BUCK BOOST CONVERTER DESIGN WITH THE HELP OF D-SPACE

A Project report submitted in 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 "**BUCK BOOST CONVERTER DESIGN WITH THE HELP OF DSPACE"** is the bona fide work carried out by **Abhishek Pal (11701614002), Soumak Dutta (11701614047) , Ankur Bose (11701614009)** , the students of B.Tech in the Dept. of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India, during the academic year 2016-17, in partial fulfillment of the requirements for the degree of Bachelor of Technology in Electrical Engineering and that this project has not submitted previously for the award of any other degree, diploma and fellowship.

Signature of the Guide
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Designation:

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Designation:

ACKNOWLEDGEMENT

It is our great fortune that we have got opportunity to carry out this project work under the supervision of **Asst. Prof. Sarbojit Mukherjee** in the Department of Electrical Engineering, RCC Institute of Information Technology (RCCIIT) , Canal South Road , Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India. We express our sincere thanks and deepest sense of gratitude to our guide for his constant support, unparalleled guidance and limitless encouragement.

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AC Alternating Current
DC Direct current
FPGA Field Programmable Gate Array
IC Integrated Circuit
IGBT Insulated Gate Bi-polar Transistor
LED Light Emitting Diode
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 master report presents a voltage tracking of dc-dc buck-boost converter. The dc-dc Buck converter is designed to tracking the output voltage with three mode of operation. This master report consists open loop control, closed loop control with the help of DSpace. The Buck-Boost converter has some advantages compare to the others type of dc converter. However the nonlinearity of the dc-dc Buck-Boost converter characteristics, cause it is difficult to handle by using conventional method such as open loop control system. In order to overcome this main problem, a close loop control system using DSpace is developed. The effectiveness of the proposed method is verified by develop simulation model in MATLAB-Simulink program. The simulation results show that the proposed method produce significant improvement control performance compare to convational converter for voltage tracking output for dc-dc Buck-Boost converter.

1. INTRODUCTION

DC - DC converters are the most widely used circuits in power electronics. They can be found in almost every electronic device nowadays, since all semiconductor components are powered by DC sources. They are basically used in all situations where there is the need of stabilizing a given dc voltage to a desired value. This is generally achieved by chopping and filtering the input voltage through an appropriate switching action, mostly implemented via a pulse width modulation (PWM) . In this project, we concentrate our research towards buck-boost DC converter.

The buck-boost is a popular non-isolated, inverting power stage topology, sometimes called a step-up/down power stage. Power supply designers choose the buck-boost power stage because; the output voltage is inverted from the input voltage, and the output voltage can be either higher or lower than the input voltage. The topology gets its name from producing an output voltage that can be higher (like a boost power stage) or lower (like a buck power stage) in magnitude than the input voltage. Buck-boost converter is an intriguing subject from the control point of view, due to its intrinsic non-linearity.

One of the design targets for electronic engineers is to improve the efficiency of power conversion. For PWM (pulse-width modulation) converters, switching loss is an important performance measure. Fuzzy logic control has been applied successfully to a wide variety of engineering problems, including dc to dc converters. Fuzzy control is an attractive control method because its structure, consisting of fuzzy sets that allow partial membership and “if - then” rules, resembles the way human intuitively approaches a control problem. This makes it easy for a designer to incorporate heuristic knowledge of a system into the controller. Fuzzy control is obviously a great value for problems where the system is difficult to model due to complexity, non-linearity, and imprecision. DC-DC converters fall into this category because they have a time-varying structure and contain elements that are non-linear and have parasitic components.

The switched mode dc-dc converters are some of the simplest power electronic circuits which convert one level of electrical voltage into another level by switching action. These converters have received an increasing deal of interest in many areas. This is due to their wide applications like power supplies for personal computers, office equipments, appliance control, telecommunication equipments, DC motor drives, automotive, aircraft, etc.

In this project, MATLAB simulink is used as a platform in designing the buck-boost converter and DSpace in order to study the dynamic behavior of dc to dc converter.

2. THEORY

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, trolleycars, marine hoists, and forklift trucks. They provide smooth acceleration control,high efficiency, and fast dynamic response. Dc converter can be used in regenerativebraking 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 lowpower applications to high power applications. The goal of any system is toemphasize and achieve the efficiency to meet the system needs and requirements.

Several topologies have been developed in this area, but all these topologies can beconsidered as apart or a combination of the basic topologies which are buck, boostand fly back.

For low power levels, linear regulators can provide a very high-quality outputvoltage. For higher power levels, switching regulators are used. Switching regulatorsuse 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 theon state, zero current through a switch in the off state), switching regulators canachieve high efficiency energy conversion.

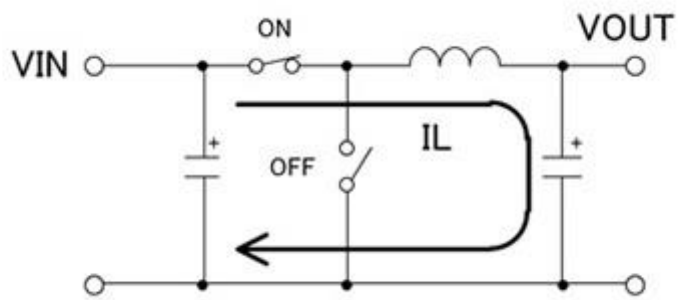
FUNCTION OF DC-DC CONVERTER

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 requiredlevel.
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.

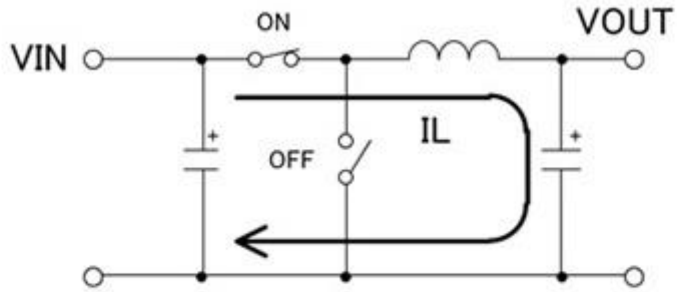


Operation of Buck Converters

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.

- 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）

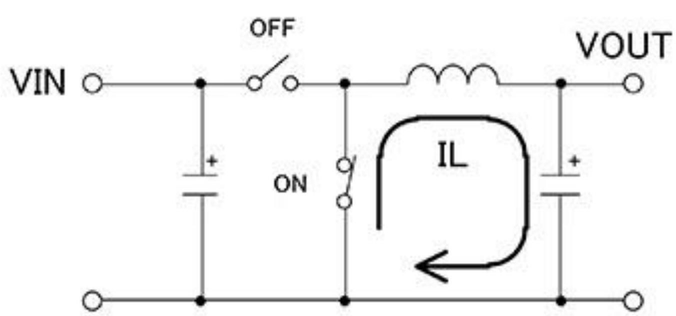
$$IL = \frac{VIN - VOUT}{L} \times ton$$

