7USIMO converters.

CHAPTER 1

Introduction

The photovoltaic systems are major contributors in the electrical power. These are utilized effectively with interface to the existing systems through DC-DC converters. The major challenge is to extract power under varying operating conditions which influence the output voltage.

Isolated converter structures with cascaded configuration enables to achieve high voltage gain. These are used up to several kW applications. The multilevel buck converters proposed are widely used in high frequency DC/DC power conversion. In the conventional boost converters, high voltage ratio is feasible without multistage cascading. The voltage ratios in these are limited by the parasitic elements and switching control used.

Today, dc–dc power converters are becoming the main branch of power electronics. Recent reports indicate that dc–dc converters represent the largest percentage of total conversion equipment production. The worldwide dc–dc converter market has grown an average of 7.5% in recent years. In addition to its high growth rate, the dc–dc converter market is undergoing drastic changes because of two major trends in the electronics industry: low voltage and high power density. The production of dc–dc converters in the world market is now much higher than that of ac–dc converters. The divided market comprises three subsegments, including low power, medium power, and high power.

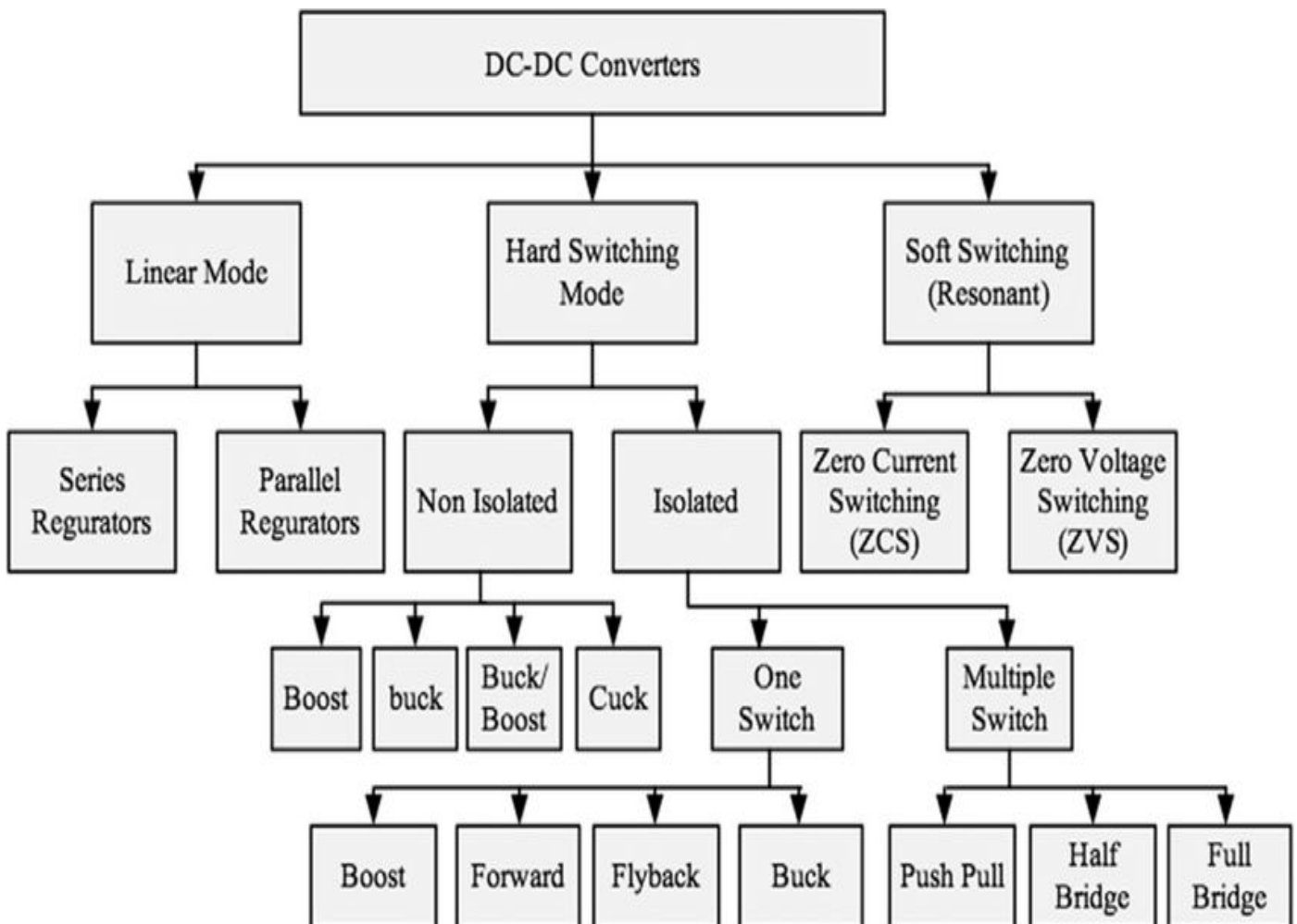
In recent years, different techniques for multiple dc outputs and different voltage levels have been studied and developed. Several applications have been studied, such as integrated dual-output converters, integrated multiple-output converters, and single-inductor multiple- output converters. Emerging power architectures oriented toward renewable energy sources batteries, and distributed-generation utility grids have proliferated in important ways.

The concept of multiport converters applies to a static power electronic converter, which is capable of interfacing with different sources and storage systems and with loads having different voltage levels. Multiport converters are particularly interesting for sustainable energy-generation systems that must integrate various low-power sources and storage elements. A first classification of the multiport converters can be performed as a function of the input and output number. These include configurations for multiple-input, multiple-output (MIMO) multiple-input, single-output (MISO) and SIMO converters. SIMO dc– dc converters, in both their isolated and nonisolated versions, have been traditionally used for multiple supplies with different output levels

in many applications, such as telecommunications, microelectronics, and lighting, that include electronic ballast and light-emitting diodes and hybrid/electric and electric vehicles.

the methodology described, based on a SEPIC/Cuk/boost combination converter. It has allowed the development of a power supply bank of six different voltages

CONVERTER	CCM	DCM
Buck converter	$V_o = V_g \cdot D$ and $I_g = I_o D$	$V_o = \frac{2 \cdot V_g}{\left(1 + \sqrt{1 + \frac{8 \cdot L}{R \cdot D^2 \cdot T_s}}\right)}$ and $I_g = \frac{2 \cdot I_o}{\left(1 + \sqrt{1 + \frac{8 \cdot L}{R \cdot D^2 \cdot T_s}}\right)}$
Boost converter	$V_o = \frac{V_g}{1-D}$ and $I_g = \frac{I_o}{1-D}$	$V_o = \frac{V_g}{2} \left(1 + \sqrt{1 + \frac{2R \cdot D^2 \cdot T_s}{L}}\right)$ and $I_g = \frac{I_o}{2} \left(1 + \sqrt{1 + \frac{2R \cdot D^2 \cdot T_s}{L}}\right)$
Buck-boost-derived converters	$V_o = V_g \frac{D}{1-D}$ and $I_g = I_o \frac{D}{1-D}$	$V_o = D \cdot V_g \sqrt{\frac{R \cdot T_s}{2 \cdot L_{eq}}}$ and $I_g = D \cdot I_o \sqrt{\frac{R \cdot T_s}{2 \cdot L_{eq}}}$



CHAPTER 2



THEORY

1. DC-DC Converter

In many industrial applications, it is required to convert a fixed-voltage dc source into a variable-voltage dc source. A DC-DC converter converts directly from dc to dc and is simply known as a DC converter. A dc converter can be considered as dc equivalent to an AC transformer with continuously variable turn ratio. Like transformer, it can be used to step down or step up a dc voltage source.

DC converters widely used for traction motor in electric automobiles, trolley cars, marine hoists, and forklift trucks. They provide smooth acceleration control, high efficiency, and fast dynamic response. Dc converter can be used in regenerative braking of dc motor to return energy back into the supply, and this feature results in energy saving for transportation system with frequent stop; and also are used, in dc voltage regulation. There are many types of DC-DC convertor which is buck (step down) converter, boost (step-up) converter, buck-boost (step up- step-down) convertor.

DC conversion is of great importance in many applications, starting from low power applications to high power applications. The goal of any system is to emphasize and achieve the efficiency to meet the system needs and requirements. Several topologies have been developed in this area, but all these topologies can be considered as apart or a combination of the basic topologies which are buck, boost and flyback.

For low power levels, linear regulators can provide a very high-quality output voltage. For higher power levels, switching regulators are used. Switching regulators use power electronic semiconductor switches in On and Off states.

Because there is a small power loss in those states (low voltage across a switch in the on state, zero current through a switch in the off state), switching regulators can achieve high efficiency energy conversion.

Functions of DC-DC Converter

The DC-DC converter has some functions. These are:

- i) Convert a DC input voltage V_s into a DC output voltage V_o .
- ii) Regulate the DC output voltage against load and line variations.
- iii) Reduce the AC voltage ripple on the DC output voltage below the required level.
- iv) Provide isolation between the input source and the load.

2.1.1 Buck Converter

The AC/DC converter we use as an example is generally called a "buck" converter. Originally a buck converter meant a step-down converter, but the term came to be used for DC/DC converters as well. While there are various theories, conventional standard step-down converters were diode-rectified (asynchronous) devices, and it became customary to refer to diode-rectified step-down converters as buck converters. Regardless of the names used, there are a number of step-down methods used in step-down converters, and the step-down converter of this example is the previously mentioned diode-rectified device.

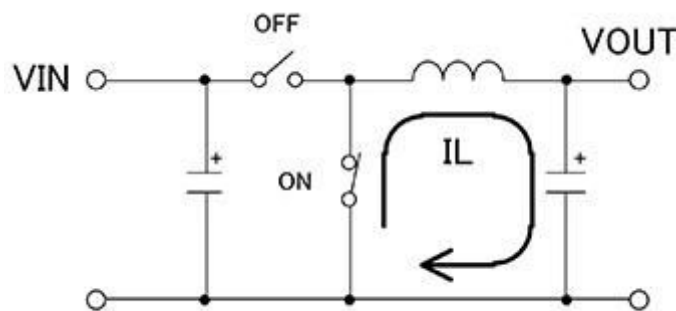


Figure 8: On mode

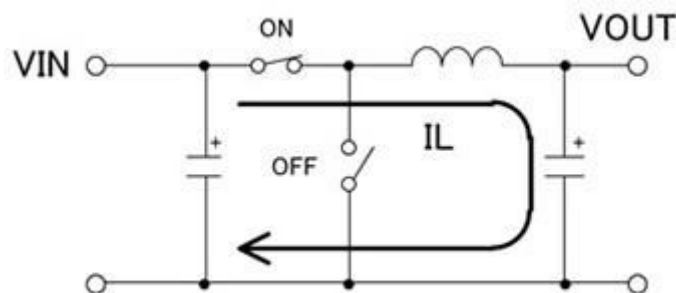


Figure 9: Off mode

Operation of Buck Converters

Below, a model of a basic step-down converter is used to explain the circuit operation. By gaining an understanding of the properties of current pathways and nodes from the basic operation, standards for selection of peripheral components and matters demanding attention will become clear. In the diagrams, we replace the high-side transistor and low-side diode with switches to explain operation schematically. The circuit principles are the same as those of diode rectification in a DC/DC converter, but the

high voltage obtained by rectifying an AC voltage is directly switched to perform step-down voltage conversion,

and so the transistor and diode acting as switches must withstand high v or so.

