A Project report on

MPPT BASED DC-DC CONVERTER DESIGN

For the partial fulfilment of the requirements for the degree of B. Tech in Electrical Engineering

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CERTIFICATE

To HOD

This is to certify that the project work entitled “**MPPT BASED DC-DC CONVERTER DESIGN”**isthe bona fide work carried out by **Pritam Mondal (11701614032),Shuvadip Das (11701614042) ,Subhadip Pal (11701614054)**, the students of B.Tech in the Dept. of Electrical Engineering, RCC Institute ofInformation Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015,affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), WestBengal, India, during the academic year 2016-17, in partial fulfillment of therequirements for the degree of Bachelor of Technology in Electrical Engineeringand that this project has not submitted previously for the award of any otherdegree, diploma and fellowship.

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List of Acronyms:-

AC	Alternating Current
ACHMLI	Asymmetric Cascaded H-Bridge Multilevel Inverter
APOD	Alternating Phase Opposition Disposition
CAN	Controller Area Network
DC	Direct current
FFT	Fast Fourier Transform
FPGA	Field Programmable Gate Array
IC	Integrated Circuit
IGBT	Insulated Gate Bi-polar Transistor
LED	Light Emitting Diode
MLI	Multilevel Inverter
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
PDPWM	Phase Disposition Pulse Width Modulation
PODPWM	Phase Opposition Disposition Pulse Width Modulation
PSIM	Power Sim
PWM	Pulse width Modulation
RTI	Real Time Interface
SOA	Safe Operating Area
SPWM	Sine Pulse Width Modulation
THD	Total Harmonic Distortion

ABSTRACT

This paper discusses the solar powered dc to dc buck boost converter which can work in both buck mode and in boost mode according to the requirement. It requires only two switches and by properly controlling the switches, buck or boost mode can be achieved.

The main purpose of this project is to design an inverter that will enable the inversion of a DC power source, supplied by Photovoltaic (PV) Cells, to an AC power source that will be either used to supply a load or connected directly to the utility grid.

The system will be controlled to operate at maximum efficiency using Maximum Power Point Tracking (MPPT) algorithm. This algorithm will be installed on a controller.

The MATLAB simulated model of the solar panel followed by the dc –dc converter is presented and waveforms obtained are discussed. The dc to dc converter model is programmed in MPPT mode using optimal duty ratio to achieve maximum output. The performance of the complete system model under varying insolation levels of solar panel is discussed.

1. INTRODUCTION

The past few years have been filled with news of fuel price hikes, oil spills, and concerns of global warming. People are finding the benefits of having their own renewable energy system more attractive than they ever have before. The biggest form of renewable energy to benefit from this is solar PV systems.

However, the output power of a PV panel is largely determined by the solar irradiation and the temperature of the panel. At a certain weather condition, the output power of a PV panel depends on the terminal voltage of the system.

To maximize the power output of the PV system, a high-efficiency, low-cost DC/DC converter with an appropriate maximum power point tracking (MPPT) algorithm is commonly employed to control the terminal voltage of the PV system at optimal values in various solar radiation conditions.

Basic boost converters work well with the MPPT control as long as the load can accept a voltage from the minimum output of the PV panel all the way up a certain value (e.g., 5 times) subject to practical limits of the duty cycle (e.g., 80%). The system needs to be robust enough that when the consumer wants to expand their energy production by adding more panels, they don’t need to replace their entire system. The DC/DC converter and MPPT control algorithm proposed in this work will implement all of these improvements in hopes creating a highly efficient, low-cost, and highly reliable solar PV system for clean and renewable power generation.

Since the power generated from the photovoltaic module depends on the temperature and the solar radiation, these factors must be taken into account while designing the maximum power point tracker. The main goal of the MPPT is to move the module operating voltage close to the voltage at which the PV produces the maximum power under all atmospheric conditions. MPPT is very important in PV systems. Different techniques have been developed to maximize the output power of the photovoltaic module. They have advantages and limitations over the others. These techniques vary in complexity, in the number of sensors required, in their convergence speed and in the cost.

In this literature survey some of MPPT methods are introduced such as open circuit voltage method, incremental conductance method, perturbation and observation methodetc. The open circuit voltage method is based on the fact that the voltage of the PV module at maximum power point is linearly proportional to the open circuit voltage.

MPPT algorithms can be classified mainly into two categoriesone is input parameter based and another is outputparameter based. MPPT algorithms such as fractional open circuit voltage , fractional short circuit current , Hillclimbing, perturb and observe (P&O) , incrementalconductance (IncCond), incremental resistance (INR), ripple correlation control (RCC) , techniques havebeen developed to extract the maximum power from the PVarrays by using the input parameter/s either VPV (PV modulevoltage) or IPV (PV module current) or both. Among thevarious MPPT techniques, fractional open circuit voltage andshort circuit current techniques provide a simple and effectiveway to extract maximum power, but they require periodicalmeasurement of open circuit voltage or short circuit currentfor reference, causing more power loss. From the literature itis observed that P&O and IncCond methods are extensivelyapplied methods because of their increased efficiency and ease of implementation.

THEORY

2.MAXIMUM POWER POINT TRACKING

A MPPT system works just as it sounds it would. The system tracks the MPP under varying conditions and then implements some sort of algorithm to adjust the converter so it will hold the panels power output at the highest point for that given time. In general, the tracking system completes this task using current and voltage measurements to find the power output of the PV panel at the current time. The specific algorithm then takes this information and calculates the adjustments that need to be made to the circuit in order to allow the panel to produce more power from outside the system, by using external data streams which are read from the outside world.

The adjustments made to the converter are usually in the form of a change in the duty cycle controlling the converter. The effect is that a change in duty cycle changes the output voltage. In a converter not connected to a PV panel this increase in output voltage would be caused by the converter allowing more input current to pass through it. The characteristics of a PV panel coupled with this effect are what allow MPPT to occur.

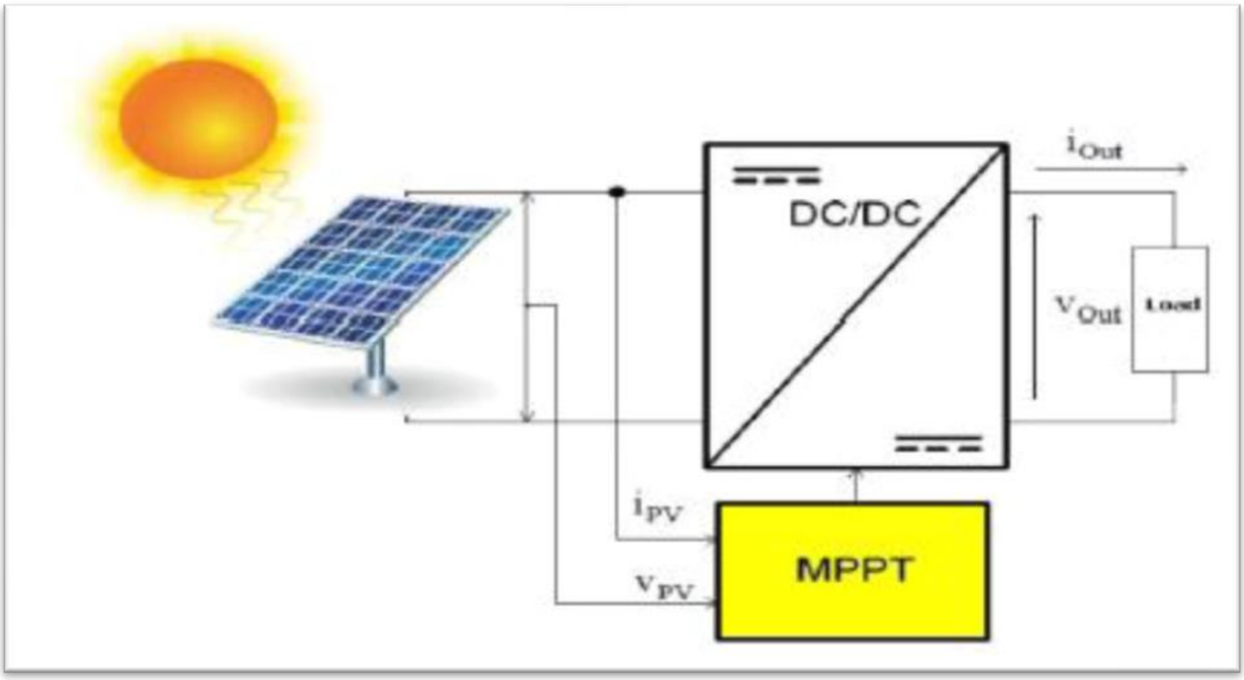


Figure 1 – Implementation of MPPT

When the current of a PV panel increases the voltage will eventually begin to decrease, and when the voltage increases the current will eventually decrease. When the duty cycle of the converter is increasedthe current allowed to pass fromthe PV panel to the converteris increased. This causes the PV panel to move from the point it is currently operating at on the I-V curve to the next point with a higher current output, moving left. This in turn decreases the voltage output by the PV panel.

Once the operating point of the panel is able to be changed an algorithm can be implemented to control this change, thus forming a MPPT system. Each algorithm may act differently but this is the basis for most all MPPT systems. After factoring in the attributes and deficiencies of each algorithm, the "**P&O**" method is used in this project.

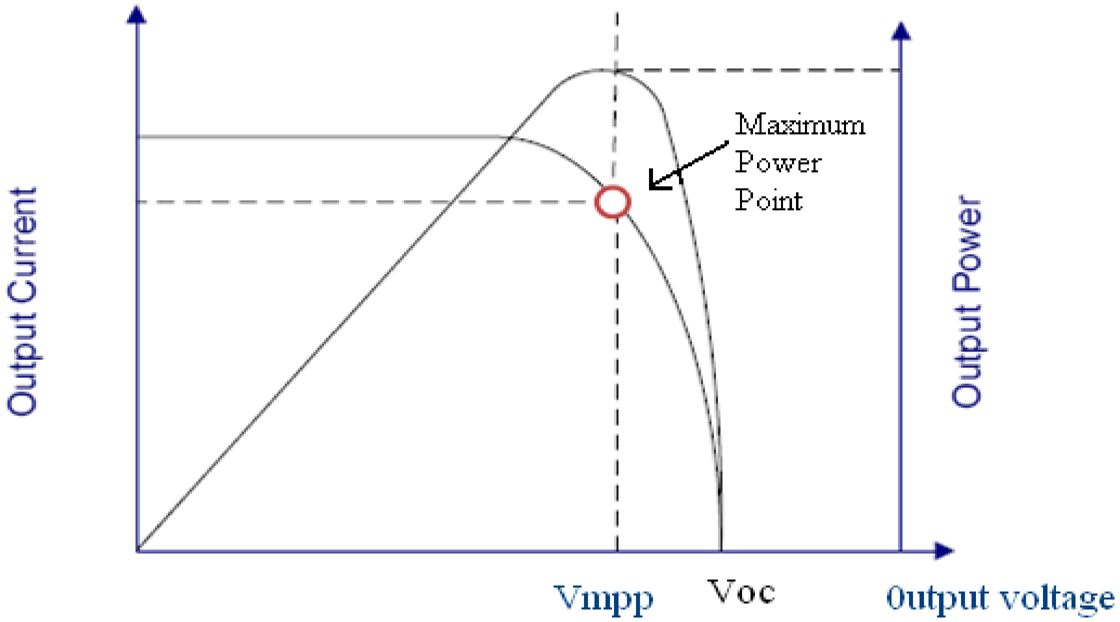


Figure 2: I-V & P-V characteristics of MPPT

1.DIFFERERENT TECHNIQUES OF MPPT

Global demand for electricity is increasing while production of energy from fossil fuels is declining and therefore the obvious choice of the clean energy source that is abundant and could provide security for development future is energy from the sun. In this paper, the characteristic of the supply voltage of the photovoltaic generator is nonlinear and exhibits multiple peaks, including many local peaks and a global peak in non-uniform irradiance.

To keep global peak, MPPT is the important component of photovoltaic systems. Although many review articles discussed conventional techniques such as P & O, incremental conductance, the correlation ripple control and very few attempts have been made with intelligent MPPT techniques. This document also discusses different algorithms based on fuzzy logic, Ant Colony Optimization, Genetic Algorithm, artificial neural networks, Particle Swarm Optimization Algorithm Firefly, Extremum seeking control method and hybrid methods applied to the monitoring of maximum value of power at point in systems of photovoltaic under changing conditions of irradiance.

The different ways to implement MPPT are: -

- Perturb and Observe (P&O).
- Incremental Conductance.
- Fuzzy Logic.
- Parasitic Capacitance

2.PERTURB AND OBSERVE (P&O) ALGORITHM

The P&O algorithm is a relatively simple yet powerful method for MPPT. The algorithm is an iteration based approach to MPPT. A flowchart of the method can be seen in Figure 3.

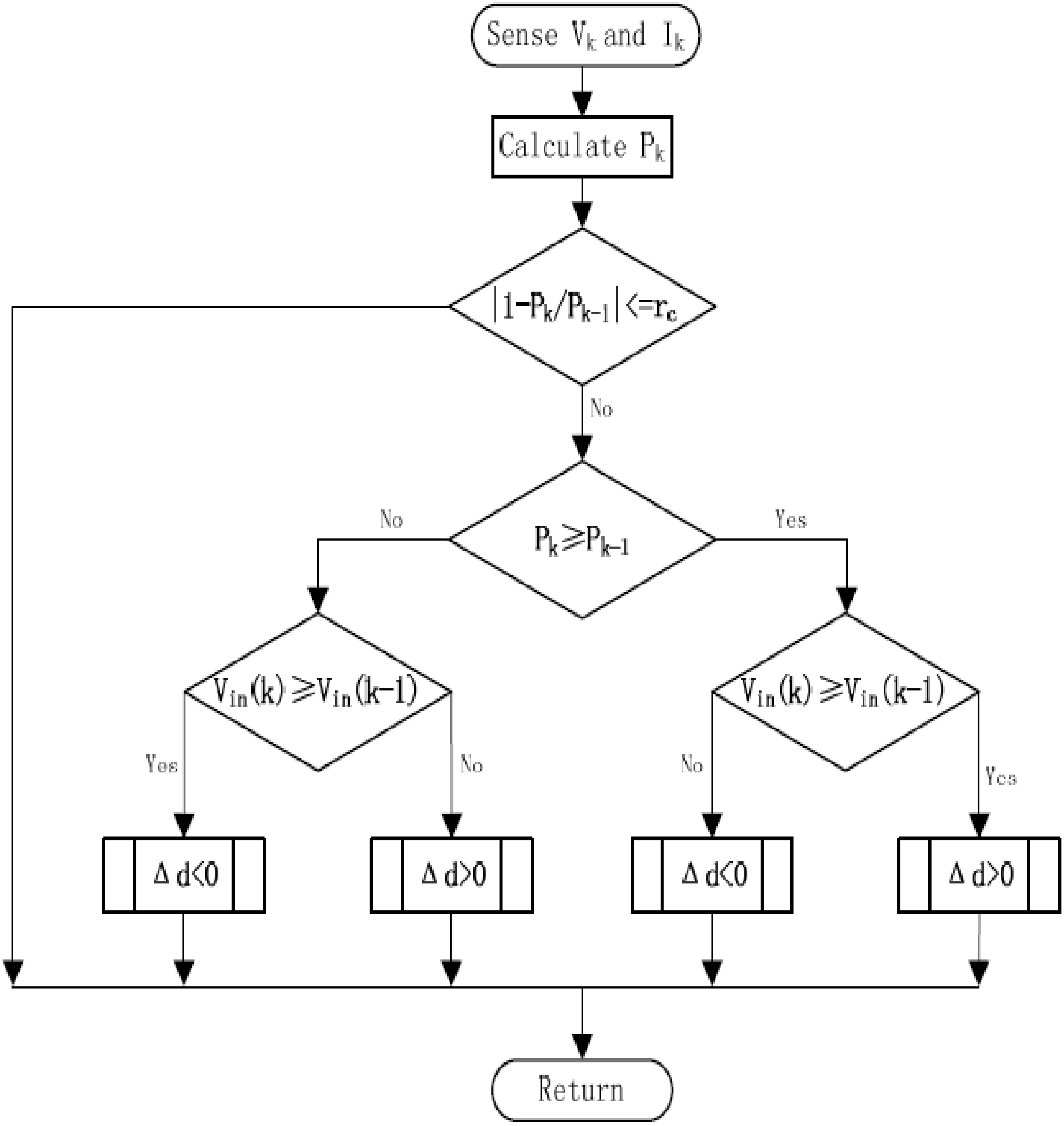


Figure 3: Perturb and Observe Algorithm

- The P&O algorithm is also called "hill-climbing", but both names refer to the same algorithm depending on how it is implemented.
- Hill-climbing involves a perturbation on the duty cycle of the power converter and P&O a perturbation in the operating voltage of the DC link between the PV array and the power converter.
- In the case of the Hill-climbing, perturbing the duty cycle of the power converter implies modifying the voltage of the DC link between the PV array and the power converter, so both names refer to the same technique.
- If there is an increment in the power, the perturbation should be kept in the same direction and if the power decreases, then the next perturbation should be in the opposite direction.
- The process is repeated until the MPP is reached. Then the operating point oscillates around the MPP.
- The P & O algorithm operated by the periodically perturbing (increasing or decreasing) the terminal voltage or current and then compare with the output power by the previous perturbation cycle.
- If the power increases then one continues increasing the voltage or current in the same direction. If power decreases then continue vary the voltage or current in the reverse direction.

Here For the project we have used P&O algorithm as it is much simpler than other algorithms to implement.

The MATLAB program for this Perturb and Observe Algorithm is show in Appendix.

3. INCREMENTAL CONDUCTANCE METHOD:-

This method consists of slop of derivative of the current with respect to the voltage to reach the MPP. To obtain this maximum point di/dv should be equal to the –i/v. By applying the variation in the voltage towards the biggest value or smallest value it affect the power value. If power increasing then should continues in the same direction, if power decrease then should reverse the direction.

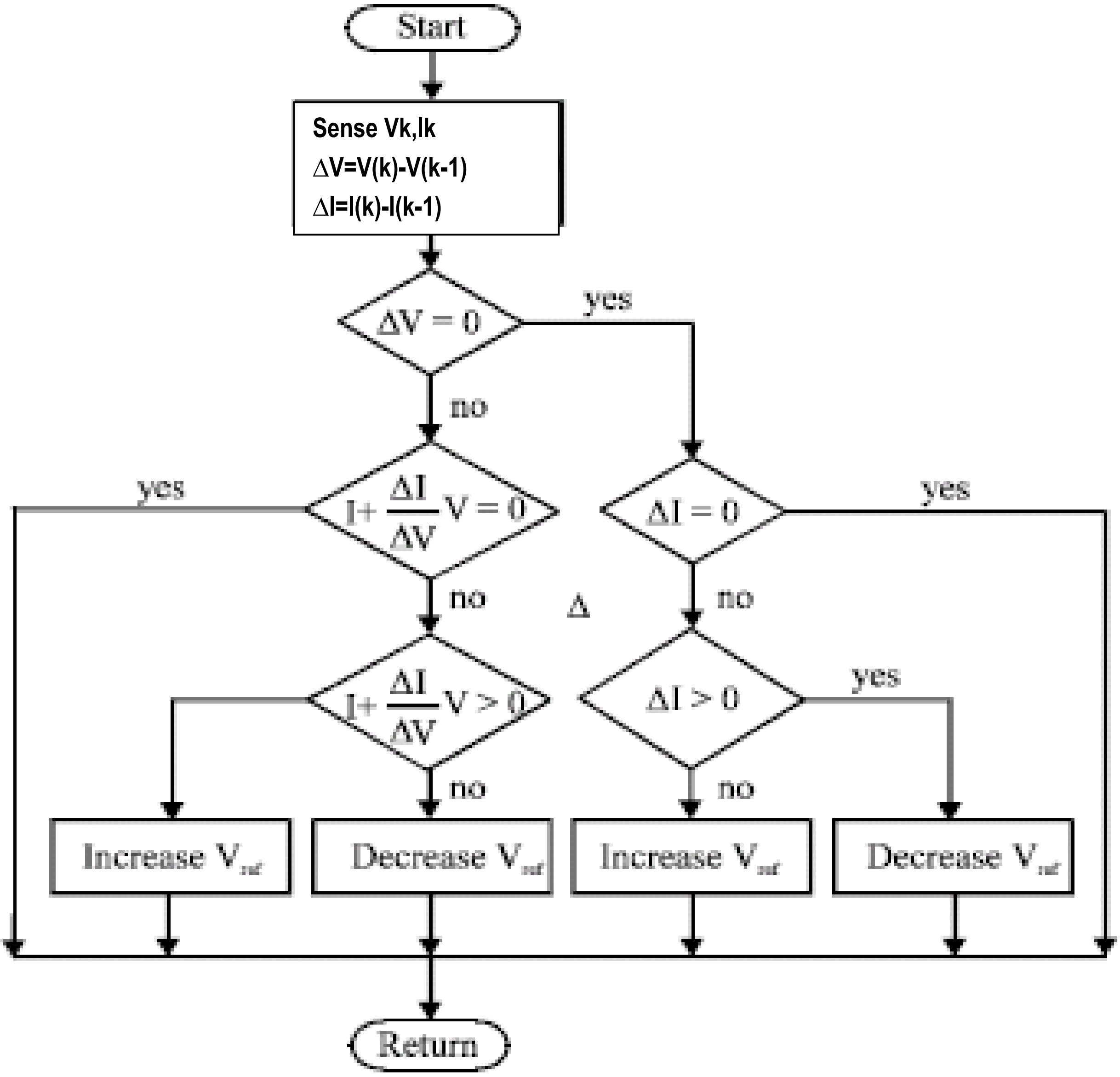


Figure 4: Incremental Conductance Method Flowchart

4. FUZZY LOGIC METHOD:-

Recently fuzzy logic controllers have been introduced in the tracking of the MPP in PV systems .They have the advantage to be robust and relatively simple to design as they do not require the knowledge of the exact model. They do require in the other hand the complete knowledge of the operation of the PV system by the designer.

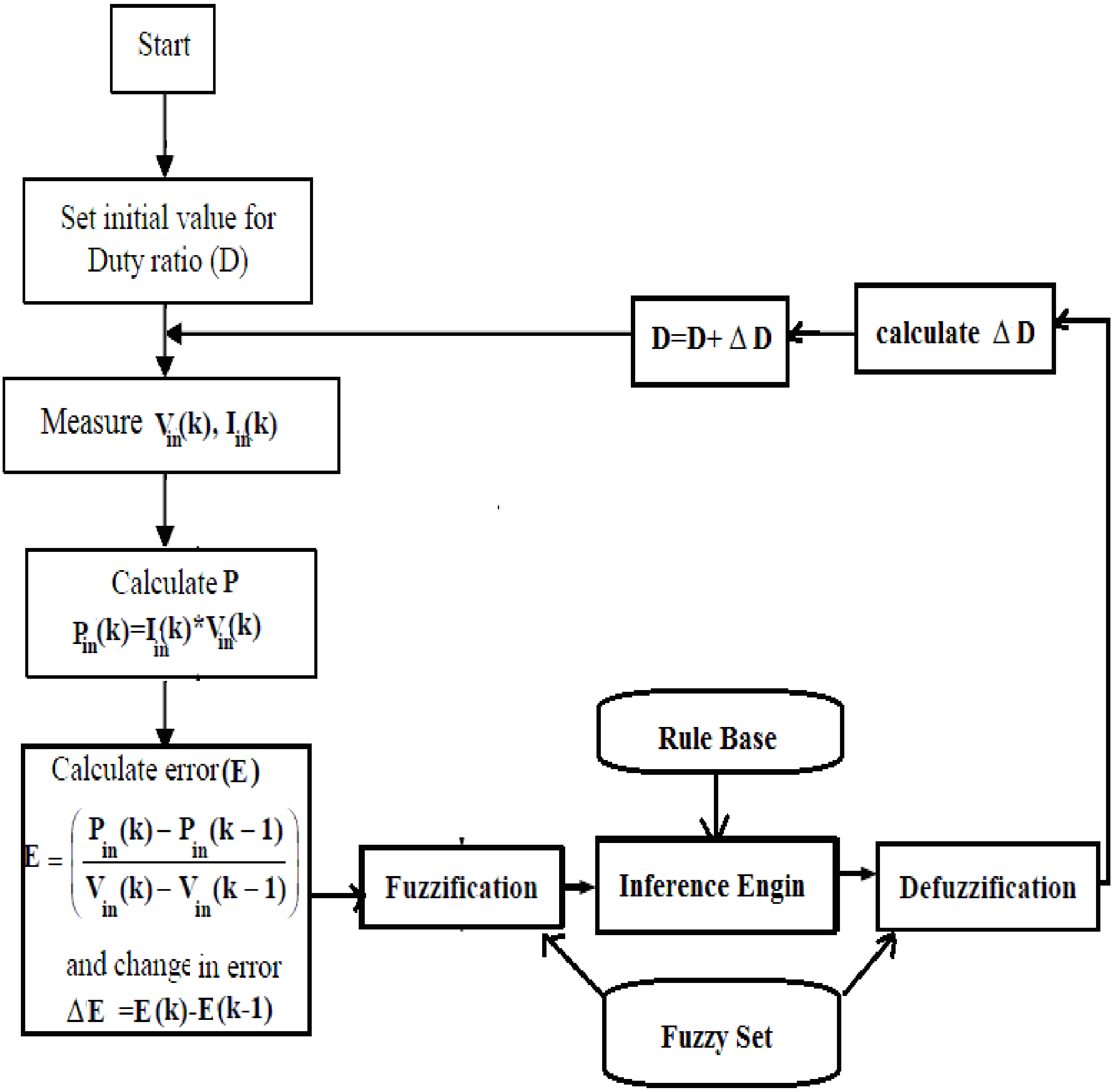


Figure 5: Fuzzy Logic Flowchart

5.PARASITIC CAPACITANCE METHOD:-

The Parasitic Capacitance is most recently MPPT techniques. This technique is similar to Incremental conductance technique. except that the effect of solar cell parasitic junction capacitance . The charge is stored in pn junction of the solar cells. if we add the capacitance to the lighted diode equation we obtained I = - [exp (+ I)/a -1] + (d /dt) = F( )+ d /dt This equation can be rewritten to show the two component of I and function of voltage and current in the parasitic capacitance.

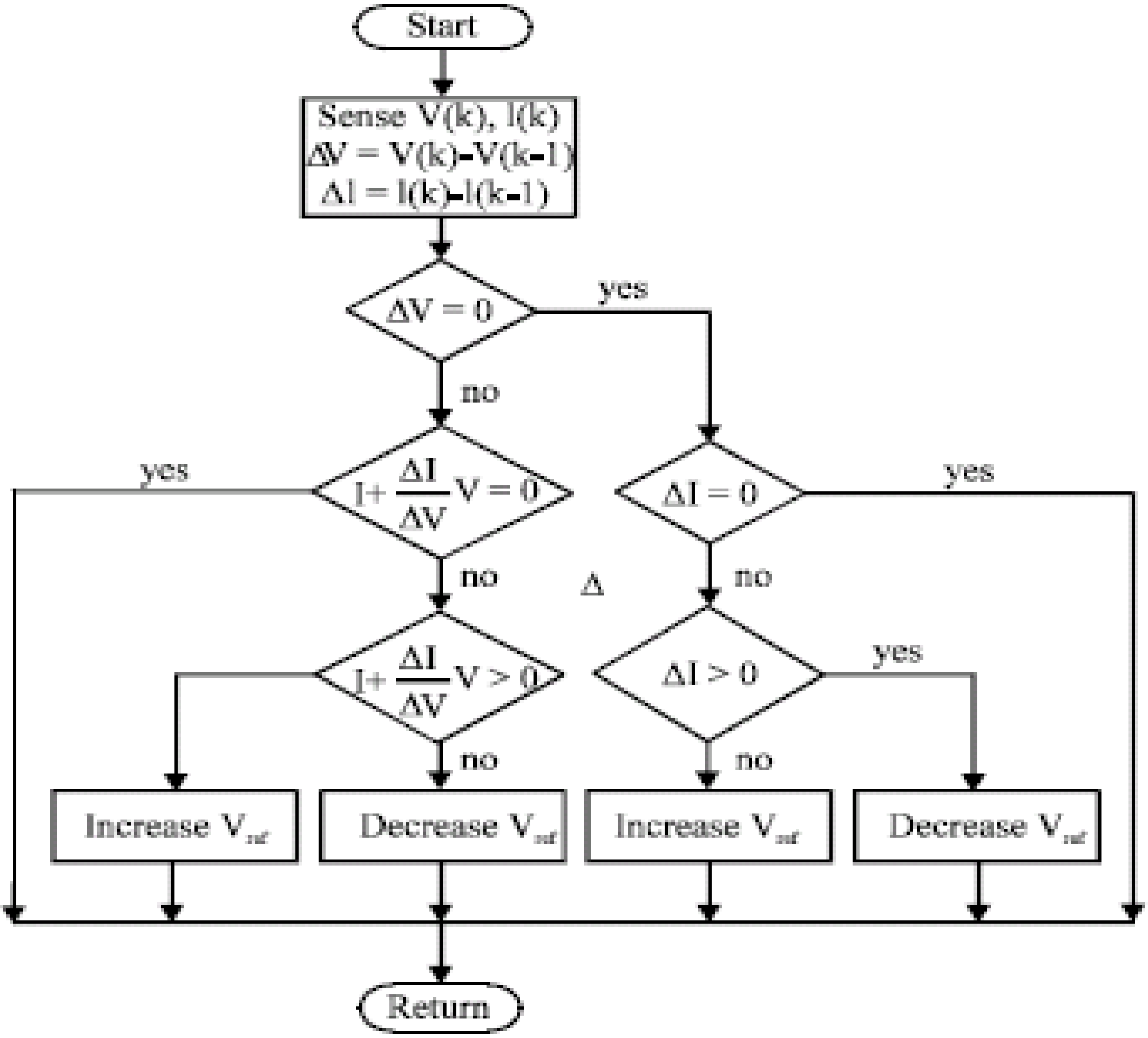


Figure 6: Parasitic Capacitance Flowchart

6. A TYPICAL PV PANEL

PV panels generate electricity through what is called the “Photovoltaic Effect”. In the simplest form the Photovoltaic Effect can be described as follows: Light particles called photons are constantly emitted from the Sun. This can be seen by the brightness on a sunny day when many of these particles make it to earth’s surface. The effect comes into play when these particles hit a PV material, such as a solar cell. When the photons impact this material it excites the atoms within the material, which causes an electron-hole pair to form. A band gap built into the material causes the electron to move along a certain predefined path. This electron-hole pair creation happens many times over, throughout the panel. All of these flowing electrons generate a current that is directed out of the panel to some type of load. Thus, the photovoltaic effect converts light into the more useful form of power, electricity.