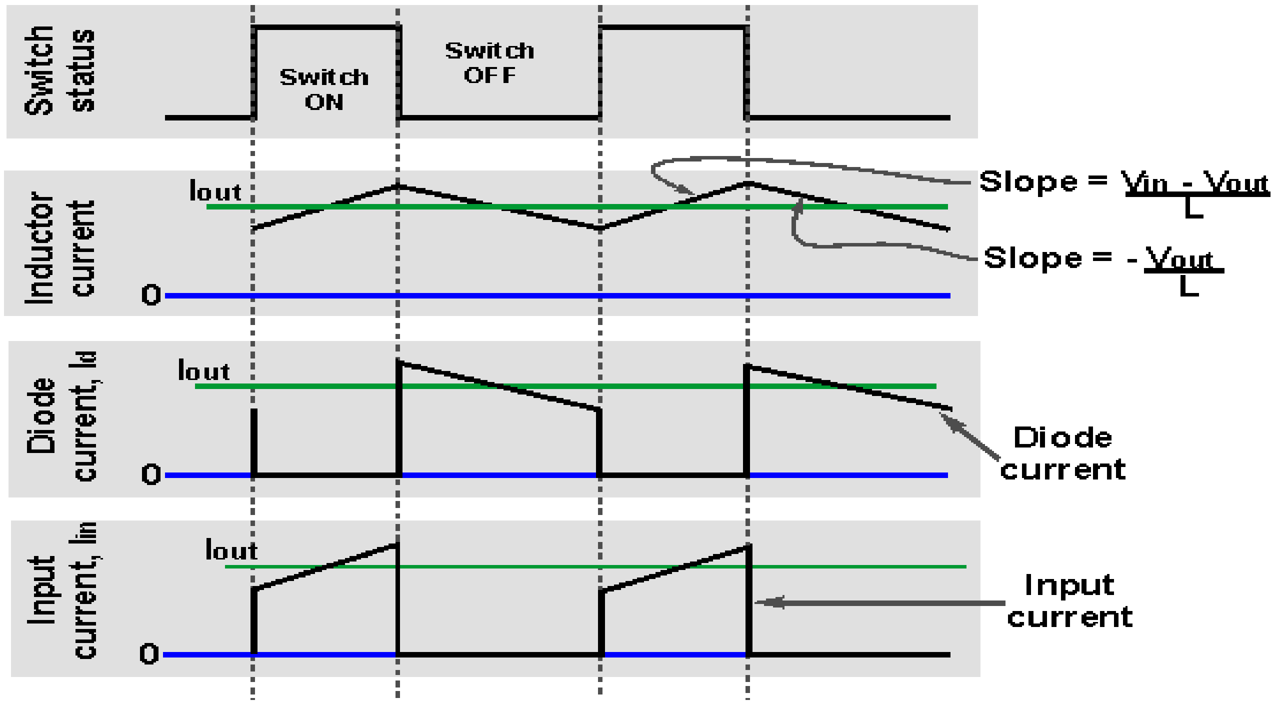


- When the high-side switch (the transistor) turns off, the energy stored in the inductor is output through the low-side switch (the diode)
- At this time, the high-side switch (the transistor) is OFF
- The inductor current IL is expressed by the following equation （toff： OFF time）

$$IL = \frac{VOUT}{L} \times toff$$

Figure 2: OFF mode





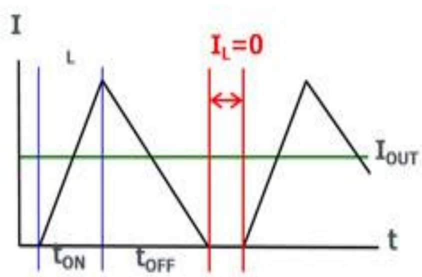
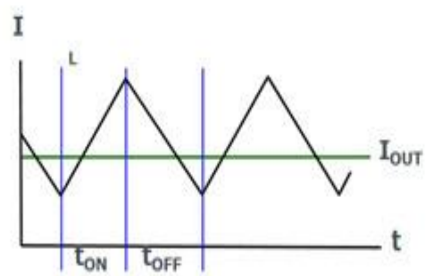
Comparison item	Discontinuous mode	Continuous mode
Operation	 There is a zero-inductor current period between ON and OFF, so that the inductor current is not continuous.	 The inductor current flows continuously, which turns ON and OFF at the same frequency as the switching frequency.
Inductor	Inductance ↓, 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

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 each mode, arrows indicate the tendencies for the inductor, the rectifying diode, the switching transistor, and the efficiency; an upward arrow "↑" means an increase, and a downward arrow "↓" indicates a decrease.

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 harmonics. However, in AC/DC conversion, the diode reverse voltage is high and a large reverse current flows, and so discontinuous mode, in which a reverse current does not flow and losses are reduced, is generally used. However, the peak current becomes large, and when the load is large, sometimes operation in continuous mode is preferred.

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.

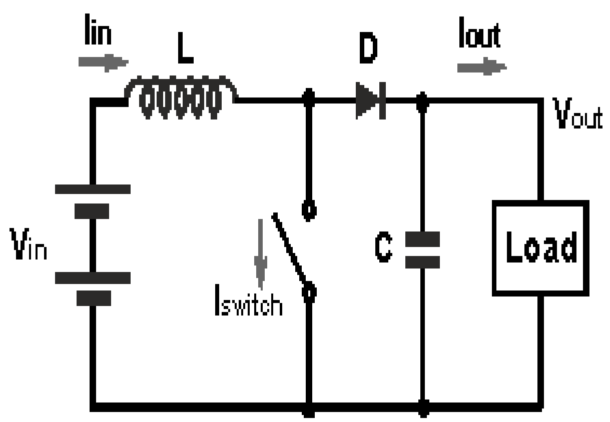


FIGURE 3 : Boost Converter Circuit

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

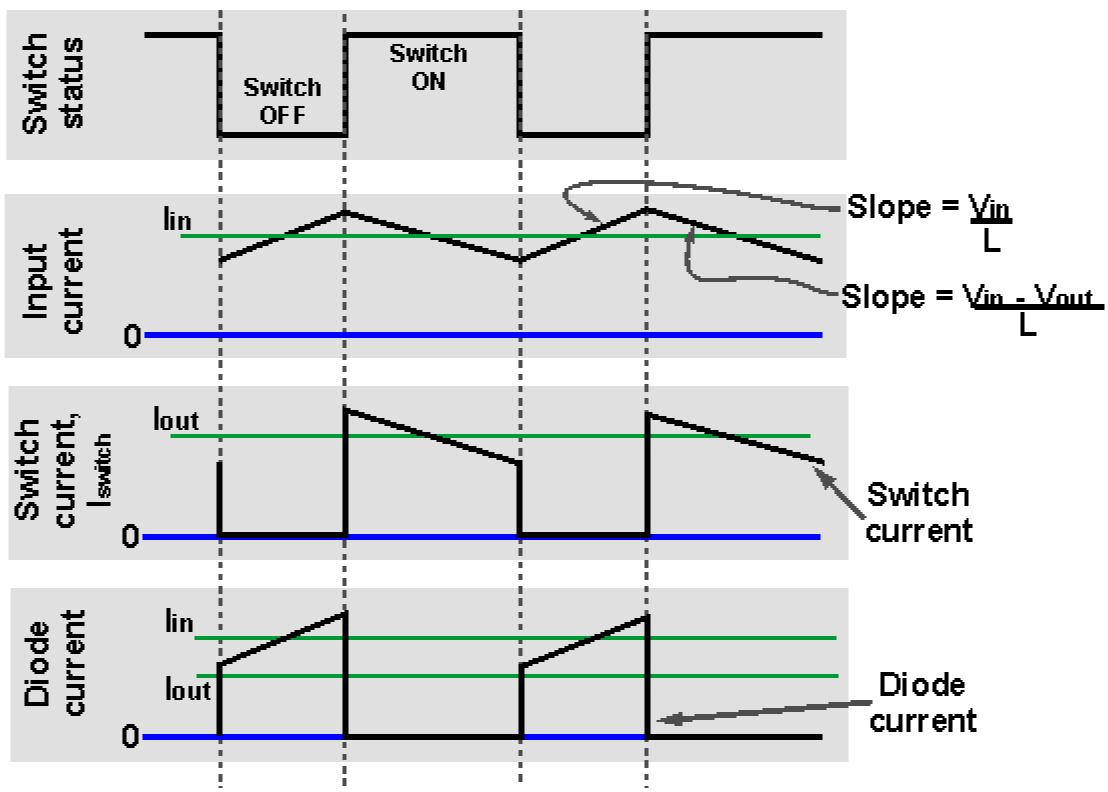


FIGURE 4: Switch Status, Input Current, Diode Current

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.

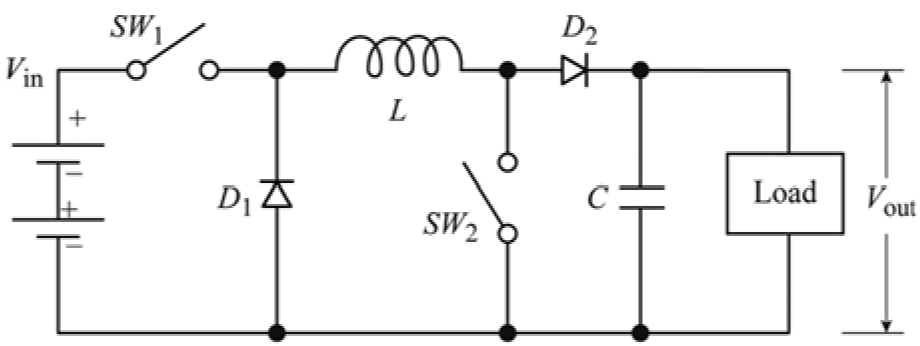


FIGURE 5: Circuit of BUCK-BOOST CONVERTER

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 normallythe most convenient format.