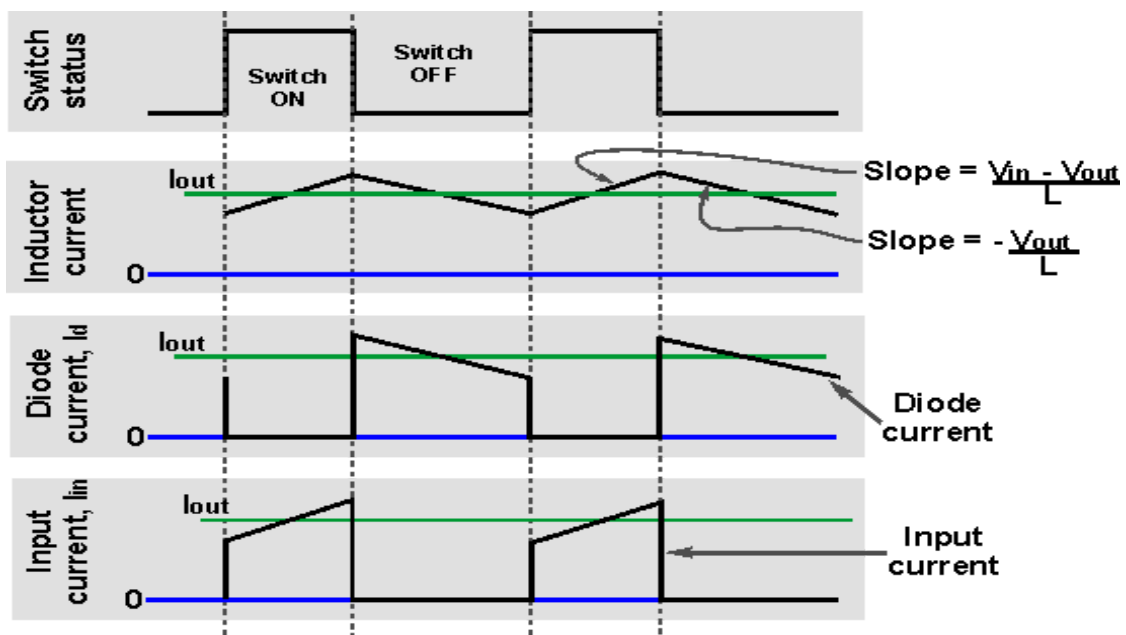
- When the high-side switch (the transistor) turns on, a current I_L flows in the inductor L , and energy is stored
- At this time, the low-side switch (the diode) is turned off
- The inductor current I_L is expressed by the following equation (t_{on} : ON-time)
- When the high-side switch (the transistor) turns off, the energy stored in the inductor is output through the low-side switch (the diode)
- At this time, the high-side switch (the transistor) is OFF
- The inductor current I_L is expressed by the following equation (t_{off} : OFF time)

1.1.1 Discontinuous and Continuous Mode

In switching operation, there are two modes, a discontinuous mode and a continuous mode. They are compared in the following table. The "operation" item for comparison is the waveform of the currents flowing in the primary windings and secondary windings of the transformer. In discontinuous mode, there is a period in which the inductor current I_L is interrupted, hence the name, discontinuous mode. In contrast, in continuous mode there is no period in which the inductor current is zero. In the case of the continuous mode, when the switches are ON, a reverse current flows during the reverse recovery time (t_{rr}) of the rectifying diode, and losses occur due to this reverse current. In low-voltage switching

DC/DC conversion, the reverse voltage of the rectifying diode is low and the reverse current is also small, and so generally the continuous mode is used, giving priority to reducing the output ripple voltage and harmonics. However, the peak current becomes large, and when the load is large, sometimes operation in continuous mode is preferred.

$$I_L = \frac{V_{IN} - V_{OUT}}{L} \times t_{on}$$



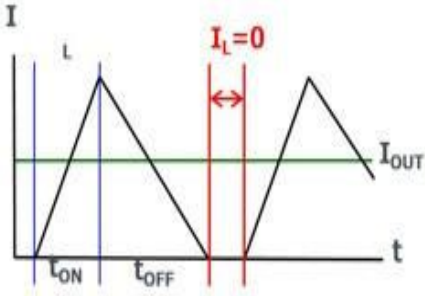
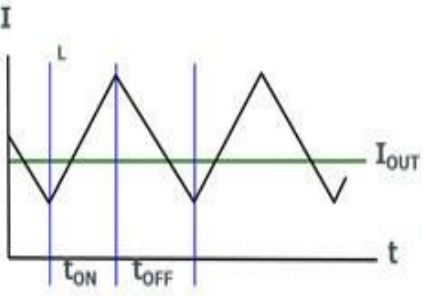
Comparison item	Discontinuous mode	Continuous mode
Operation	 <p>There is a zero-inductor current period between ON and OFF, so that the inductor current is not continuous.</p>	 <p>The inductor current flows continuously, which turns ON and OFF at the same frequency as the switching frequency.</p>
Inductor	Inductance ↓, size ↓, cost ↓	Inductance ↑, size ↑, cost ↑
Rectifying Diode	Fast recovery type, cost ↓	Requires a faster recovery type, cost ↑
Switching Transistor	Allowable power ↑, size ↑, cost ↑	Allowable power ↓, size ↓, cost ↓
Efficiency	Switching loss ↓, efficiency ↑	Switching loss ↑, efficiency ↓

TABLE 1: Comparison of Continuous And Discontinuous Mode

2.1.2. Boost Converter:

The main working principle of boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures a constant output voltage $V_o(t) = V_o(\text{constant})$.

When the switch is in the ON position, the inductor output is connected to ground and the voltage V_{in} is placed across it. The inductor current increases at a rate equal to V_{in}/L .

When the switch is placed in the OFF position, the voltage across the inductor changes and is equal to $V_{out}-V_{in}$. Current that was flowing in the inductor decays at a rate equal to $(V_{out}-V_{in})/L$.

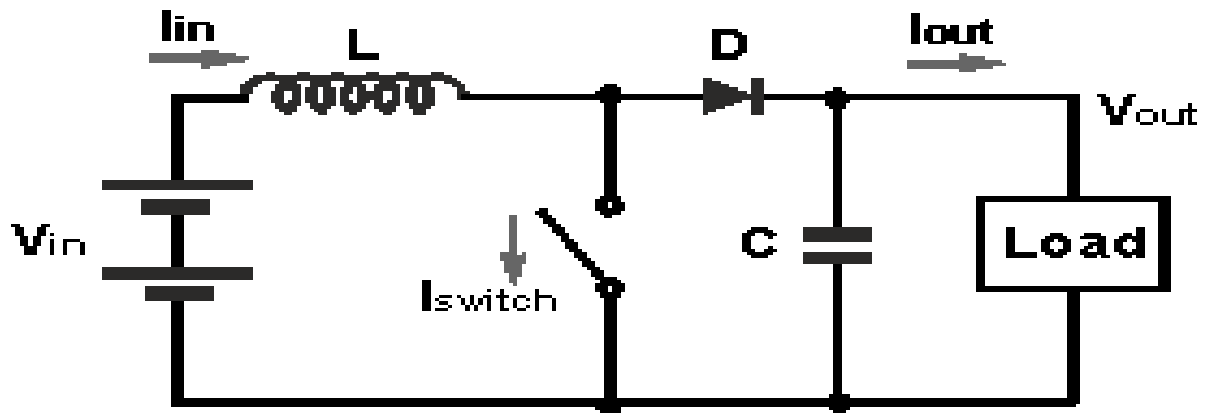


Figure 10. Boost Converter Circuit

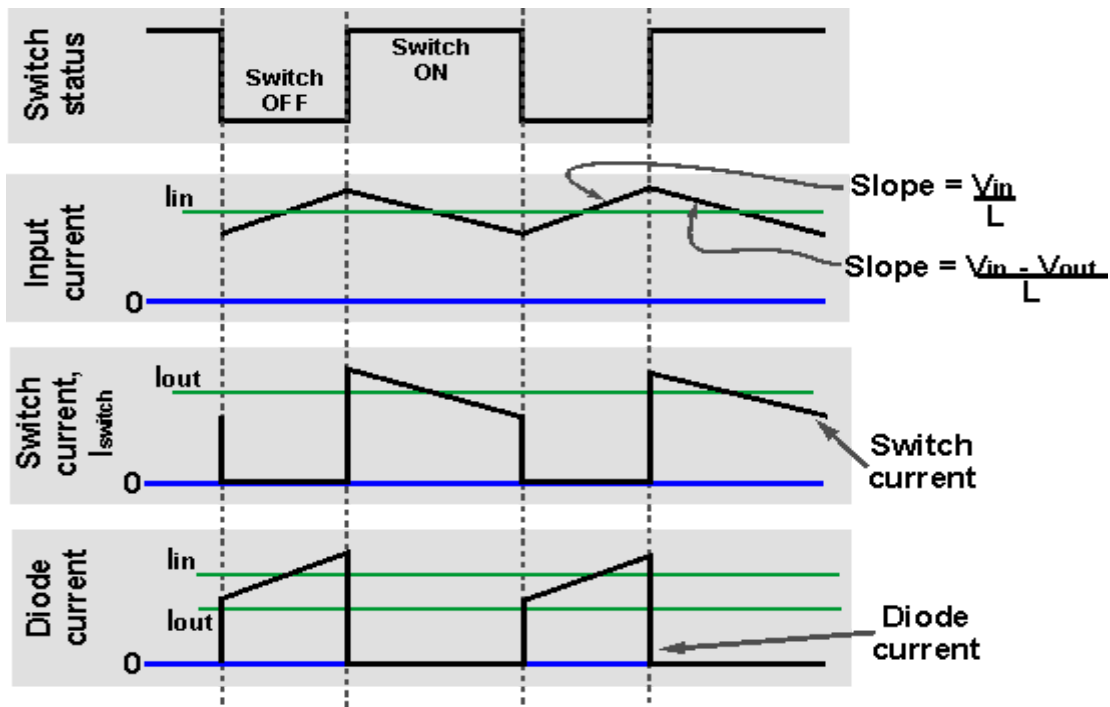


Figure 11. Switch Status, Input Current, Diode Current

It can be seen from the waveform diagrams that the input current to the boost converter is higher than the output current. Assuming a perfectly efficient, i.e. lossless, boost converter, the power out must equal the power in, i.e. $V_{in} \cdot I_{in} = V_{out} \cdot I_{out}$. From this it can be seen if the output voltage is higher than the input voltage, then the input current must be higher than the output current.

Modes of operation of Boost converter

The boost converter can be operated in two modes

- a) **Continuous conduction mode** in which the current through inductor never goes to zero i.e. inductor partially discharges before the start of the switching cycle.
- b) **Discontinuous conduction mode** in which the current through inductor goes to zero i.e. inductor is completely discharged at the end of switch.

Continuous conduction mode

case-1: When switch S is ON

When switch is ON the diode will be open circuited since the n side of diode is at higher voltage compared to p side which is shorted to ground through the switch. During this state the inductor charges and the inductor current increases. The current through the inductor is given as

$$I_L = (1/L) * \int V * dt$$

case 2: When switch is off

When switch is OFF the diode will be short circuited and the boost converter circuit can be redrawn as follows

The inductor now discharges through the diode and RC combination. Assume that prior to the closing of switch the inductor current is $I''_{L,off}$. The current through the inductor is given as

$$I'''_{L,off} = -(1/L) * \int (V_{in} - V_{out}) * dt + I''_{L,off}$$

Discontinuous conduction mode

The inductor in discontinuous mode drains all the current which it piled up in charging interval of same switching cycle. The current through the inductor is given as

$$I_L = (1/L) \int V_L * dt = (1/L) * \text{area under the curve of voltage v/s time.}$$

Applications of Boost converter

- They are used in regulated DC power supplies.
- They are used in regenerative braking of DC motor.
- Low power boost converters are used in portable device applications
- As switching regulator circuit in highly efficient white LED drives
- Boost converters are used in battery powered applications where there is space constraint to stack more number of batteries in series to achieve higher voltages.

2.1.3. Buck-Boost Converter

Buck – boost converter is “a DC to DC converter which either steps up or steps down the input voltage level”. The step up or step down of input voltage level depends on the duty ratio. Duty ratio or duty cycle is the ratio of output voltage to the input voltage in the circuit. Buck – bust converter provides regulated DC output.

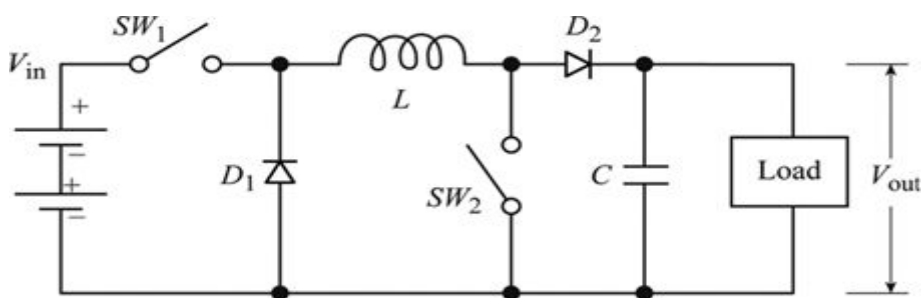


Figure 1

Figure 12: Circuit of BUCK-BOOST CONVERTER

When it is in buck mode, the output voltage obtained is less than input applied voltage. In this mode, the output current is more than input current. However, the output power is equal to the input power.

When it is in boost mode, the output voltage obtained is more than the input applied voltage. In this mode, the output current is less than input current. However, the output power is equal to the input power.

To operate the buck – boost converter, the two switches will operate simultaneously. When switches are closed, inductor stores energy in a magnetic field. When switches are open, the inductors get discharged and give the supply to the load. The inductors in the circuit do not allow sudden variations in the current. The capacitor across the load provides a regulated DC output.