Solar cells output power in what is called an I-V curve. A typical I-V and P-V curve of a solar cell can be seen in Figure 1. This curve represents what the current output by the solar cell would be as the output voltage is varied and vice versa. This curve can be easily obtained from the I-V curve through the equation P = V x I.

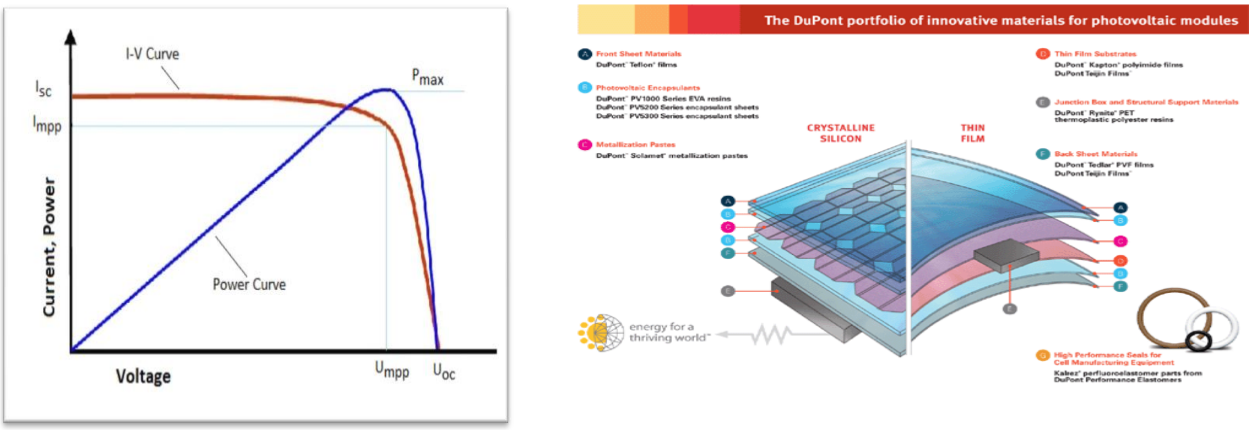


Figure 7: A representative I-V and P-V curve for a solar cell showing the MPP and A PV cell.

There are three other important aspects of a solar cell also shown in Figure 1. The first two are the open circuit voltage (Voc) and the short circuit current (Isc) of the cell. The open circuit voltage is the voltage that is output to the cell terminals when the cell is exposed to light and there is no current flowing between the terminals. This is also the maximum voltage that can be produced by the cell, which makes knowing this number useful when designing a circuit or load to connect to the cell terminals. The short circuit current is the current that will flow when the cell is under light and the terminals are shorted together. This is the maximum current that can be output by the specific solar cell. The third important aspect of a solar cell is the MPP. This is the point where the cell is operating at maximum efficiency and outputting the highest power available. The MPP also has voltage at maximum power (Vmp) and current at maximum power (Imp) points associated with it.

Each individual cell is relatively little in size and can only produce a small amount of power. The Voc of an individual solar cell is usually approximately 0.6 V. The cells become much more useful when combined in an array to create a PV panel. When connected together the cells properties add together to create an I-V curve that has the same appearance as that of an individual cell but is larger in magnitude. The cells in an array are usually connected in series to obtain a higher and more appropriate terminal voltage.

CHARACTERISTICS OF SOLAR MODULE:

- A PV cell model must be initially established. An equivalent electrical circuit makes it possible to model the characteristic of a PV cell.
- In a practical PV cell, there are two resistances: series resistance and parallel resistance. Series resistance accounts for the losses

The output current to the load can be expressed as

$$\boldsymbol{I = IPV - Io\ ((V+\ )\ nkTa - 1)}$$

Where:

- I is the output current of the solar module (A),
- V is the output voltage of the solar cell (V), which can be obtained by dividing the output voltage of the PV module by the number of cells in series,
- IPV is the current source of the solar module by solar irradiance (A),
- Io is the reverse saturation current of a diode (A), NS is the series connection number of the solar module,
- n is the ideal factor of the diode (n = 1~2),
- q is the electric charge of an electron (1.6 × e−19c),
- k is the Boltzmann’s constant (1.38 × 10−23j/K),
- T is the absolute temperature of the solar cell.

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 bake 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.

FUNCTION OF DC-DC CONVERTER

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

i) Convert a DC input voltage Vs into a DC output voltage Vo.

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.

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.

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 voltages, for example 600 V or so.

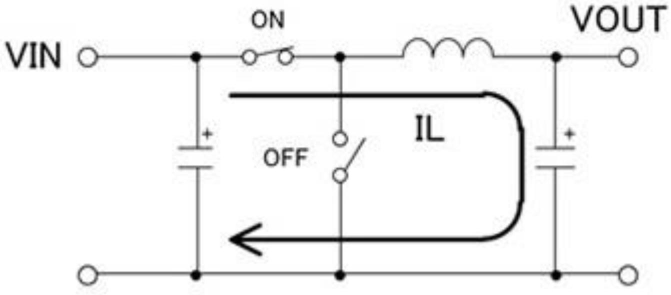


Figure 8: On mode

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

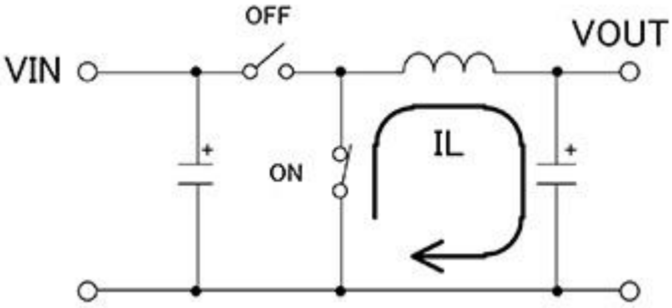


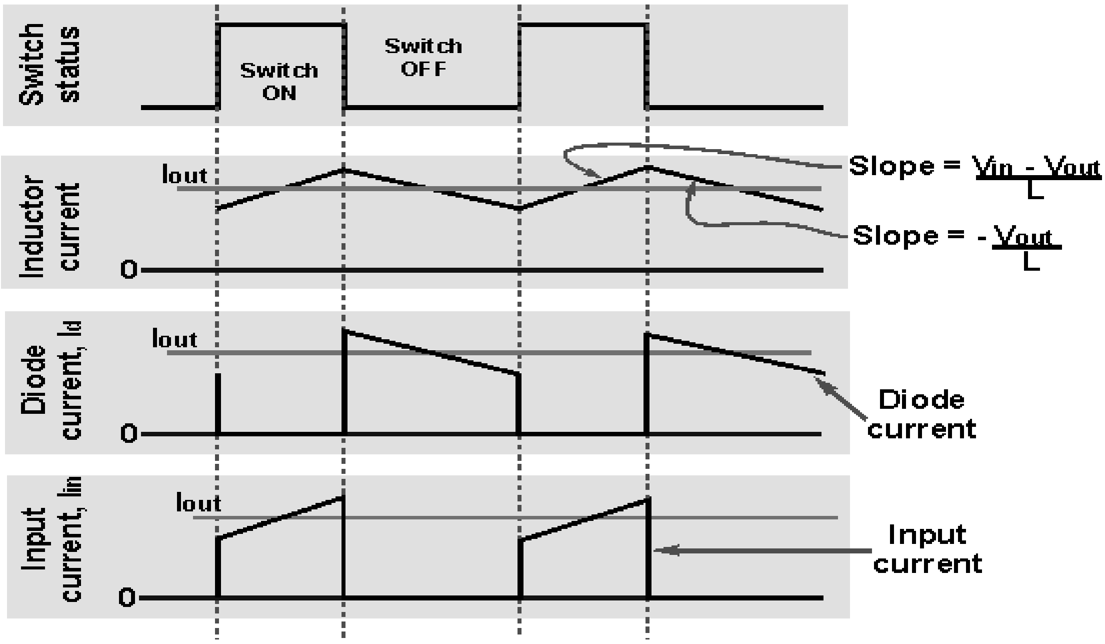
Figure 9: OFF mode

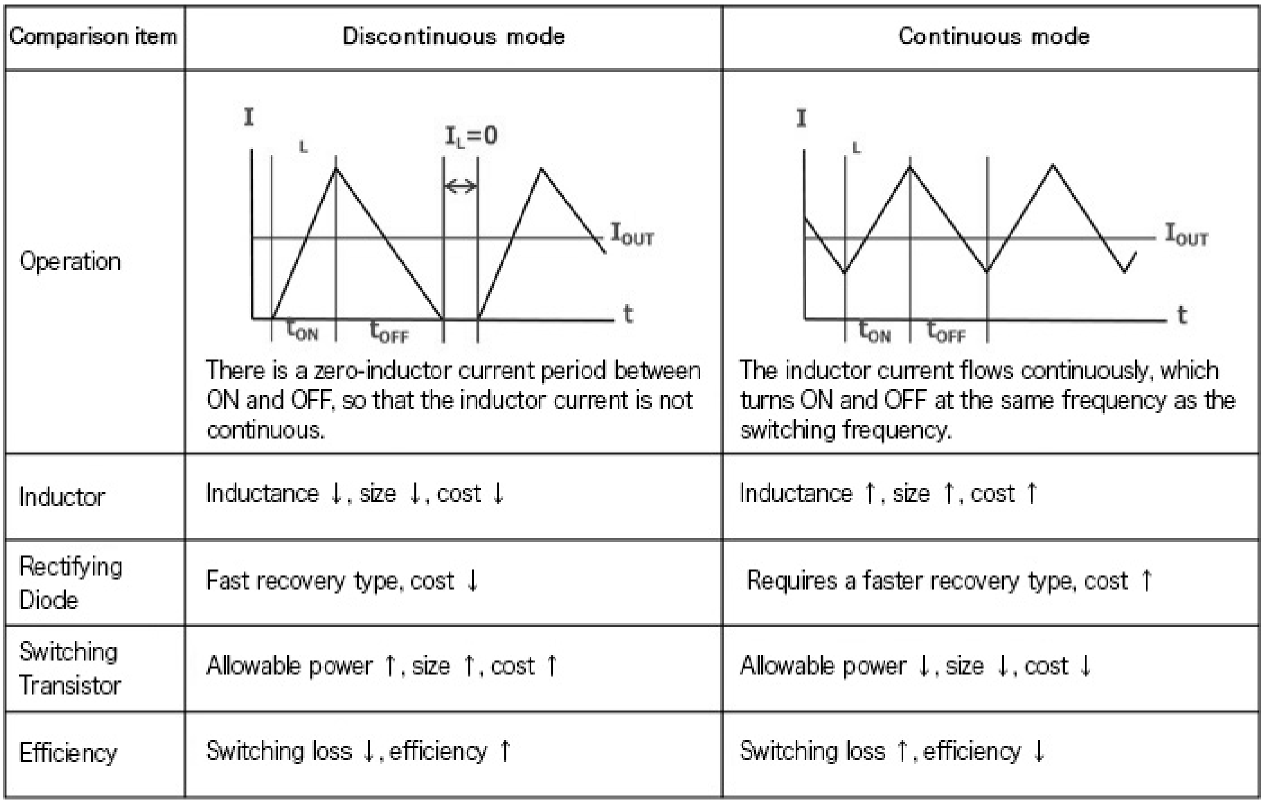
- When the high-side switch (the transistor) turns off, the energy stored in the inductor is output through the low-side switch (the diode)
- At this time, the high-side switch (the transistor) is OFF
- The inductor current IL is expressed by the following equation （toff： OFF time）

$$IL = \frac{VIN - VOUT}{L} \times ton$$

Discontinuous Mode 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 IL 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 (trr) 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 harmonicsHowever, the peak current becomes large, and when the load is large, sometimes operation in continuous mode is preferred.





Comparison item	Discontinuous mode	Continuous mode
Operation	There is a zero-inductor current period between ON and OFF, so that the inductor current is not continuous.	The inductor current flows continuously, which turns ON and OFF at the same frequency as the switching frequency.
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. 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 $V_o(t) = V_o$(constant).

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

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

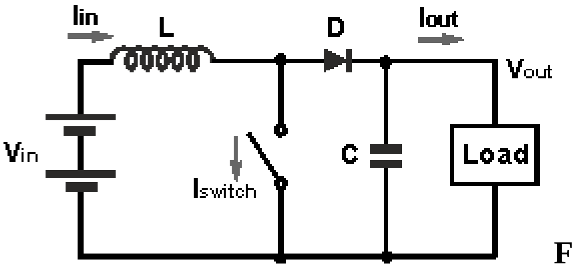


FIGURE 10 Boost Converter Circuit

Referring to the boost converter circuit diagram, the current waveforms for the different areas of the circuit can be seen as below.

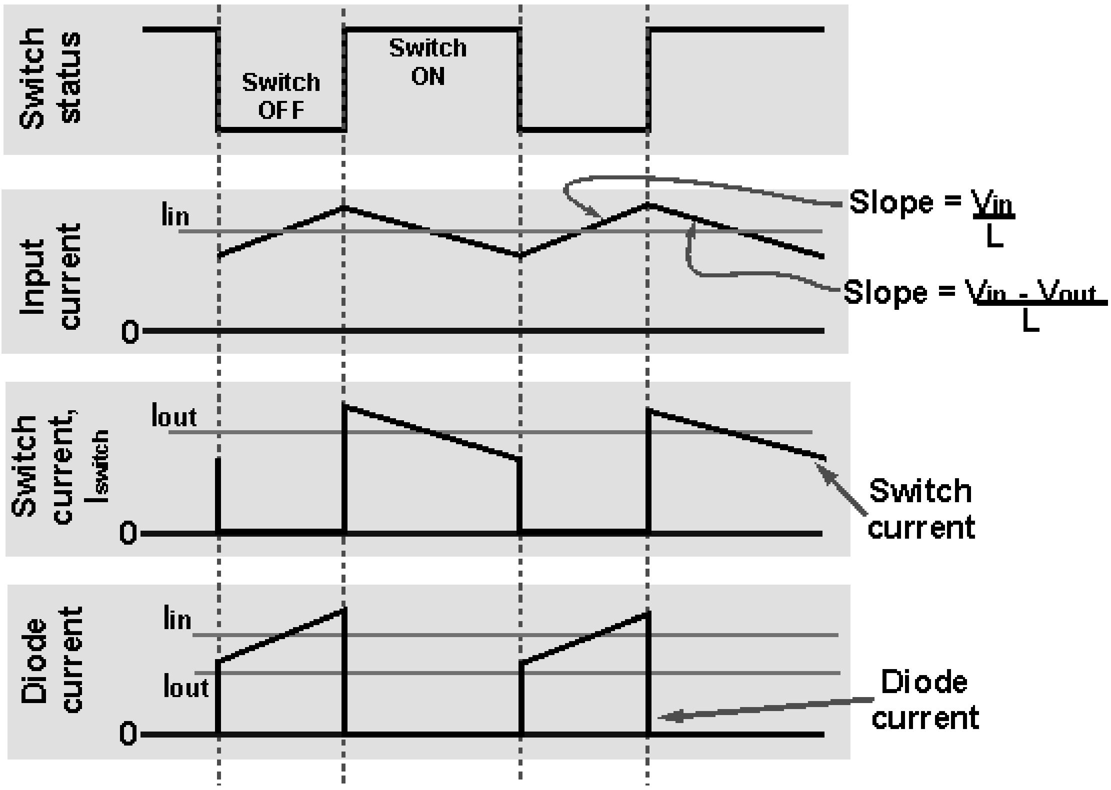


FIGURE 11: Switch Status, Input Current, Diode Current

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. Vin · Iin = Vout · Iout. 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 switching cycle.

Continuous conduction mode

case-1: When switch S is ON

When switch in 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 in 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

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

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)*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 motors
- 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.

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.

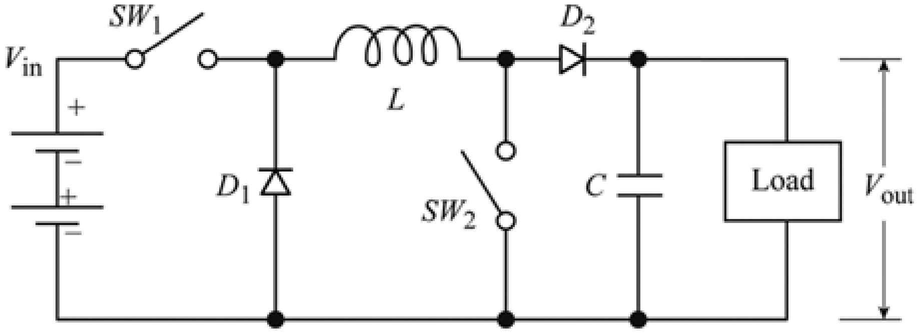


FIGURE 12: Circuit of BUCK-BOOST CONVERTER

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:

- ***+Vin, -Vout:*** 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.

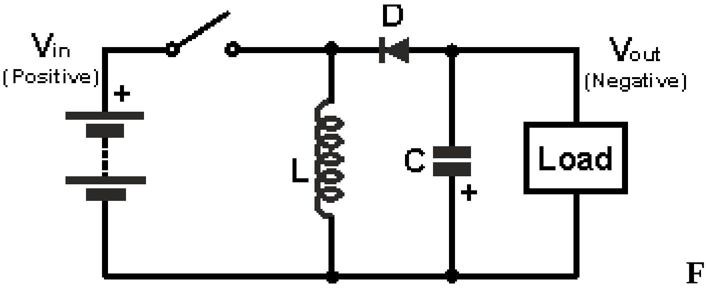
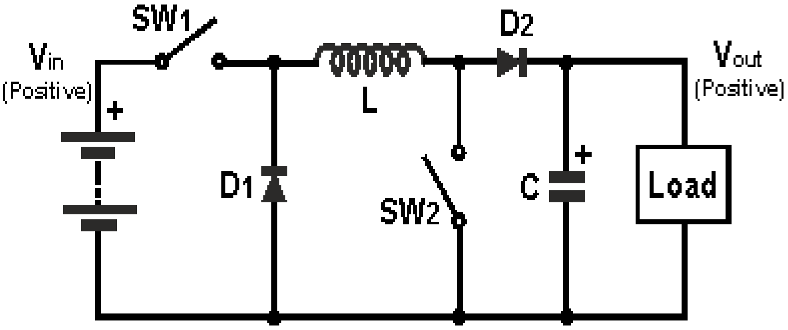


FIGURE 13: SW 1 is Open

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

+Vin, +Vout: 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.

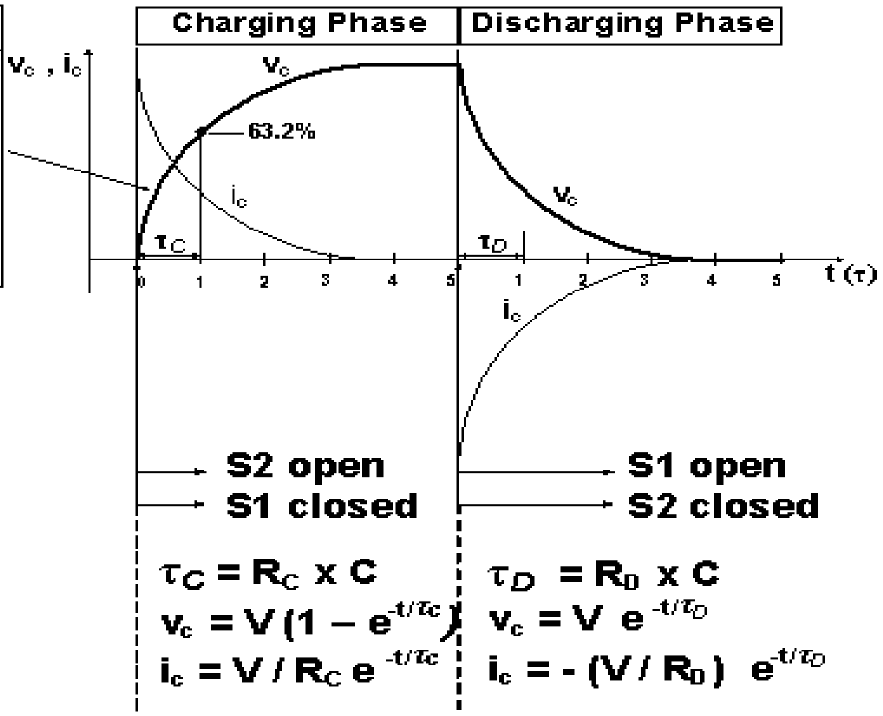
FIGURE 14:SW 1 &SW 2both Open

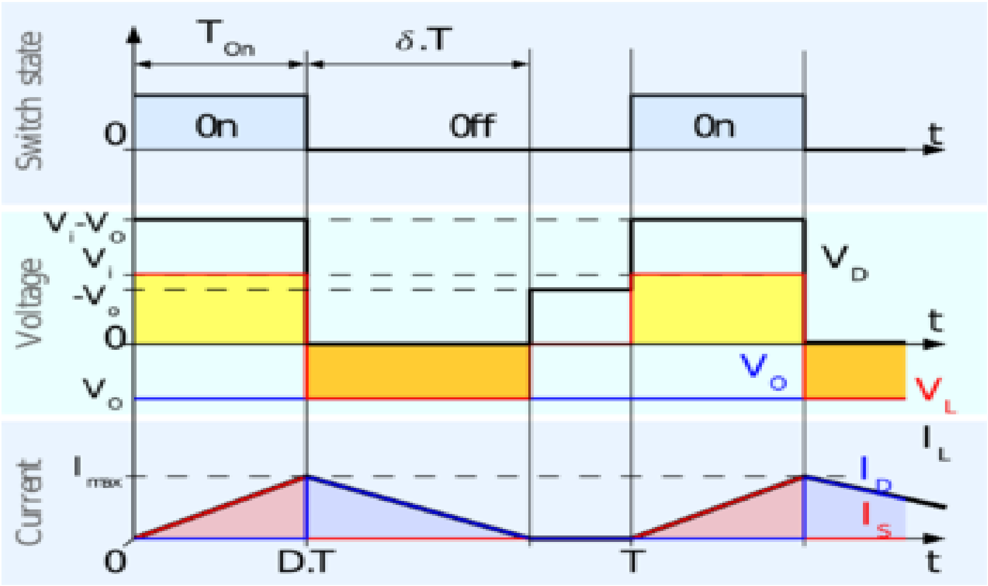


In this circuit, both switches act together, i.e. both are closed or open. When the switches are open, the inductor current builds. At a suitable point, the switches are opened. The inductor then supplies current to the load through a path incorporating both diodes, D1 and D2.

Charging Phase
v_c versus τ_c

τ_c	Magnitude (V)
0	0%
1 τ_c	63.2%
2 τ_c	86.5%
3 τ_c	95%
4 τ_c	98.2%
5 τ_c	100%





3. COMPONENTS

This part consists of all the components we have used during this project work, it includes two parts: one is **software section** and another part is **hardware section**.

Software Section:-

This section consists of the all the software we used during this project. The softwares used are-

1. MATLAB(Simulink)
2. d-SPACE

MATLAB: -

MATrix LABoratory is basically popular with the name MATLAB. In one sentence *MATLAB is the Language of Technical Computing*.

The MATLAB platform is optimized for solving engineering and scientific problems. The matrix-based MATLAB language is the world's most natural way to express computational mathematics. Built-in graphics make it easy to visualize and gain insights from data. A vast library of prebuilt toolboxes lets us get started right away with algorithms essential to our domain. The desktop environment invites experimentation, exploration, and discovery. These MATLAB tools and capabilities are all rigorously tested and designed to work together.

Features of Matlab:-

- *Simulink:* Simulink® is a block diagram environment for multidomain simulation and Model-Based Design. It supports simulation, automatic code generation, and continuous test and verification of embedded systems.
- *Language Fundamentals:* Syntax, operators, data types, array indexing and manipulation
- *Mathematics:* Linear algebra, differentiation and integrals, Fourier transforms, and other mathematics
- *Graphics:* Two- and three-dimensional plots, images, animation, visualization
- *Data Import and Analysis:* Import and export, preprocessing, visual exploration
- *Programming Scripts and Functions:* Program files, control flow, editing, debugging
- *App Building:* App development using App Designer, GUIDE, or a programmatic

workflow

- *Advanced Software Development:* Object-oriented programming; code performance;

unit testing; external interfaces to Java®, C/C++, .NET and other languages

- *Desktop Environment:* Preferences and settings, platform differences

- *Supported Hardware:* Support for third-party hardware, such as webcam, Arduino®,

and Raspberry Pi™ hardware. Also the MicroLab box can be used to get the real time output from the Simulink files

About Simulink:

Simulink® is a block diagram environment for multidomain simulation and Model-Based Design. It supports simulation, automatic code generation, and continuous test and verification of embedded systems.
Simulink provides a graphical editor, customizable block libraries, and solvers for modeling and simulating dynamic systems. It is integrated with MATLAB®, enabling us to incorporate MATLAB algorithms into models and export simulation results to MATLAB for further analysis. To run the model in real time on a target computer, we made use of the Simulink Real-Time™ for HIL simulation, rapid control prototyping, and other real-time testing applications. In this project, our Hardware and Software part both are based on Simulink. In the software part the whole thing is simulated in Simulink and in the hardware part the control signal is also generated using the Simulink file by getting a real time output using ***MicroLab Box and dSPACE*** software

MicroLab Box and dSPACE:

This hardware MicroLab box is a great product for the real time output using the MATLAB, and the dSPACE is the software part of this package which helps to connect the hardware section (MicroLab Box) with the user and interface it according to the user input.

About MicroLab box-

- Compact all-in-one development system for laboratory purposes
- Dual-core real-time processor at 2 GHz
- User-programmable FPGA
- More than 100 channels of high- performance I/O
- Ethernet and CAN bus interfaces
- Easy I/O access via integrated connector panel

Application Areas-

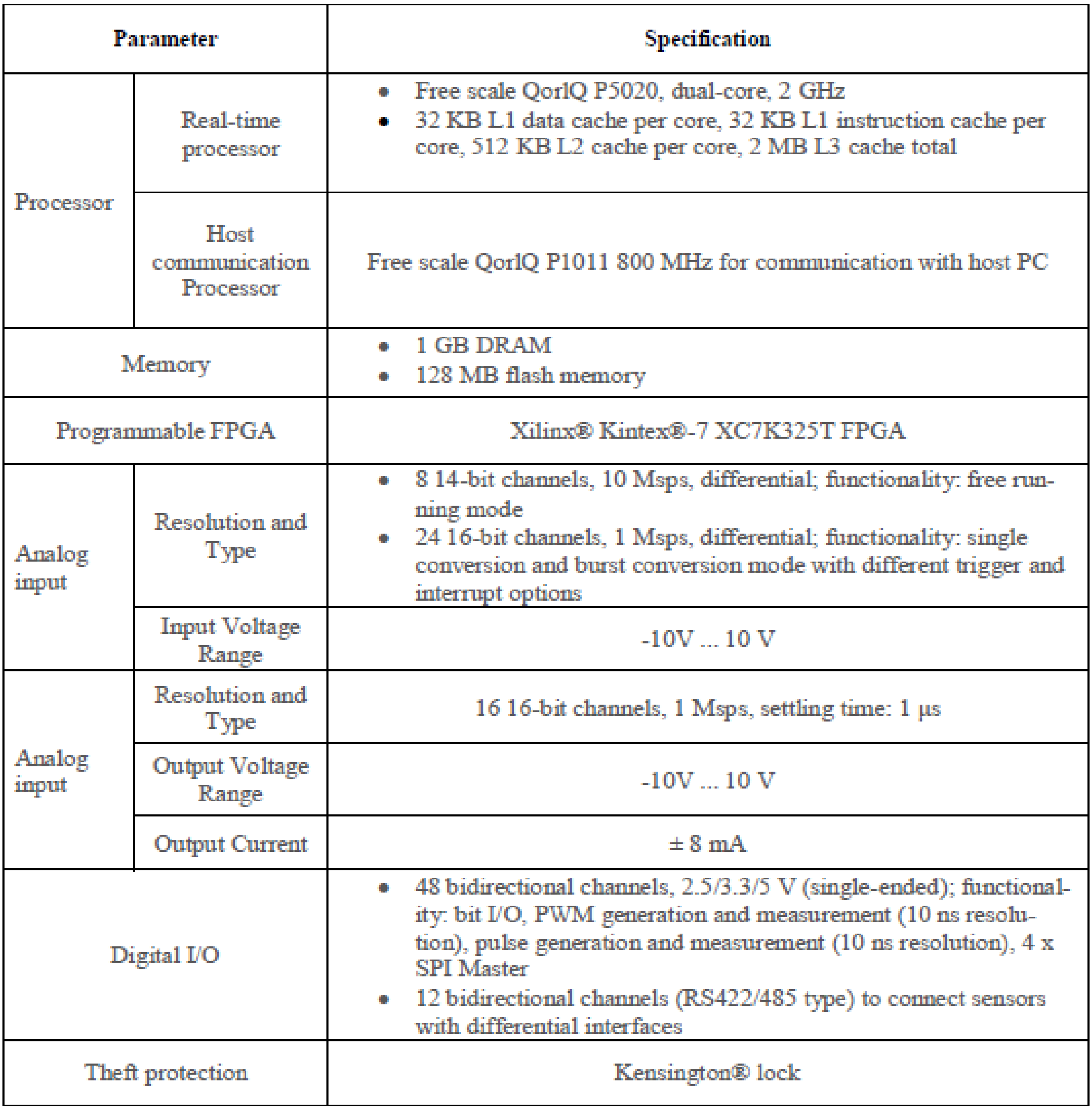
MicroLab Box is a compact development system for the laboratory that combines compact size and cost-effectiveness with high performance and versatility. MicroLab Box lets to set up control, test or measurement applications quickly and easily, and helps to turn new control concepts into reality. More than 100 I/O channels of different types make MicroLab Box a versatile system that can be used in mechatronic research and development areas, such as robotics, medical engineering, electric drives control, renewable energy, vehicle engineering, or aerospace.