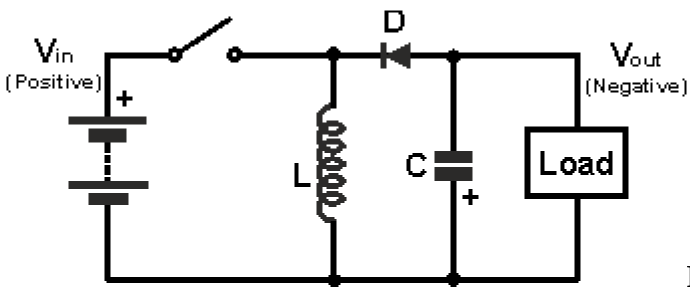


FIGURE 6: SW 1 is Open

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.

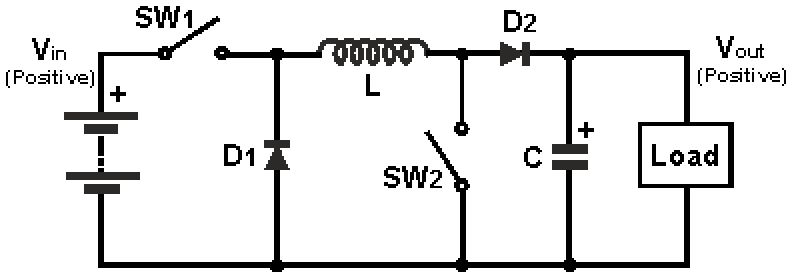
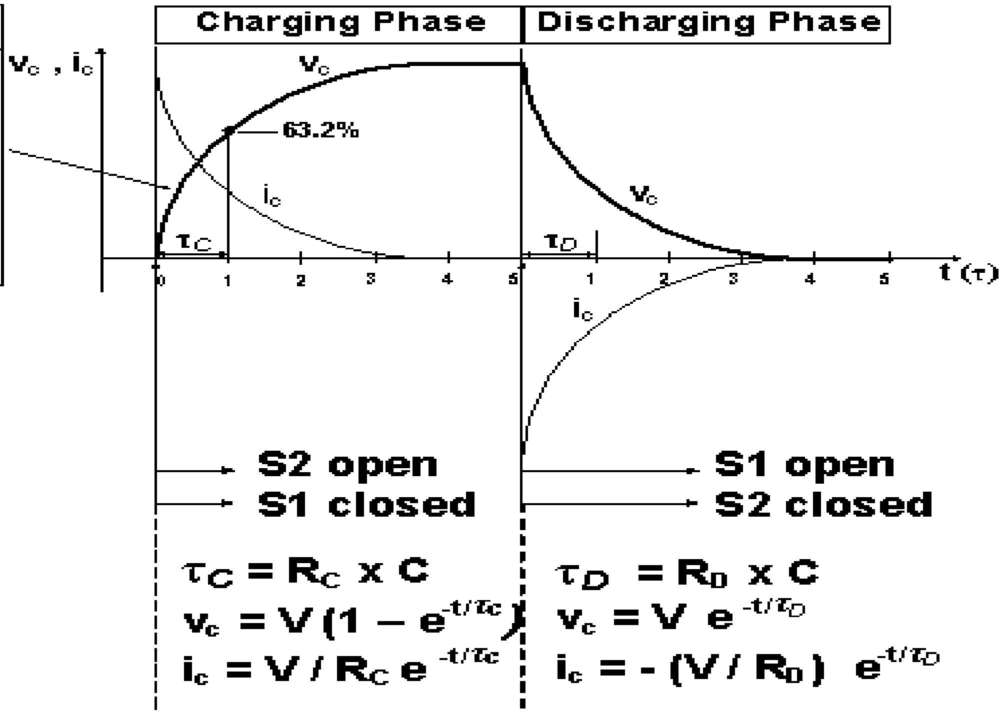


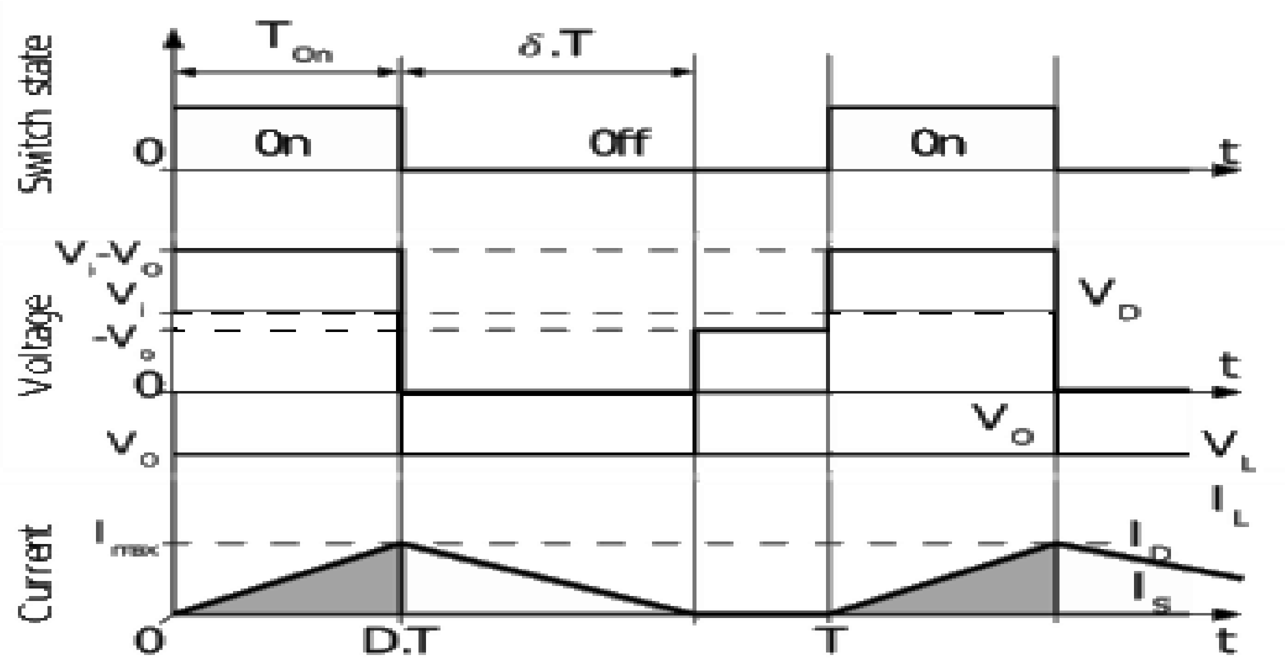
FIGURE 7 :SW 1 &SW 2 both Open

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

<u>About MicroLab box-</u>

- 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

Fig. 8 : Microlab box

<u>Application Areas-</u>

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.

<u>Key Benefits-</u>

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.