There are several formats that can be used for buck-boost converters:

+ V_{in} , - V_{out} : This configuration of a buck-boost converter circuit uses the same number of components as the simple buck or boost converters. However this buck-boost regulator or DC-DC converter produces a negative output for a positive input. While this may be required or can be accommodated for a limited number of applications, it is not normally the most convenient format.

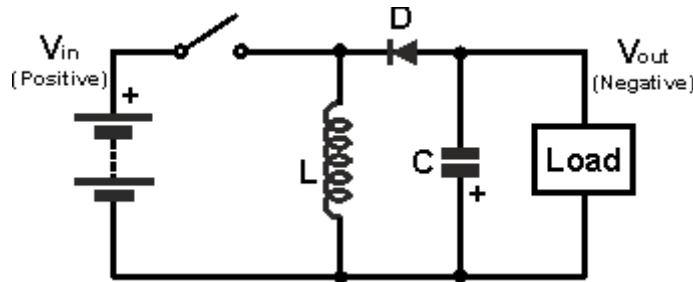


Figure 13: SW 1 is Open

When the switch is closed, current builds up through the inductor. When the switch is opened the inductor supplies current through the diode to the load.

+ V_{in} , + V_{out} : The second buck-boost converter circuit allows both input and output to be the same polarity. However to achieve this, more components are required. The circuit for this buck boost converter is shown below.

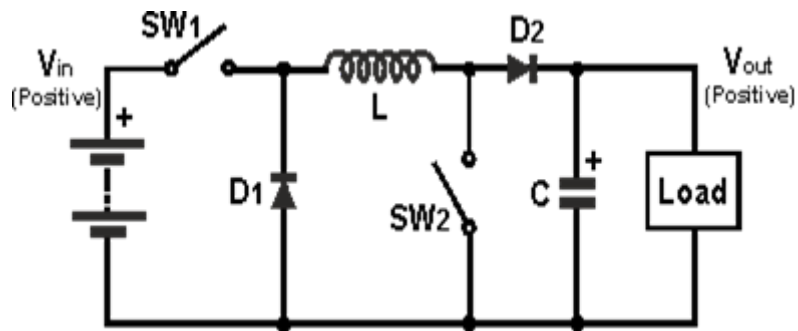


Figure 14: SW 1 & SW 2 both Open

In this circuit, both switches act together, i.e. both are closed or open. When the switches are open, the inductor current builds. At a suitable point, the switches are opened. The inductor then supplies current to the load through a path incorporating both diode.

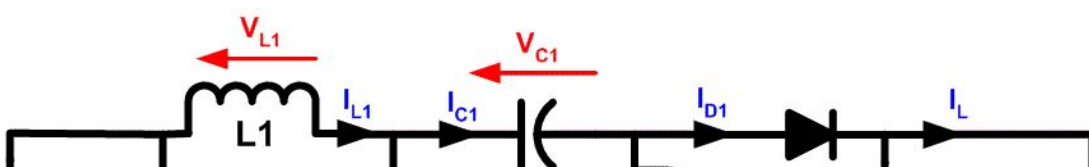
2.1.4 SEPIC CONVERTER:

The single-ended primary-inductor converter (SEPIC) is a type of DC/DC converter that allows 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 (S1).

A SEPIC is essentially a boost converter followed by an inverted 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 S1 is turned off enough, the output (V0) 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.



Circuit operation

The schematic diagram for a basic SEPIC is shown in Figure 1. As with other switched mode power supplies (specifically DC-to-DC converters), the SEPIC exchanges energy between the capacitors and inductors in order to convert from one voltage to another. The amount of energy exchanged is controlled by switch S1, which is typically a transistor such as a MOSFET. MOSFETs offer much higher input impedance and lower voltage drop than bipolar junction transistors (BJTs), and do not require biasing resistors as MOSFET switching is controlled by differences in voltage rather than a current, as with BJTs.

Continuous mode

A SEPIC is said to be in continuous-conduction mode ("continuous mode") if the current through the inductor L1 never falls to zero. During a SEPIC's steady-state operation, the average voltage across capacitor C1 (V_{C1}) is equal to the input voltage (V_{in}). Because capacitor C1 blocks direct current (DC), the average current through it (I_{C1}) is zero, making inductor L2 the only source of DC load current. Therefore, the average current through inductor L2 (I_{L2}) is the same as the average load current and hence independent of the input voltage.

Looking at average voltages, the following can be written:

$$V_{IN} = V_{L1} + V_{C1} + V_{L2}$$

Because the average voltage of V_{C1} is equal to V_{IN} , $V_{L1} = -V_{L2}$. For this reason, the two inductors can be wound on the same core. Since the voltages are the same in magnitude, their effects of the mutual inductance will be zero, assuming the polarity of the windings is correct. Also, since the voltages are the same in magnitude, the ripple currents from the two inductors will be equal in magnitude.

The average currents can be summed as follows (average capacitor currents must be zero): $I_{D1} = I_{L1} - I_{L2}$

When switch S1 is turned on, current I_{L1} increases and the current I_{L2} goes more negative. (Mathematically, it decreases due to arrow direction.) The energy to increase the current I_{L1} comes from the input source. Since S1 is a short while closed, and the instantaneous voltage V_{L1} is approximately V_{IN} , the voltage V_{L2} is approximately $-V_{C1}$. Therefore, D1 is opened and the capacitor C1 supplies the energy to increase the magnitude of the current in I_{L2} and thus increase the energy stored in L2. I_L is supplied by C2. The easiest way to visualize this is to consider the bias voltages of the circuit in a d.c. state, then close S1.

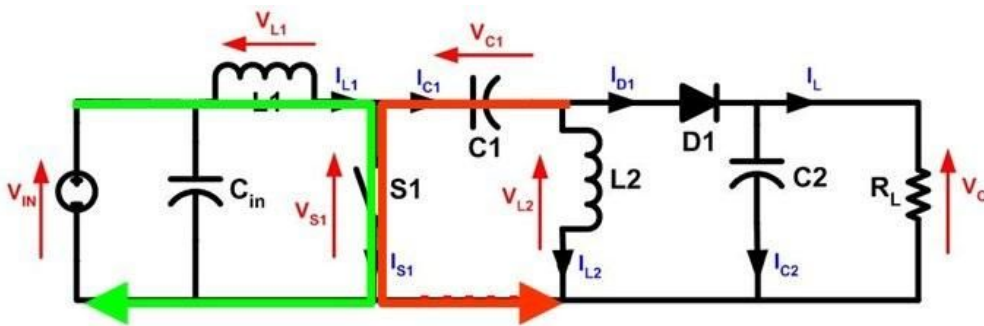


Figure 2: With S1 closed current increases through L1 (green) and C1 discharges increasing current in L2 (red)

When switch S1 is turned off, the current I_{C1} becomes the same as the current I_{L1} , since inductors do not allow instantaneous changes in current. The current I_{L2} will continue in the negative direction, in fact it never reverses direction. It can be seen from the diagram that a negative I_{L2} will add to the current I_{L1} to increase the current delivered to the load. Using Kirchhoff's Current Law, it can be shown that $I_{D1} = I_{C1} - I_{L2}$. It can then be concluded, that while S1 is off, power is delivered to the load from both L2 and L1. C1, however is being charged by L1 during this off cycle (as C2 by L1 and L2), and will in turn recharge L2 during the following on cycle.

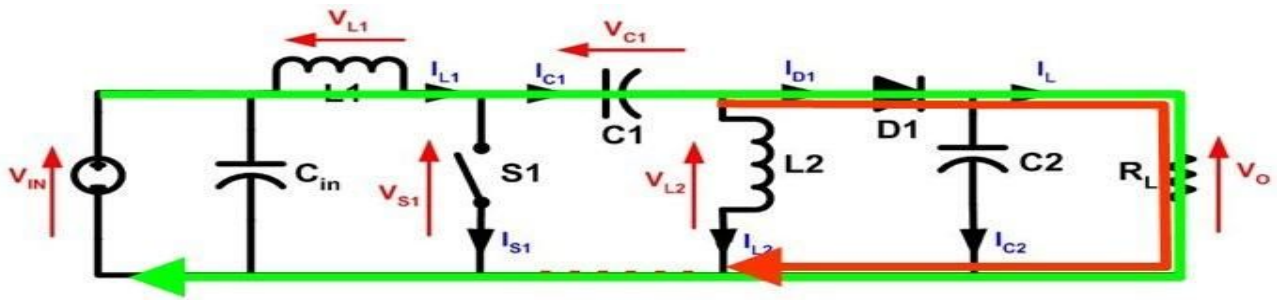


Figure 3: With S1 open current through L1 (green) and current through L2 (red) produce current through the load

Because the potential (voltage) across capacitor C1 may reverse direction every cycle, a non-polarized capacitor should be used. However, a polarized tantalum or electrolytic capacitor may be used in some cases,[2] because the potential (voltage) across capacitor C1 will not change unless the switch is closed long enough for a half cycle of resonance with inductor L2, and by this time the current in inductor L1 could be quite large.

The capacitor C_{IN} is required to reduce the effects of the parasitic inductance and internal resistance of the power supply. The boost/buck capabilities of the SEPIC are possible because of capacitor C1 and inductor L2. Inductor L1 and switch S1 create a standard boost converter, which generates a voltage (V_{S1}) that is higher than V_{IN}, whose magnitude is determined by the duty cycle of the switch S1. Since the average voltage across C1 is V_{IN}, the output voltage (V_O) is V_{S1} - V_{IN}. If V_{S1} is less than double V_{IN}, then the output voltage will be less than the input voltage. If V_{S1} is greater than double V_{IN}, then the output voltage will be greater than the input voltage.

The evolution of switched-power supplies can be seen by coupling the two inductors in a SEPIC converter together, which begins to resemble a Flyback converter, the most basic of the transformer-isolated SMPS topologies.

Discontinuous mode

A SEPIC is said to be in discontinuous-conduction mode or discontinuous mode if the current through the inductor L2 is allowed to fall to zero.

Reliability and efficiency

The voltage drop and switching time of diode D1 is critical to a SEPIC's reliability and efficiency. The diode's switching time needs to be extremely fast in order to not generate high voltage spikes across the inductors, which could cause damage to components. Fast conventional diodes or Schottky diodes may be used.

The resistances in the inductors and the capacitors can also have large effects on the converter efficiency and output ripple. Inductors with lower series resistance allow less energy to be dissipated as heat, resulting in greater efficiency (a larger portion of the input power being transferred to the load). Capacitors with low equivalent series resistance (ESR) should also be used for C1 and C2 to minimize ripple and prevent heat build-up, especially in C1 where the current is changing direction frequently.

Disadvantages

Like the buck–boost converter, the SEPIC has a pulsating output current. The similar Ćuk converter does not have this disadvantage, but it can only have negative output polarity, unless the isolated Ćuk converter is used.

Since the SEPIC converter transfers all its energy via the series capacitor, a capacitor with high capacitance and current handling capability is required.

The fourth-order nature of the converter also makes the SEPIC converter difficult to control, making it only suitable for very slow varying applications.

CUK CONVERTER:

The Ćuk converter (pronounced *chook*; sometimes incorrectly spelled Cuk, Ćuk 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.

Similar to the buck–boost converter with inverting topology, the output voltage of non-isolated Ćuk is typically also inverting, and can be lower or higher than the input. 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.

Operating principle

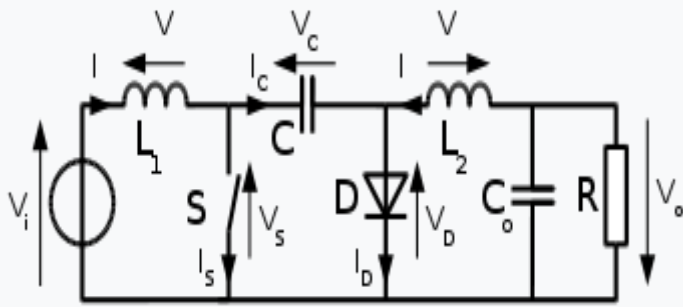
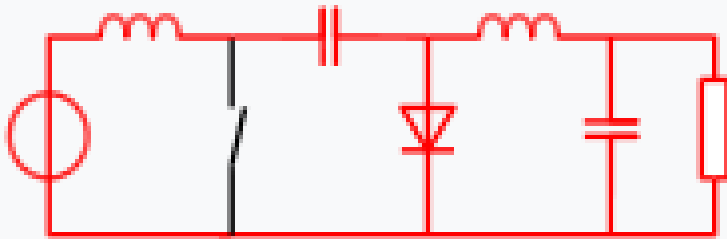


Fig 1: Schematic of a non-isolated Ćuk converter.

ate



ate

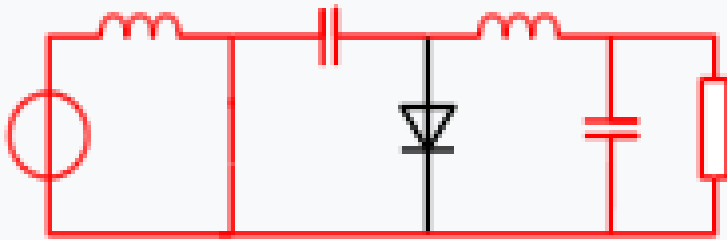


Fig 2: The two operating states of a non-isolated Ćuk converter.