Fig. 15 Microlab box

Key Benefits-

High computation power combined with very low I/O latencies provide great real-time performance. A programmable FPGA gives a high degree of flexibility and let’s to run even extremely fast control loops, as required in applications such as electric motor control or active noise and vibration cancellation. MicroLab Box is supported by a comprehensive dSPACE software package (see options on p. 5), including, e.g., Real-Time Interface (RTI) for Simulink ® for model-based I/O integration and the experiment software Control Desk®, which provides access to the real-time application during run time by means of graphical instruments.

Technical Details: -



Parameter		**Specification**
Processor	Real-time processor	• Free scale QorIQ P5020, dual-core, 2 GHz • 32 KB L1 data cache per core, 32 KB L1 instruction cache per core, 512 KB L2 cache per core, 2 MB L3 cache total
	Host communication Processor	Free scale QorIQ P1011 800 MHz for communication with host PC
Memory		• 1 GB DRAM • 128 MB flash memory
Programmable FPGA		Xilinx® Kintex®-7 XC7K325T FPGA
Analog input	Resolution and Type	• 8 14-bit channels, 10 Msps, differential; functionality: free running mode • 24 16-bit channels, 1 Msps, differential; functionality: single conversion and burst conversion mode with different trigger and interrupt options
	Input Voltage Range	-10V ... 10 V
Analog input	Resolution and Type	16 16-bit channels, 1 Msps, settling time: 1 µs
	Output Voltage Range	-10V ... 10 V
	Output Current	± 8 mA
Digital I/O		• 48 bidirectional channels, 2.5/3.3/5 V (single-ended); functionality: bit I/O, PWM generation and measurement (10 ns resolution), pulse generation and measurement (10 ns resolution), 4 x SPI Master • 12 bidirectional channels (RS422/485 type) to connect sensors with differential interfaces
Theft protection		Kensington® lock

Table 2: Parameters of d-SPACE.

For more Technical details go through the Annexure Section.

Real-Time Interface (RTI) using MicroLab box-

RTI lets to concentrate fully on the actual design process and carry out fast design iterations. It extends the C code generator Simulink Coder™ (formerly Real-Time Workshop®) for the seamless, automatic implementation of your Simulink and State flow models on the real-time hardware.

Working with RTI

To connect the model to a dSPACE I/O board, just drag the I/O module from the RTI block library onto the model and then connect it to the Simulink blocks. All settings, such as parameterization, are available by clicking the appropriate blocks. Simulink Coder™ (formerly Real-Time Workshop®) generates the model code while RTI provides blocks that implement the I/O capabilities of dSPACE systems in Simulink models, thus preparing the model for the realtime application. Your real-time model is compiled, downloaded, and started automatically on the real-time hardware, without having to write a single line of code. RTI guides through the configuration. RTI provides consistency checks, so potential errors can be identified and corrected before or during the build process.

To find about more about the MicroLab box please go through the annexure.

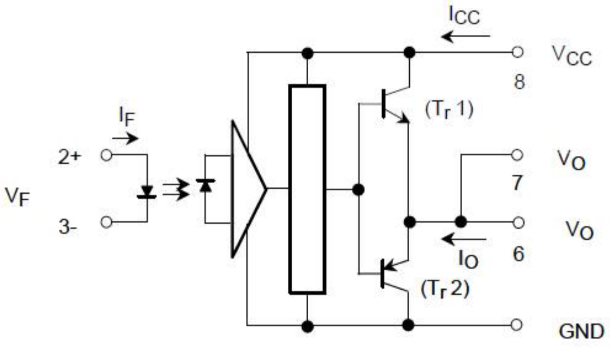
Hardware Section:-

- *The Circuit for Gate driver (TLP 250h)-*

Basically this circuit consist of 1 gate divers for the 1 MOSFETs we used, all the driver circuits are identical so as the components.

The Gate driver circuit consists of-

- TLP250h
- Resistors (470Ω, 10Ω, 10kΩ)
- Capacitors(100μF, 100nF)
- 12 V dc source
- 12V dc female port



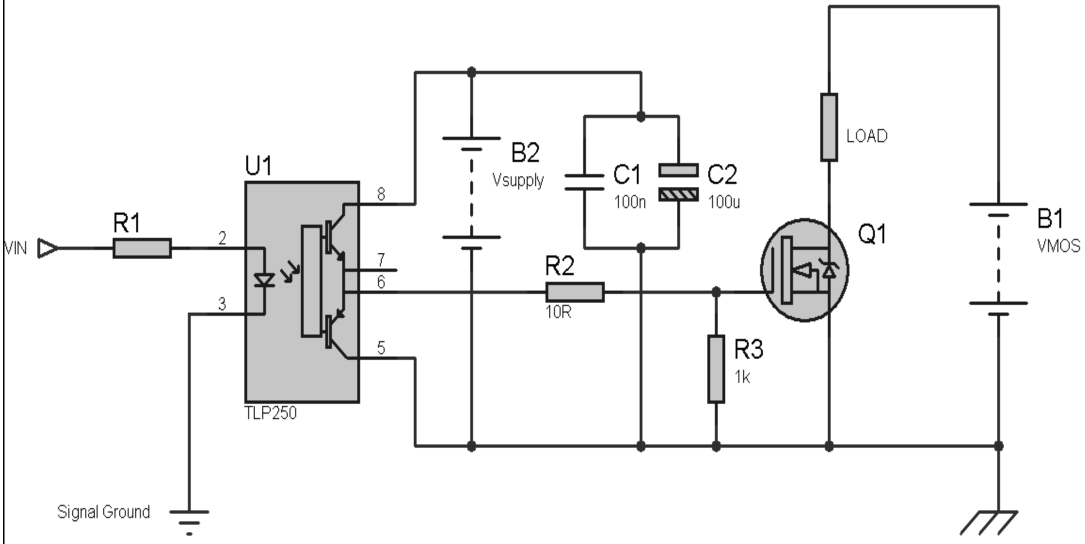


Fig. 17 Individual gate driver circuit

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

I. The Gate Driver Circuit (IR2110)-

In many situations, we need to use MOSFETs configured as high-side switches. Many a times we need to use MOSFETs configured as high-side and low-side switches. Such as in bridge circuits. In half-bridge circuits, we have 1 high-side MOSFET and 1 low-side MOSFET. In full-bridge circuits we have 2 high-side MOSFETs and 2 low-side MOSFETs. In such situations, there is a need to use high-side drive circuitry alongside low-side drive circuitry. The most common way of driving MOSFETs in such cases is to use high-low side MOSFET drivers. Undoubtedly, the most popular such driver chip is the IR2110. And in this article, we will talk about the IR2110.

First let’s take a look at the block diagram and the pin assignments and pin definitions:

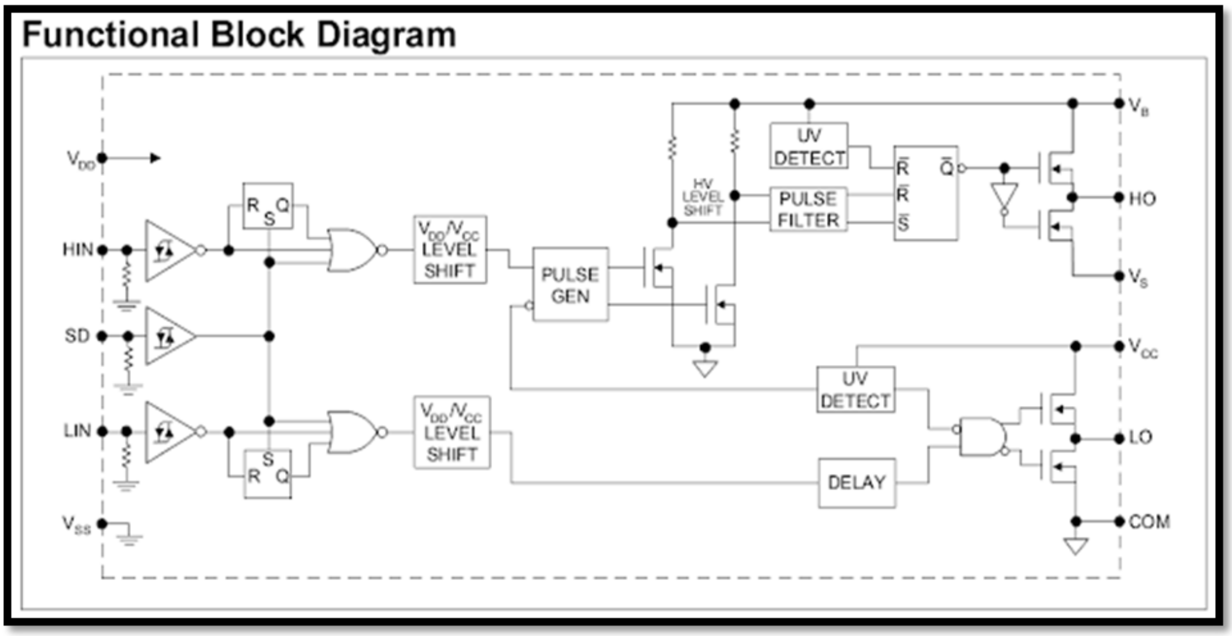


Figure 18 : IR2110 block diagram

Figure 19 : IR2110 IC Chip

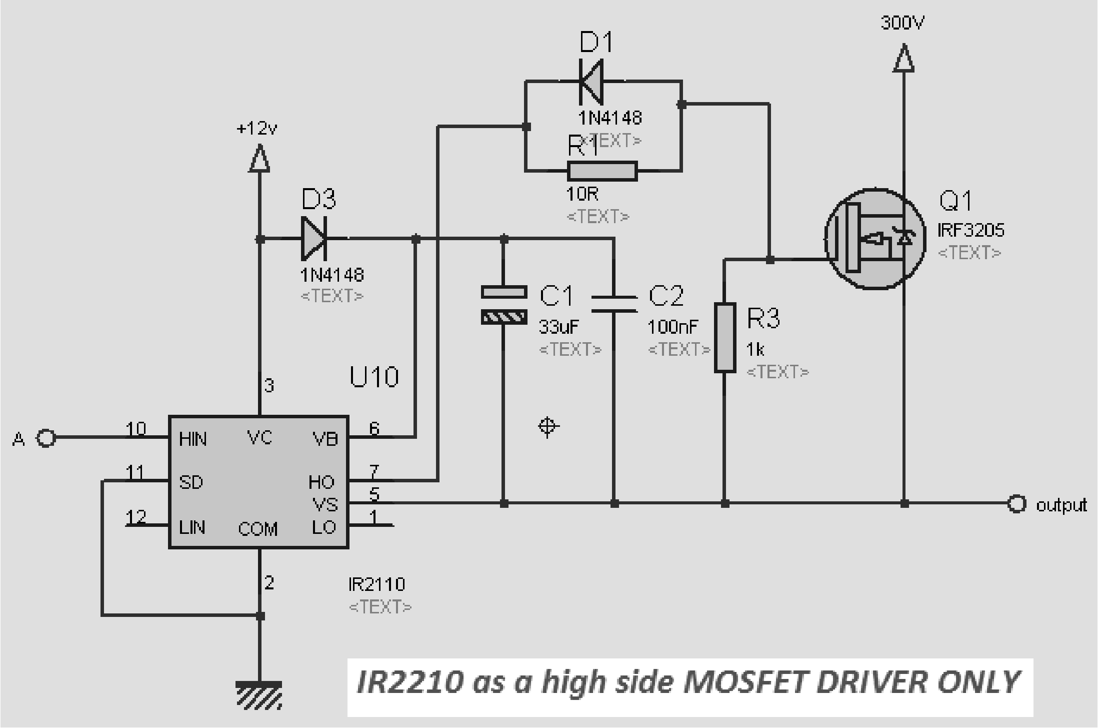


Figure 20: IR2110 Circuit as a single high-voltage high-side driver

Pin Configuration of IR 2110:-

Pin Number	Pin Name	Function
1	LO	Output of Low Side MOSFET Drive
2	COM	Return Path for Low Side MOSFET
3	VCC	Low Side Supply Voltage
4	-	-
5	VS	High side floating supply return or offset voltage
6	VB	High side floating supply voltage
7	HO	High side gate driver output
8	-	-
9	VDD	Logic supply voltage
10	HIN	Input signal for high side MOSFET driver output
11	SD	Logic input for shutdown
12	LIN	Input signal for low side MOSFET driver output
13	VSS	Logic Ground
14	-	-

DESIGNING OF INDUCTOR:-

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, Pt , 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 permittivity greater than µO 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 :

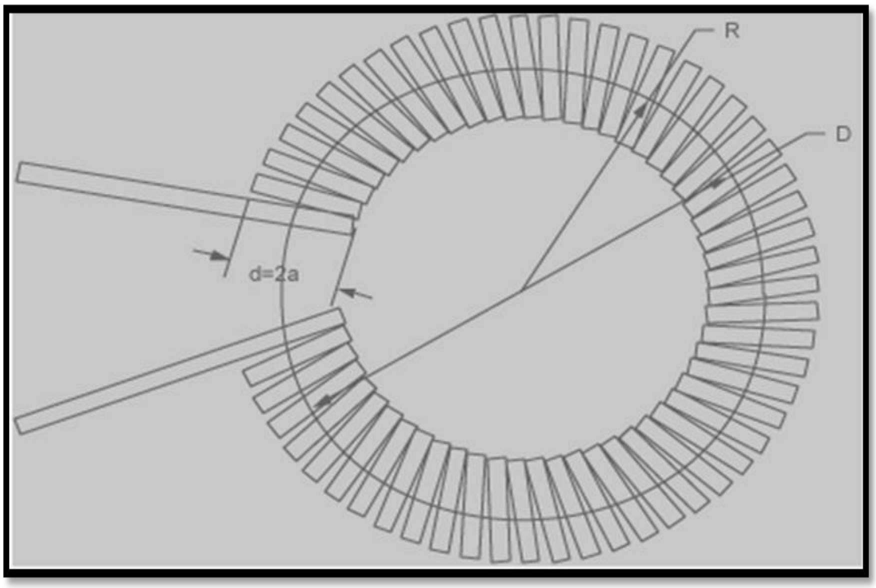


Figure 22 : Diagram of a Circular Cross Section Toroid Inductor

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

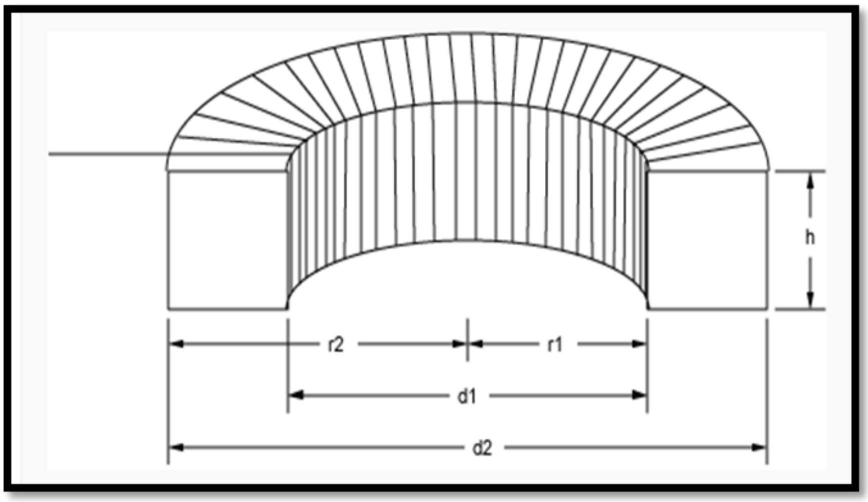


Figure 23 : Diagram of a Square Cross Section Toroid Inductor

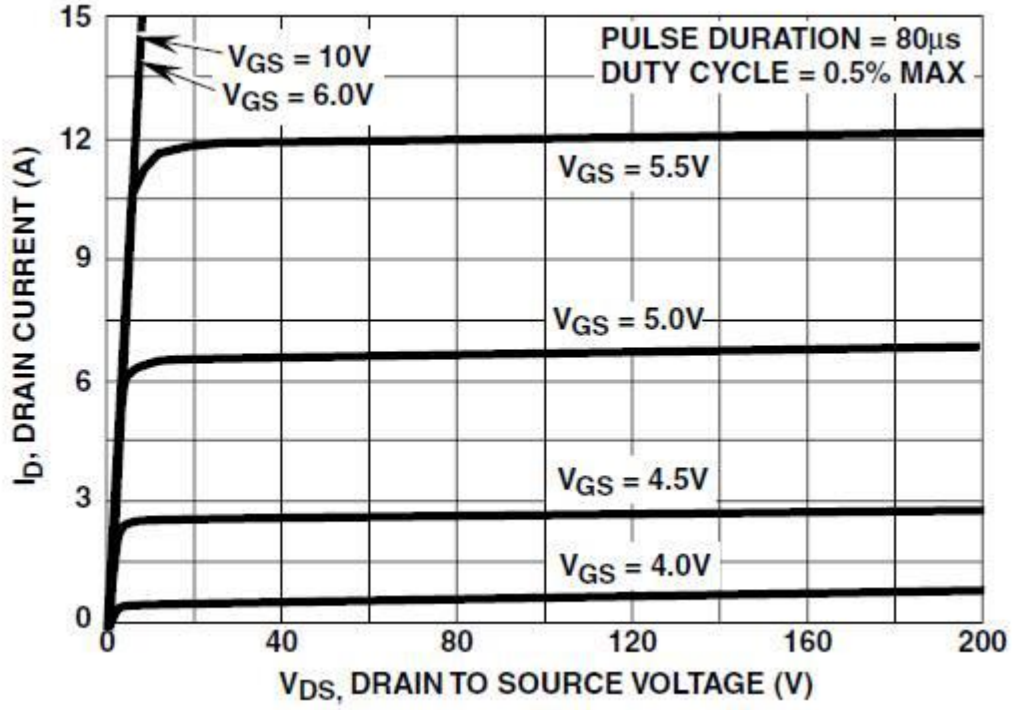
Another formula for the inductance of a Circular Cross Section Toroid is :

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

The component details are given below-

MOSFET (IRF740):

10A, 400V, 0.550 Ohm, N-Channel Power MOSFET. This N-Channel enhancement mode silicon gate power field effect transistor is an advanced power MOSFET designed, tested, and guaranteed to withstand a specified level of energy in the breakdown avalanche mode of operation. All of these power MOSFETs are designed for applications such as switching regulators, switching converters, motor drivers, relay drivers, and drivers for high power bipolar switching transistors requiring high speed and low gate drive power. They can be operated directly from integrated circuits.



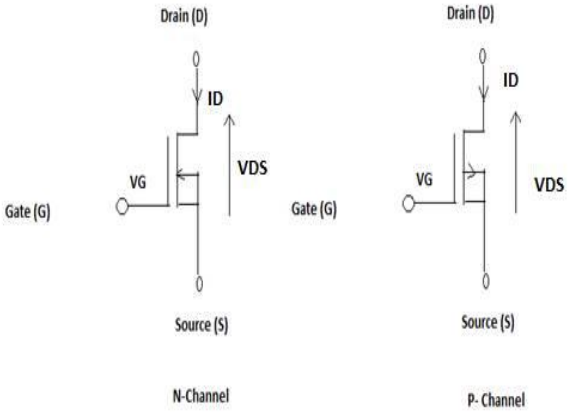
About MOSFET:-

The MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is a semiconductor device which is widely used for switching and amplifying electronic signals in the electronic devices. The MOSFET is a core of integrated circuit and it can be designed and fabricated in a single chip because of these very small sizes. The MOSFET is a four terminal device with source(S), gate (G), drain (D) and body (B) terminals. The body of the MOSFET is frequently connected to the source terminal so making it a three terminal device like field effect transistor. The MOSFET is very far the most common transistor and can be used in both analog and digital circuits. The MOSFET works by electronically varying the width of a channel along which charge carriers flow (electrons or holes). The charge carriers enter the channel at source and exit via the drain. The width of the channel is controlled by the voltage on an electrode is called gate which is located between source and drain. It is insulated from the channel near an extremely thin layer of metal oxide. The MOSFET can be function in two ways

1. Depletion Mode 2. Enhancement Mode

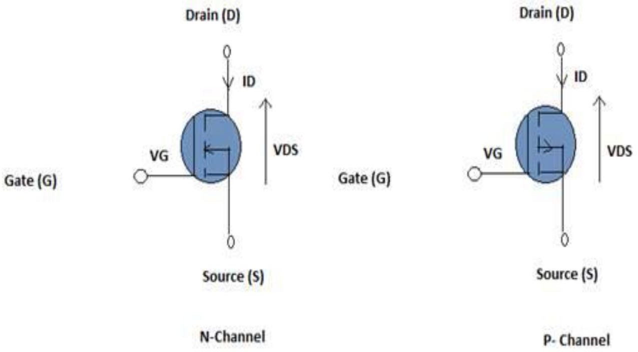
Depletion Mode:

When there is no voltage on the gate, the channel shows its maximum conductance. As the voltage on the gate is either positive or negative, the channel conductivity decreases.



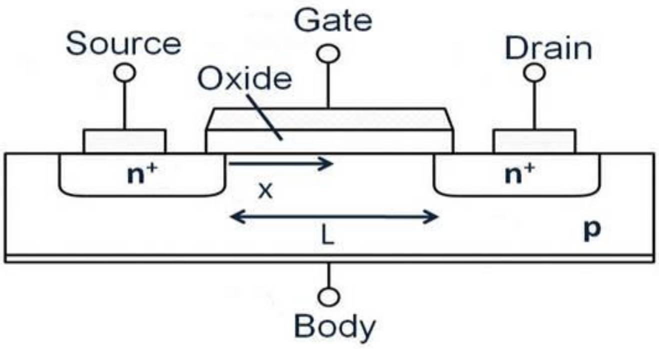
Enhancement mode:

When there is no voltage on the gate the device does not conduct. More is the voltage on the gate, the better the device can conduct.



Working Principle of MOSFET:

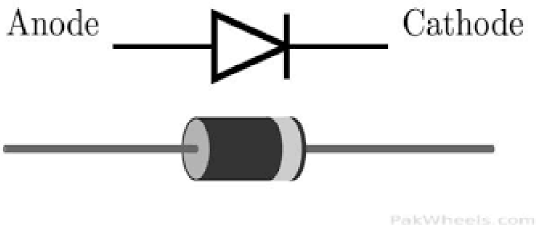
The aim of the MOSFET is to be able to control the voltage and current flow between the source and drain. It works almost as a switch. The working of MOSFET depends upon the MOS capacitor. The MOS capacitor is the main part of MOSFET. The semiconductor surface at the below oxide layer which is located between source and drain terminal. It can be inverted from p-type to n-type by applying a positive or negative gate voltages respectively. When we apply the positive gate voltage the holes present under the oxide layer with a repulsive force and holes are pushed downward with the substrate. The deflection region populated by the bound negative charges which are associated with the acceptor atoms. The electrons reach channel is formed. The positive voltage also attracts electrons from the n+ source and drain regions into the channel. Now, if a voltage



is applied between the drain and source, the current flows freely between the source and drain and the gate voltage controls the electrons in the channel. Instead of positive voltage if we apply negative voltage, a hole channel will be formed under the oxide layer.

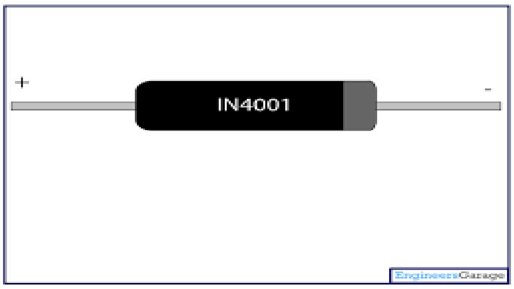
DIODE (1n4001):

1N4001 is a member of 1N400x diodes. Diode is a rectifying device which conducts only from anode to cathode. Diode behaves open circuited for the current flow from cathode to anode.



1N4001 is a 1A diode with low forward voltage drop and high surge current capability. It comprises of diffused PN junction and has low reverse leakage current of 5µA. Its DC blocking voltage is 50V.

The cathode is identified by a bar on diode case. The other terminal is the anode.



Features:

- Low forward voltage drop
- Low leakage current
- High forward surge capability
- Solder dip 275 °C max. 10 s

RESISTANCES:

Resistances that are used are (10Ω, 470 Ω, 1kΩ, 10kΩ), 0.25W and 33 Ω, 0.5W.

- The 10 Ω & 10 kΩ resistances are used for the output of the TLP gate driver circuit.
- The 470 Ω resistances are used in the input side of the TLP gate driver circuit
- The 1 kΩ are used as load and also in voltage divider circuit.
- The 33Ω resistance is used for the snubber circuit

CAPACITANCES:

Capacitances that are used are 0.1 µf, 0.33 µf, 100µf, 470pF of 50V

- The 0.1μf, 100μf capacitors are used in the TLP driver circuit.
- The 0.1 μf and 0.33 μf capacitances are used in the power source circuit.
- The 470pf capacitance is used in the snubber design of the MOSFET.

DC FEMALE POWER CONNECTOR:

This is used to connect the jack from 12V DC supply.

12V DC ADAPTER:-

We used 12 V dc adapters as a replacement of power source

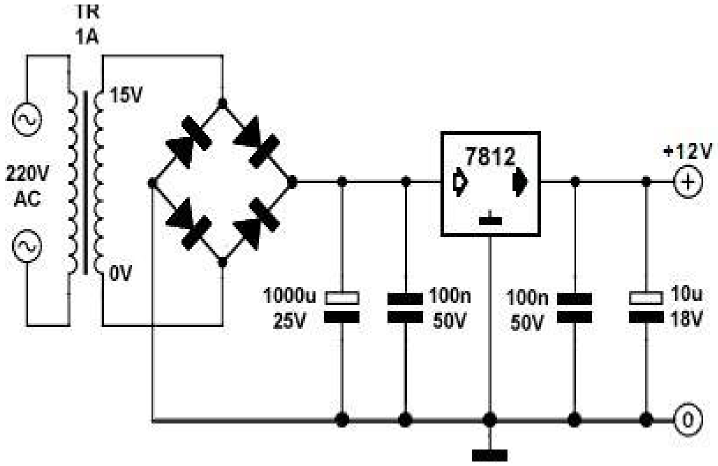


FIGURE 24:Circuit Diagram of 12v DC Adapter

List of the components used

Sl. no.	Name of the components	Specification		Quantity
1.	MOSFET (IRF540)	10A, 400V, 0.550 Ohm, N-Channel Power MOSFET		1
2.	Optocoupler IC (TLP250h)	Input threshold current: IF=5mA (max.) Supply current (ICC): 11mA (max.) Supply voltage (VCC): 10−35V Output current (IO): ±1.5A (max.) Switching time (tpLH/tpHL):1.5μs (max.) Isolation voltage: 2500Vrms(min.)		1
3.	Diode (1n4007)	I_F(AV) =1.0 A V_{RRM}= 50 V to 1000 V I_{FSM} (8.3 ms sine-wave)= 30 A I_{FSM} (square wave tp = 1 ms)= 45 A V_F =1.1 V I_R =5.0 µA		2
4.	IC (IR 2110)	VOFFSET (IR2110) 500V max. (IR2113) 600V max. IO+/- 2A / 2A VOUT 10 - 20V ton/off (typ.) 120 & 94 ns Delay Matching (IR2110) 10 ns max. (IR2113) 20ns max		1
5.	Resistances	1 K ohm	25 Watt	2
		10 ohm		2
		22 K ohm		2
		100 ohm		1
6.	Capacitances	47 micro farad	50 volt	2
		100micro farad		2
		10 farad		2
		22 micro farad		2
7.	DC female power Connector	____________		As per requirement
8.	DC adapter	Input- 230V, output -12V		1
9.	Connecting wires	_____________		As per requirement
10.	Male port, Female port	_____________		As per requirement
11.	MicroLab Box	_____________		1

4.CIRCUIT DIAGRAMS AND THEIR OPERATION

POWER CIRCUIT:

An AC/DC adapter or AC/DC converter is a type of external power supply. AC adapters are used with electrical devices that require power but do not contain internal components to derive the required voltage and power from mains power. The internal circuitry of an external power supply is very similar to the design that would be used for a built-in or internal supply. We use it for main power supply.

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.
TL250 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

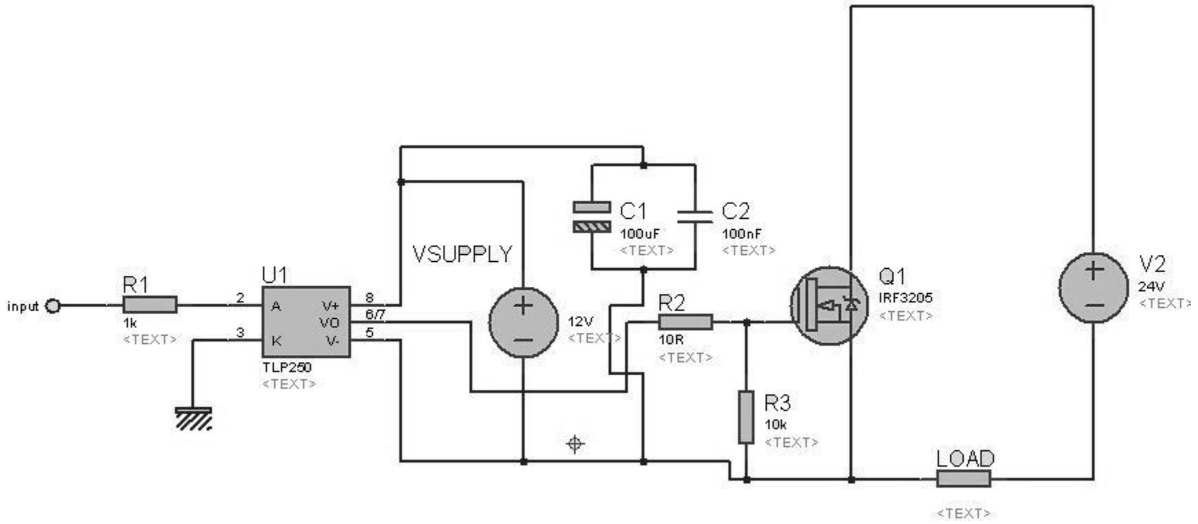


Fig 25: TLP250 working Circuit

IR 2110 Driver Circuit Operation:

The circuit is simple enough and follows the same functionality described above. One thing to remember is that, since there is no low-side switch, there is a load connected from OUT to ground. Otherwise the bootstrap capacitors cannot charge.