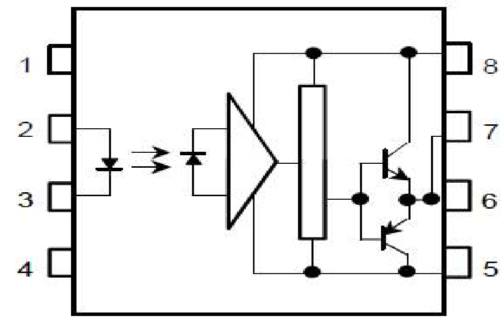
Hardware Section:-

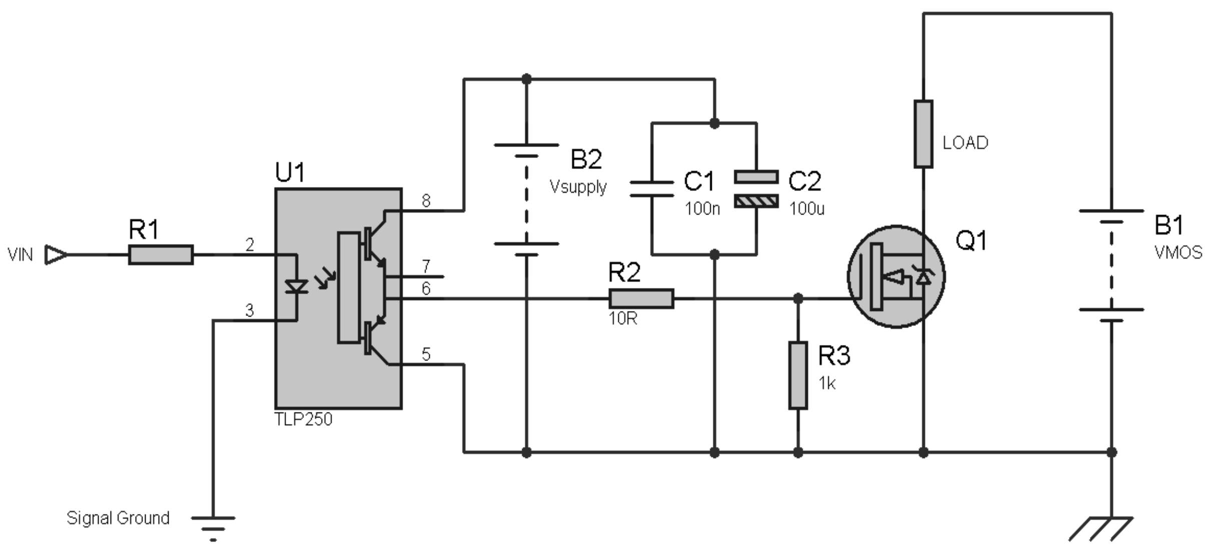
- *The Circuit for Gate driver (TLP 250h)-*

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





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:

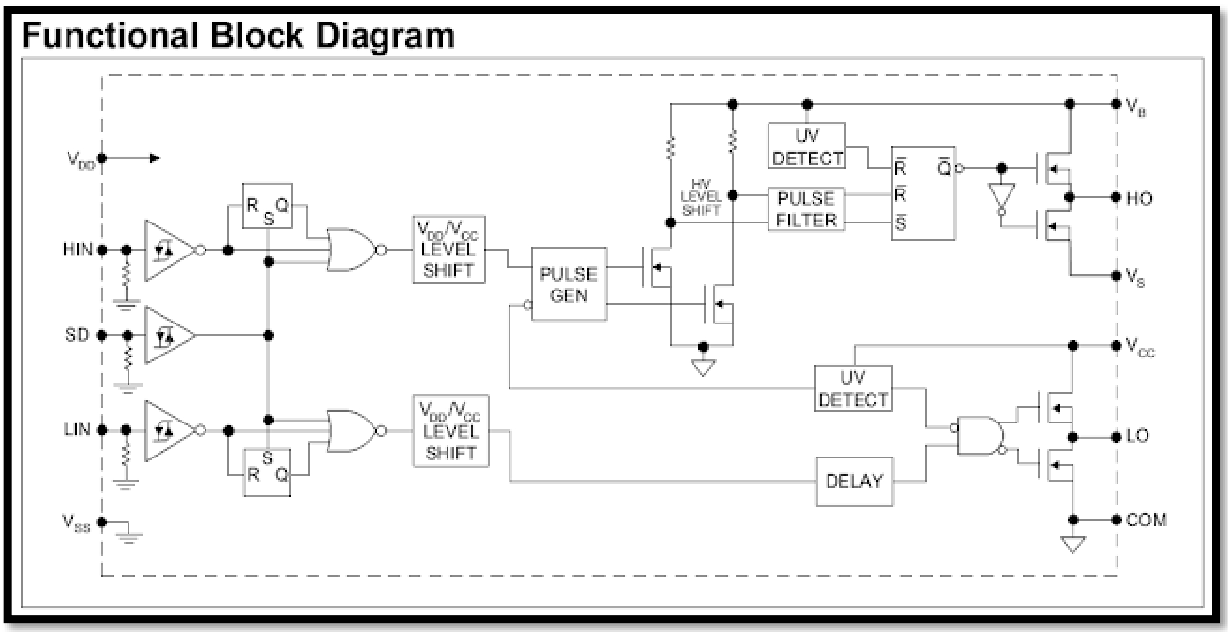


Figure 11 : IR2110 block diagram

Figure 12 : IR2110 IC Chip

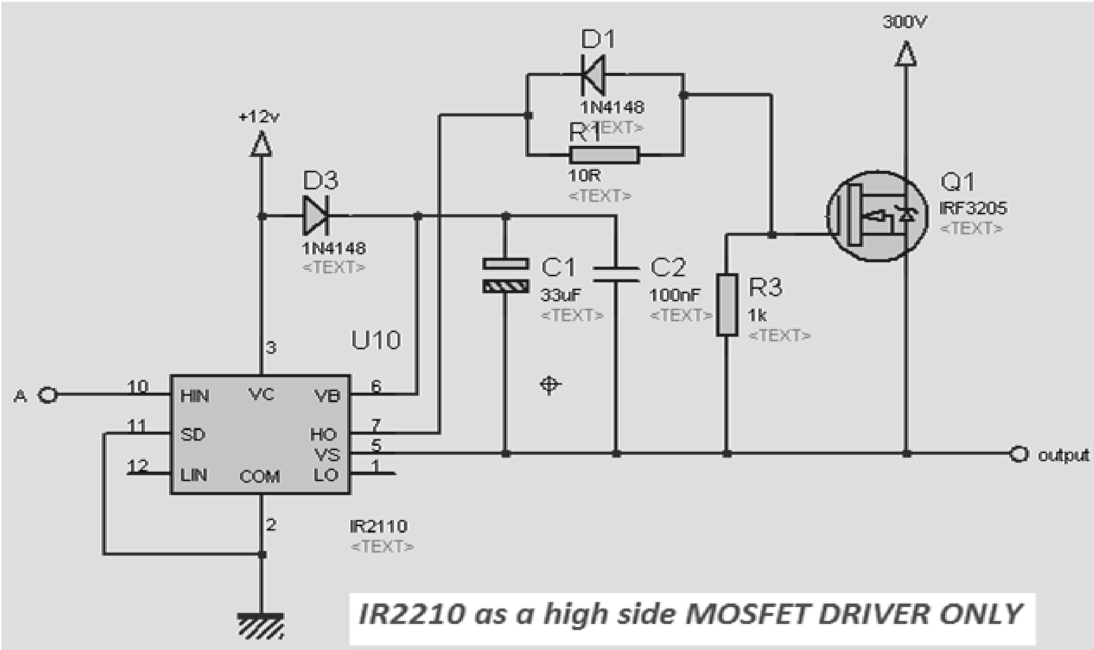


Figure 13: IR2110 Circuit as a single high-voltage high-side driver

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 :