State

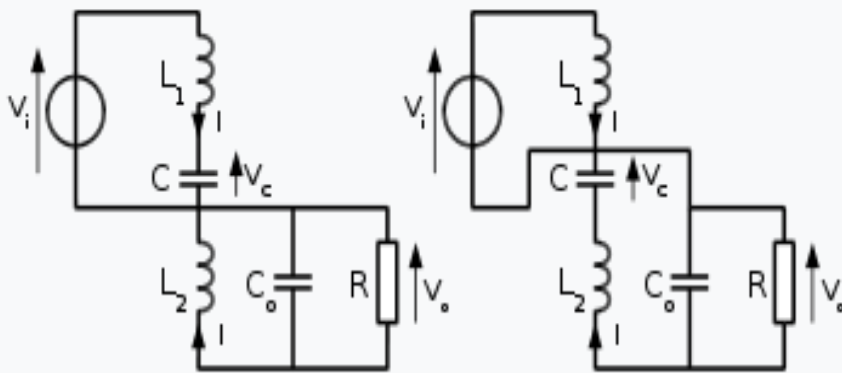


Fig 3: The two operating states of a non-isolated Ćuk converter. In this figure, the diode and the switch are either replaced by a short circuit when they are on or by an open circuit when they are off. It can be seen that when in the off-state, the capacitor C is being charged by the input source through the inductor L_1 . When in the on-state, the capacitor C transfers the energy to the output capacitor through the inductance L_2 .

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 1. 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 (see figures 2 and 3).

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 these converters, it can also operate in *discontinuous voltage mode* (the voltage across the capacitor drops to zero during the commutation cycle).

Continuous mode

In steady state, the energy stored in the inductors has to remain the same at the beginning and at the end of a commutation cycle. The energy in an inductor is given by:

This implies that the current through the inductors has to be the same at the beginning and the end of the commutation cycle. As the evolution of the current through an inductor is related to the voltage across it:

it can be seen that the average value of the inductor voltages over a commutation period have to be zero to satisfy the steady-state requirements.

If we consider that the capacitors C and C_o are large enough for the voltage ripple across them to be negligible, the inductor voltages become:

- in the off-state, inductor L_1 is connected in series with V_i and C (see figure 2). Therefore . As the diode D is forward biased (we consider zero voltage drop), L_2 is directly connected to the output capacitor. Therefore
- in the on-state, inductor L_1 is directly connected to the input source. Therefore ,Inductor L_2 is connected in series with C and the output capacitor, so

The converter operates in on state from $t=0$ to $t=D \cdot T$ (D is the duty cycle), and in off state from $D \cdot T$ to T (that is, during a period equal to $(1-D) \cdot T$). The average values of V_{L1} and V_{L2} are therefore:

$$V_{L1} = DV_i = (1-D) \cdot (V_i - V_c) = (V_i - (1-D) \cdot V_c)$$

$$V_{L2} = D(V_o + V_c) + (1-D) \cdot V_o = (V_o + D \cdot V_c)$$

As both average voltage have to be zero to satisfy the steady-state conditions, using the last equation we can write:

$$V_c = -V_o/D$$

So the average voltage across L_1 becomes:

$$V_{L1} = (V_i + (1-D) \cdot V_o/D) = 0$$

Which can be written as:

$$V_o/V_i = -D/(1-D)$$

It can be seen that this relation is the same as that obtained for the buck–boost converter.

Discontinuous mode

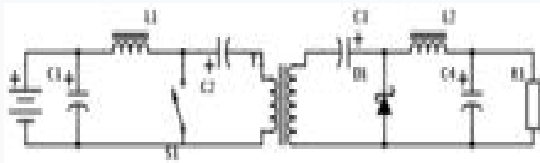
Like all DC/DC converters Ćuk converters rely on the ability of the inductors in the circuit to provide continuous current, in much the same way a capacitor in a rectifier filter provides continuous voltage. If this inductor is too small or below the "critical inductance", then the inductor current slope will be discontinuous where the current goes to zero. This state of operation is usually not studied in much depth as it is generally not used beyond a demonstrating of why the minimum inductance is crucial, although it may occur when maintaining a standby voltage at a much lower current than the converter was designed for.

The minimum inductance is given by:

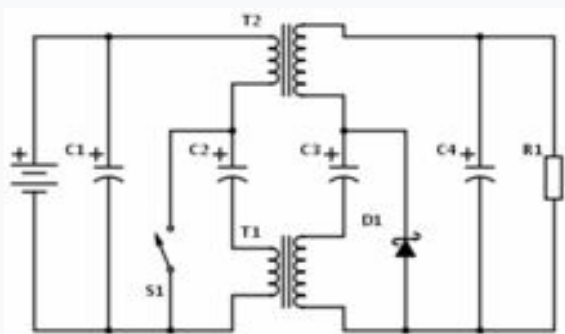
$$L_{1min} = (1-D)^2 \cdot R / 2Df_s$$

Where f_s is the switching frequency.

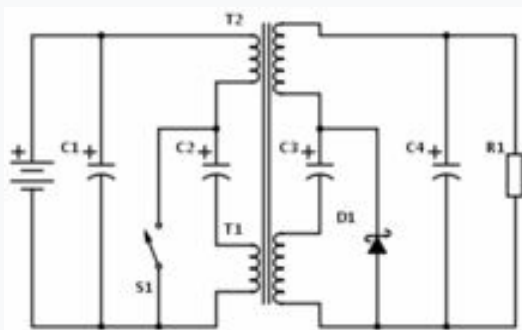
Isolated Ćuk converter



Isolated Ćuk converter with gapless AC transformer in the middle



Coupled inductor isolated Ćuk converter



Integrated magnetics Ćuk converter

The Ćuk converter can be made in an isolated kind. An AC transformer and an additional capacitor must be added.

Because the isolated Ćuk converter is isolated, the output-voltage polarity can be chosen freely.

As the non-isolated Ćuk converter, the isolated Ćuk converter can have an output voltage magnitude that is either greater than or less than the input voltage magnitude, even with a 1:1 AC transformer.

Related structures

Inductor coupling

Instead of using two discrete inductor components, many designers implement a *coupled inductor Ćuk converter*, using a single magnetic component that includes both inductors on the same core. The transformer action between the inductors inside that component gives a *coupled inductor Ćuk converter* with lower output ripple than a Ćuk converter using two independent discrete inductor components.

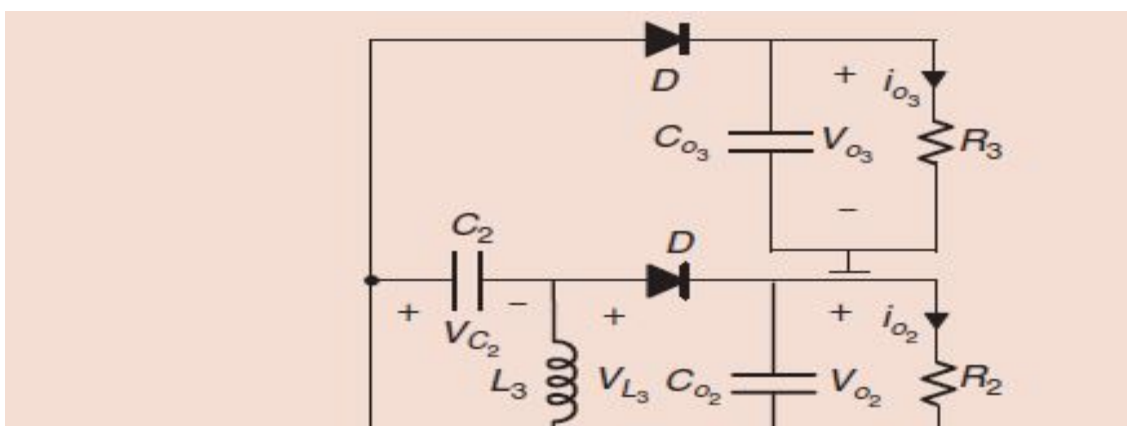
Zeta Converter

A zeta converter provides an output voltage that is the opposite of the output voltage of a Ćuk converter.

SEPIC-Cuk-Boost-CSC Combination Converter

A SEPIC-Cuk-boost-CSC combination converter (SECuBoCSCCC) is obtained from the combination of the converters shown in Figure 1(b), (d), (e), and (g). This is a four-output converter topology. The combined converter provides a dc bipolar voltage, a third output with higher magnitude, and a fourth output with negative and floating voltage. Finally, this methodology can also obtain a five-output and a six-output

single-switch combination converter. Figure 4 shows a six-output single-switch combination converter. Furthermore, these topologies allow the obtaining of other voltage levels connecting in a series of two or more outputs.



CHAPTER 3

COMPONENT DESCRIPTION

3.1 Resistor:

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors that can dissipate many watts of electrical power as heat, may be used as part of motor controls, in power distribution systems, or as test loads for generators. Fixed resistors have resistances that only change slightly with temperature, time or operating voltage. Variable resistors can be used to adjust circuit elements (such as a volume control or a lamp dimmer), or as sensing devices for heat, light, humidity, force, or chemical activity.



Resistors



symbol of resistor

3.2: Inductor:

An inductor, also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it.[1] An inductor typically consists of an insulated wire wound into a coil around a core.

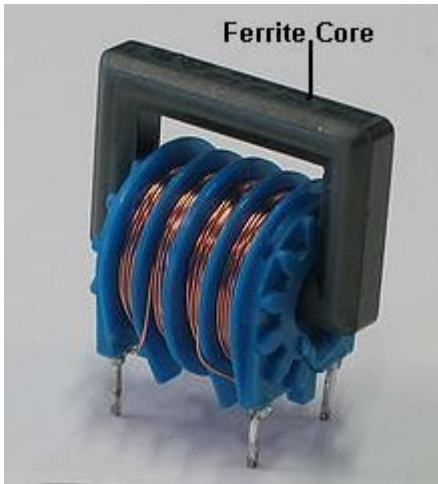
When the current flowing through an inductor changes, the time-varying magnetic field induces an electromotive force (e.m.f.) (voltage) in the conductor, described by Faraday's law of induction. According to Lenz's law, the induced voltage has a polarity (direction) which opposes the change in current that created it. As a result, inductors oppose any changes in current through them.



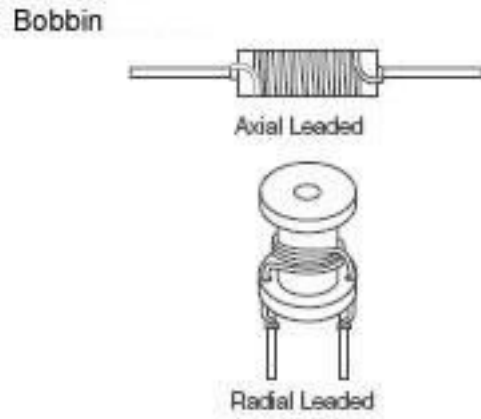
Inductor

Inductor types based on core

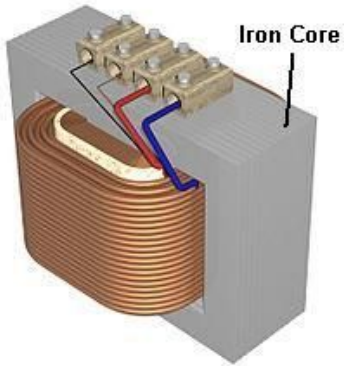
1. Air Core Inductor
 2. Iron Core Inductor
 3. Ferrite Core Inductor
 - 3.1. Soft Ferrite
 - 3.2. Hard Ferrite
 4. Iron Powder Inductor
 5. Laminated Core Inductor
 6. Bobbin based inductor
 7. Toroidal Inductor
 8. Multi-layer Ceramic Inductors
 9. Film Inductor
 10. Variable Inductor
 11. Coupled Inductors
-



(a)



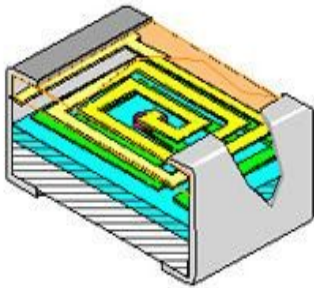
(b)



(c)