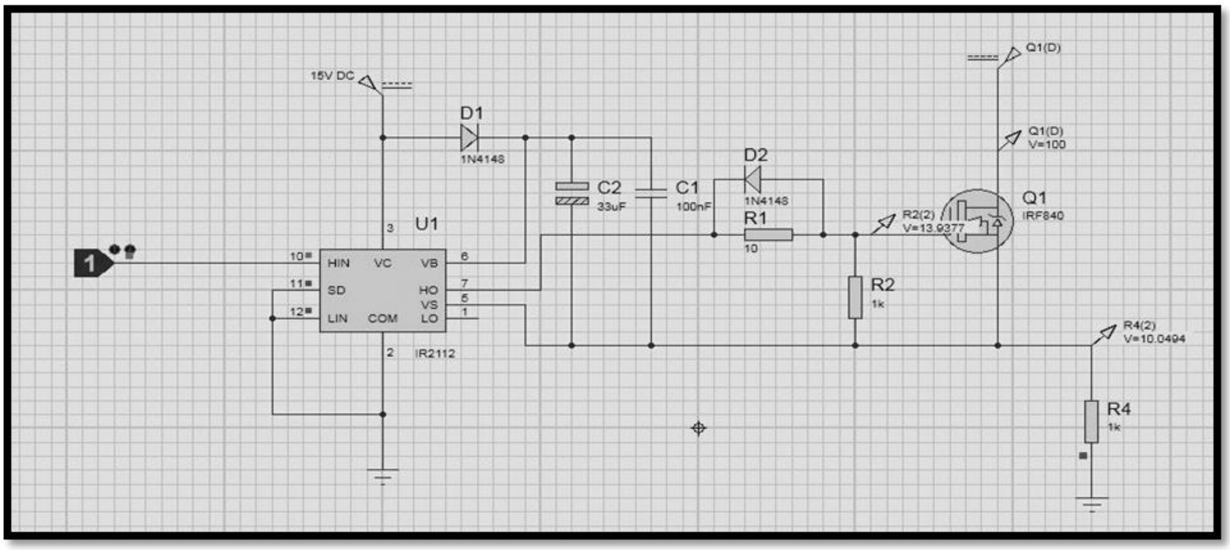


Figure 26 : Using the IR2110 as a single high-voltage high-side driver

It is common practice to use VDD = +5V. When VDD = +5V, the logic 1 input threshold is slightly higher than 3V. Thus when VDD = +5V, the IR2110 can be used to drive loads when input “1” is higher than 3 point something volts. This means that it can be used for almost all circuits, since most circuits tend to have around 5V outputs. When you’re using microcontrollers the output voltage will be higher than 4V (when the microcontroller has VDD = +5V, which is quite common). When you’re using SG3525 or TL494 or other PWM controller, you are probably going to have them powered off greater than 10V, meaning the outputs will be higher than 8V when high. So, the IR2110 can be easily used.

In most of the circuits, we do not have signal levels which have voltages less than 4V as high and so we use VDD = +5V.

Now let’s talk about VSS and COM. VSS is the logic supply ground. COM is “low side return” – basically, low side drive ground connection. While they are not internally connected, IR2110 is a non-isolated driver, meaning that VSS and COM should both be connected to ground.

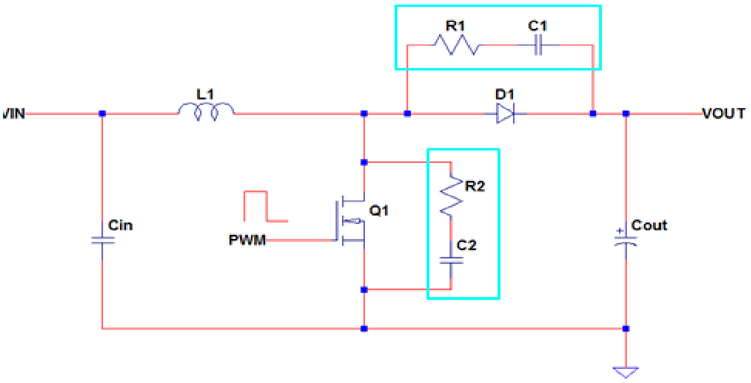
Snubber can do many things: -

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 ·

There are many different kinds of snubber but we used only RC snubber circuit.

RC snubber design:

An RC snubber, placed across the MOSFET as shown in figure 5, can be used to reduce the peak voltage at turn-off and to damp the ringing. In most cases a very simple design technique can be used to determine suitable values for the snubber components (R and C). In those cases where a more optimum design is needed, a somewhat more complex procedure is used. The values of resistance R=33 Ω, 0.5 W and capacitance C= 470 pF are used in our snubber
circuit.



Software Simulation Circuit:

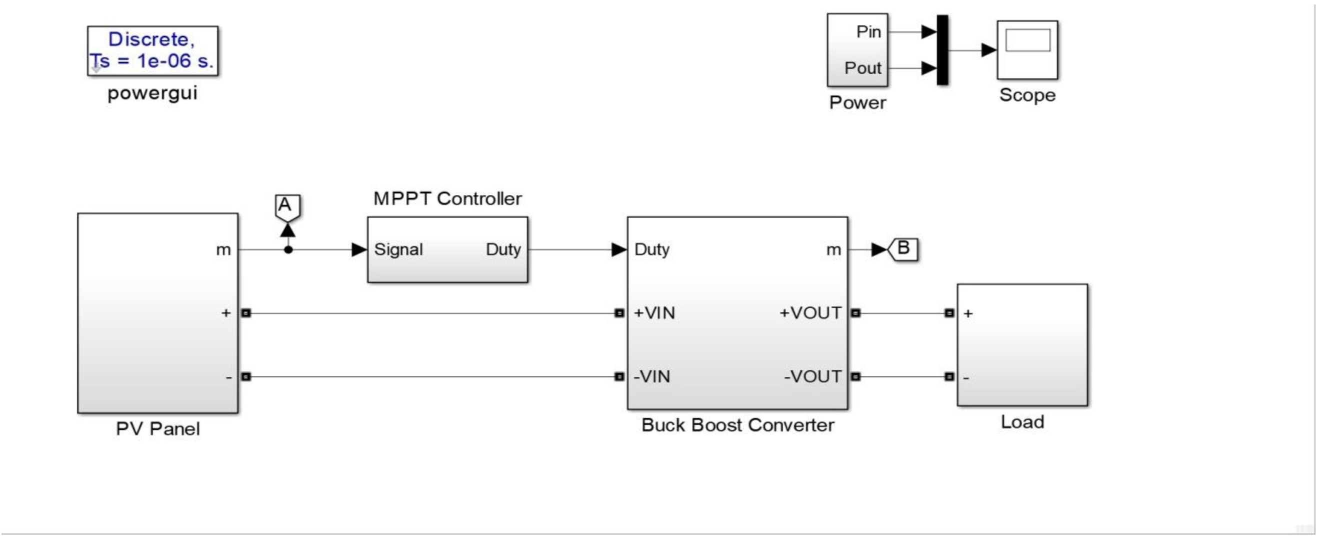


Fig 27: Circuit Diagram for subsystem of Buck-Boost Converter

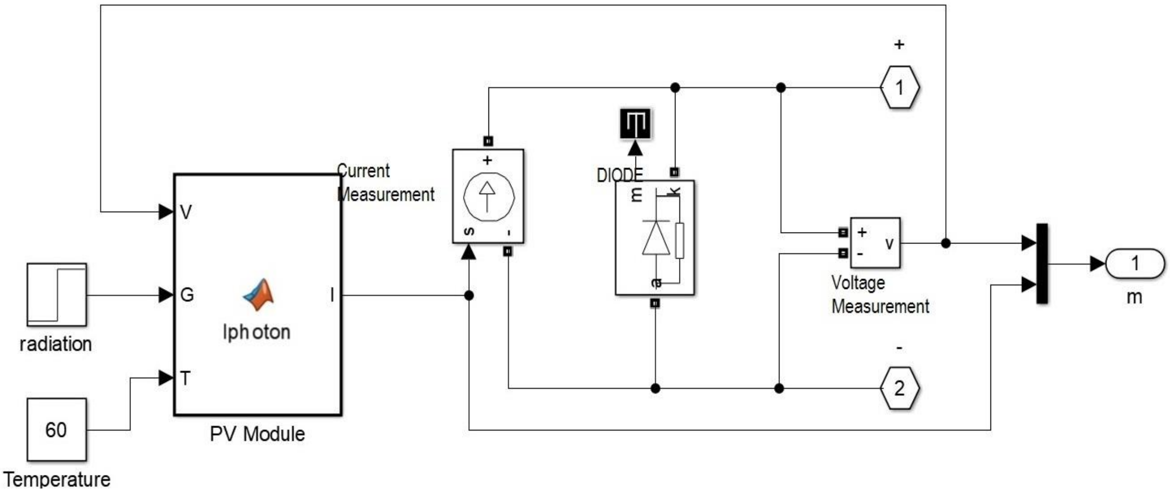


Fig 28: Circuit Diagram for subsystem of PV Panel

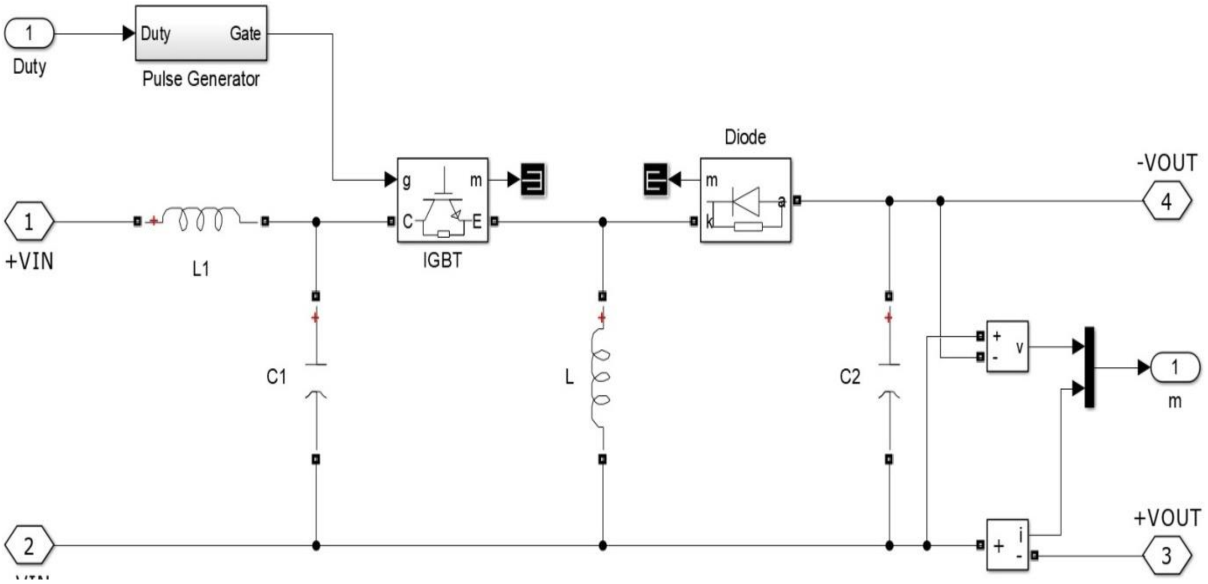


Fig 29: Circuit Diagram of MPPT Controller along with Converter in MATLAB

Simulation Results:

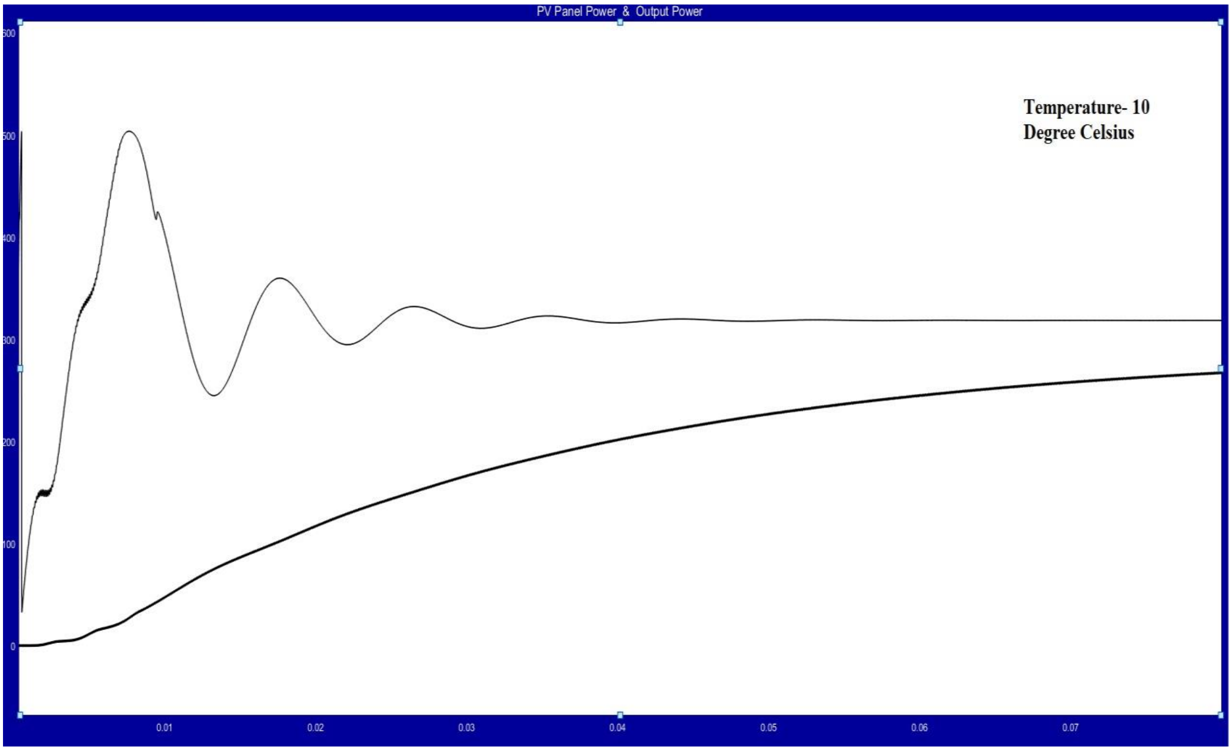


Fig.30:PV panel power and output power for temperature of 10 degree Celsius

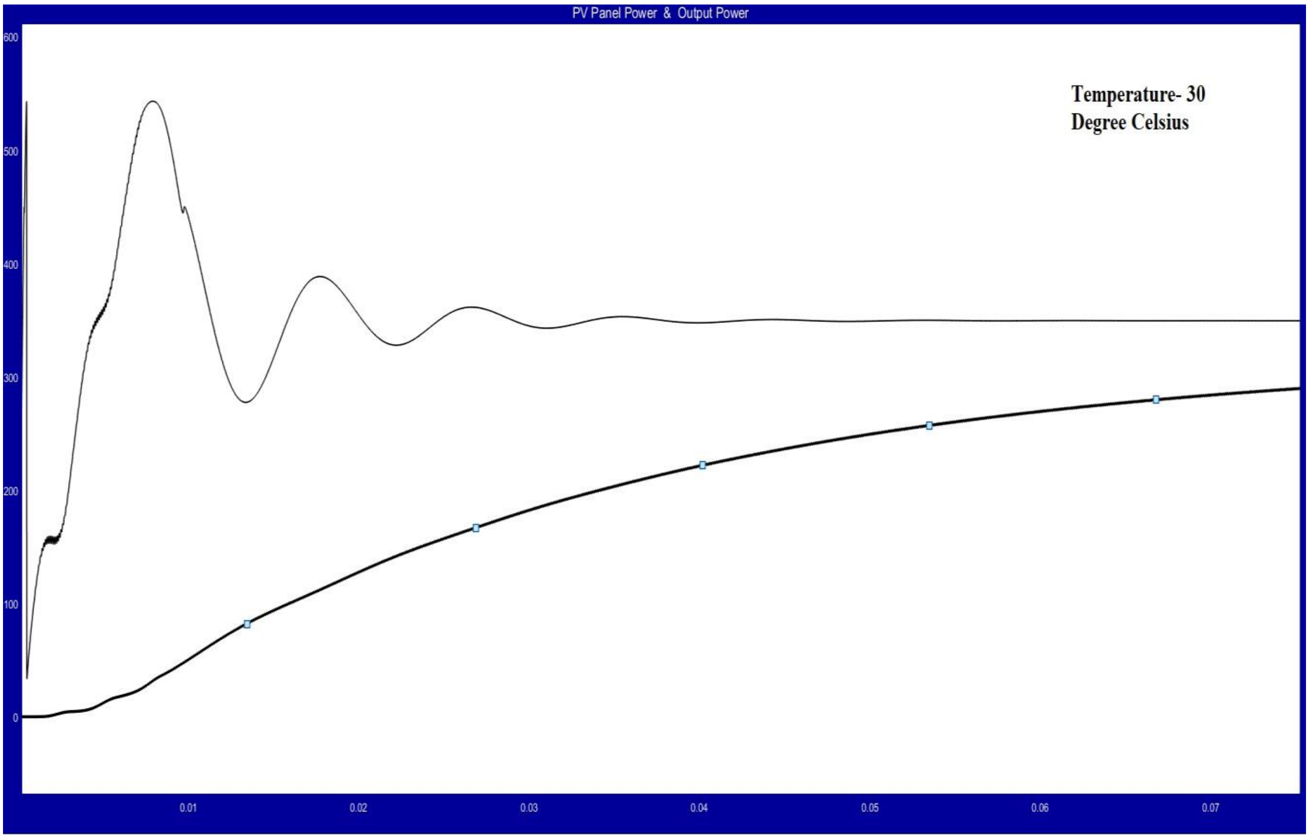


Fig.31 :PV panel power and output power for temperature of 30 degree Celsius

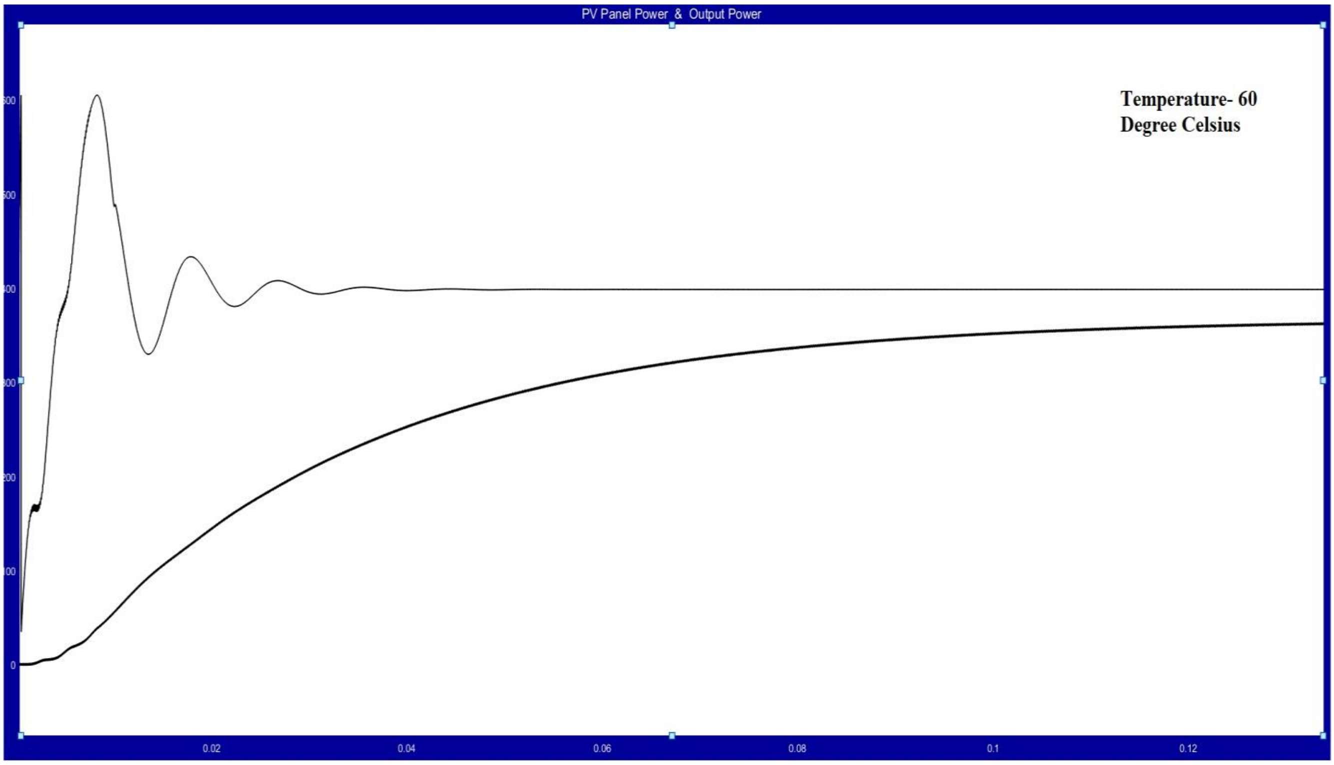
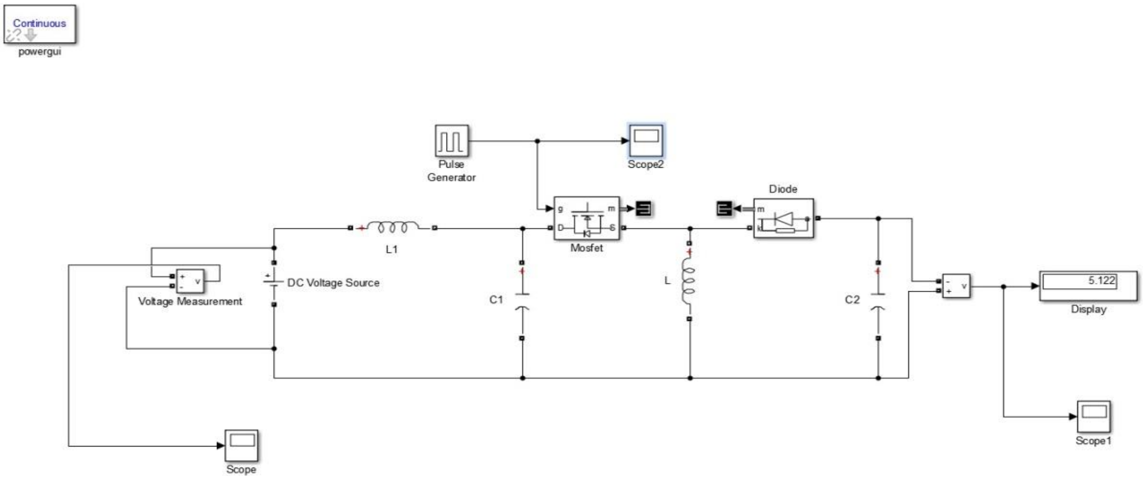


Fig. 32:PV panel power and output power for temperature of 60 degree Celsius

Fig



33:Circuit for BuckConverter.