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

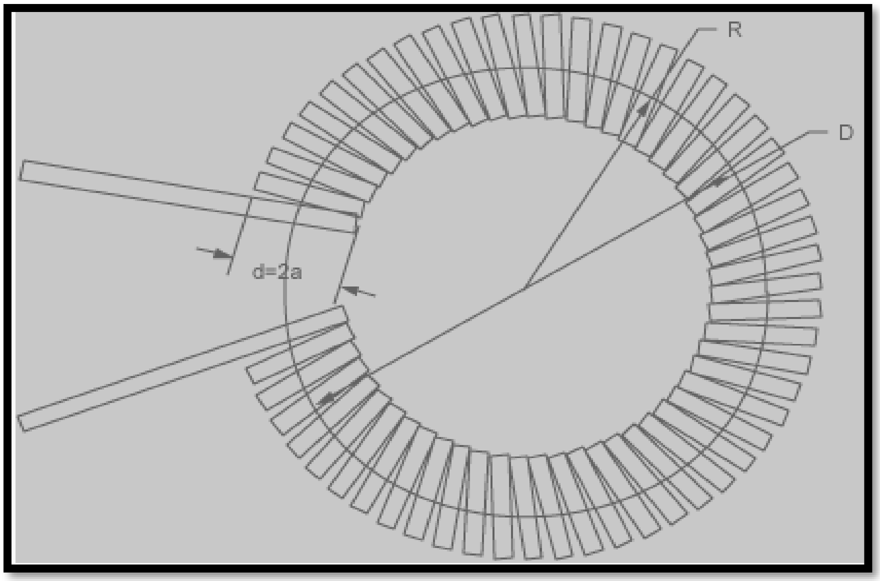


Figure 14 : Diagram of a Circular Cross Section Toroid Inductor

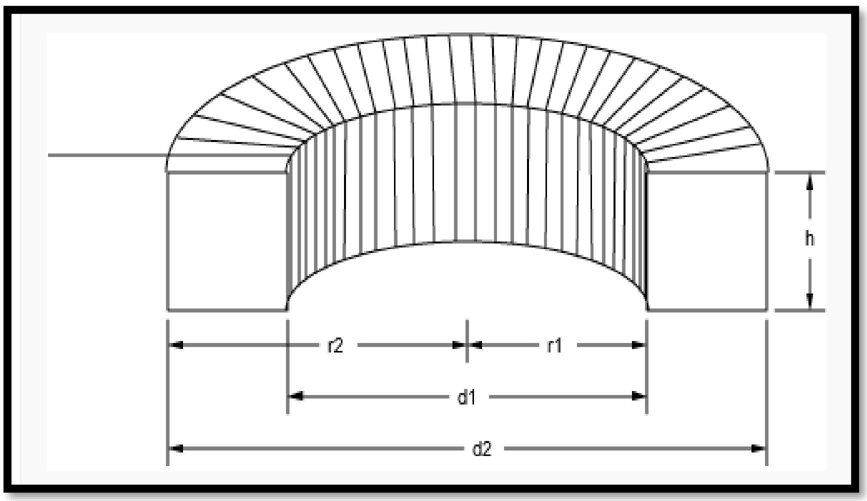


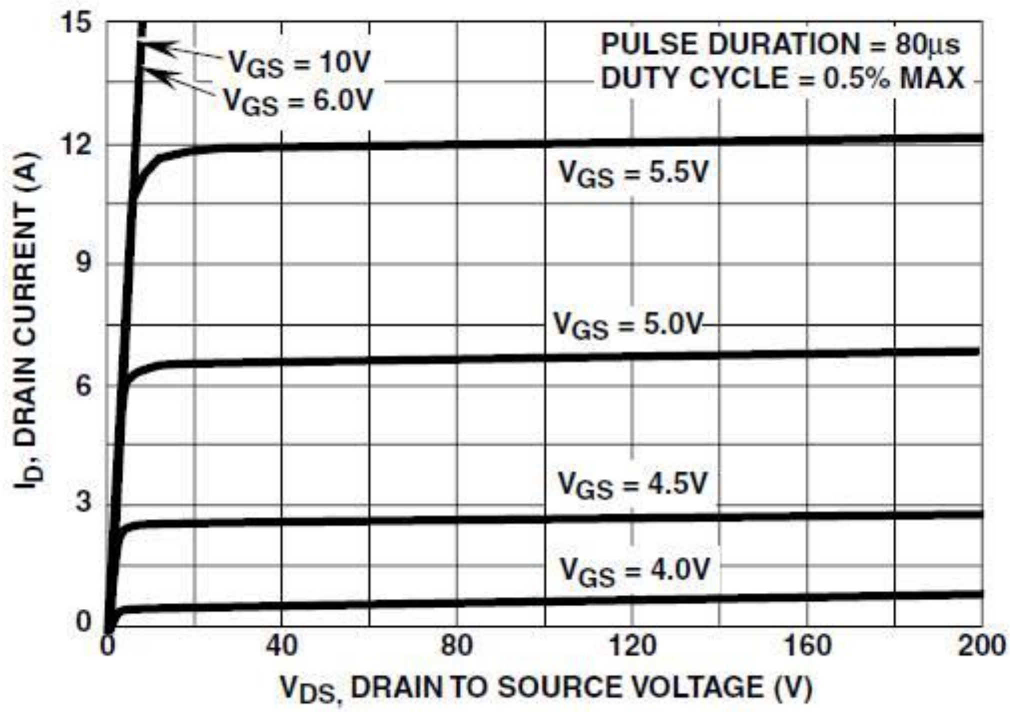
Figure 15 : Diagram of a Square Cross Section Toroid Inductor

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

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

MOSFET (IRF540):

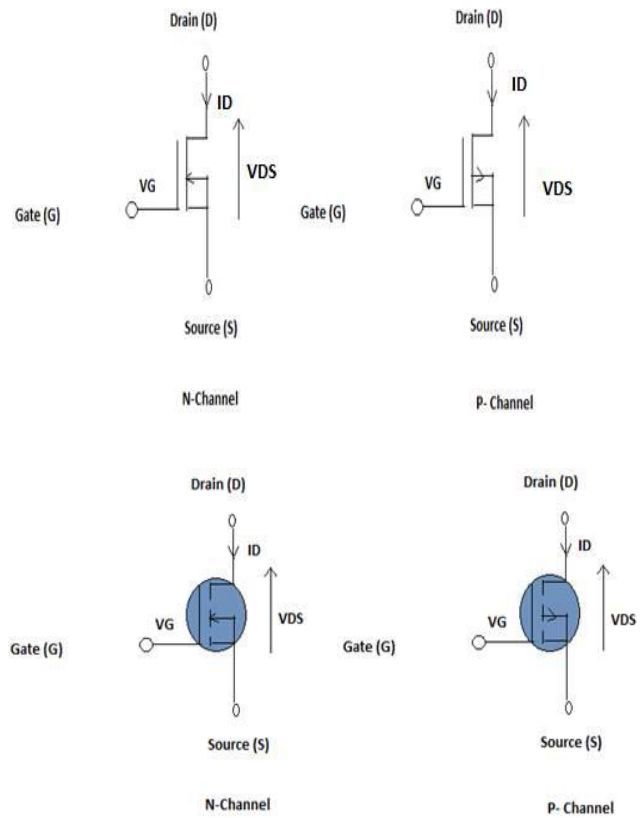
10A, 400V, 0.550 Ohm, N-Channel Power MOSFET. This N-Channel enhancement mode silicon gate power field effect transistor is an advanced power MOSFET designed, tested, and guaranteed to withstand a specified level of energy in the breakdown avalanche mode of operation. All of these power MOSFETs are designed 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

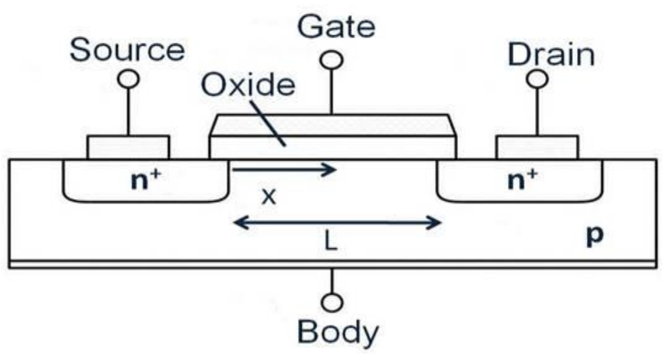
1. Depletion Mode 2. Enhancement Mode

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

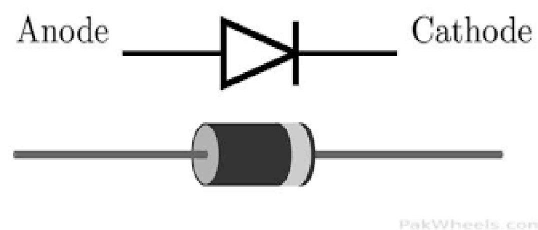


substrate. The deflection region populated by the bound negative charges which are associated with the acceptor atoms. The electrons reach channel is formed. The positive voltage also attracts electrons from the n+ source and drain regions into the channel.

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.

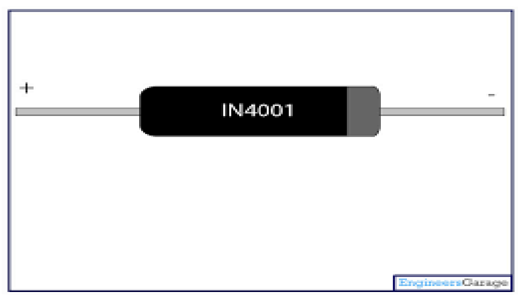
1N4001 is a 1A diode with low forward voltage drop and high surge current capability. It comprises of diffused PN junction and has low reverse leakage current of 5µA. Its DC blocking voltage is 50V.



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 4 12 V dc adapters as a replacement of power source.12 V supply in needed for all the TLP circuit and the other 3 are needed to build the sources of 12V, 6V, 3V.