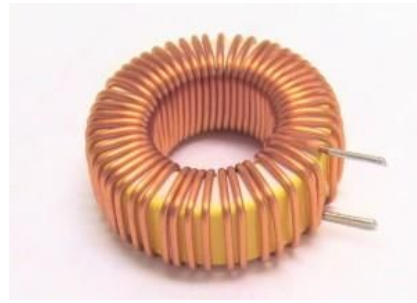
(d)



(e)



(f)



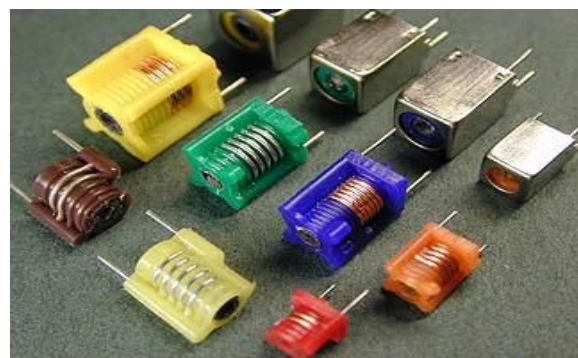
(g)



(h)



(i)



(j)

Fig: ferrite core inductor(a), two bobbin inductor(b), iron core inductor(c), ceramic type(d), film type(e), air core type(f), toroidal type(g), iron powder type(h), variable inductor(i), molded inductor(j)

CAPACITOR:

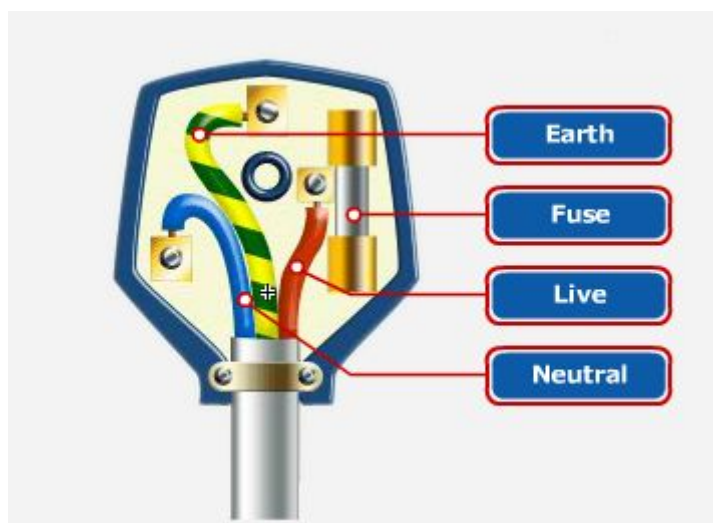
A capacitor is a passive two-terminal electronic component that stores electrical energy in an electric field. The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit. The capacitor was originally known as a

condenser or condensator. The original name is still widely used in many languages, but not commonly in English.



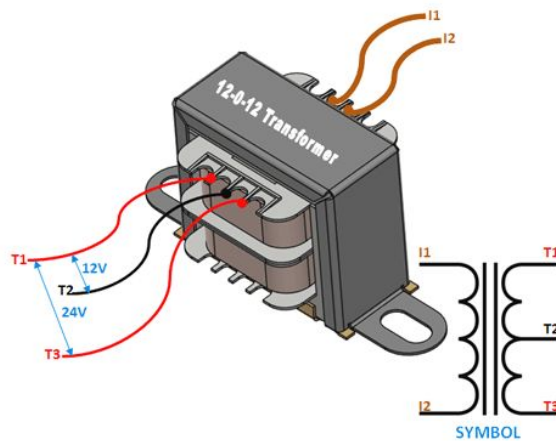
3 Pin Plug:

A 3-pin plug consists of three pins (hence the name). It is important to know how to wire a 3-pin plug correctly. The 3-pin plugs are designed so that electricity can be supplied to electrical appliances safely. It can be fitted into local 3-pin socket with plastic adapter.



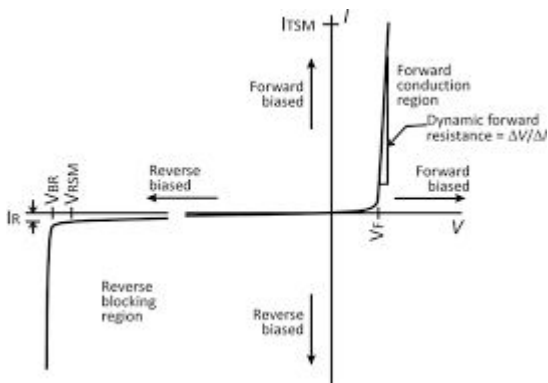
Centre Tap Transformer:

A centre-tapped transformer also known as two phase three wire transformer is normally used for rectifier circuits. When a digital project has to work with AC mains a Transformer is used to step-down the voltage (in our case, to 24V or 12V) and then convert it to DC by using a rectifier circuit. In a center-tapped transformer the peak inverse voltage is twice as in bridge rectifier hence this transformer is commonly used in full wave rectifier circuits.



Diode:

A diode is a two-terminal electronic component that conducts current primarily in one direction (asymmetric conductance); it has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other. A diode vacuum tube or thermionic diode is a vacuum tube with two electrodes, a heated cathode and a plate, in which electrons can flow in only one direction, from cathode to plate. A semiconductor diode, the most common type today, is a crystalline piece of semiconductor material with a p-n junction connected to two electrical terminals. Semiconductor diodes were the first semiconductor electronic devices.



Ic 78XX series:

There are common configurations for 78xx ICs, including 7805 (5 V), 7806 (6 V), 7808 (8 V), 7809 (9 V), 7810 (10 V), 7812 (12 V), 7815 (15 V), 7818 (18 V), and 7824 (24 V) versions. The 7805 is the most common, as its regulated 5-volt supply provides a convenient power source for most TTL components. Less common are lower-power versions such as the LM78Mxx series (500 mA) and LM78Lxx series (100 mA) from National Semiconductor.

7812

+12V 1A Three-Terminal Positive Voltage Regulator

TO-220 Case Style

Pin 1. Input

2. Ground

3. Output

LED:

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the

form of photons. This effect is called electroluminescence. The color of the light (corresponding to the energy of the photons) is determined by the energy required for electrons to cross the band gap of the semiconductor. White light is obtained by using multiple semiconductors or a layer of light-emitting phosphor on the semiconductor device.



MOSFET:

The metal–oxide–semiconductor field-effect transistor (MOSFET, MOS-FET, or MOS FET) is a type of field-effect transistor (FET), most commonly fabricated by the controlled oxidation of silicon. It has an insulated gate, whose voltage determines the conductivity of the device. This ability to change conductivity with the amount of applied voltage can be used for amplifying or switching electronic signals. A metal-insulator-semiconductor field-effect transistor or MOSFET is a term almost synonymous with MOSFET. Another synonym is IGFET for insulated-gate field-effect transistor.

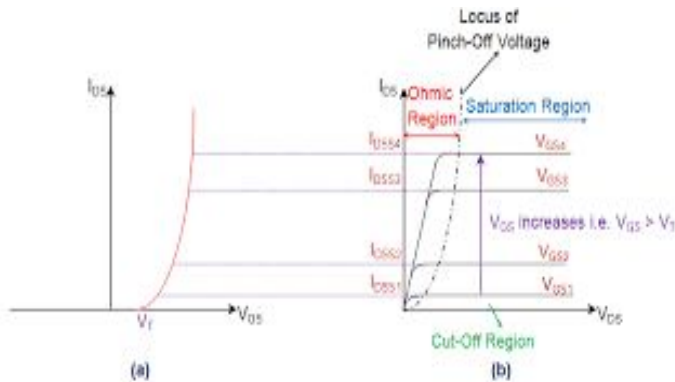
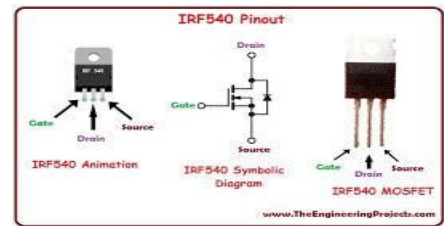
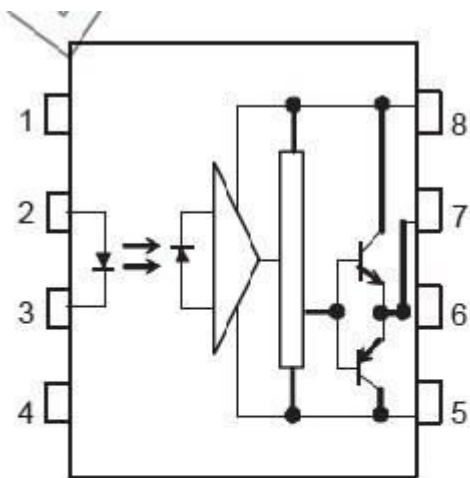


Figure 1 n-Channel Enhancement type MOSFET (a) Transfer Characteristics (b) Output Characteristics

TLP250:

The TOSHIBA TLP250 consists of a GaAlAs light emitting diode and a integrated photodetector. This unit is 8-lead DIP package. TLP250 is suitable for gate driving circuit of IGBT or power MOS FET.

schematic:



- | | |
|------------|----------------------------|
| 1: N.C. | 5: GND |
| 2: Anode | 6: V _O (Output) |
| 3: Cathode | 7: V _O |
| 4: N.C. | 8: V _{CC} |

Pin configuration:

Pin no	Function	Pin no	Function
1	No connection	5	Ground
2	Anode	6	Output
3	Cathode	7	Output(Shorted with pin 6)
4	No Connection	8	Supply Voltage

Pin number one and four is not connected to any point physically. Therefore they are not in use.

Pin number 8 is use to provide power supply to TLP250 and pin number 5 is ground pin which provides return path to power supply ground. Maximum power supply voltage between 15-30 volt dc can be given to TLP250. But it also depends on temperature of environment in which you are using TLP250.

Pin number 2 and 3 are anode and cathode points of input stage LED. It works like a normal light emitting diode. It has similar characteristics of forward voltage and input current. Maximum input current is in the range of 7-10mA and forward voltage drop is about 0.8 volt. TLP250 provides output from low to high with minimum threshold current of 1.2mA and above.

Pin number six and seven is internally connected to each other. Ouput can be taken from either pin number 6 and 7. Totem pole configuration of two transistor is used in TLP250. In case of high input , output becomes high with output voltage equal to supply voltage and in case of low input, output become low with output voltage level equal to ground.

Mosfet driver TLP250 can be used up to 25khz frequency due to slow propagation delay.

Truth Table

		Tr1	Tr2
Input LED	On	On	Off
	Off	Off	On

DSPIC MICROCONTROLLER:

MCLR	1	40	AVDD
EMUD3/AN0/VREF+/CN2/RB0	2	39	AVSS
EMUC3/AN1/VREF-/CN3/RB1	3	38	PWM1L/RE0
AN2/SS1/CN4/RB2	4	37	PWM1H/RE1
AN3/INDX/CN5/RB3	5	36	PWM2L/RE2
AN4/QEA/IC7/CN6/RB4	6	35	PWM2H/RE3
AN5/QEB/IC8/CN7/RB5	7	34	PWM3L/RE4
AN6/OCFA/RB6	8	33	PWM3H/RE5
AN7/RB7	9	32	VDD
AN8/RB8	10	31	VSS
VDD	11	30	C1RX/RF0
VSS	12	29	C1TX/RF1
OSC1/CLKIN	13	28	U2RX/CN17/RF4
OSC2/CLKO/RC15	14	27	U2TX/CN18/RF5
EMUD1/SOSCI/T2CK/U1ATX/CN1/RC13	15	26	PGC/EMUC/U1RX/SDI1/SDA/RF2
EMUC1/SOSCO/T1CK/U1ARX/CN0/RC14	16	25	PGD/EMUD/U1TX/SDO1/SCL/RF3
FLTA/INT0/RE8	17	24	SCK1/RF6
EMUD2/OC2/IC2/INT2/RD1	18	23	EMUC2/OC1/IC1/INT1/RD0
OC4/RD3	19	22	OC3/RD2
VCC	20	21	VDD

dsPIC30F4011

High Performance Modified RISC CPU:

- Modified Harvard architecture
- C compiler optimized instruction set architecture with flexible addressing modes
- 84 base instructions
- 24-bit wide instructions, 16-bit wide data path
- 48 Kbytes on-chip Flash program space (16K Instruction words)
- 2 Kbytes of on-chip data RAM
- 1 Kbytes of non-volatile data EEPROM
- Up to 30 MIPS operation:
 - DC to 40 MHz external clock input
 - 4 MHz-10 MHz oscillator input with PLL active (4x, 8x, 16x)
- 30 interrupt sources
 - 3 external interrupt sources
 - 8 user selectable priority levels for each interrupt source
 - 4 processor trap sources
- 16 x 16-bit working register array