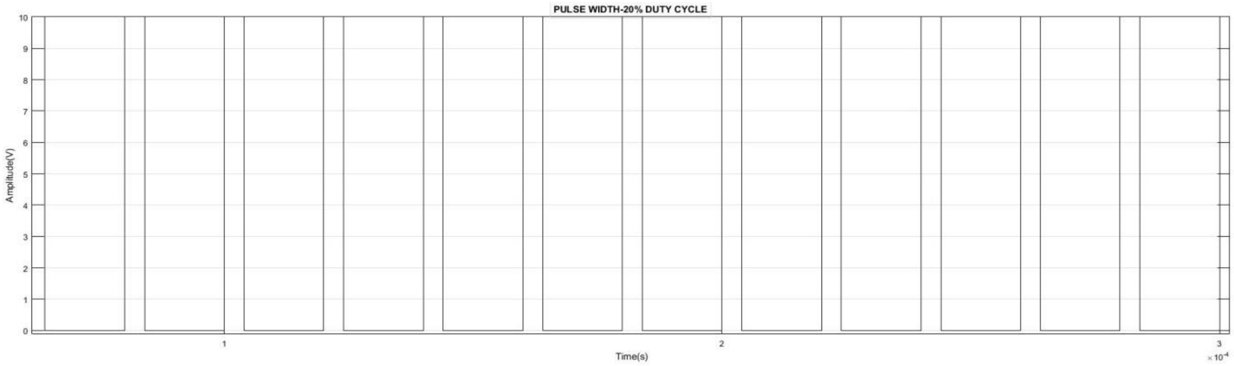


Fig 34: Pulse Width of
20%DutyCycle

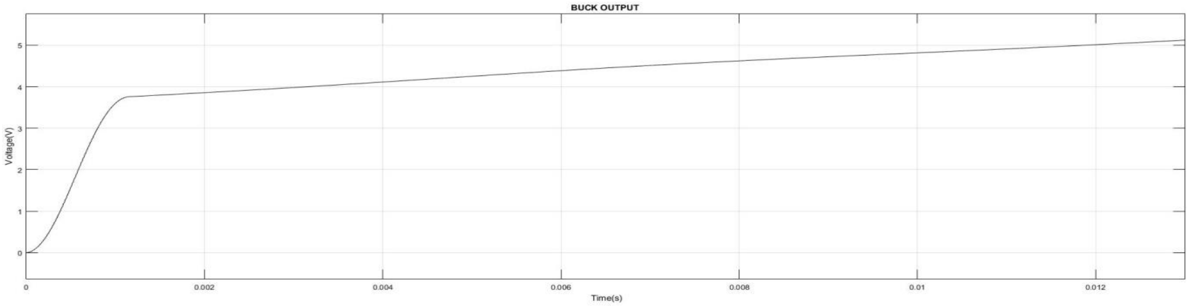


Fig 35: Output waveform of buck converter

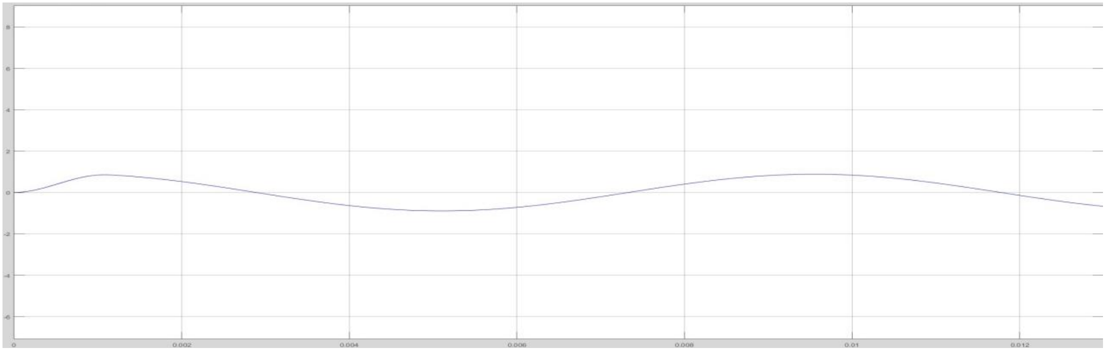


Fig 35: Output voltage waveform across inductor 1

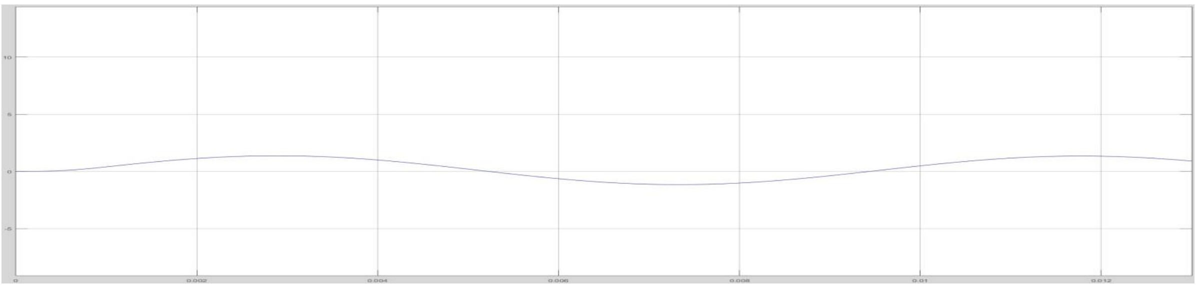


Fig 36: Output current waveform across inductor 1

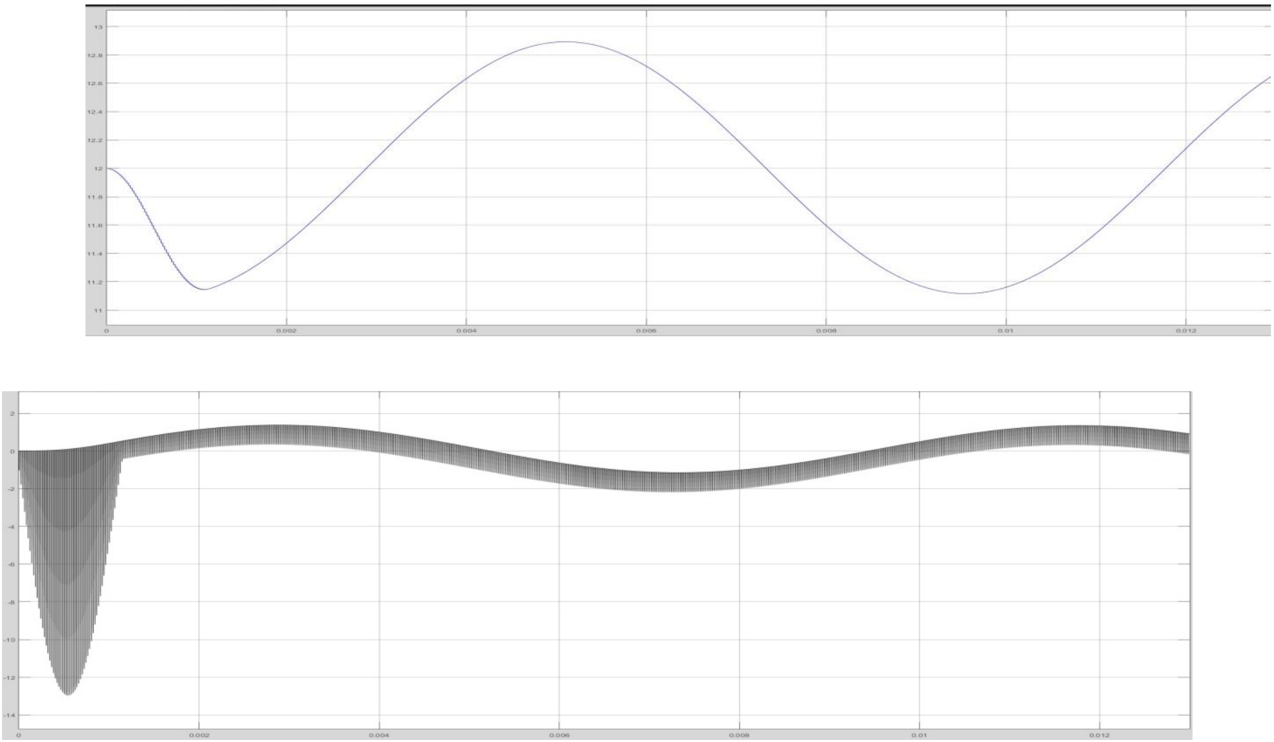


Fig 37: Output voltage waveform across capacitor 1

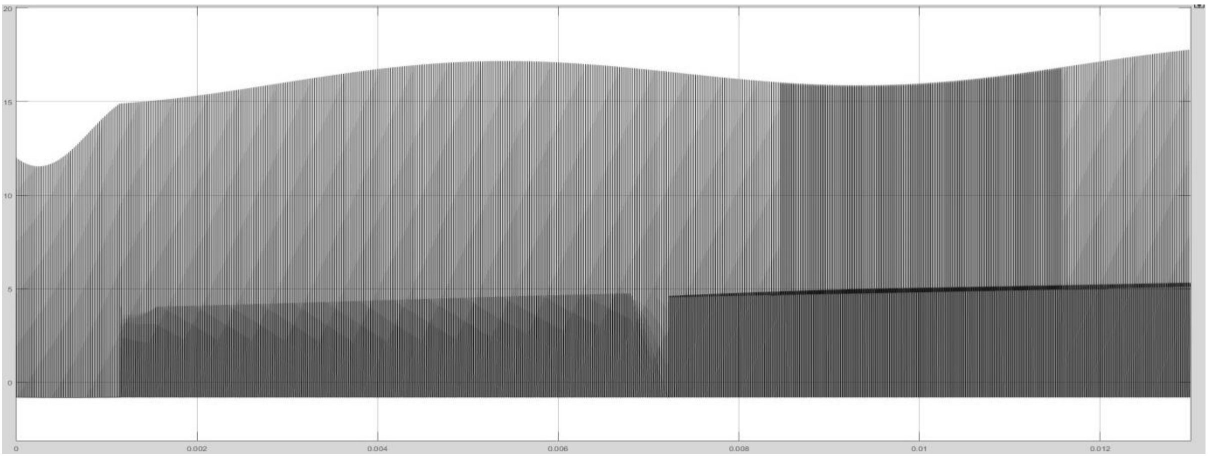


Fig 38: Output current waveform across capacitor 1

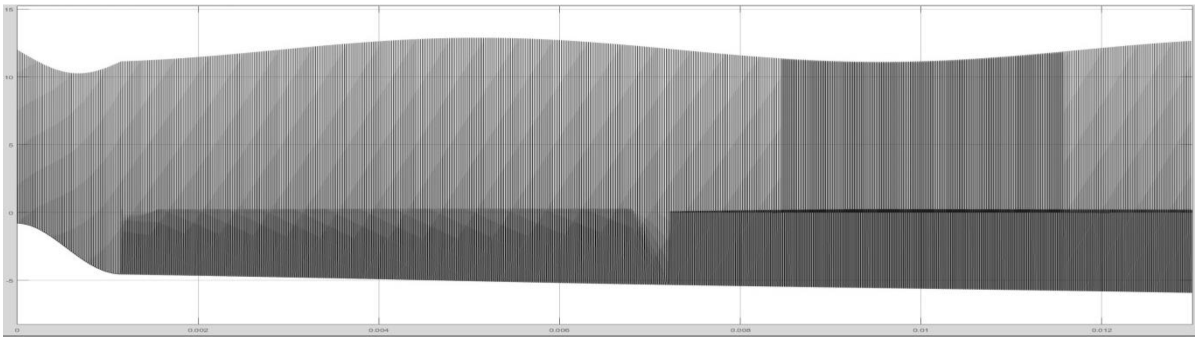


Fig 40: Output voltage waveform across inductor 2

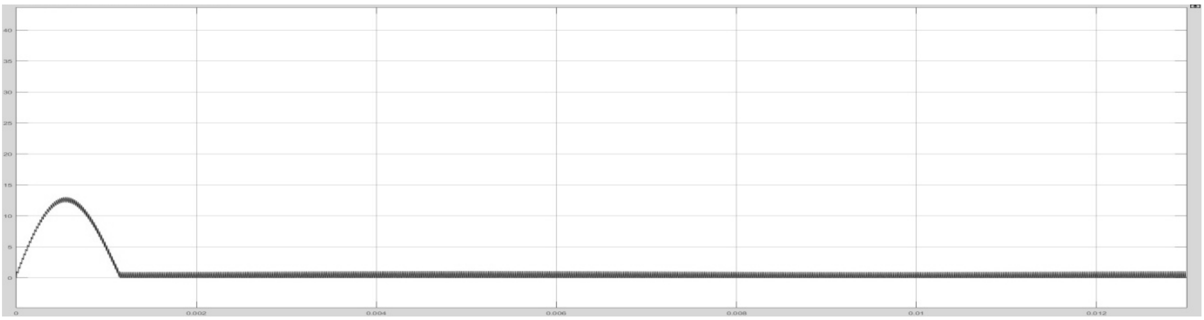


Fig 41: Output current waveform across inductor2

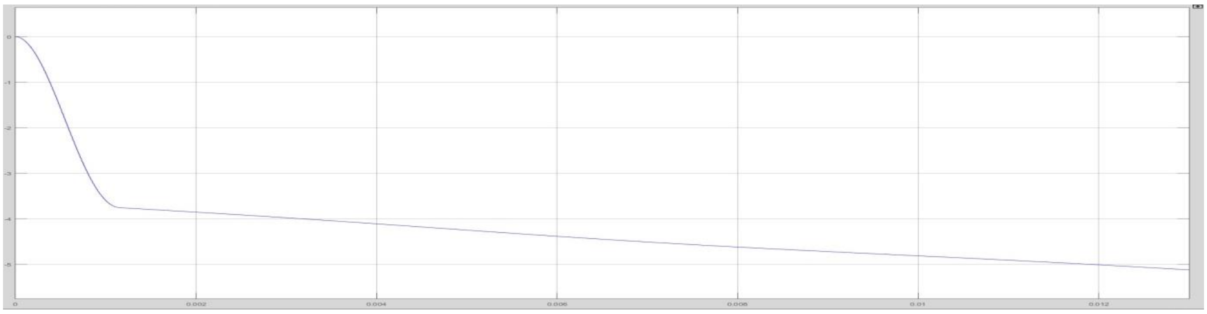


Fig 42: Output voltage waveform across capacitor 2

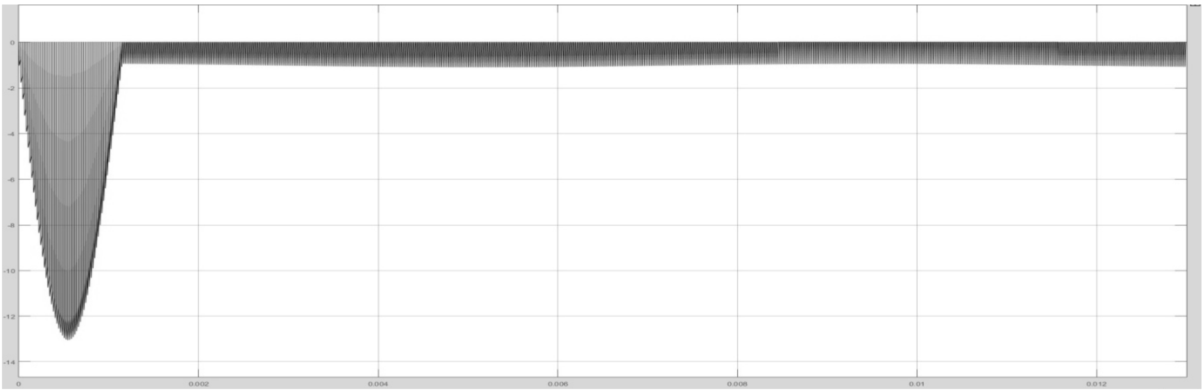


Fig 43: Output current waveform across capacitor 2

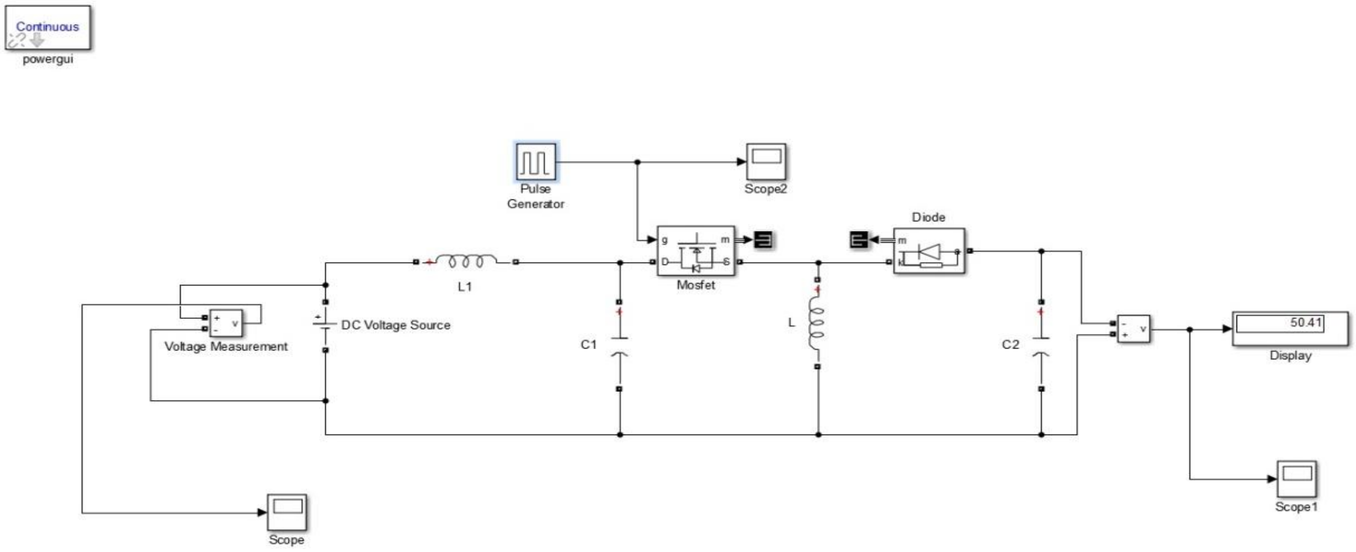


Fig 44: Circuit for Boost Converter.

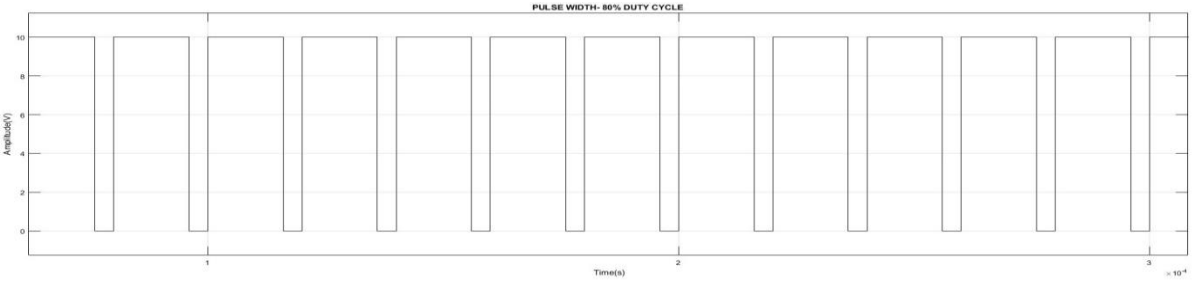


Fig 45: Pulse Width of 80% Duty Cycle

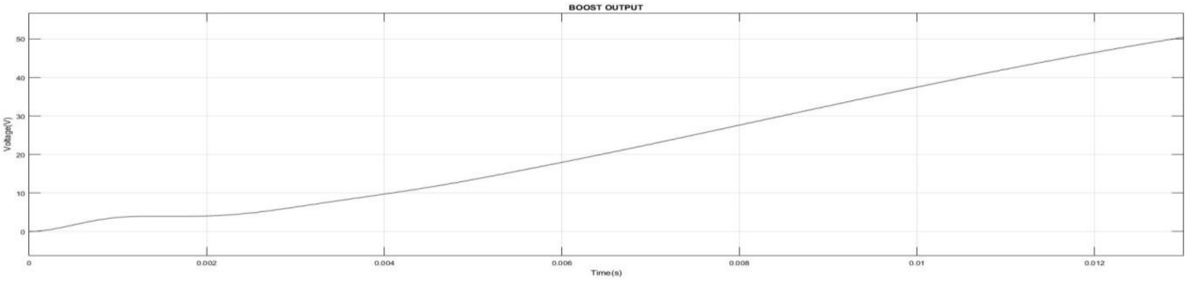


Fig 46: Output waveform of boost converter

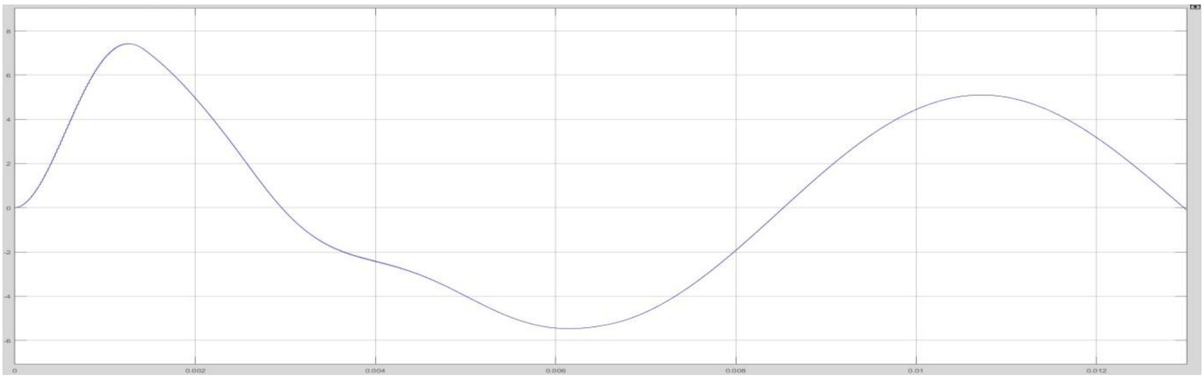


Fig 47: Output voltage waveform across inductor 1

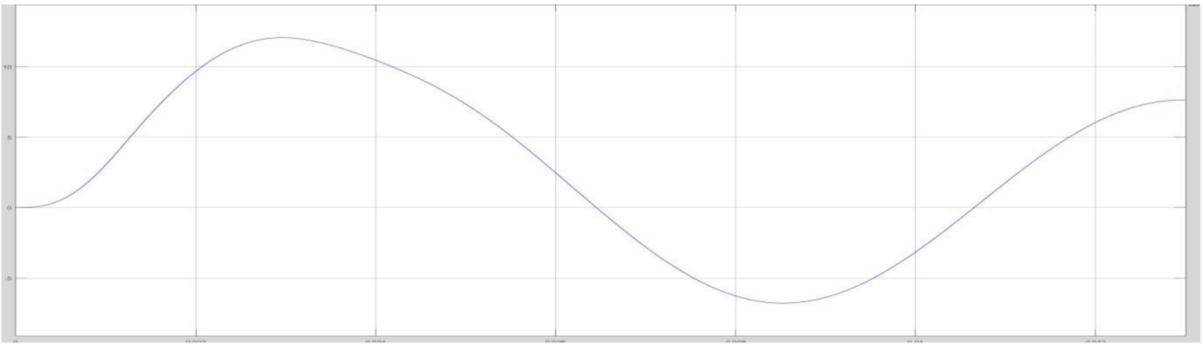


Fig 48: Output current waveform across inductor 1

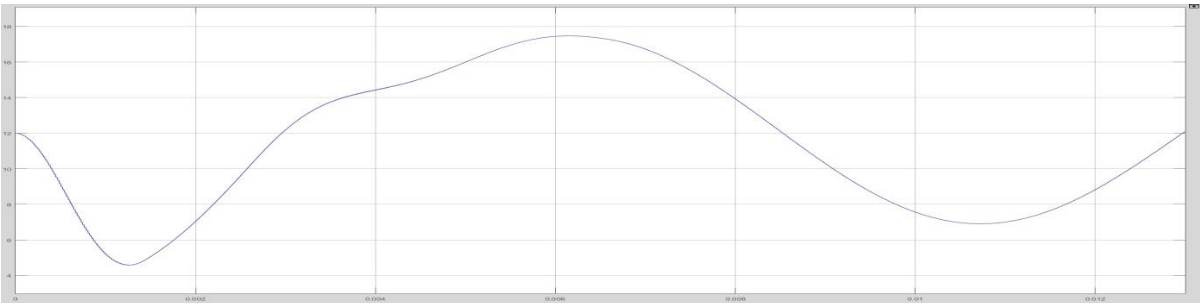


Fig 49: Output voltage waveform across capacitor 1

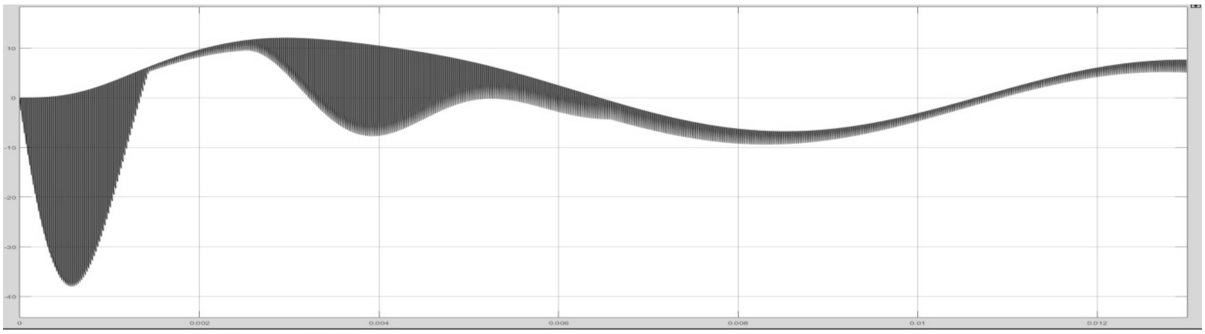


Fig 50: Output current waveform across capacitor 1

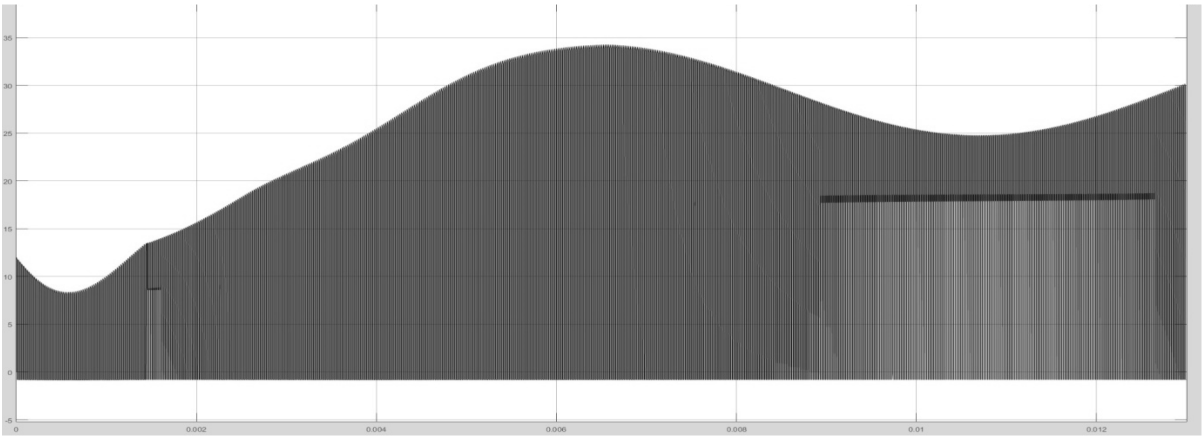


Fig 51: Output voltage waveform across diode

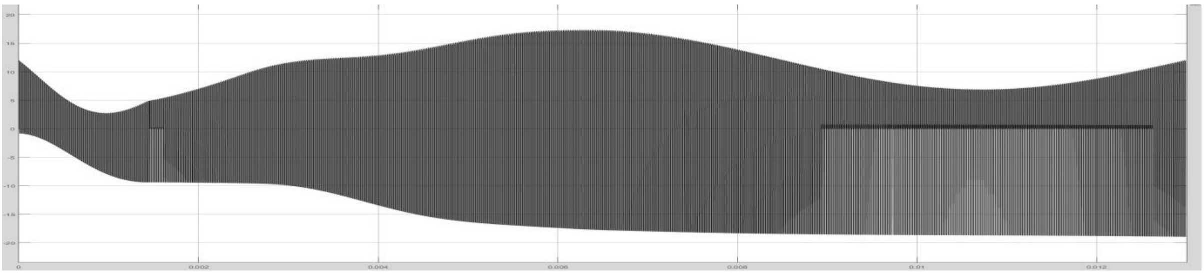


Fig 52: Output voltage waveform across inductor 2

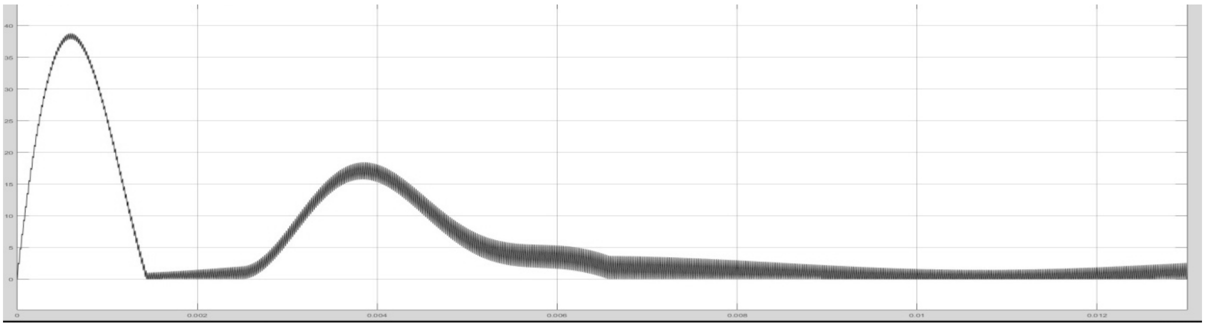


Fig 53: Output current waveform across inductor 2

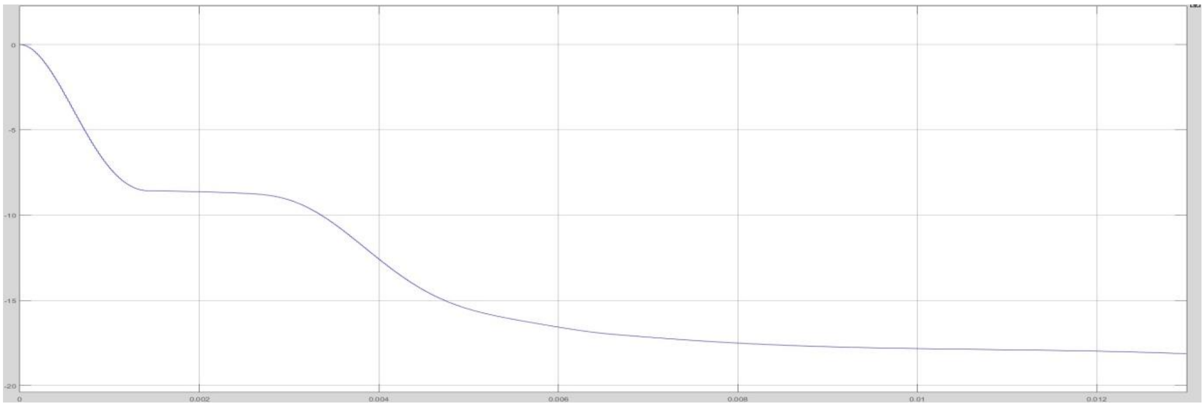


Fig 54: Output voltage waveform across capacitor

A Brief Comparison of all the parameters of voltages and currents across different components for different pulse width

Pulse Width	20%	80%
Source Voltage	12 V	12 V
Output Voltage	5.1 V	50.41V
Voltage Across Capacitor 1	12.67 V	16.05V
Current Across Inductor 1	0.909A	30.65A
Current Across Inductor 2	4.13e-5 A	35.08A
Voltage Across Diode	0.512V	0.835V

HARDWARE CIRCUITS:

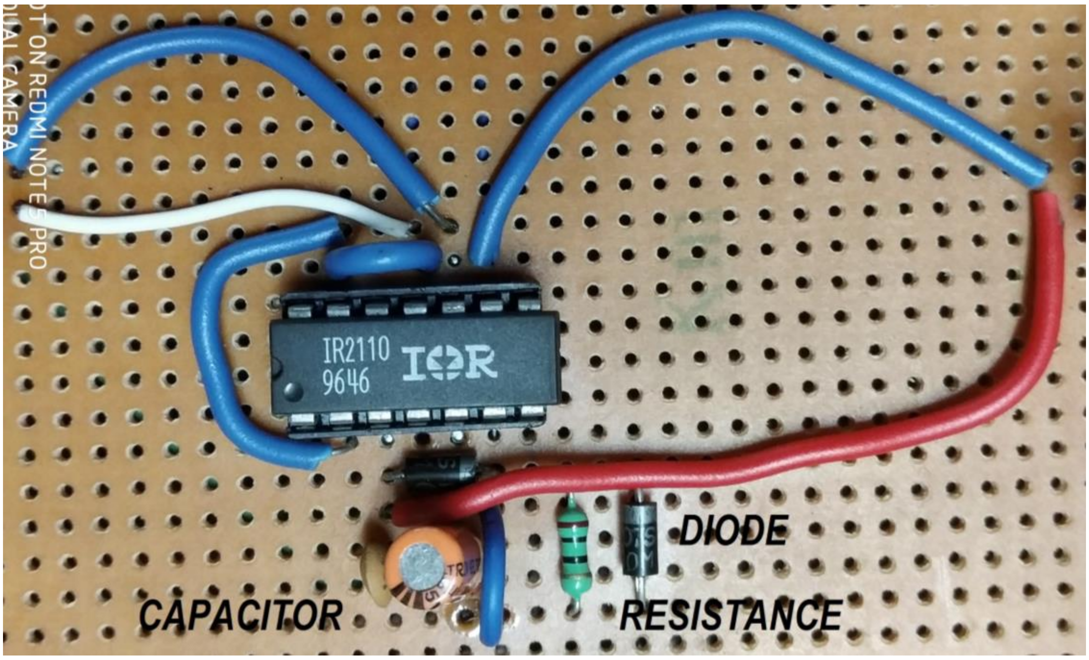


Fig. 55 Top view of IR2110 IC circuit

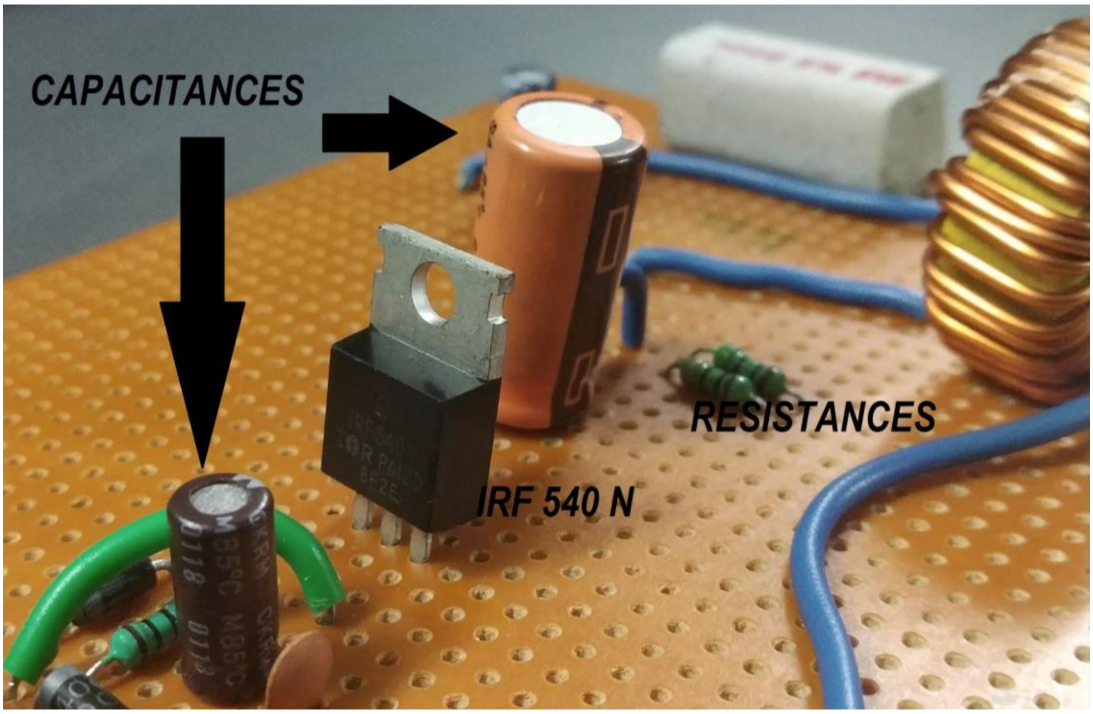


Fig. 56 MosFET IRF 540 Along with its Snubber Circuit.