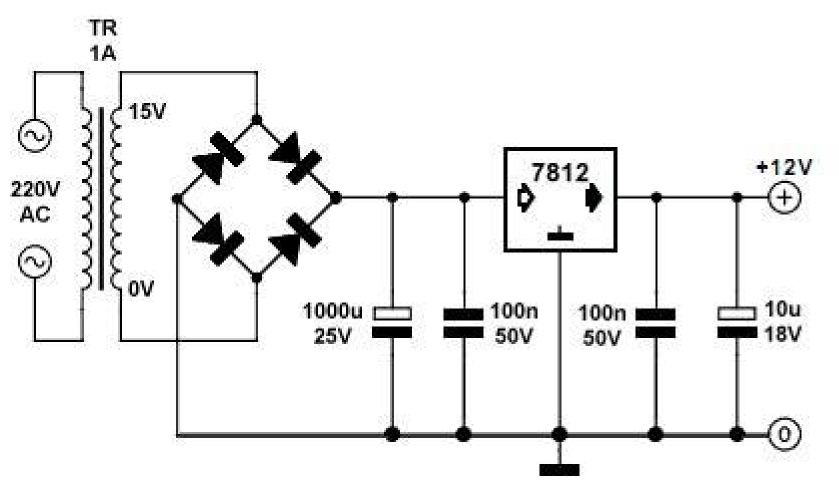


FIGURE 16: Circuit Diagram of 12v DC Adapter

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 30

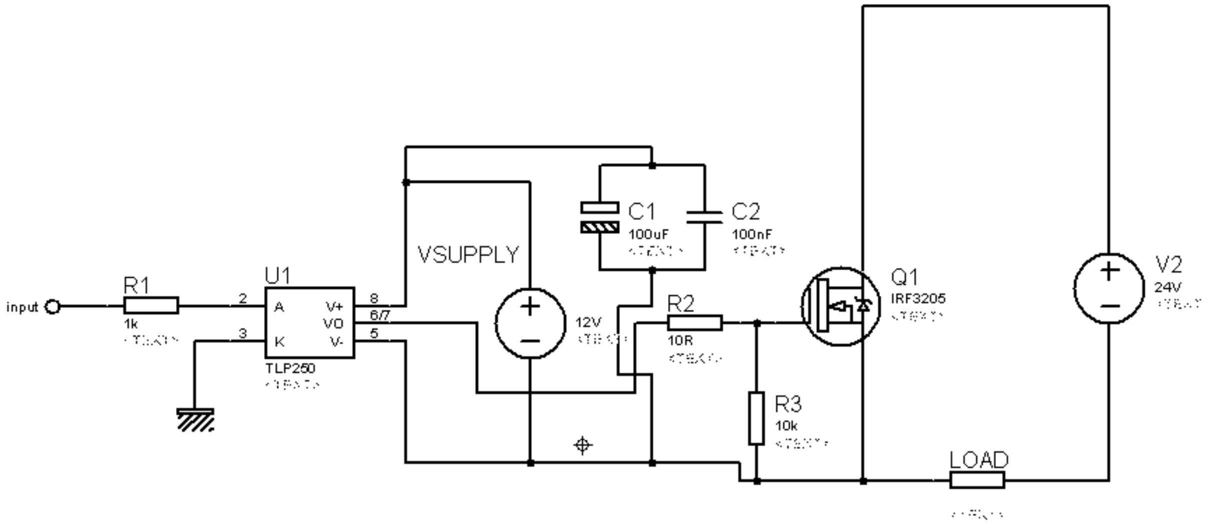


Fig 17: TLP250 working Circuit

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.

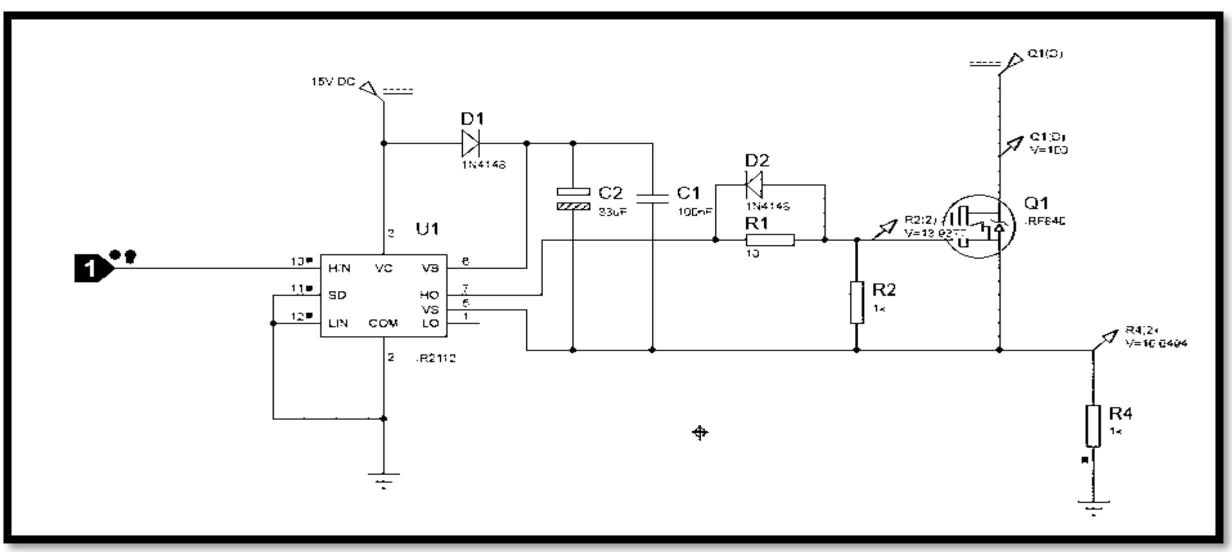


Figure 18 : Using the IR2110 as a single high-voltage high-side driver

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).

Snubber can do many things: -

1. Reduce or eliminate voltage or current spikes ·

2. Limit dI/dt or dV/dt ·

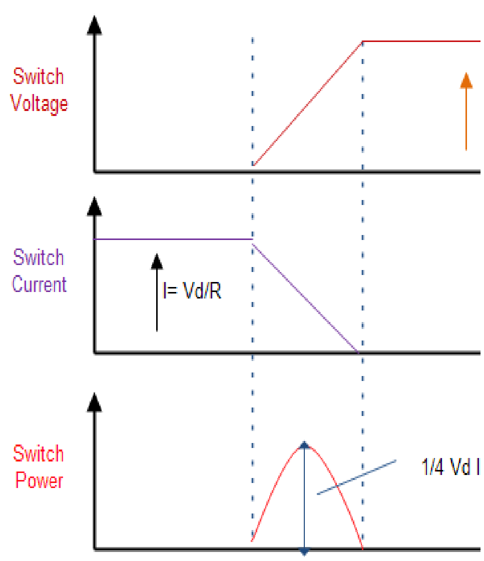
3. Shape the load line to keep it within the safe operating area (SOA) ·

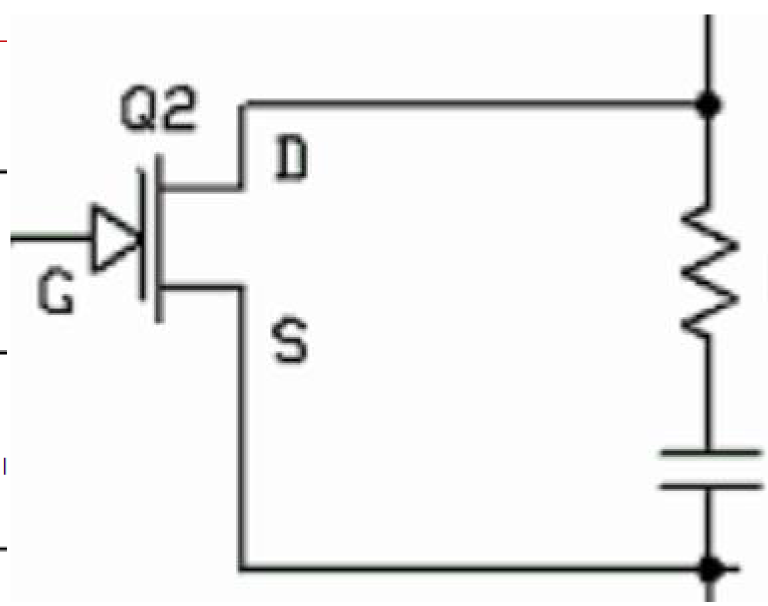
4. Transfer power dissipation from the switch to a resistor or a useful load ·

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:

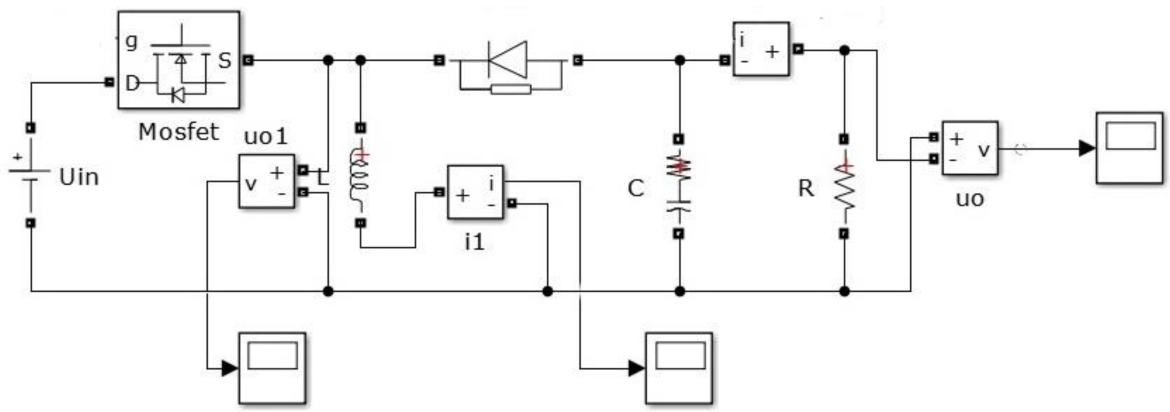


Fig 19 : Circuit Diagram for Buck-Boost Converter

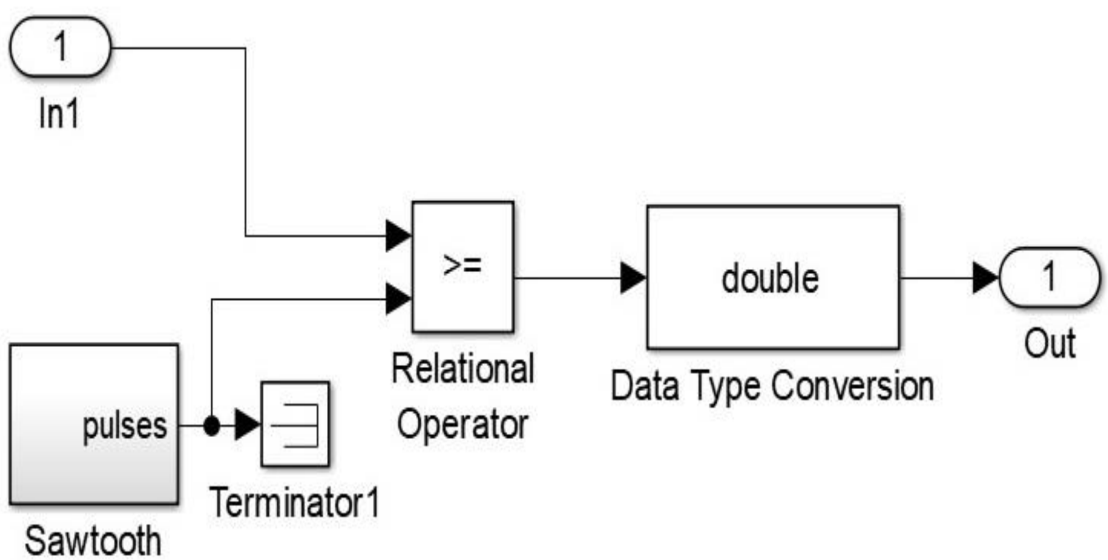


Fig 20 : PWM for creating pulse signal

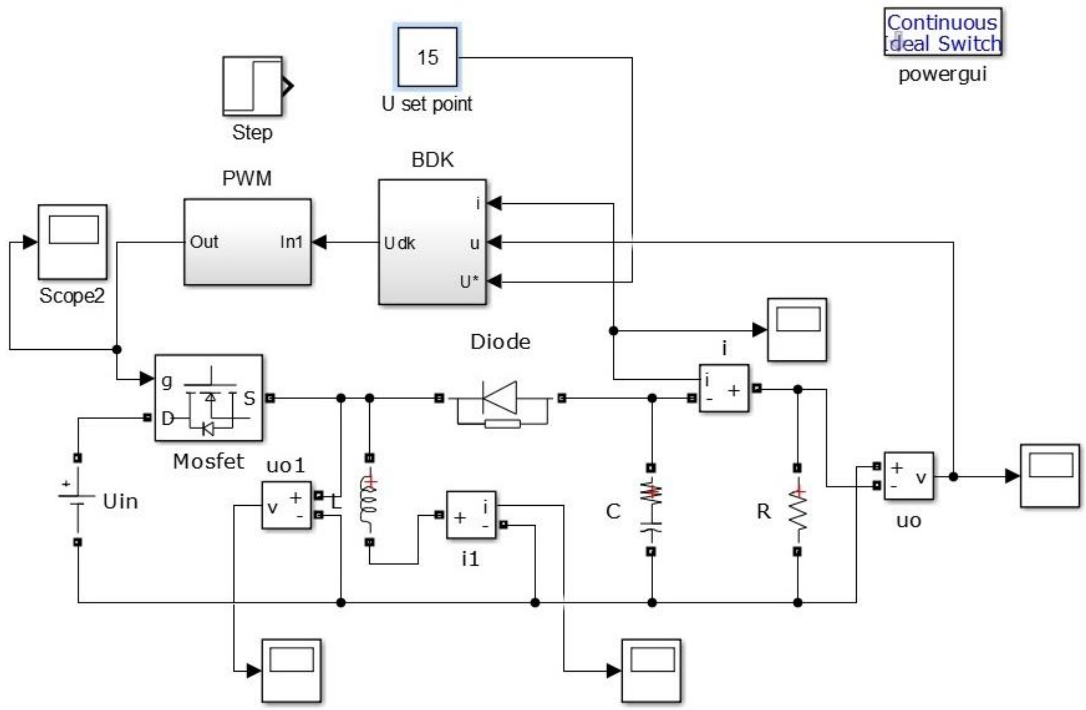


Fig 21 : MATLAB circuit for DC-Dc converter

Software Results :