DSP Engine Features:

- Dual data fetch
- Accumulator write back for DSP operations
- Modulo and Bit-Reversed Addressing modes
- Two, 40-bit wide accumulators with optional saturation logic
- 17-bit x 17-bit single cycle hardware fractional/integer multiplier
- All DSP instructions single cycle
- \pm 16-bit single cycle shift

Peripheral Features:

- High current sink/source I/O pins: 25 mA/25 mA
- Timer module with programmable prescaler:
 - Five 16-bit timers/counters; optionally pair 16-bit timers into 32-bit timer modules
- 16-bit Capture input functions
- 16-bit Compare/PWM output functions
- 3-wire SPI™ modules (supports 4 Frame modes)
- I2C™ module supports Multi-Master/Slave mode and 7-bit/10-bit addressing
- 2 UART modules with FIFO Buffers
- 1 CAN modules, 2.0B compliant

Motor Control PWM Module Features:

- 6 PWM output channels
 - Complementary or Independent Output modes
 - Edge and Center Aligned modes
-

- 3 duty cycle generators
- Dedicated time base
- Programmable output polarity
- Dead-time control for Complementary mode
- Manual output control
- Trigger for A/D conversions

Quadrature Encoder Interface Module Features:

- Phase A, Phase B and Index Pulse input
 - 16-bit up/down position counter
 - Count direction status
 - Position Measurement (x2 and x4) mode
 - Programmable digital noise filters on inputs
 - Alternate 16-bit Timer/Counter mode
 - Interrupt on position counter rollover/underflow
-

CHAPTER 4

INDUCTOR DESIGN

The design of an ac inductor is quite similar to that of a transformer. If there is no dc flux in the core, the design calculations are straightforward. The apparent power, P_t , of an inductor is the VA of the inductor; that is, the product of the excitation voltage and the current through the inductor.

The design of the ac inductor requires the calculation of the volt-amp (VA) capability. In some applications the inductance is specified, and in others, the current is specified. If the inductance is specified, then, the current has to be calculated. If the current is specified, then the inductance has to be calculated.

The design of a linear ac inductor depends upon five related factors:

1. Desired inductance
-

2. Applied voltage, (across inductor)

3. Frequency

4. Operating Flux density

5. Temperature Rise

Cores of Inductor:

An electric current through a wire wound into a coil creates a magnetic field through the center of the coil, due to Ampere's circuital law. Coils are widely used in electronic components such as electromagnets, inductors, transformers, electric motors and generators. A coil without a magnetic core is called an "air core" coil. Adding a piece of ferromagnetic or ferrimagnetic material in the center of the coil can increase the magnetic field by hundreds or thousands of times; this is called a magnetic core. The field of the wire penetrates the core material, magnetizing it, so that the strong magnetic field of the core adds to the field created by the wire. The amount that the magnetic field is increased by the core depends on the magnetic permeability of the core material. Because side effects such as eddy currents and hysteresis can cause frequency-dependent energy losses, different core materials are used for coils used at different frequencies.

The cores can be of different types. Some of them are:

1. Single "I" core

Like a cylindrical rod but square, rarely used on its own. This type of core is most likely to be found in car ignition coils.

2. "C" or "U" core

U and C-shaped cores are used with I or another C or U core to make a square closed core, the simplest closed core shape. Windings may be put on one or both legs of the core.

3. "E" core

E-shaped core are more symmetric solutions to form a closed magnetic system. Most of the time, the electric circuit is wound around the center leg, whose section area is twice that of each individual outer leg. In 3-phase transformer cores, the legs are of equal size, and all three legs are wound.

4. Pair of "E" cores

Again used for iron cores. Similar to using an "E" and "I" together, a pair of "E" cores will accommodate a larger coil former and can produce a larger inductor or transformer. If an air gap is

required, the centre leg of the "E" is shortened so that the air gap sits in the middle of the coil to minimize fringing and reduce electromagnetic interference.

5. Planar core

A planar core consists of two flat pieces of magnetic material, one above and one below the coil. It is typically used with a flat coil that is part of a printed circuit board. This design is excellent for mass production and allows a high power, small volume transformer to be constructed for low cost. It is not as ideal as either a pot core or toroidal core [citation needed] but costs less to produce.

6. Pot Core

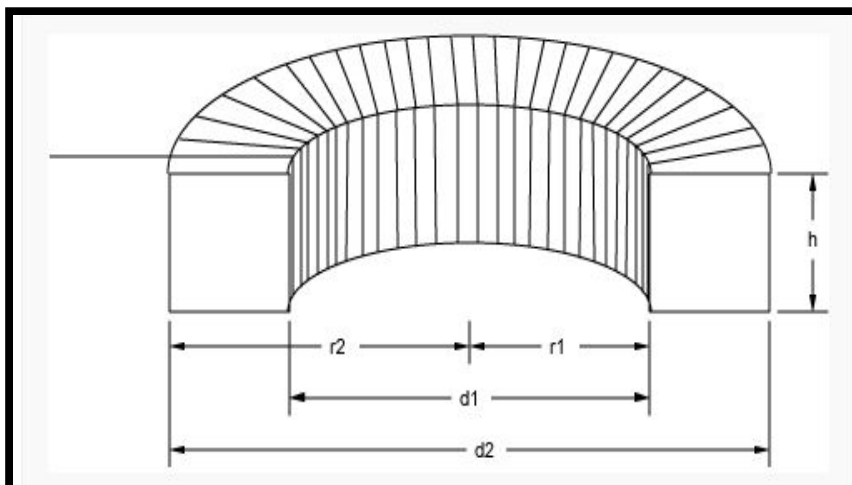
Usually ferrite or similar. This is used for inductors and transformers. The shape of a pot core is round with an internal hollow that almost completely encloses the coil. Usually a pot core is made in two halves which fit together around a coil former (bobbin). This design of core has a shielding effect, preventing radiation and reducing electromagnetic interference.

7. Ring or bead

The ring is essentially identical in shape and performance to the toroid, except that inductors commonly pass only through the center of the core, without wrapping around the core multiple times.

The ring core may also be composed of two separate C-shaped hemispheres secured together within a plastic shell, permitting it to be placed on finished cables with large connectors already installed, that would prevent threading the cable through the small inner diameter of a solid ring.

8. Toroidal Cores.

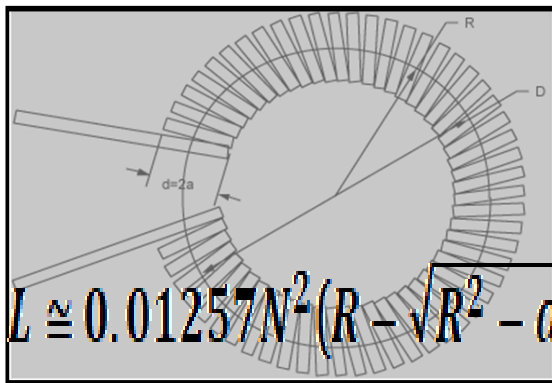


There are many different types of magnetic material used for fabricating inductors. The purpose of the material is to provide permeability greater than μ_0 so that the inductors can be made more compactly and with fewer turns of wire. This can reduce skin effect

losses in the wire and reduce coupling to other inductive components in the circuit, but the circuit losses then may be limited by the magnetic material itself. There are charts of typical unloaded Q's that can be obtained from various materials.

For this project we have used the toroidal cores for the designing of inductors .As it is easily available and due to its easy access and easy to turn the coils around it. Hence, toroidal cores are being used for the designing purpose in our project.

Wire size.Since our projects are all low power, smaller wire diameters are useful. Experience has shown that #26 enamel-coated wire works well for the small diameter toroidal inductors. It holds its



form and is easy to wind. You need to scrape the enamel paint off the ends in order to solder to it.

The inductance for such a Toroid can be calculated from the equation below :

$$L \cong 0.01257 N^2 (R - \sqrt{R^2 - a^2}) \mu H$$

Diagram of a Circular Cross Section Toroid Inductor

Another formula for the inductance of a Circular Cross Section Toroid is :

$$L \cong 0.007975 \frac{d^2 N^2}{D} \mu H$$

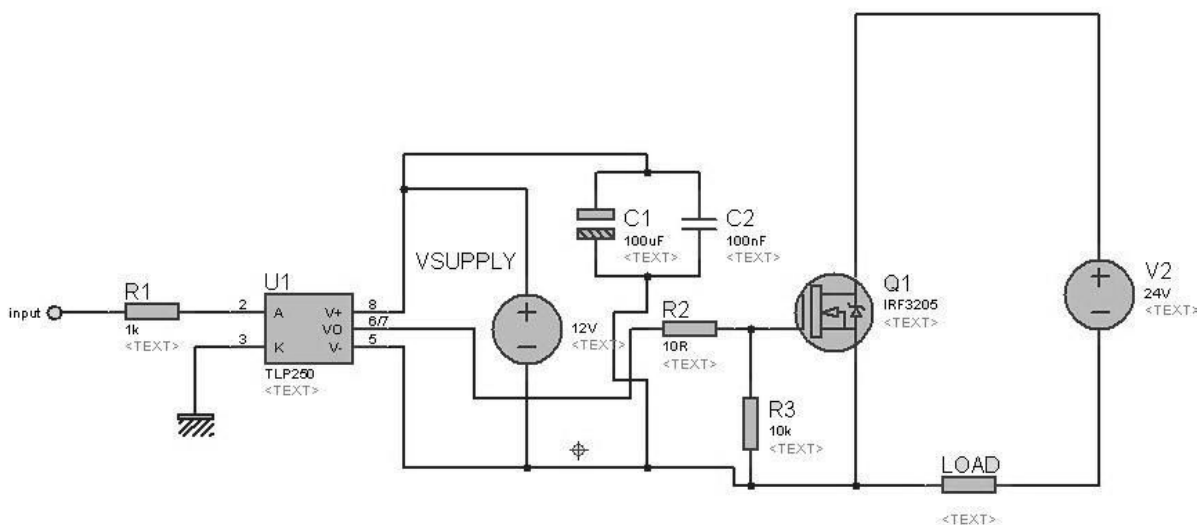
Chapter 5

TLP250 CIRCUIT OPERATION:

MOSFET driver is one of the main component of our circuits. MOSFET drivers are dedicated integrated circuits which are used to drive MOSFET in low side and high side configuration. In our project five number of MOSFETs (S1, S2, S3, S4, and S6) are operated as high side operation and two MOSFETs (S5 & S7) are operated as low side operation. TLP250 like other MOSFET drivers have input stage and output stage. The main difference between TLP250 and other MOSFET drivers is that TLP250 MOSFET driver is optically isolated. It means that input and output of TLP250 MOSFET driver is isolated from each other. Its works like an optocoupler. Input stage has a light emitting diode and output stage has a photo diode. Whenever input stage LED light falls on output stage photo detector

diode, output becomes high. MOSFET drivers are dedicated integrated circuits which are used to drive MOSFETs in low side and high side configuration.

According to our project we need seven TLP250 driver circuits for the seven MOSFETs of our main power circuit. The circuit shown in figure 25



TLP250 working Circuit

Snubber can do many things: -

1. Reduce or eliminate voltage or current spikes
2. Limit dI/dt or dV/dt
3. Shape the load line to keep it within the safe operating area (SOA)

4. Transfer power dissipation from the switch to a resistor or a useful load
5. Reduce total losses due to switching

POWER CIRCUIT:

This can be achieved in simple three steps:

1. Firstly, 220V AC is converted into 12V AC by using simple step-down (220V/12V) transformer.
2. Secondly, output of this transformer is given to the rectifier circuit, which will convert the ac supply into dc supply. The output of the rectifier circuit that is DC contains the ripples in the output voltage. To filter out these ripples, capacitor of 2200 uf, 25V is used.
3. Lastly, the output of the capacitor that is pure DC is given to voltage regulator IC 7812 and IC7912 which will regulate the output voltage at 12V and -12V DC, despite the change in input voltage.

Required Components:

1. Centre tapped transformer (220V/12V)
2. Power Diodes (6A) – 4No.
3. Capacitor (2200 μ F, 25V) – 2No.
4. Voltage regulator (IC 7812 & 7912)
5. Toggle switch
6. DC load (DC motor)

Step-I: Converting 220v AC into 12v AC using Step Down Transformer

The primary terminals of the centre tapped transformer is connected with household supply (220V ac, 50Hz) and output is taken from secondary terminals of the transformer. The centre tapped describes the voltage output of a center tapped transformer. For example: A 24V centre tapped transformer will measure 24V ac across the outer two taps (winding as a whole), and 12V ac from each outer tap to the center-tap (half winding). These two 12V ac supplies are 180 degrees out of phase with each other, thus making it easy to derive positive and negative 12 volt dc power supplies from them. The advantage of using a centre tapped transformer is we can get the both +12V and -12V dc supply using only one transformer.