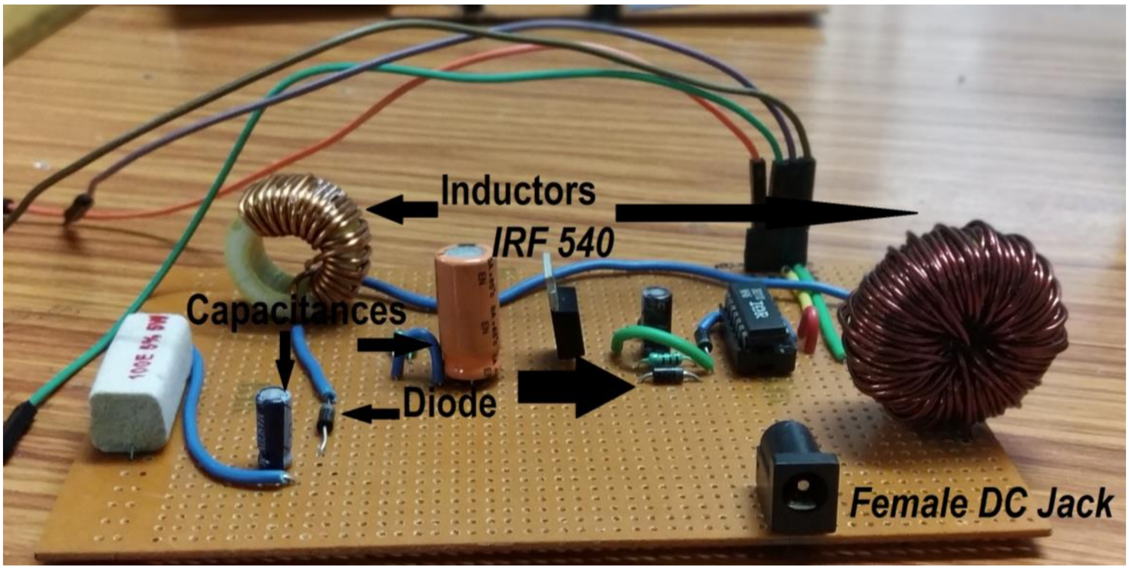


Fig.57 Side View of the power circuit of MPPT based DC-DC Converter.

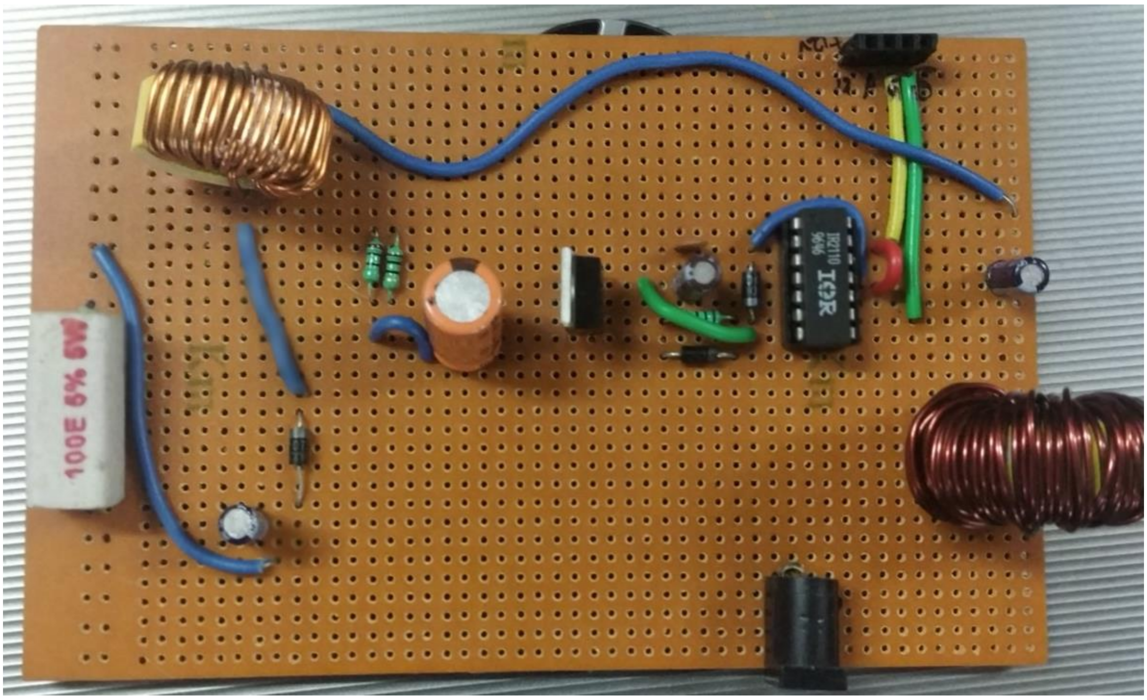


Fig.58 Top view of the circuit

HARDWARE OUTPUT RESULTS:

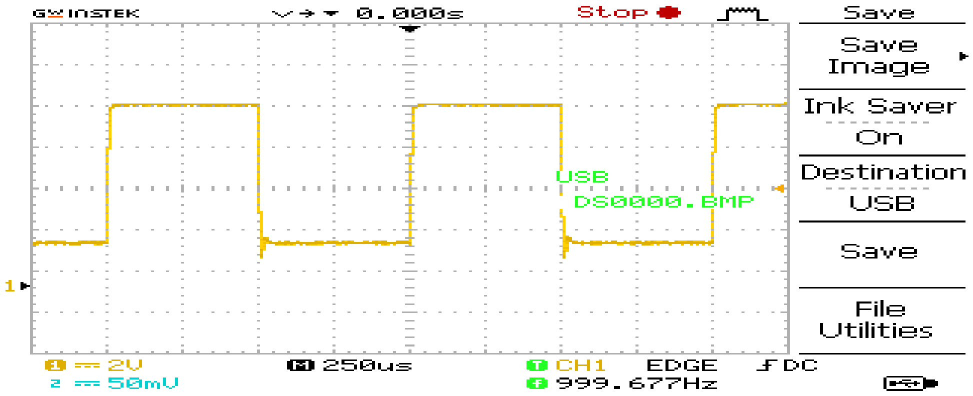


Fig. 59 1KHz of Input Pulse applied to the IR 2110 (for testing)

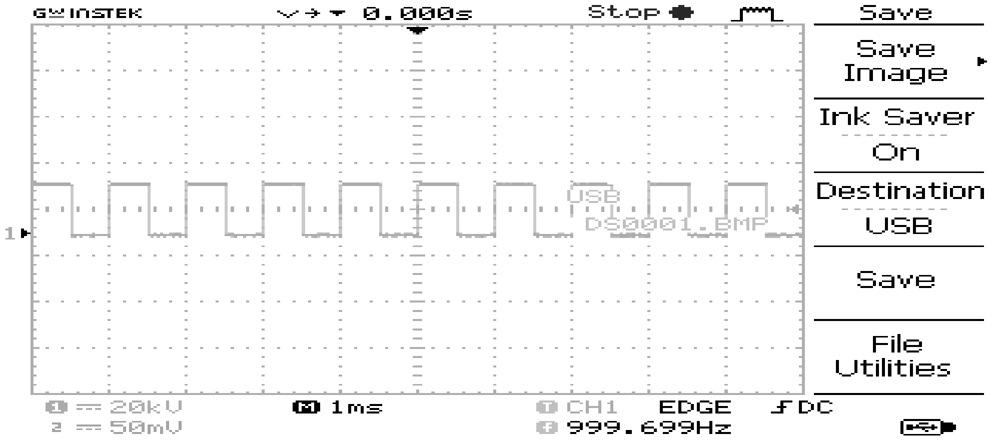


Fig. 60 Output Pulse received from IR 2110 for 1kHz

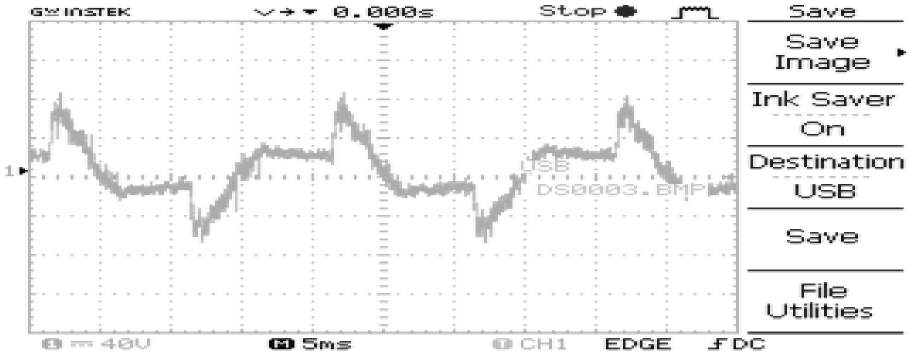


Fig. 61 Curve across Inductor 1

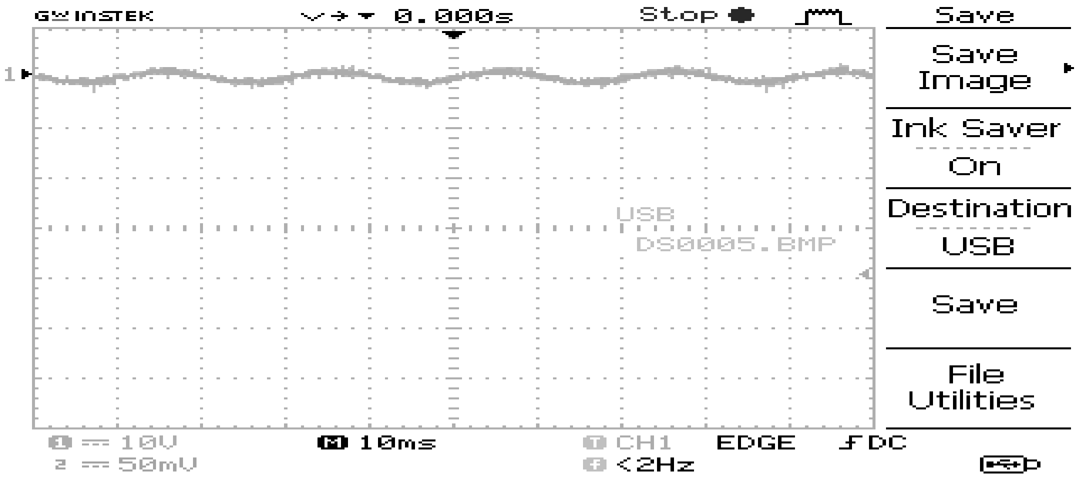


Fig. 62 Curve across Inductor 2

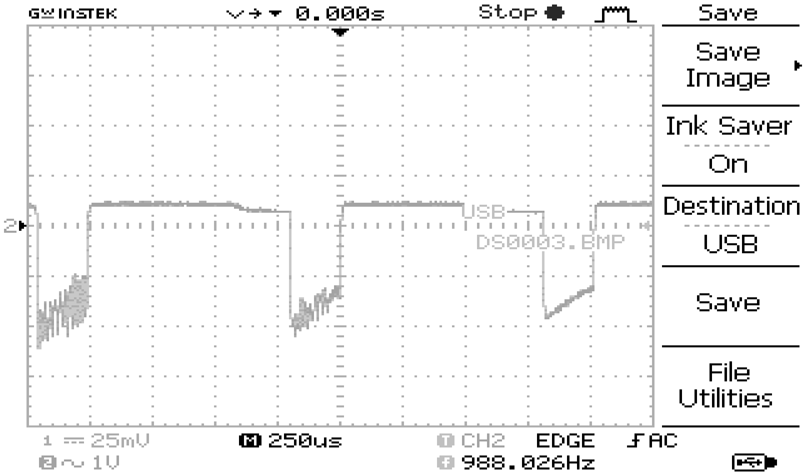


Fig 63 Output Curve Across the load showing the operation being performed and the output being 10volts.

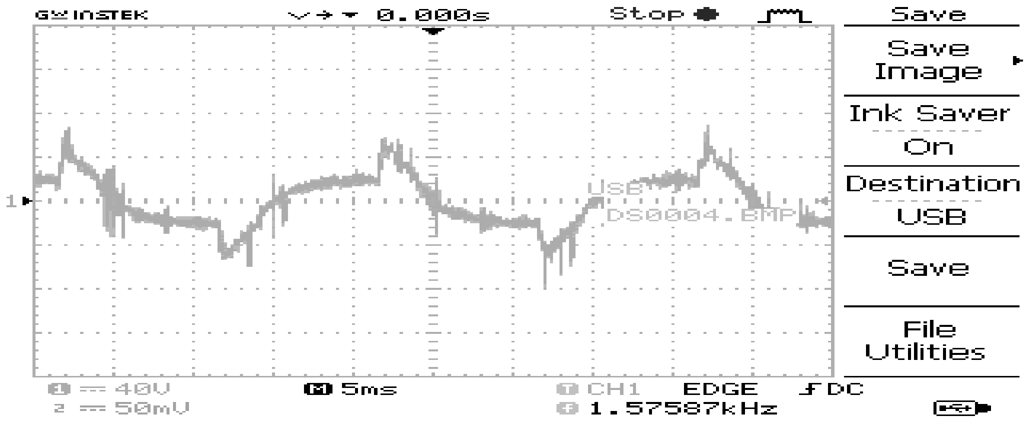


Fig. 64 Output Pulse received from IR 2110 for 1kHz (80% Duty)

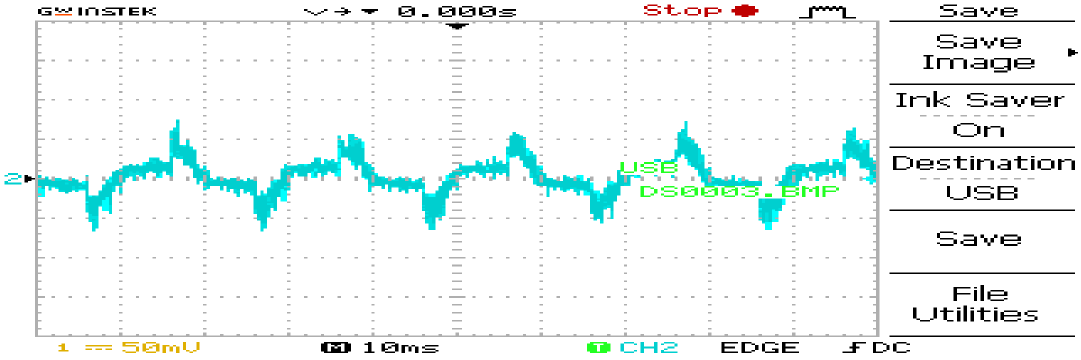


Fig. 65 Curve across Inductor 1

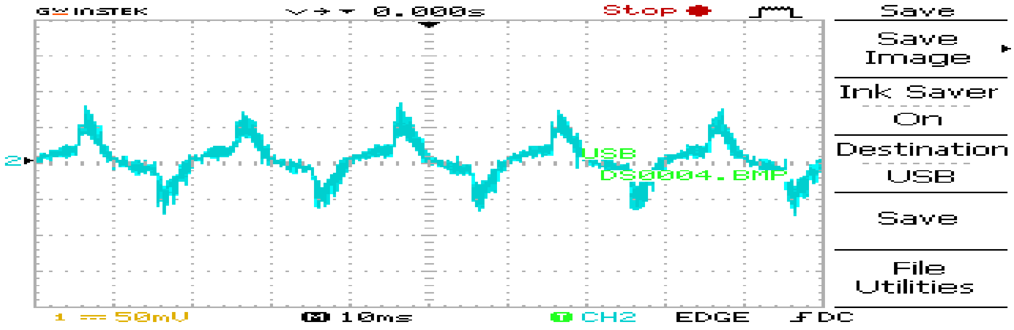


Fig. 66 Curve across Inductor 2

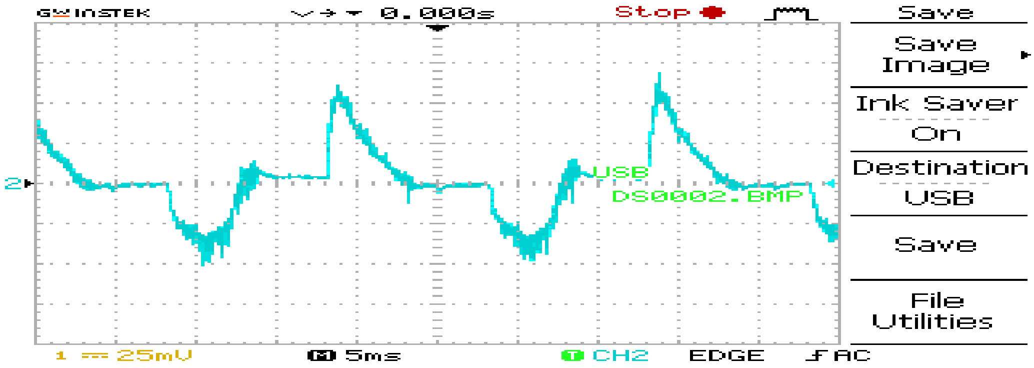


Fig 67 Output Curve Across the load showing the operation being performed

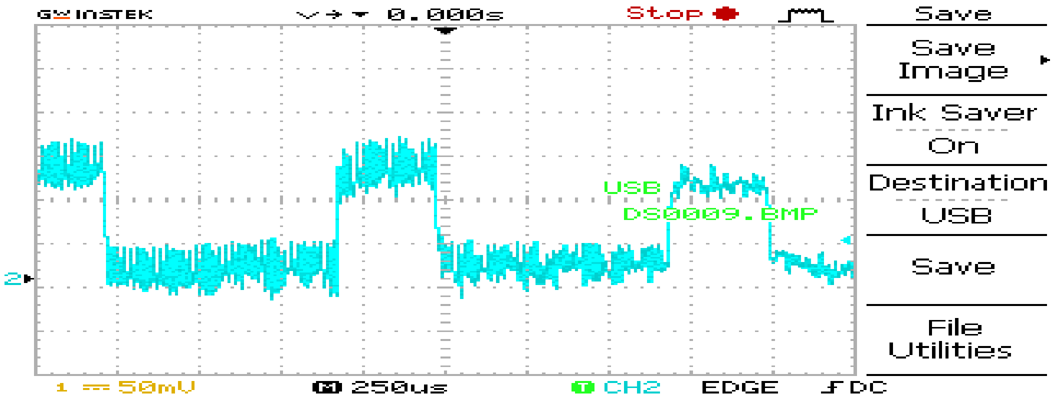


Fig. 68 Output Pulse received from IR 2110 for 1kHz (20% Duty)

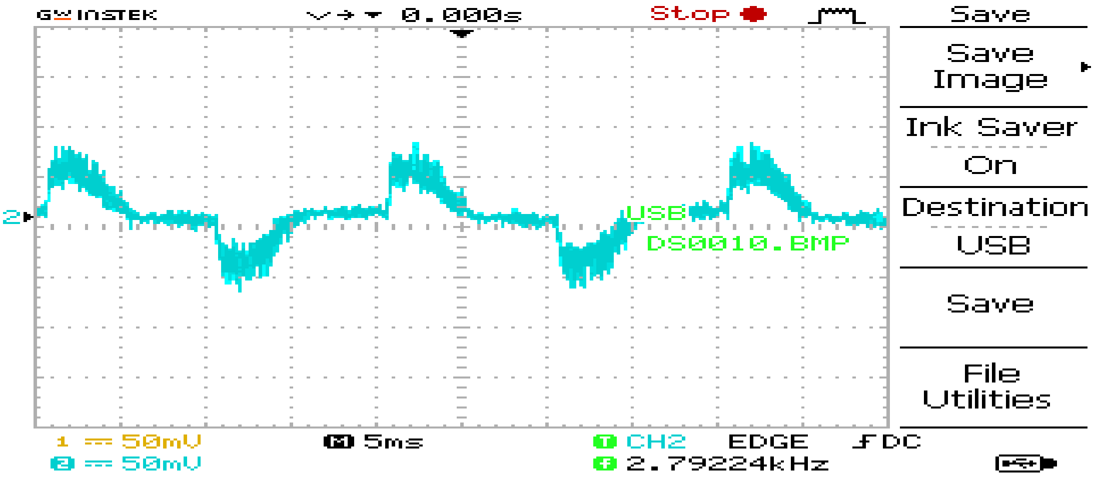


Fig. 69 Curve across Inductor 1

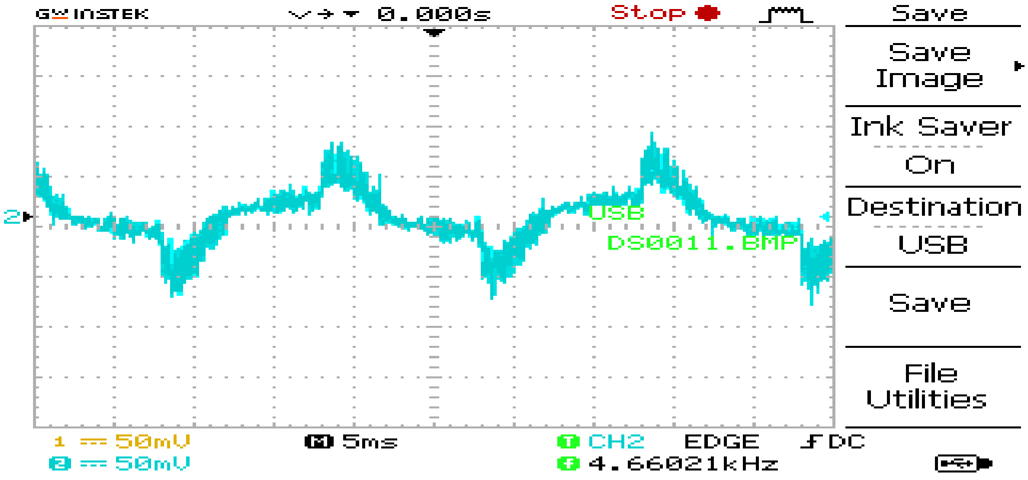


Fig. 70 Curve across Inductor 2

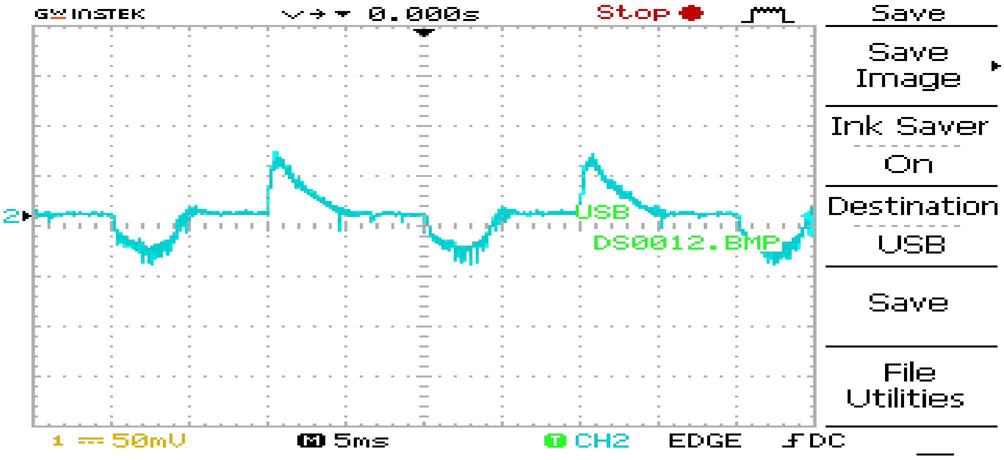


Fig 71 Output Curve Across the load showing the operation being performed

RESULT ANALYSIS:

From this project report we can easily see all the outputs were as exepected and were easily traceable to simulation.

1. From fig. 60 we can see the output pulse from the IR 2110 is as expected of almost 1kHz

2.Fig. 61 shows the charging discharging nature across the first inductor.

3.Fig. 62 shows the waveform across the inductor 2 which is as expected and is almost near to 10 volts peak to peak.

4.Fig. 65 shows the output waveform across the first inductor for 80% pulse width which shows proper charging and discharging.

5.Fig 67 demonstrates the curve across the output load which is on for on time and the voltage is almost 20 volts as it works as a boost converter.

6.The fig 68 shows the output pulse received from the 1st pin of IC IR2110 which is used to drive the MOSFET for 20% pulse width.

7.Fig. 70 shows the output curve received across the inductor 2 for the duty cycle of pulse width 20%

8.Fig.71 demonstrates the curve across the output load for the given duty cycle which shows a voltage of atmost 5 volts and acts as a buck converter.

CONCLUSION:

The concept of MPPT can be extended from the DC-DC converter to form a system, by connecting an inverter at the output terminals of the DC-DC converter. Many solar panels can be connected in series and a solar tied system can be implemented so as to feed the grid.

An accurate PV module electrical model is presented and demonstrated in Matlab for a typical 80W solar panel. Given solar insulation and temperature, the model calculates the current for a given voltage. The results from the Matlab model show excellent correspondence to manufacturer's published curves.

The P&O algorithm gives a slow but accurate tracking of the MPP and so it is better than the other algorithms.

Thus, MPPT can be considered an important and useful algorithm to track and maximize the output of any system. This idea can also be extended to other renewable sources of energy.

Finally, to conclude, it can be said that to find any system so as to maximize output from renewable sources is beneficial and MPPT can be considered its most prominent example.

FUTURE SCOPE

The work that had been carried out by the researchers, the designing of MPPT controller, should be extended by tracking larger number of input parameters which are varying with respect to the time such as parameters variations of the system. In order to get accurate MPPT point, the recent mathematical algorithms such as Z-infinity algorithms should be implemented. The work that has been carried out to the DC-DC converter is limited only by considering high switching frequency.

But the output voltage THD values are not improved much so that the research should be carried out in this area; a filter circuits configuration should be improved. For the inverter circuits, the grid tied inverters are having the problem that if the grid fails, the customer will not get any supply even though there is power generation from the PV system. This should be considered as a serious problem and the research should be carried out in this area.

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5. Morales-Saldana, J. A. (2006). Modeling and Control of Boost Converter with a Single Switch. 32nd Annual Conference on IEEE Industrial Electronics, 591-596.

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10. Salas, V. (2006). Review of the Maximum Power Point Tracking Algorithms for Stand-Alone Photovoltaic Systems. Solar Energy Materials & Solar Cells, vol. 90, no. 11, 1555-1578.

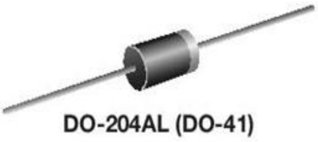
ANNEXURE

MATLAB Program for P&O Algorithm

```
function D   = PO(V, I, T)

persistent Pn  Po  dP d dd n;

if isempty(V)
    V=20;
end
if isempty(I)
    I=0;
end
if isempty(Po)
    Po=0;
end
if isempty(Pn)
    Pn=0;
end
if isempty(dP)
    dP=0;
end
if isempty(d)
    d=1;
end
if isempty(dd)
    dd=0;
end
if isempty(n)
    n=1;
end

if  (T>n*0.02)
    n=n+1;
    Po=Pn;
    Pn=V*I;
    dP=Pn-Po;

    if (dd==0)                % to avoid dP/dd=inf
        if dP>1
            dd=0.01;
```

```
            d=d+dd;
        else
            if (dP<-1)
                dd=-0.01;
                d=d+dd;
            else
                dd=0;
            end
        end
    else
        if ((dP<1)&&(dP>-1)) % leave little margin
            dd=0;
            d=d+dd;
        else
            if ((dP/dd)>0)  % positive slop
                dd=0.01;
                d=d+dd;
            else            % negative and zero slop
                dd=-0.01;
                d=d+dd;
            end
        end
    end
end

D=d/(d+1);  % calculate duty

% code to avoid duty less than 0.1 and more than 0.9
if (D<0.1)
    D=0.1;
    d=D/(1-D);
else
    if (D>0.9)
        D=0.9;
        d=D/(1-D);
    else
    end
end
end
```

General Purpose Plastic Rectifier



DO-204AL (DO-41)

FEATURES

- Low forward voltage drop
- Low leakage current
- High forward surge capability
- Solder dip 275 °C max. 10 s, per JESD 22-B106
- Compliant to RoHS Directive 2002/95/EC and in accordance to WEEE 2002/96/EC

e3

RoHS
COMPLIANT

TYPICAL APPLICATIONS

For use in general purpose rectification of power supplies, inverters, converters and freewheeling diodes application.

Note

- These devices are not AEC-Q101 qualified.