Step – II: Converting 12v AC into 12v DC using Full Bridge Rectifier

The outer two terminals of the centre tapped transformer are connected to the bridge rectifier circuit. Rectifier circuit is a converter, which converts ac supply in to dc supply. It is generally made up of diode switches as shown in Circuit Diagram.

To convert ac into dc, we can make two types of rectifiers, one is half bridge rectifier and second is full bridge rectifier. In half bridge rectifier, output voltage is half of the input voltage. For example, if input voltage is 24V, then output dc voltage is 12V and number of diode used in this type of rectifier is 2. In full bridge rectifier, number of diodes is 4 and it is connected as shown in figure and output voltage is same as the input voltage.

Here, full bridge rectifier is used. So, number of diodes are 4 and input voltage (24V ac) and output voltage is also 24V dc with ripples in it.

For, full bridge rectifier output voltage,

$$V_{dc} = 2V_m / \Pi \text{ where, } V_m = \text{peak value of ac supply voltage and } \Pi \text{ is Pi}$$

Step-III: Filter the Ripples from the output:

Now, 24V dc output which contains peak to peak ripples can't be connected directly to the load. So, to remove ripples from the supply, filter capacitors are used. Now, two filter capacitor of rating 2200uF and 25 V are used as shown in circuit diagram. The connection of both capacitors are such that the common terminal of the capacitors is connected directly to the centre terminal of the centre tapped transformer. Now, this capacitor will get charged upto 12V dc as both are connected with the common terminal of a transformer. Furthermore, the capacitors will remove the ripples from the dc supply and give a pure dc output. But, the output of both the capacitors are not regulated. So, to make the supply regulated, output of the capacitors are given to the voltage regulator ICs which is explained in next step.

Step-IV: Regulate the 12v DC Power Supply

The next important thing is to regulate the output voltage of the capacitors which will otherwise be varying as per the input voltage change. For that depending upon the output voltage requirement, regulator ICs are used. If we need the output voltage +12V then IC 7812 is used. If required output voltage is +5V, then 7805 IC is used. Last two digits of the IC gives output voltage rating. Third last digit shows voltage is positive or negative. For positive voltage (8) and for negative voltage (9)

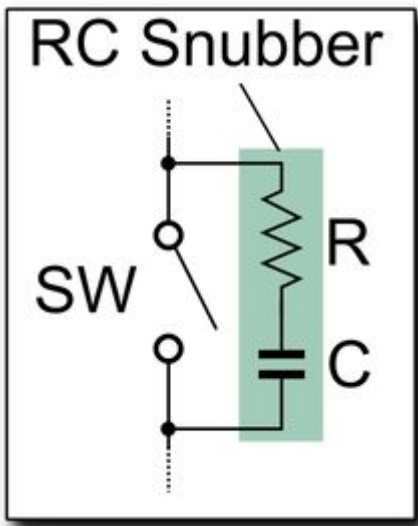
number is used. So IC7812 is used for +12v regulation and IC7912 is used for -12v voltage regulation.

Now connection of two ICs are done as shown in circuit diagram. The ground terminal of both ICs are connected with the centre tap terminal of the transformer in order to create a reference. Now, the output voltages are measured between the output terminal and ground terminal for both ICs.

RC SNUBBER DESIGN:

RC SNUBBERS (SMPS)

Snubbers are energy-absorbing circuits used to suppress the voltage spikes caused by the circuit's inductance when a switch, electrical or mechanical, opens. The most common snubber circuit is a capacitor and resistor connected in series across the switch (transistor).



The design procedure is as follows:

If you assume the source has negligible impedance, the worst-case peak current in the snubber circuit is --

$$I_{PK} = V_0/R_s$$

R_s = snubber resistance

V_0 = open circuit voltage

and the circuit dv/dt is determined from the following:

$$IP = C \, dv/dt \quad (2)$$

substituting (1) into (2)

$$dv/dt = V_0 C / R_s$$

The energy stored in the capacitor is : $E = 1/2 C(V_0)^2$

Ohm's Law says that the snubber resistance is equal to:

$$R = V_0/I$$

I = switching current

V_0 = open circuit voltage

The amount of energy the snubber resistance is to dissipate is the amount of energy stored in the snubber

capacitor. It is recommended that you choose a capacitance value that causes the resistor to dissipate one

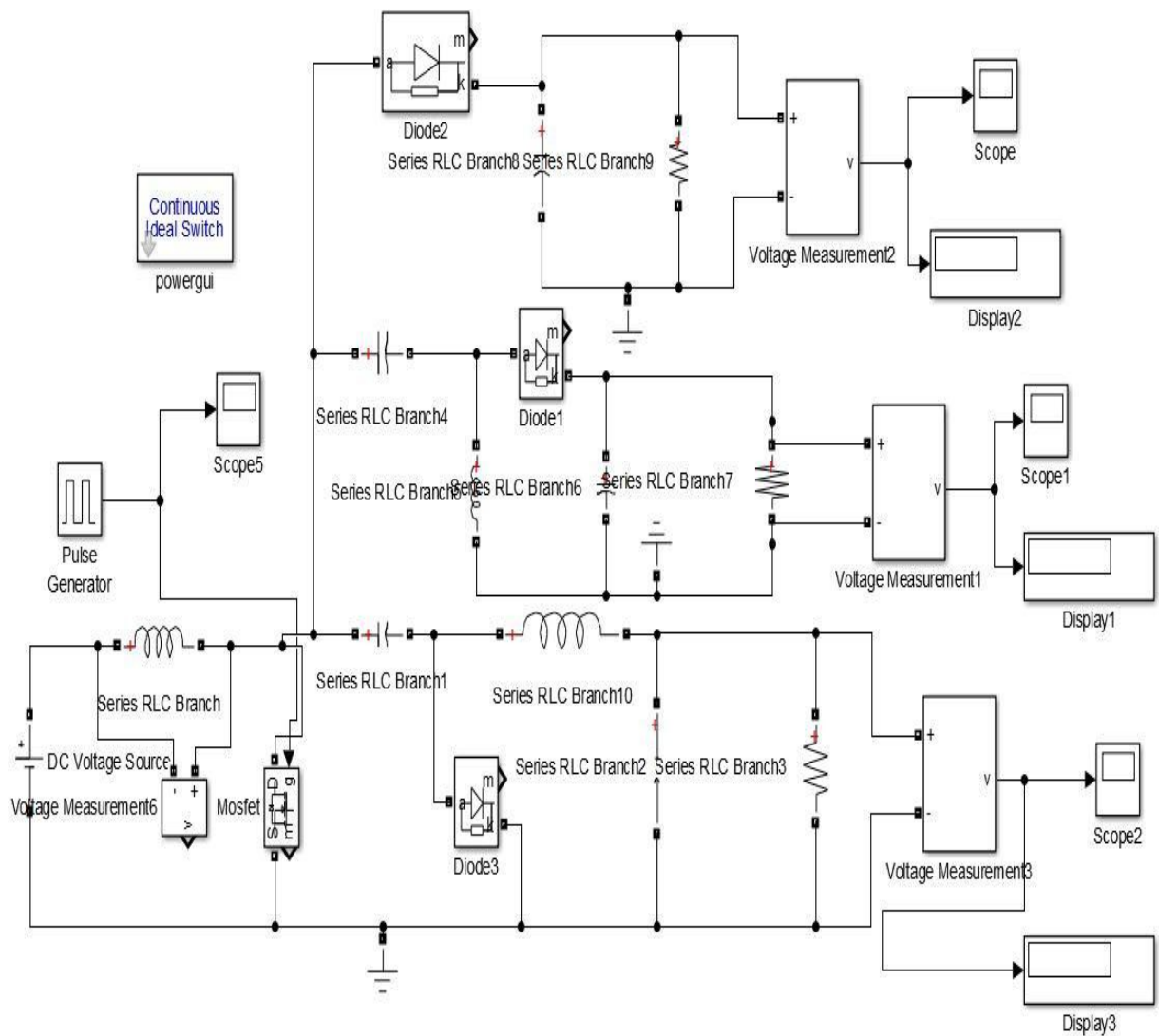
half the wattage rating of the resistor.

$$P = \frac{1}{2} C(V_0)^2 2f \quad \text{Where } f = \text{switching frequency}$$

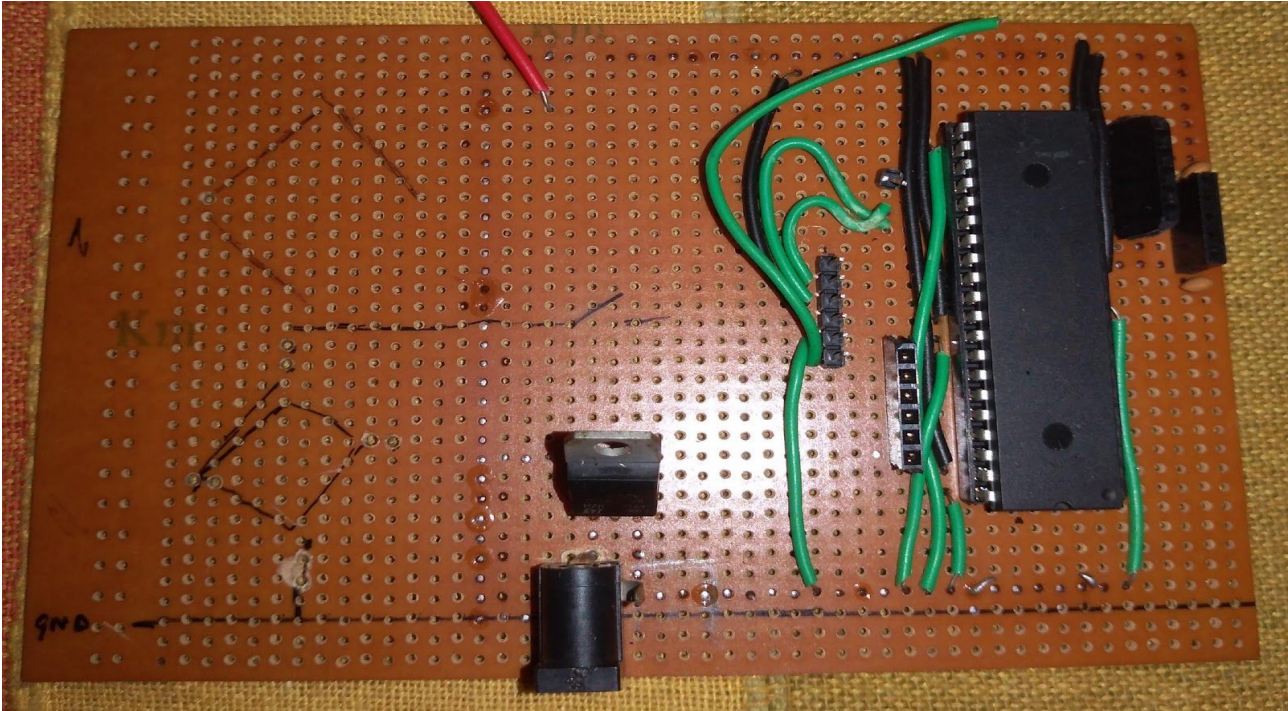
$$= C(V_0)^2 f \quad 2f = \text{number of transitions per cycle}$$

$$C = P/f(V_0)^2$$

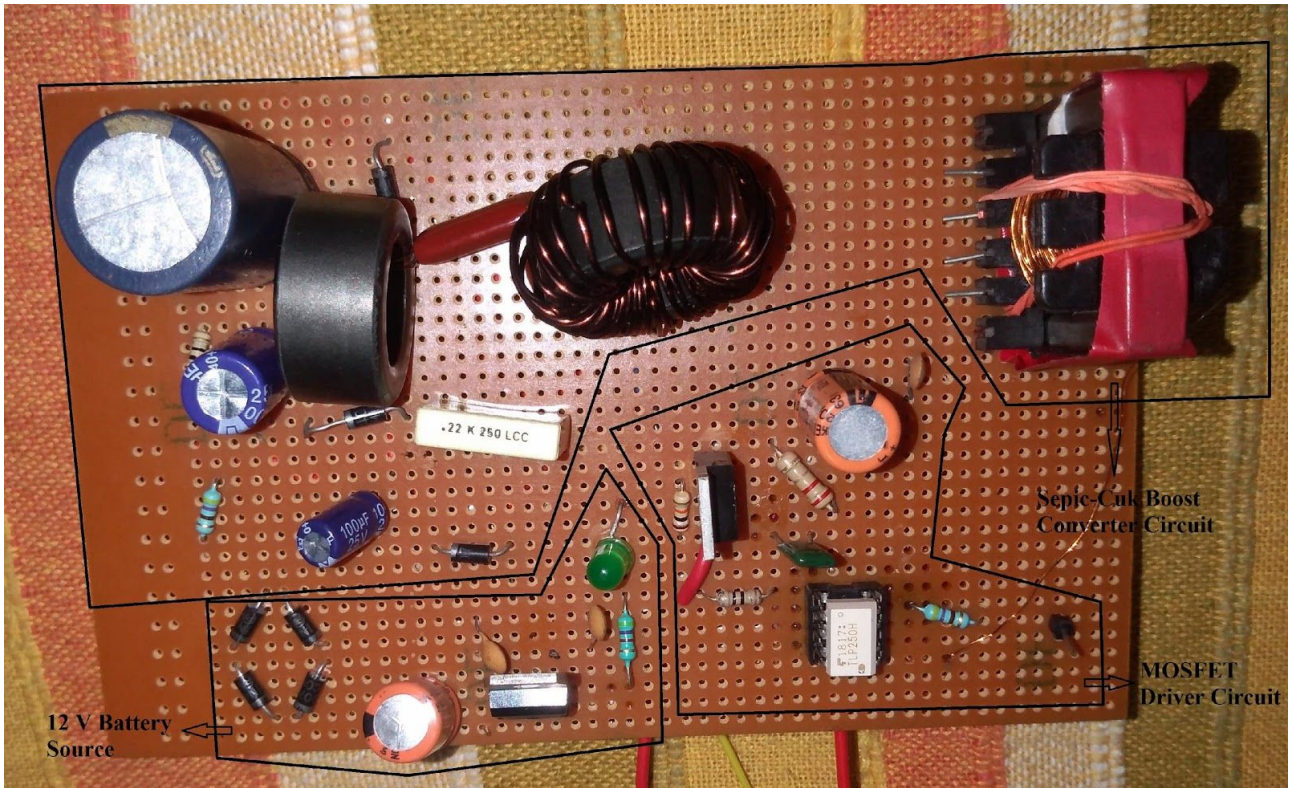
SOFTWARE CIRCUIT



Hardware Circuit



dsPIC Microcontroller Circuit

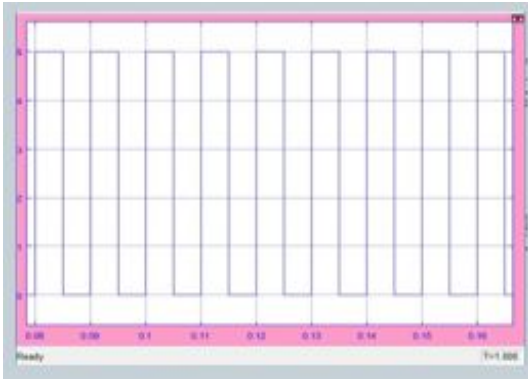


Battery, Switching and Converter Circuit

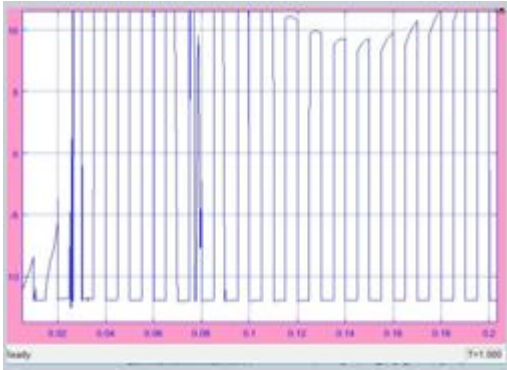
CHAPTER 6

Results

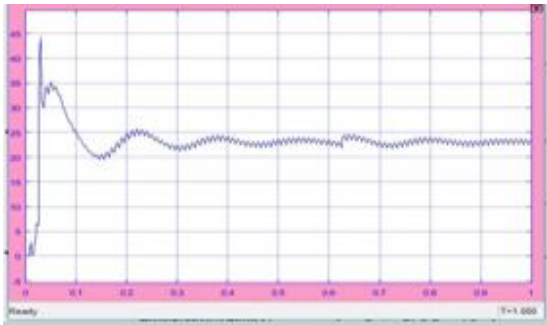
Software Waveforms:-



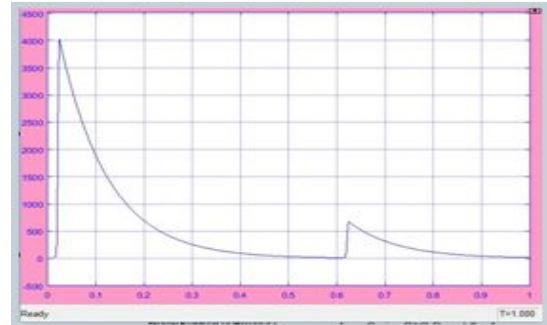
FOR GATE PULSE



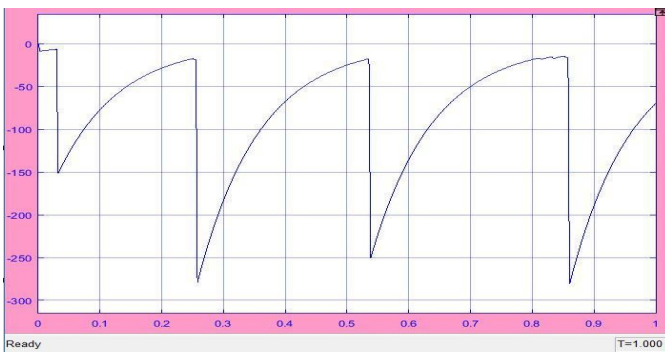
INDUCTOR VOLTAGE



FIRST OUTPUT VOLTAGE

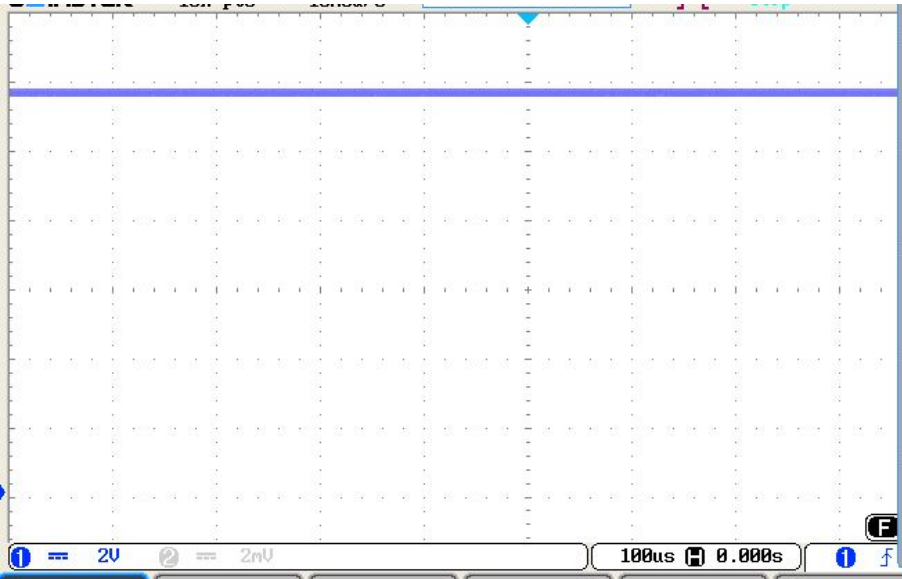


SECOND OUTPUT VOLTAGE

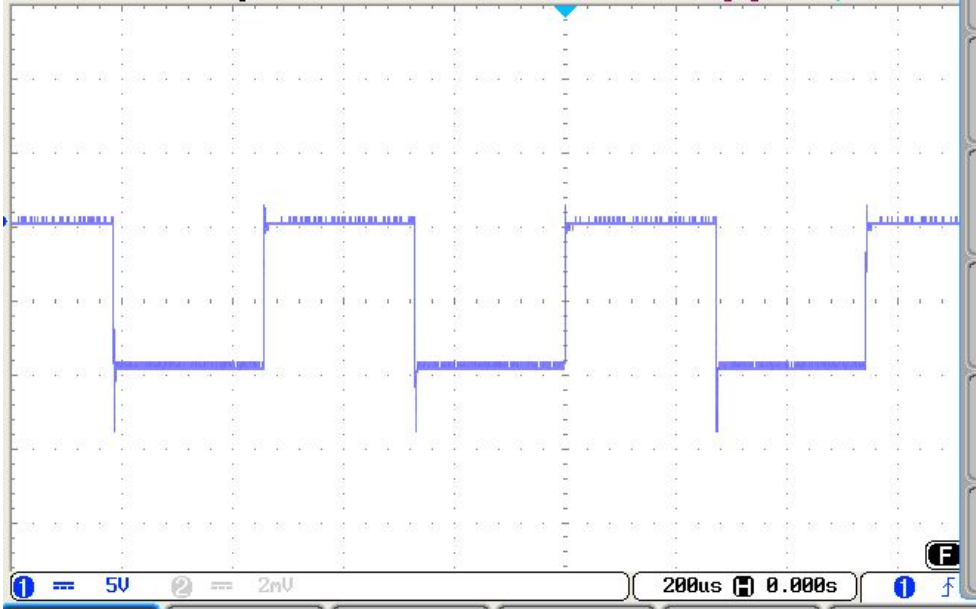


THIRD OUTPUT VOLTAGE

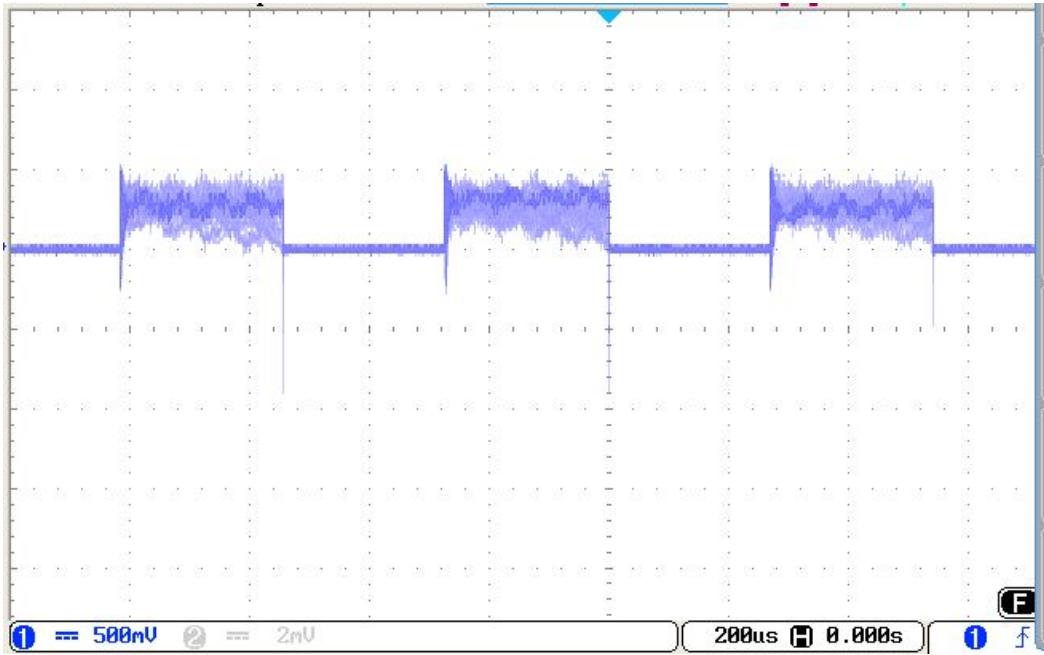
Hardware Waveforms:-



Capacitor Voltage



TLP Waveform



V_{ds} for MOSFET

CHAPTER 7

RESULT ANALYSIS

- The voltage across capacitor is 2V
- Voltage at TLP input is 10V
- Drain to Source Voltage for MOSFET is 1V

Here we want to generate pulse of 2kHz from Rdo pin of dsPIC. But due to operation delay we are getting pulse of 1.87kHz. But this can be adjusted to 2kHz by NOP operation . We are MPLAB X-16 compiler.

CONCLUSION

A dsPIC processor has been programmed to generate the trigger pulses for the power switch in a SEPIC buck/boost converter and function as a PI/SM controller. The implementation of the designed control algorithm has been found to offer very good time response performance and acceptable power quality, in addition to regulating the output voltage. The results having demonstrated the suitability of the proposed approach for use in critical applications, will go a long way in enhancing the scope of such converters.

CHAPTER 8



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ANNEXURE