MECHANICAL DATA

Case: DO-204AL, molded epoxy body
Molding compound meets UL 94 V-0 flammability rating
Base P/N-E3 - RoHS compliant, commercial grade

Terminals: Matte tin plated leads, solderable per J-STD-002 and JESD 22-B102
E3 suffix meets JESD 201 class 1A whisker test

Polarity: Color band denotes cathode end

PRIMARY CHARACTERISTICS	
$I_{F(AV)}$	1.0 A
V_{RRM}	50 V to 1000 V
I_{FSM} (8.3 ms sine-wave)	30 A
I_{FSM} (square wave t_p = 1 ms)	45 A
V_F	1.1 V
I_R	5.0 µA
T_J max.	150 °C

MAXIMUM RATINGS (T_A = 25 °C unless otherwise noted)

PARAMETER	SYMBOL	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	UNIT
Maximum repetitive peak reverse voltage	V_{RRM}	50	100	200	400	600	800	1000	V
Maximum RMS voltage	V_{RMS}	35	70	140	280	420	560	700	V
Maximum DC blocking voltage	V_{DC}	50	100	200	400	600	800	1000	V
Maximum average forward rectified current 0.375" (9.5 mm) lead length at T_A = 75 °C	$I_{F(AV)}$	1.0							A
Peak forward surge current 8.3 ms single half sine-wave superimposed on rated load	I_{FSM}	30							A
Non-repetitive peak forward surge current square waveform T_A = 25 °C (fig. 3) t_p = 1 ms	I_{FSM}	45							A
t_p = 2 ms		35							
t_p = 5 ms		30							
Maximum full load reverse current, full cycle average 0.375" (9.5 mm) lead length T_L = 75 °C	$I_{R(AV)}$	30							µA
Rating for fusing (t < 8.3 ms)	I^2t [1]	3.7							A^2s
Operating junction and storage temperature range	T_J, T_{STG}	- 50 to + 150							°C

Note

[1] For device using on bridge rectifier appliaction

ELECTRICAL CHARACTERISTICS (T_A = 25 °C unless otherwise noted)

PARAMETER	TEST CONDITIONS		SYMBOL	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	UNIT
Maximum instantaneous forward voltage	1.0 A		V_F	1.1							V
Maximum DC reverse current at rated DC blocking voltage		T_A = 25 °C	I_R	5.0							μA
		T_A = 125 °C		50							
Typical junction capacitance	4.0 V, 1 MHz		C_J	15							pF

THERMAL CHARACTERISTICS (T_A = 25 °C unless otherwise noted)

PARAMETER	SYMBOL	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	UNIT
Typical thermal resistance	$R_{\theta JA}$ [1]	50							°C/W
	$R_{\theta JL}$ [1]	25							

Note

[1] Thermal resistance from junction to ambient at 0.375" (9.5 mm) lead length, PCB mounted

ORDERING INFORMATION (Example)

PREFERRED P/N	UNIT WEIGHT (g)	PREFERRED PACKAGE CODE	BASE QUANTITY	DELIVERY MODE
1N4004-E3/54	0.33	54	5500	13" diameter paper tape and reel
1N4004-E3/73	0.33	73	3000	Ammo pack packaging

RATINGS AND CHARACTERISTICS CURVES

(T_A = 25 °C unless otherwise noted)

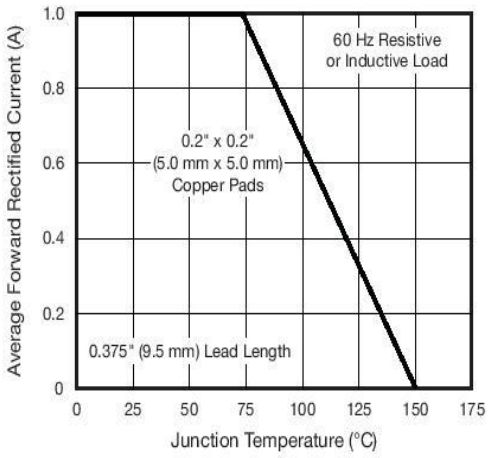


Fig. 1 - Forward Current Derating Curve

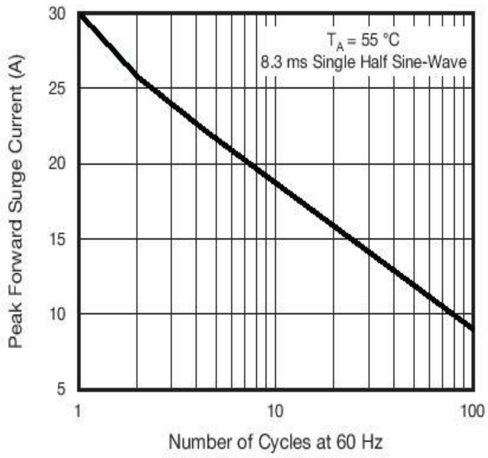
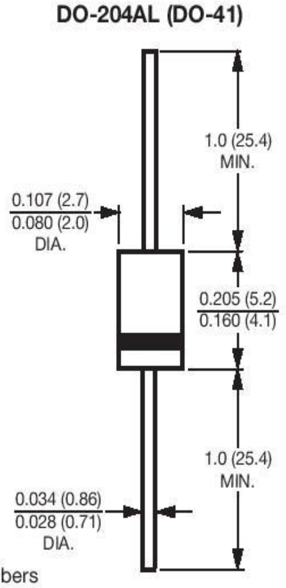


Fig. 2 - Maximum Non-repetitive Peak Forward Surge Current

PACKAGE OUTLINE DIMENSIONS in inches (millimeters)



Note

- Lead diameter is $\frac{0.026\ (0.66)}{0.023\ (0.58)}$ for suffix "E" part numbers

International
IOR Rectifier

Data Sheet No. PD60147 rev.U

IR2110(-1-2)(S)PbF/IR2113(-1-2)(S)PbF

HIGH AND LOW SIDE DRIVER

Features

- Floating channel designed for bootstrap operation
  Fully operational to +500V or +600V
  Tolerant to negative transient voltage
  dV/dt immune
- Gate drive supply range from 10 to 20V
- Undervoltage lockout for both channels
- 3.3V logic compatible
  Separate logic supply range from 3.3V to 20V
  Logic and power ground ±5V offset
- CMOS Schmitt-triggered inputs with pull-down
- Cycle by cycle edge-triggered shutdown logic
- Matched propagation delay for both channels
- Outputs in phase with inputs

Product Summary

V_{OFFSET}	(IR2110)	500V max.
	(IR2113)	600V max.
I_O+/-		2A / 2A
V_{OUT}		10 - 20V
$t_{on/off}$ (typ.)		120 & 94 ns
Delay Matching	(IR2110)	10 ns max.
	(IR2113)	20ns max.

Packages

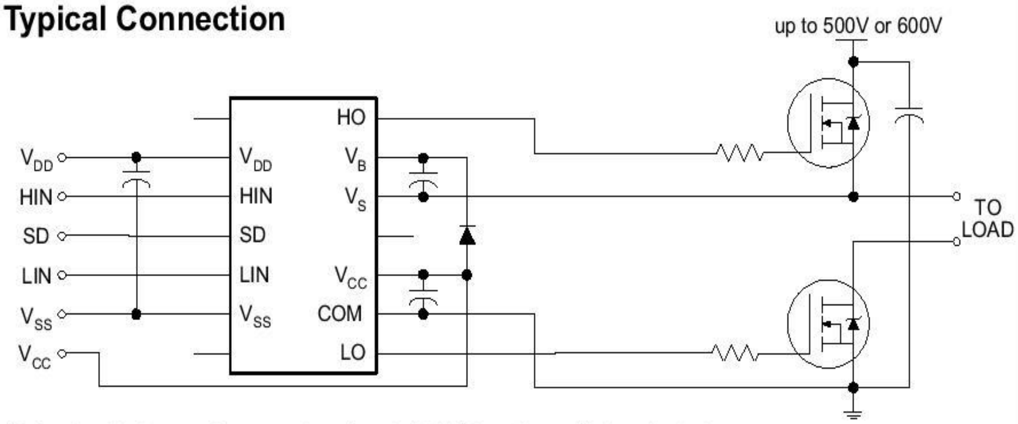

14-Lead PDIP
IR2110/IR2113


16-Lead SOIC
IR2110S/IR2113S

Description

The IR2110/IR2113 are high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels. Proprietary HVIC and latch immune CMOS technologies enable ruggedized monolithic construction. Logic inputs are compatible with standard CMOS or LSTTL output, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. Propagation delays are matched to simplify use in high frequency applications. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration which operates up to 500 or 600 volts.

Typical Connection



(Refer to Lead Assignments for correct pin configuration). This/These diagram(s) show electrical connections only. Please refer to our Application Notes and DesignTips for proper circuit board layout.

Absolute Maximum Ratings

Absolute maximum ratings indicate sustained limits beyond which damage to the device may occur. All voltage parameters are absolute voltages referenced to COM. The thermal resistance and power dissipation ratings are measured under board mounted and still air conditions. Additional information is shown in Figures 28 through 35.

Symbol	Definition	Min.	Max.	Units
V_B	High side floating supply voltage (IR2110)	-0.3	525	V
	(IR2113)	-0.3	625	
V_S	High side floating supply offset voltage	V_B - 25	V_B + 0.3	
V_{HO}	High side floating output voltage	V_S - 0.3	V_B + 0.3	
V_{CC}	Low side fixed supply voltage	-0.3	25	
V_{LO}	Low side output voltage	-0.3	V_{CC} + 0.3	
V_{DD}	Logic supply voltage	-0.3	V_{SS} + 25	
V_{SS}	Logic supply offset voltage	V_{CC} - 25	V_{CC} + 0.3	
V_{IN}	Logic input voltage (HIN, LIN & SD)	V_{SS} - 0.3	V_{DD} + 0.3	
dV_s/dt	Allowable offset supply voltage transient (figure 2)	—	50	V/ns
P_D	Package power dissipation @ $T_A \le$ +25°C (14 lead DIP)	—	1.6	W
	(16 lead SOIC)	—	1.25	
R_{THJA}	Thermal resistance, junction to ambient (14 lead DIP)	—	75	°C/W
	(16 lead SOIC)	—	100	
T_J	Junction temperature	—	150	°C
T_S	Storage temperature	-55	150	
T_L	Lead temperature (soldering, 10 seconds)	—	300	

Recommended Operating Conditions

The input/output logic timing diagram is shown in figure 1. For proper operation the device should be used within the recommended conditions. The V_S and V_{SS} offset ratings are tested with all supplies biased at 15V differential. Typical ratings at other bias conditions are shown in figures 36 and 37.

Symbol	Definition	Min.	Max.	Units
V_B	High side floating supply absolute voltage	V_S + 10	V_S + 20	V
V_S	High side floating supply offset voltage (IR2110)	Note 1	500	
	(IR2113)	Note 1	600	
V_{HO}	High side floating output voltage	V_S	V_B	
V_{CC}	Low side fixed supply voltage	10	20	
V_{LO}	Low side output voltage	0	VCC	
V_{DD}	Logic supply voltage	V_{SS} + 3	V_{SS} + 20	
V_{SS}	Logic supply offset voltage	-5 (Note 2)	5	
V_{IN}	Logic input voltage (HIN, LIN & SD)	V_{SS}	V_{DD}	
T_A	Ambient temperature	-40	125	°C

Note 1: Logic operational for V_S of -4 to +500V. Logic state held for V_S of -4V to $-V_{BS}$. (Please refer to the Design Tip DT97-3 for more details).

Note 2: When V_{DD} < 5V, the minimum V_{SS} offset is limited to $-V_{DD}$.

Dynamic Electrical Characteristics

V_{BIAS} (V_{CC}, V_{BS}, V_{DD}) = 15V, C_L = 1000 pF, T_A = 25°C and V_{SS} = COM unless otherwise specified. The dynamic electrical characteristics are measured using the test circuit shown in Figure 3.

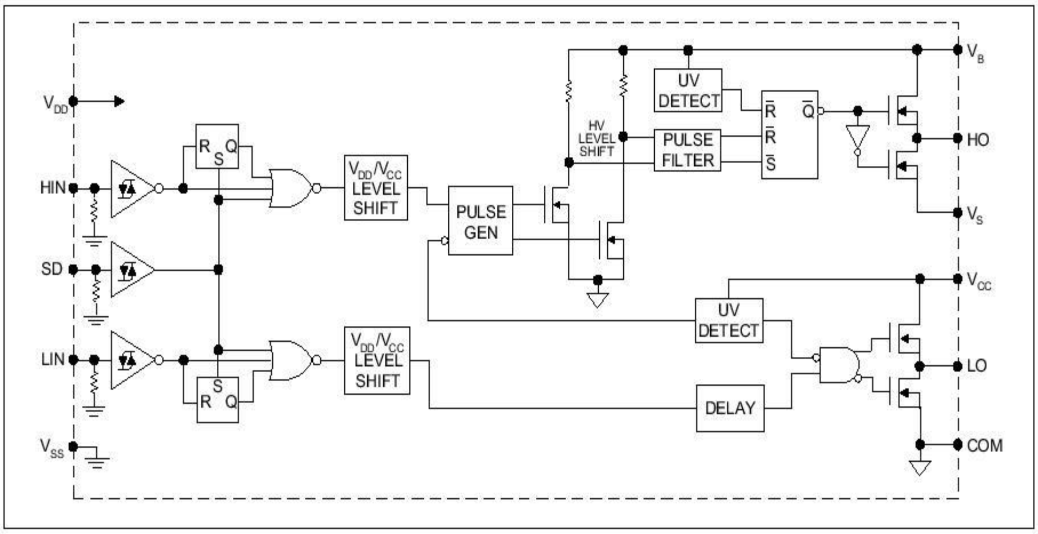
Symbol	Definition		Figure	Min.	Typ.	Max.	Units	Test Conditions
t_{on}	Turn-on propagation delay		7	—	120	150	ns	V_S = 0V
t_{off}	Turn-off propagation delay		8	—	94	125		V_S = 500V/600V
t_{sd}	Shutdown propagation delay		9	—	110	140		V_S = 500V/600V
t_r	Turn-on rise time		10	—	25	35		
t_f	Turn-off fall time		11	—	17	25		
MT	Delay matching, HS & LS	(IR2110)	—	—	—	10		
	turn-on/off	(IR2113)	—	—	—	20		

Static Electrical Characteristics

V_{BIAS} (V_{CC}, V_{BS}, V_{DD}) = 15V, T_A = 25°C and V_{SS} = COM unless otherwise specified. The V_{IN}, V_{TH} and I_{IN} parameters are referenced to V_{SS} and are applicable to all three logic input leads: HIN, LIN and SD. The V_O and I_O parameters are referenced to COM and are applicable to the respective output leads: HO or LO.

Symbol	Definition	Figure	Min.	Typ.	Max.	Units	Test Conditions
V_{IH}	Logic "1" input voltage	12	9.5	—	—	V	
V_{IL}	Logic "0" input voltage	13	—	—	6.0		
V_{OH}	High level output voltage, V_{BIAS} - V_O	14	—	—	1.2		I_O = 0A
V_{OL}	Low level output voltage, V_O	15	—	—	0.1		I_O = 0A
I_{LK}	Offset supply leakage current	16	—	—	50	µA	V_B=V_S = 500V/600V
I_{QBS}	Quiescent V_{BS} supply current	17	—	125	230		V_{IN} = 0V or V_{DD}
I_{QCC}	Quiescent V_{CC} supply current	18	—	180	340		V_{IN} = 0V or V_{DD}
I_{QDD}	Quiescent V_{DD} supply current	19	—	15	30		V_{IN} = 0V or V_{DD}
I_{IN+}	Logic "1" input bias current	20	—	20	40		V_{IN} = V_{DD}
I_{IN-}	Logic "0" input bias current	21	—	—	1.0		V_{IN} = 0V
V_{BSUV+}	V_{BS} supply undervoltage positive going threshold	22	7.5	8.6	9.7	V	
V_{BSUV-}	V_{BS} supply undervoltage negative going threshold	23	7.0	8.2	9.4		
V_{CCUV+}	V_{CC} supply undervoltage positive going threshold	24	7.4	8.5	9.6		
V_{CCUV-}	V_{CC} supply undervoltage negative going threshold	25	7.0	8.2	9.4		
I_{O+}	Output high short circuit pulsed current	26	2.0	2.5	—	A	V_O = 0V, V_{IN} = V_{DD} PW ≤ 10 µs
I_{O-}	Output low short circuit pulsed current	27	2.0	2.5	—		V_O = 15V, V_{IN} = 0V PW ≤ 10 µs

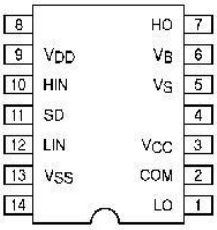
Functional Block Diagram



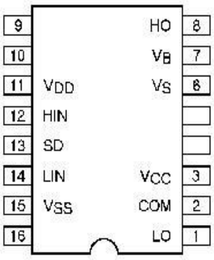
Lead Definitions

Symbol	Description
V_{DD}	Logic supply
HIN	Logic input for high side gate driver output (HO), in phase
SD	Logic input for shutdown
LIN	Logic input for low side gate driver output (LO), in phase
V_{SS}	Logic ground
V_B	High side floating supply
HO	High side gate drive output
V_S	High side floating supply return
V_{CC}	Low side supply
LO	Low side gate drive output
COM	Low side return

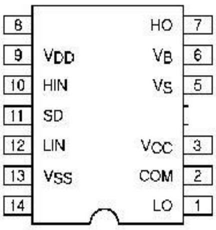
Lead Assignments



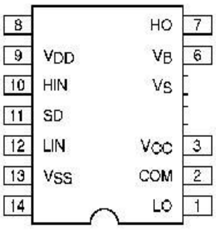
14 Lead PDIP
IR2110/IR2113



16 Lead SOIC (Wide Body)
IR2110S/IR2113S



14 Lead PDIP w/o lead 4
IR2110-1/IR2113-1



14 Lead PDIP w/o leads 4 & 5
IR2110-2/IR2113-2

Part Number

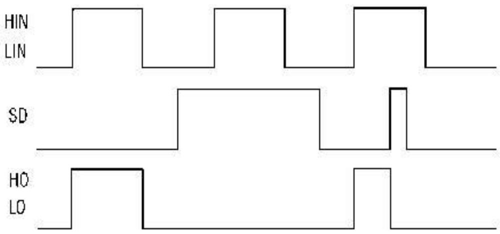


Figure 1. Input/Output Timing Diagram

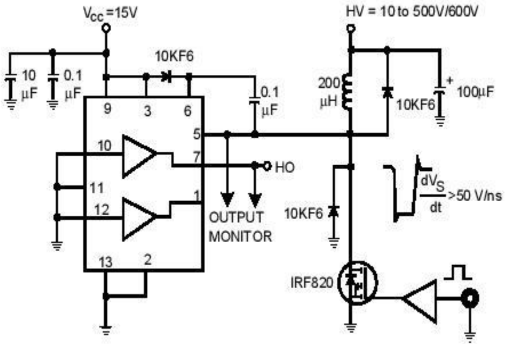


Figure 2. Floating Supply Voltage Transient Test Circuit

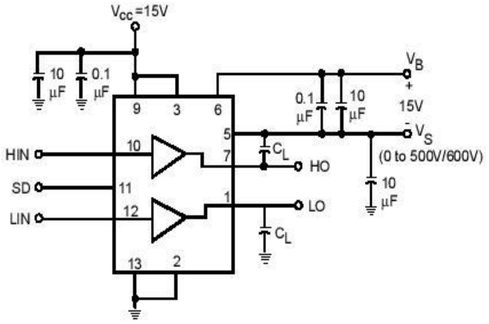


Figure 3. Switching Time Test Circuit

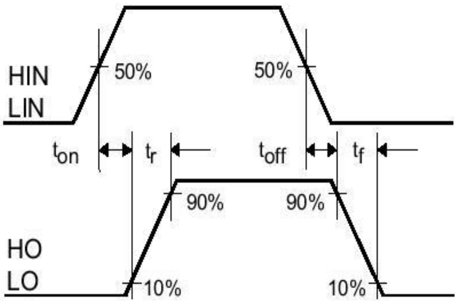


Figure 4. Switching Time Waveform Definition

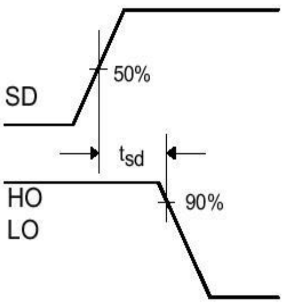


Figure 5. Shutdown Waveform Definitions

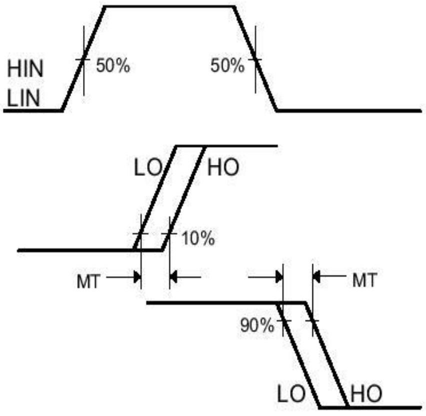


Figure 6. Delay Matching Waveform Definitions

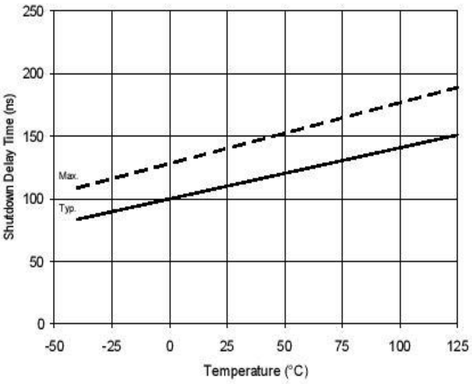


Figure 9A. Shutdown Time vs. Temperature

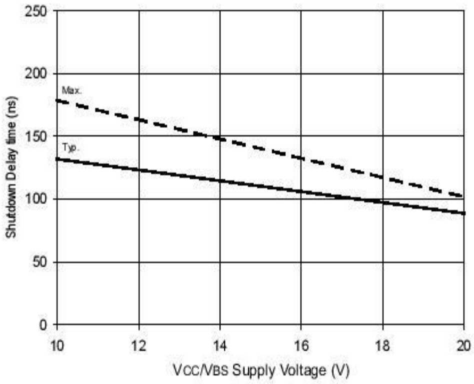


Figure 9B. Shutdown Time vs. VCC/VBS Supply Voltage

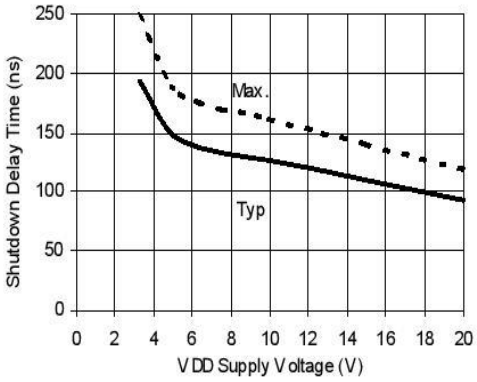


Figure 9C. Shutdown Time vs. VDD Supply Voltage

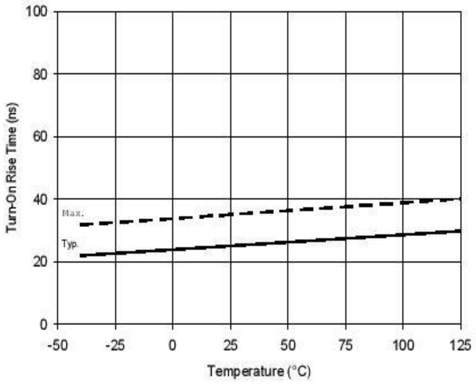


Figure 10A. Turn-On Rise Time vs. Temperature

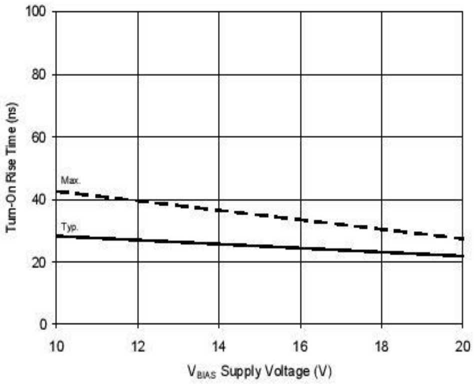


Figure 10B. Turn-On Rise Time vs. Voltage

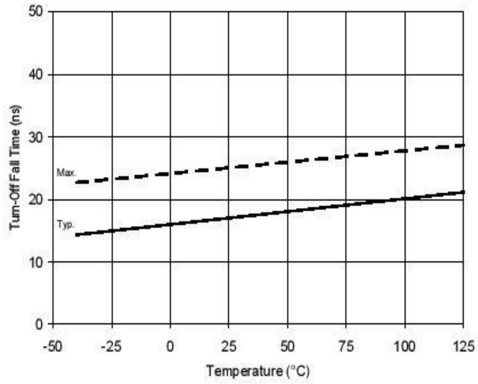


Figure 11A. Turn-Off Fall Time vs. Temperature

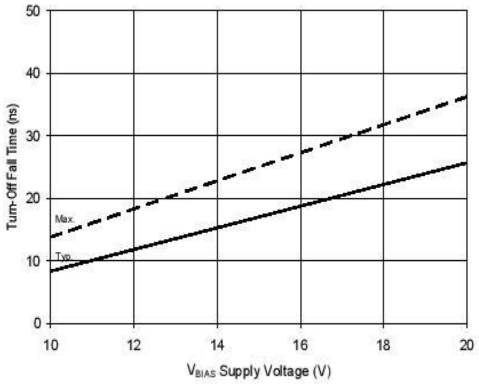


Figure 11B. Turn-Off Fall Time vs. Voltage

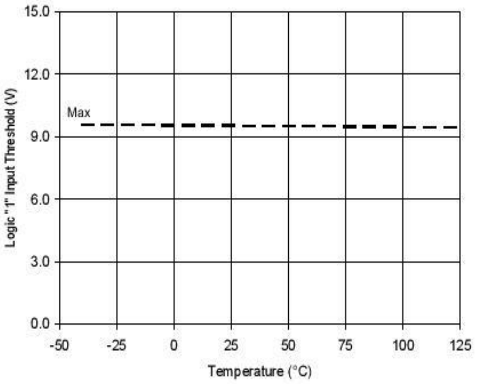


Figure 12A. Logic "1" Input Threshold vs. Temperature

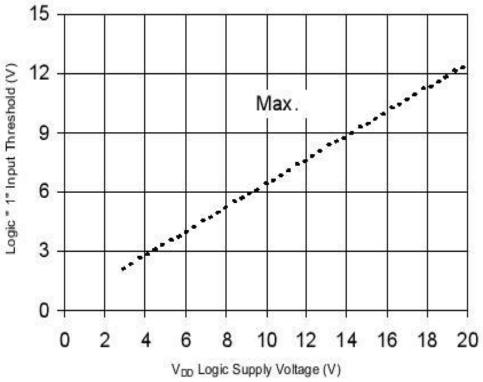


Figure 12B. Logic "1" Input Threshold vs. Voltage

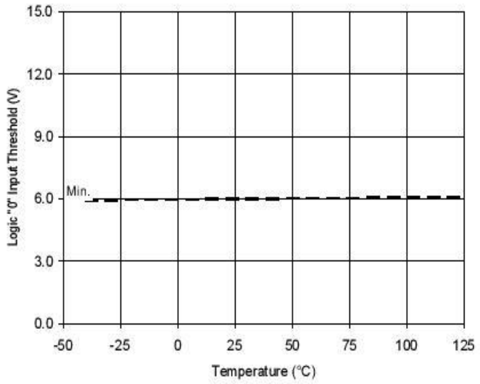


Figure 13A. Logic "0" Input Threshold vs. Temperature

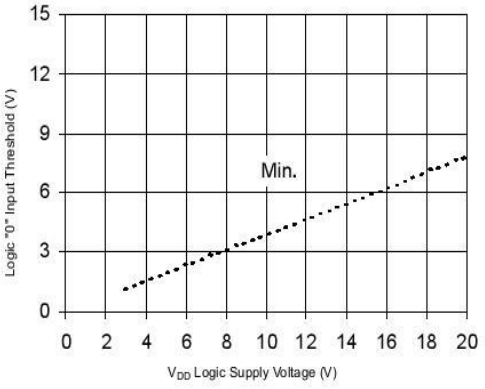


Figure 13B. Logic "0" Input Threshold vs. Voltage

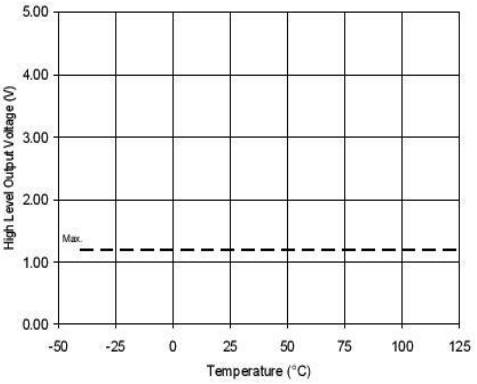


Figure 14A. High Level Output vs. Temperature

TYPICAL CHARACTERISTICS (25 °C, unless otherwise noted)

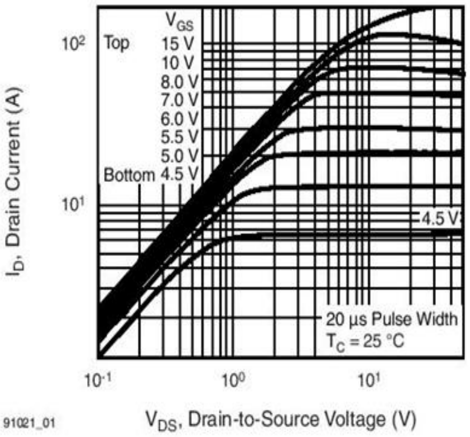


Fig. 1 - Typical Output Characteristics, $T_C = 25$ °C

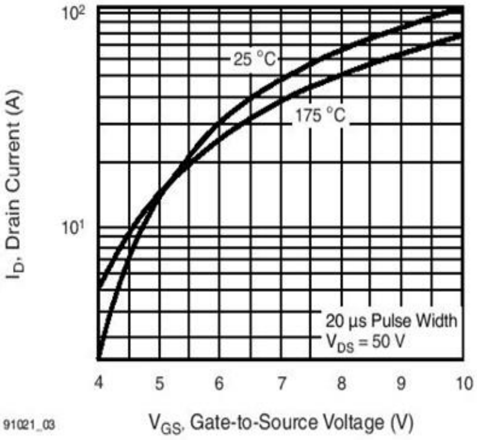


Fig. 3 - Typical Transfer Characteristics

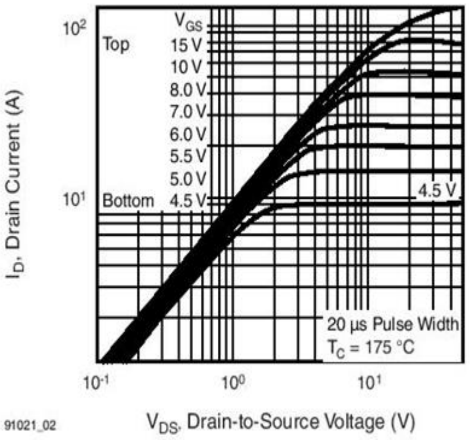


Fig. 2 - Typical Output Characteristics, $T_C = 175$ °C

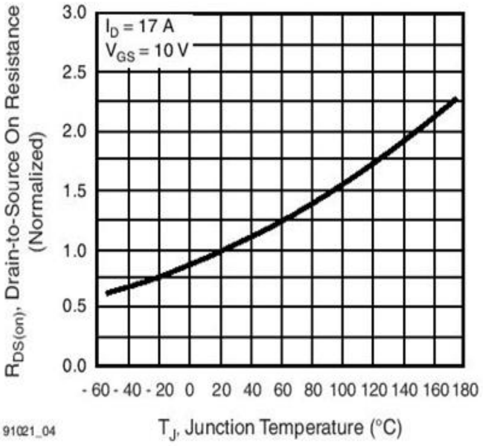


Fig. 4 - Normalized On-Resistance vs. Temperature

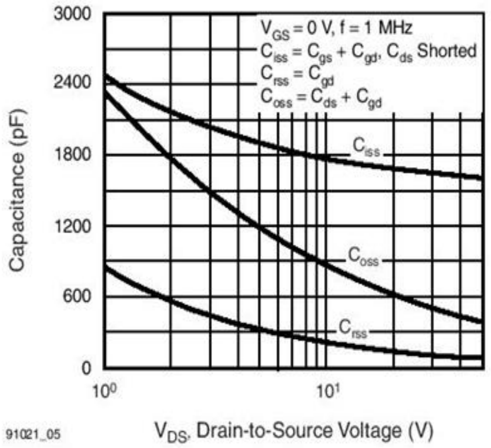


Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage

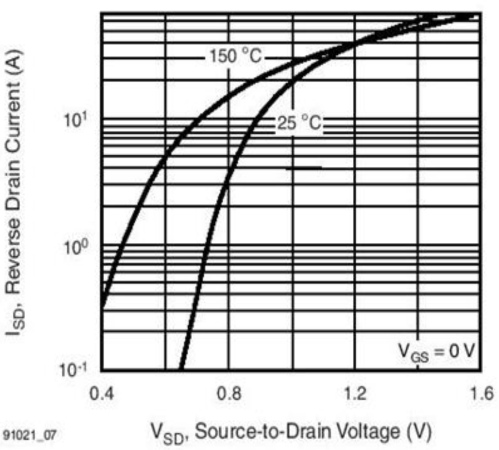


Fig. 7 - Typical Source-Drain Diode Forward Voltage

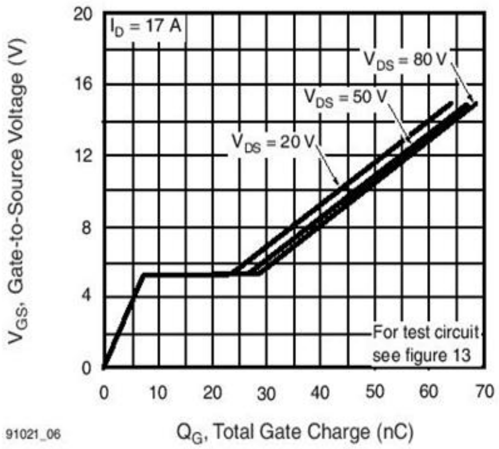


Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage

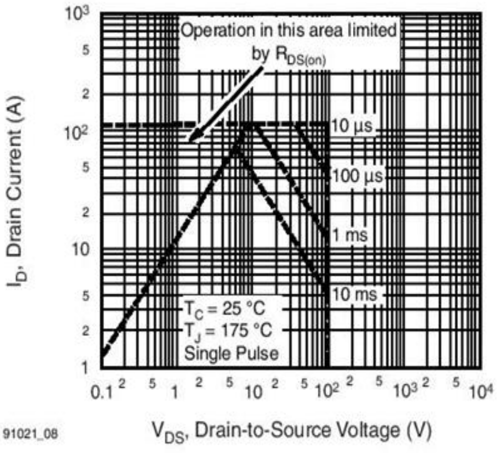
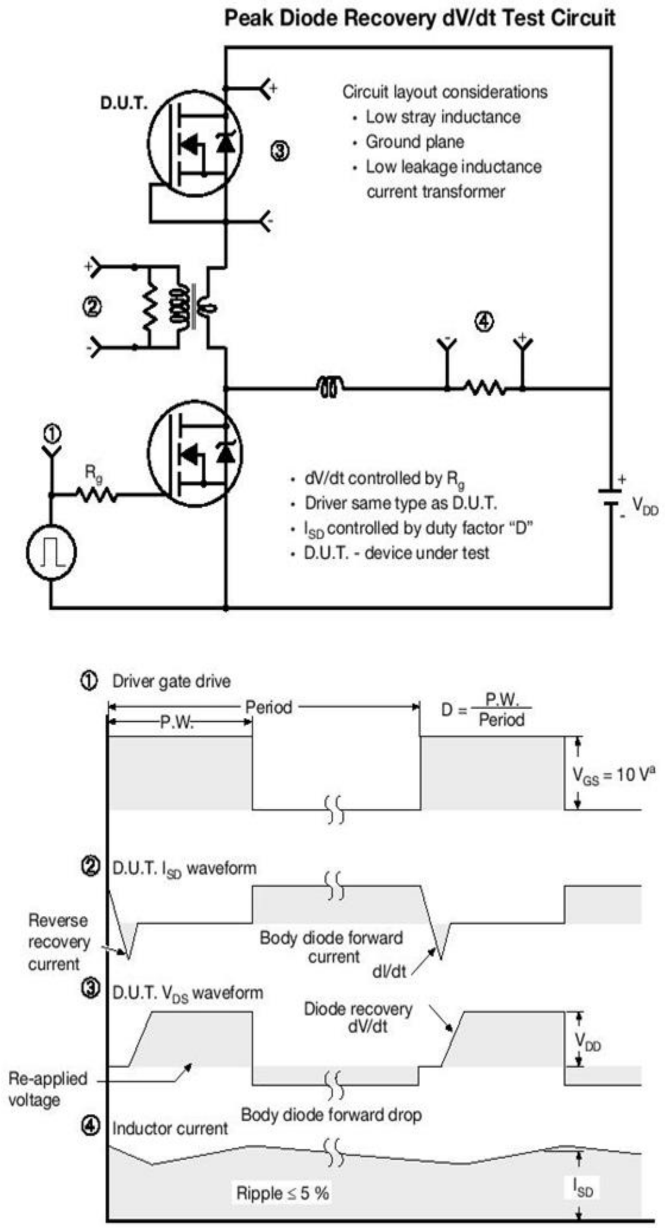


Fig. 8 - Maximum Safe Operating Area


Peak Diode Recovery dV/dt Test Circuit

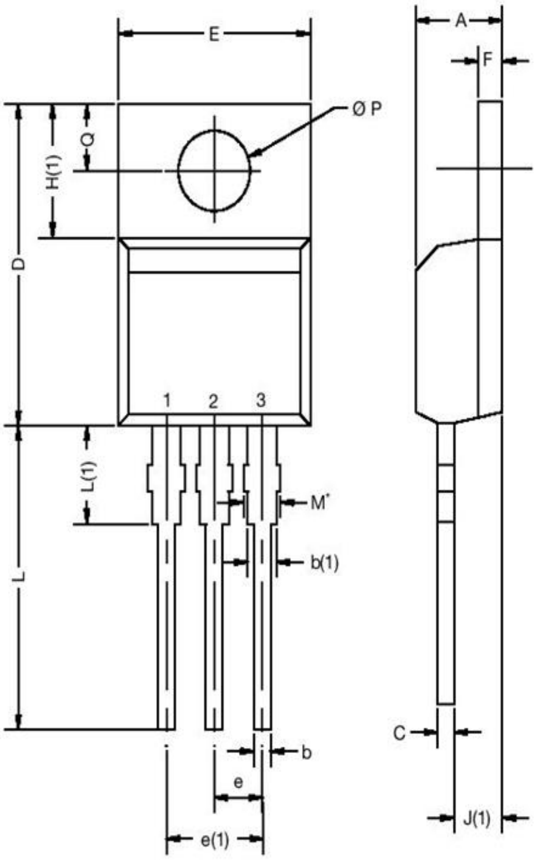
Note

a. V_{GS} = 5 V for logic level devices

Fig. 14 - For N-Channel

Vishay Siliconix maintains worldwide manufacturing capability. Products may be manufactured at one of several qualified locations. Reliability data for Silicon Technology and Package Reliability represent a composite of all qualified locations. For related documents such as package/tape drawings, part marking, and reliability data, see http://www.vishay.com/ppg?91021.

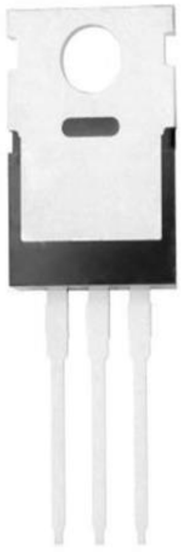
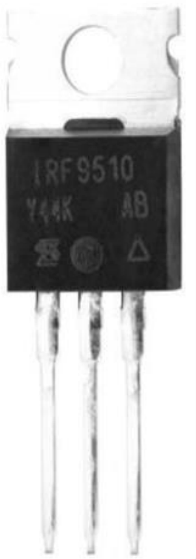
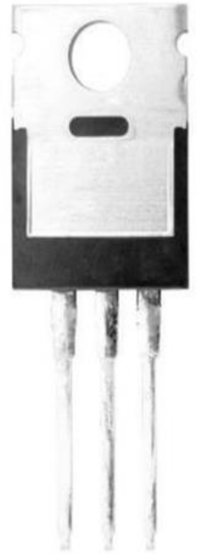
TO-220-1



DIM.	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	4.24	4.65	0.167	0.183
b	0.69	1.02	0.027	0.040
b(1)	1.14	1.78	0.045	0.070
c	0.36	0.61	0.014	0.024
D	14.33	15.85	0.564	0.624
E	9.96	10.52	0.392	0.414
e	2.41	2.67	0.095	0.105
e(1)	4.88	5.28	0.192	0.208
F	1.14	1.40	0.045	0.055
H(1)	6.10	6.71	0.240	0.264
J(1)	2.41	2.92	0.095	0.115
L	13.36	14.40	0.526	0.567
L(1)	3.33	4.04	0.131	0.159
Ø P	3.53	3.94	0.139	0.155
Q	2.54	3.00	0.100	0.118
ECN: X15-0364-Rev. C, 14-Dec-15 DWG: 6031				

Note

- M* = 0.052 inches to 0.064 inches (dimension including protrusion), heatsink hole for HVM

Package Picture			
ASE		Xi'an	
			

TOSHIBA Photocoupler GaAℓAs Ired & Photo-IC

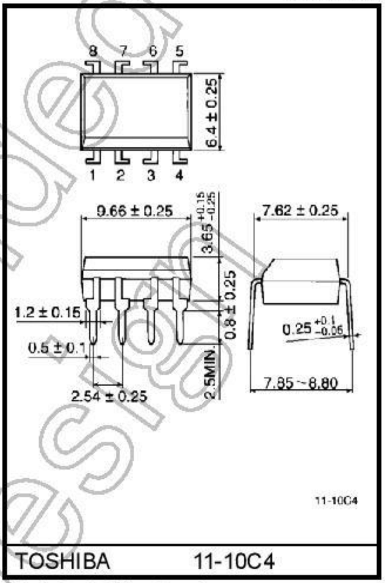
TLP250

Industrial Inverter
Inverter For Air Conditioner
IGBT Gate Drive
Power MOS FET Gate Drive

The TOSHIBA TLP250 consists of a GaAIAs 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.

- Input threshold current: 5mA(max)
- Supply current : 11mA(max)
- Supply voltage : 10-35V
- Output current : ±1.5A (max)
- Switching time t_{pLH}/t_{pHL}): 0.5μs(max)
- Isolation voltage: 2500V_{rms}(min)
- UL recognized: UL1577, file No.E67349
- c-UL approved : CSA Component Acceptance Service
  No. 5A, File No.E67349
- Option(D4)
  VDE Approved : EN60747-5- 5
  Note: When a EN60747-5-5 approved type is needed,
  Please designate "Option(D4)"

Unit: mm

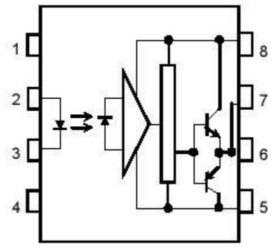


Weight: 0.54 g (typ.)

Truth Table

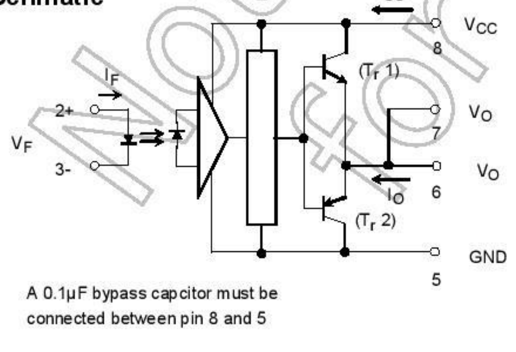
		Tr1	Tr2
Input LED	On	On	Off
	Off	Off	On

Pin Configuration (top view)



1 : N.C.
2 : Anode
3 : Cathode
4 : N.C.
5 : GND
6 : V_O (Output)
7 : V_O
8 : V_{CC}

Schmatic



A 0.1μF bypass capcitor must be connected between pin 8 and 5

Start of commercial production
1990-11

Absolute Maximum Ratings (Ta = 25°C)

	Characteristic		Symbol	Rating	Unit
LED	Forward current		I_F	20	mA
	Forward current derating (Ta ≥ 70°C)		ΔI_F / ΔTa	-0.36	mA / °C
	Peak transient forward curent	(Note 1)	I_{FPT}	1	A
	Reverse voltage		V_R	5	V
	Diode power dissipation		P_D	40	mW
	Diode power dissipation derating (Ta≥70°C)		ΔP_D /°C	-0.72	mW / °C
	Junction temperature		Tj	125	°C
Detector	"H"peak output current (P_W ≤ 2.5μs,f ≤ 15kHz)	(Note 2)	I_{OPH}	-1.5	A
	"L"peak output current (P_W ≤ 2.5μs,f ≤ 15kHz)	(Note 2)	I_{OPL}	+1.5	A
	Output voltage	(Ta ≤ 70°C)	V_O	35	V
		(Ta ≤ 85°C)		24	
	Supply voltage	(Ta ≤ 70°C)	V_{CC}	35	V
		(Ta ≤ 85°C)		24	
	Output voltage derating (Ta ≥ 70°C)		ΔV_O / ΔTa	-0.73	V / °C
	Supply voltage derating (Ta ≥ 70°C)		ΔV_{CC} / ΔTa	-0.73	V / °C
	Power dissipation		P_C	800	mW
	Power dissipation derating (Ta ≥ 70°C)		ΔP_C / °C	-14.5	mW / °C
	Junction temperature		Tj	125	°C
Operating frequency		(Note 3)	f	25	kHz
Operating temperature range			T_{opr}	-20 to 85	°C
Storage temperature range			T_{stg}	-55 to 125	°C
Lead soldering temperature (10 s)			T_{sol}	260	°C
Isolation voltage (AC, 60 s., R.H.≤ 60%)		(Note 4)	BV_S	2500	Vrms

Note: Using continuously under heavy loads (e.g. the application of high temperature/current/voltage and the significant change in temperature, etc.) may cause this product to decrease in the reliability significantly even if the operating conditions (i.e. operating temperature/current/voltage, etc.) are within the absolute maximum ratings.
Please design the appropriate reliability upon reviewing the Toshiba Semiconductor Reliability Handbook ("Handling Precautions"/"Derating Concept and Methods") and individual reliability data (i.e. reliability test report and estimated failure rate, etc).

Note 1: Pulse width P_W ≤ 1μs, 300pps

Note 2: Exporenential wavefom

Note 3: Exporenential wavefom, I_{OPH} ≤ -1.0A(≤ 2.5μs), I_{OPL} ≤ +1.0A(≤ 2.5μs)

Note 4: Device considerd a two terminal device: Pins 1, 2, 3 and 4 shorted together, and pins 5, 6, 7 and 8 shorted together.

Recommended Operating Conditions

Characteristic	Symbol	Min	Typ.	Max	Unit
Input current, on	$I_{F(ON)}$	7	8	10	mA
Input voltage, off	$V_{F(OFF)}$	0	—	0.8	V
Supply voltage	V_{CC}	15	—	30	V
Peak output current	I_{OPH}/I_{OPL}	—	—	±0.5	A
Operating temperature	T_{opr}	-20	25	85	°C

Note: Recommended operating conditions are given as a design guideline to obtain expected performance of the device. Additionally, each item is an independent guideline respectively. In developing designs using this product, please confirm specified characteristics shown in this document.

Note : A ceramic capacitor(0.1μF) should be connected from pin 8 to pin 5 to stabilize the operation of the high gain linear amplifier. Failure to provide the bypassing may impair the switching proparty. The total lead length between capacitor and coupler should not exceed 1cm.

Note : Input signal rise time(fall time)<0.5μs.

Electrical Characteristics (Ta = -20 to 70°C, unless otherwise specified)

Characteristic		Symbol	Test Circuit	Test Condition		Min	Typ.*	Max	Unit
Input forward voltage		V_F	—	I_F = 10 mA, Ta = 25°C		—	1.6	1.8	V
Temperature coefficient of forward voltage		$\Delta V_F / \Delta Ta$	—	I_F = 10 mA		—	-2.0	—	mV / °C
Input reverse current		I_R	—	V_R = 5V, Ta = 25°C		—	—	10	μA
Input capacitance		C_T	—	V = 0 V, f = 1MHz , Ta = 25°C		—	45	250	pF
Output current	"H" level	I_{OPH}	1	V_{CC} = 30V (Note 1)	I_F = 10 mA $V_{8\text{-}6}$ = 4V	-0.5	-1.5	—	A
	"L" level	I_{OPL}	2		I_F = 0 mA $V_{6\text{-}5}$ = 2.5V	0.5	2	—	
Output voltage	"H" level	V_{OH}	3	V_{CC1} = +15V, V_{EE1} = -15V R_L = 200Ω, I_F = 5mA		11	12.8	—	V
	"L" level	V_{OL}	4	V_{CC1} = +15V, V_{EE1} = -15V R_L = 200Ω, V_F = 0.8V		—	-14.2	-12.5	
Supply current	"H" level	I_{CCH}	—	V_{CC} = 30V, I_F = 10mA Ta = 25°C		—	7	—	mA
				V_{CC} = 30V, I_F = 10mA		—	—	11	
	"L" level	I_{CCL}	—	V_{CC} = 30V, I_F = 0mA Ta = 25°C		—	7.5	—	
				V_{CC} = 30V, I_F = 0mA		—	—	11	
Threshold input current	"Output L→H"	I_{FLH}	—	V_{CC1} = +15V, V_{EE1} = -15V R_L = 200Ω, V_O > 0V		—	1.2	5	mA
Threshold input voltage	"Output H→L"	V_{FHL}	—	V_{CC1} = +15V, V_{EE1} = -15V R_L = 200Ω, V_O < 0V		0.8	—	—	V
Supply voltage		V_{CC}	—	—		10	—	35	V
Capacitance (input-output)		C_S	—	V_S = 0 V, f = 1MHz Ta = 25°C		—	1.0	2.0	pF
Resistance(input-output)		R_S	—	V_S = 500V , Ta = 25°C R.H.≤ 60%		1×10^{12}	10^{14}	—	Ω

* All typical values are at Ta = 25°C

Note 1: Duration of I_O time ≤ 50μs

MicroLabBox®

Compact prototyping unit for the laboratory

Highlights

- Compact all-in-one development system for laboratory purposes
- Dual-core real-time processor at 2 GHz
- User-programmable FPGA
- More than 100 channels of high-performance I/O
- Dedicated electric motor control features
- Ethernet and CAN bus interfaces
- Easy I/O access via integrated connector panel

Application Areas

MicroLabBox is a compact development system for the laboratory that combines compact size and cost-effectiveness with high performance and versatility. MicroLabBox lets you set up your control, test or measurement applications quickly and easily, and helps you turn your new control concepts into reality. More than 100 I/O channels of different types make MicroLabBox a versatile system that can be used in mechatronic research and development areas, such as robotics, medical engineering, electric drives control, renewable energy, vehicle engineering, or aerospace.

Key Benefits

High computation power combined with very low I/O latencies provide great real-time performance. A programmable FPGA gives you a high degree of flexibility and lets you run even extremely fast control loops, as required in applications such as electric motor control or active noise and vibration cancellation.

MicroLabBox is supported by a comprehensive dSPACE software package (see options on p. 5), including, e.g., Real-Time Interface (RTI) for Simulink® for model-based I/O integration and the experiment software ControlDesk®, which provides access to the real-time application during run time by means of graphical instruments.

Two Connector Panel Variants

MicroLabBox is available in two connector panel variants (see p. 3-4), each offering a different position for the I/O connectors. The top panel variant provides Sub-D and BNC connectors and allows easy access to the I/O when the MicroLabBox sits on the user's desk. The front panel variant provides Sub-D connectors, so you can use MicroLabBox when it is stacked with other laboratory equipment, for example. For easy wiring and signal tracing, the pinout information is shown on the units themselves and is referred to in the I/O blockset of RTI.

Technical Details

Parameter		**Specification**	
MicroLabBox		**Front Panel Variant**	**Top Panel Variant**
Processor	Real-time processor	■ Freescale QorIQ P5020, dual-core, 2 GHz ■ 32 KB L1 data cache per core, 32 KB L1 instruction cache per core, 512 KB L2 cache per core, 2 MB L3 cache total	
	Host communication co-processor	■ Freescale QorIQ P1011 800 MHz for communication with host PC	
Memory		■ 1 GB DRAM ■ 128 MB flash memory	
Boot time		■ Autonomous booting of applications from flash (depending on application size), ~5 s for a 5 MB application	
Interfaces	Host interface	■ Integrated Gigabit Ethernet host interface	
	Ethernet real-time I/O interface	■ Integrated low-latency Gigabit Ethernet I/O interface	
	USB interface	■ USB 2.0 interface for data logging ("flight recorder") and booting applications via USB mass storage device (max. 32 GB supported)	
	CAN interface	■ 2 CAN channels (partial networking supported)	
	Serial interface	■ 2 x UART (RS232/422/485) interface	
	LVDS interface	■ 1 x LVDS interface to connect with the Programmable Generic Interface PGI1	
Programmable FPGA[1]		■ Xilinx® Kintex®-7 XC7K325T FPGA	
Analog input	Resolution and type	■ 8 14-bit channels, 10 Msps, differential; functionality: free running mode ■ 24 16-bit channels, 1 Msps, differential; functionality: single conversion and burst conversion mode with different trigger and interrupt options	
	Input voltage range	■ -10 ... 10 V	
Analog output	Resolution and type	■ 16 16-bit channels, 1 Msps, settling time: 1 µs	
	Output voltage range	■ -10 ... 10 V	
	Output current	■ ± 8 mA	
Digital I/O		■ 48 bidirectional channels, 2.5/3.3/5 V (single-ended); functionality: bit I/O, PWM generation and measurement (10 ns resolution), pulse generation and measurement (10 ns resolution), 4 x SPI Master ■ 12 bidirectional channels (RS422/485 type) to connect sensors with differential interfaces	
Electric motor control I/O functionality	Seperate interfaces	■ 2 x Resolver interface	
	Functionality on digital I/O channels	■ 6 x Encoder sensor input ■ 2 x Hall sensor input ■ 2 x EnDat interface ■ 2 x SSI interface ■ Synchronous multi-channel PWM ■ Block commutational PWM	
Sensor supply		■ 1 x 12 V, max. 3 W/250 mA (fixed) ■ 1 x 2 ... 20 V, max. 1 W/200 mA (variable)	
Feedback elements		■ Programmable buzzer ■ Programmable status LEDs	
Theft protection		■ Kensington® lock	
Cooling		■ Active cooling (temperature-controlled fan)	
Physical connections		■ 4 x Sub-D 50 I/O connectors ■ 4 x Sub-D 9 I/O connectors	■ 2 x Sub-D 50 I/O connectors ■ 48 x BNC I/O connectors ■ 4 x Sub-D 9 I/O connectors
		■ 3 x RJ45 for Ethernet (host and I/O) ■ USB Type A (for data logging) ■ 2 x 2 banana connectors for sensor supply ■ Power supply	

[1] *User-programmable via RTI FPGA Programming Blockset. Using the RTI FPGA Programming Blockset requires additional software.*

Order Information

Products	Order Number
MicroLabBox, front panel variant	■ MLBX_1302F
MicroLabBox, top panel variant	■ MLBX_1302T

Relevant Software and Hardware

Software		Order Number
Included	■ Data retrieval utility for flight recorder read-out	–
	■ Comprehensive C libraries (e.g., digital I/O support)	–
Required	■ For Simulink®-based use cases: Real-Time Interface (RTI)	■ RTI
	■ GNU C Compiler for Power PC	■ MLBX_COMP
Optional	■ ControlDesk®	Please see the ControlDesk product information.
	■ For multi-core applications: RTI-MP	■ RTI_MP
	■ RTI CAN Blockset	■ RTICAN_BS
	■ RTI CAN MultiMessage Blockset	■ RTICANMM_BS
	■ RTI Electric Motor Control Blockset (p. 10)	■ RTI_EMC_BS
	■ RTI USB Flight Recorder Blockset (part of Real-Time Interface)	■ RTI
	■ RTI Ethernet Blockset	■ RTI_ETHERNET_IO
	■ RTI FPGA Programming Blockset	Please see the RTI FPGA Programming Blockset product information.
	■ Platform API Package	■ PLATFORM_API

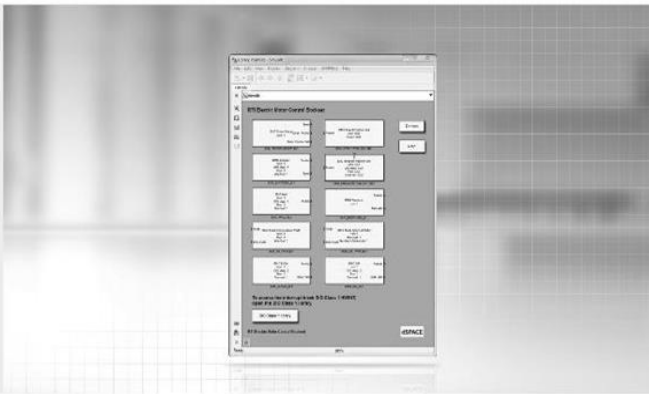
Hardware		Order Number
Included	■ Ethernet patch cable (HSL_PATCH) for host connection	–
	■ Power supply cable	–
	■ Set of Sub-D plugs	–
	■ Case for storage and transportation	–
Optional	■ Adapter cable 50-pin Sub-D to WAGO terminal panel	■ MLBX_CAB1
	■ RapidPro SC Unit	Please see the RapidPro product information.
	■ RapidPro Power Unit	Please see the RapidPro product information.

RTI Electric Motor Control Blockset

Configuring electric motor control I/O functions of MicroLabBox®

Highlights

- Access to the electric motor control I/O functionalities of MicroLabBox
- Easy configuration and implementation of Hall sensor inputs, incremental encoder, Resolver, EnDat, and SSI interfaces as well as PWM signal generation
- Automatic calculation and interpolation of the current motor speed, position, and angle, plus generation of asynchronous events



Application Areas

Electric motor controls play an important role in various application fields such as automotives, robotics, medical engineering, and many more, e.g., to comply with new, strict emission regulations or to build up more precise machines in industrial environments. Often, the control algorithm for an electric motor is a key point in fulfilling customers' requirements. But the effort of developing, validating and implementing the required control algorithms in traditional tool chains can be very high, and these tool chains often lack flexibility. The MicroLabBox in combination with the RTI Electric Motor Control Blockset is the ideal system to reduce this effort. Developing and testing new control algorithms takes place in a model-based software environment with a minimum amount of time. The RTI Electric Motor Control Blockset is a user-friendly software interface that provides a link between your real-time hardware platform MicroLabBox and the model-based development software MATLAB®/Simulink®/Stateflow® from Mathworks.

Key Benefits

The RTI Electric Motor Control Blockset provides access to the electric motor control I/O functionalities of MicroLabBox and allows you to configure them easily and conveniently. No additional modeling effort is needed to use sensor interfaces commonly applied in electric motor applications such as Hall, incremental encoder, Resolver, EnDat or SSI. In addition, ready-to-use Simulink blocks for generating different synchronous PWM signals are available. The current speed, position and angle of the electric motor are automatically calculated. If sensor interfaces with low resolution such as Hall sensors are used, an automatic interpolation can be enabled to achieve a higher sensor resolution and to improve the quality of the position measurement. When first starting the motor to get the current motor position it is possible to use the Hall sensor interface immediately, and then switch to a sensor with the higher resolution such as the encoder interface after one revolution of the electric motor. With this process, a valid position and the best resolution is always available for the controller. Simulink-based control models can be easily connected with the required I/O interfaces and then be downloaded to the MicroLabBox at the push of a button. The controller can be tested in a real environment with different sensors and actuators, and new motor control strategies can be developed much faster than in traditional tool chains.

Functionality Overview

Functionality	Description

General	■ Accessing and configuring dedicated I/O functions for:
	  ■ Resolver interfaces
	  ■ Encoder sensor inputs
	  ■ Hall sensor inputs
	  ■ EnDat interfaces
	  ■ SSI interfaces
	  ■ Synchronous multi-channel PWMs
	  ■ Block commutational PWMs
	■ For electric motors with up to 6 phases and 16 pole pairs
	■ Controlling 2 or more electric motors at the same time
	■ Combining 2 sensors to extrapolate the position of the motor's rotor
	■ Generating events for algorithm execution triggered by specified motor positions

Order Information

Product	Order Number
RTI Electric Motor Control Blockset	■ RTI_EMC_BS

Relevant Software and Hardware

Software			Order Number
Required	For MicroLabBox	■ Real-Time Interface[1]	■ RTI

Hardware			Order Number
Required	For MicroLabBox	■ MicroLabBox[2] with front or top panel	■ See p. 5

[1] *For information on standard hardware and software requirements for Real-Time Interface (RTI), please see the RTI product information.*

[2] *A corresponding compiler is required, see p. 5.*