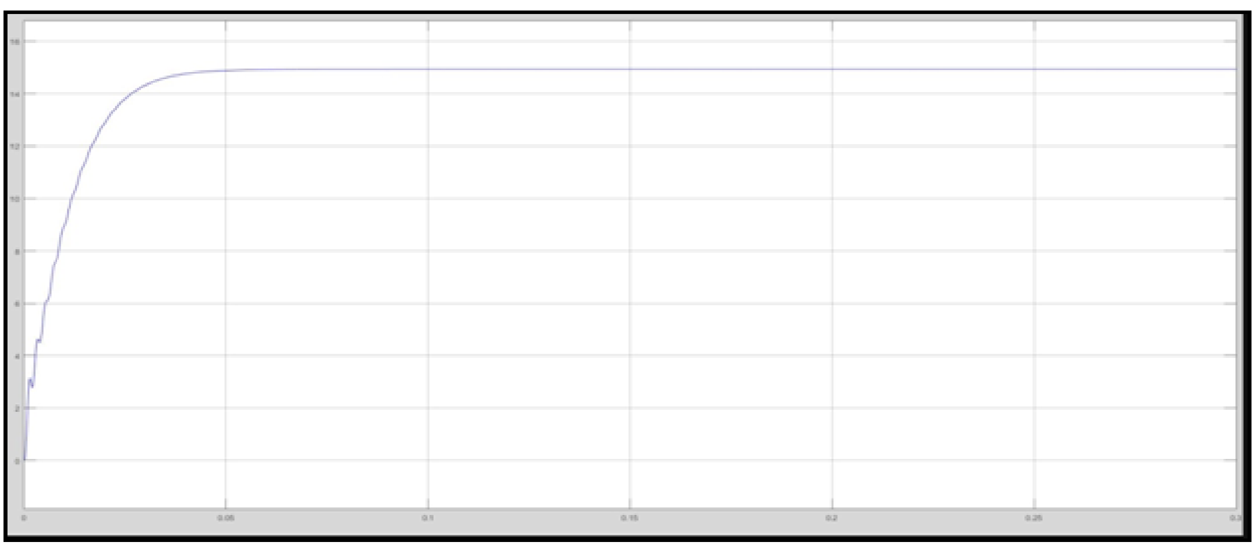


Fig 22 : MATLAB Simulation Graph

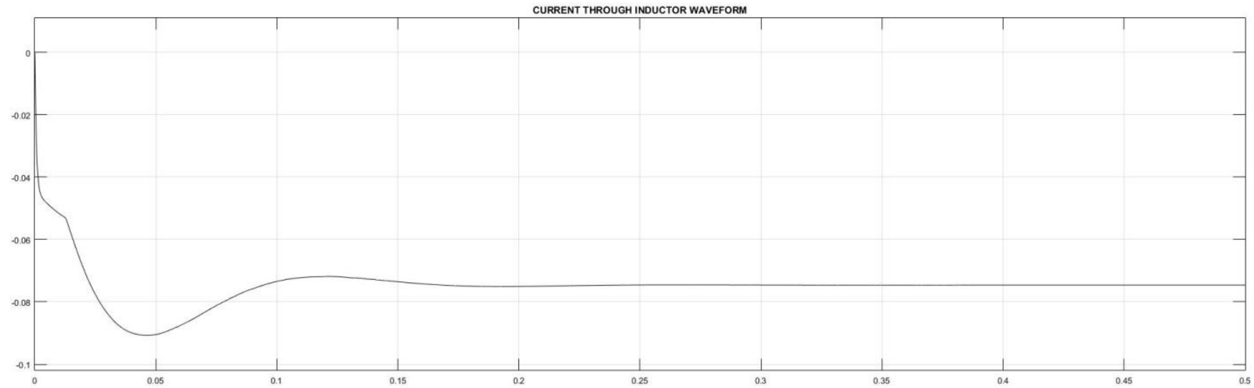


Fig 23 : Current through inductor for 20% duty

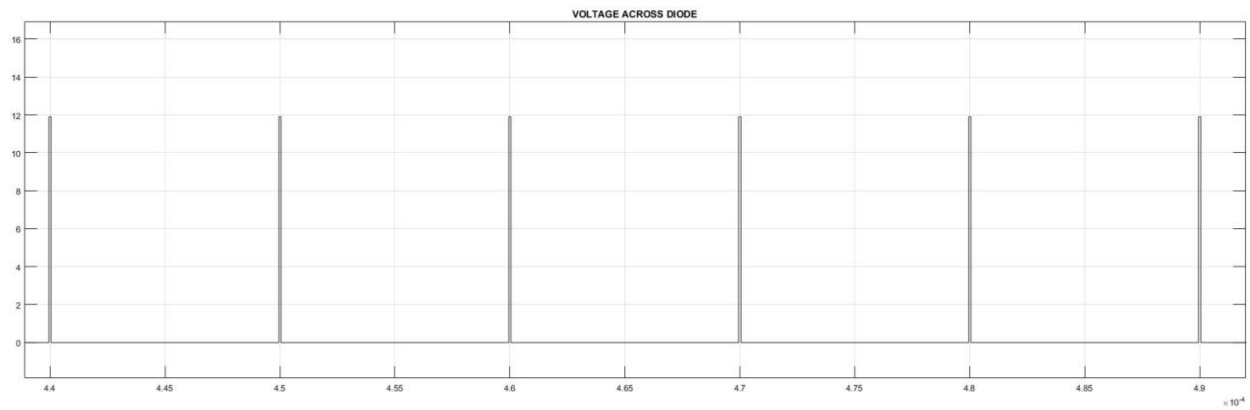


Fig 24 : V across Diode for 20% duty

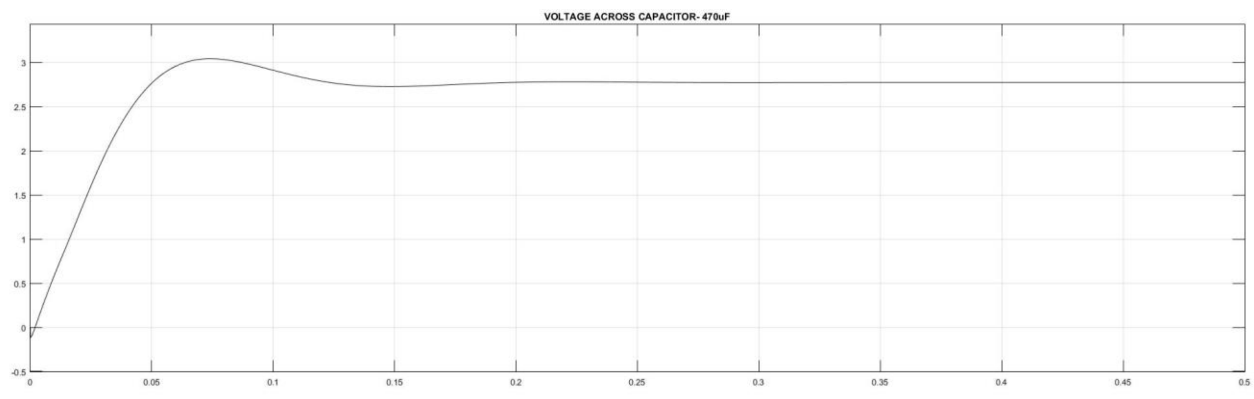
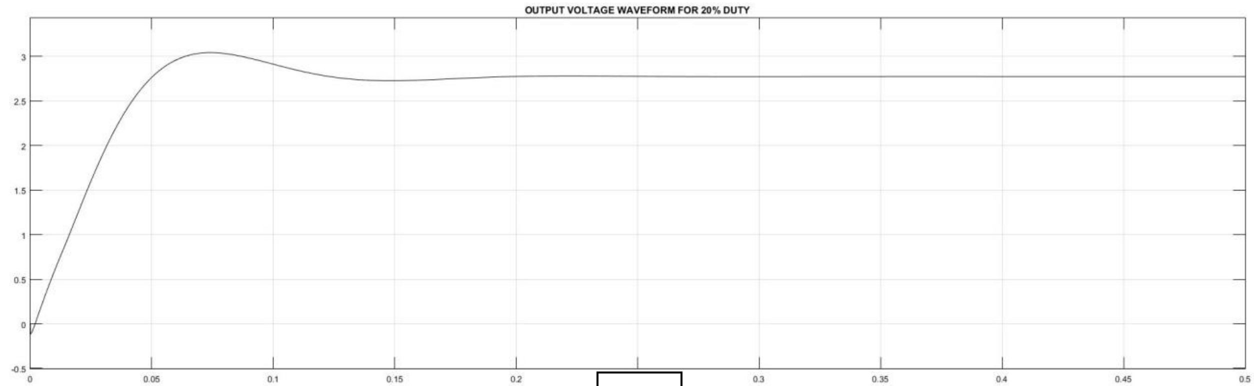
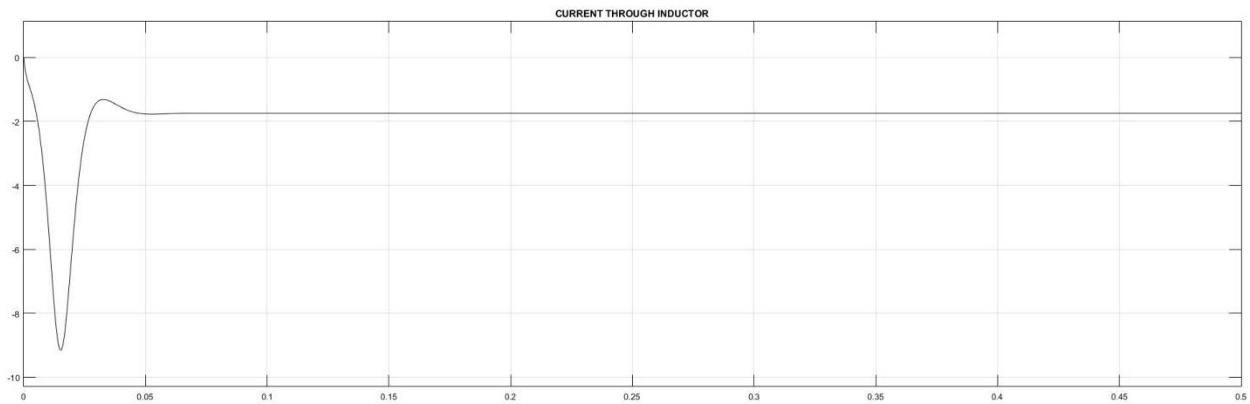


Fig 25 : V across C for 20% Duty

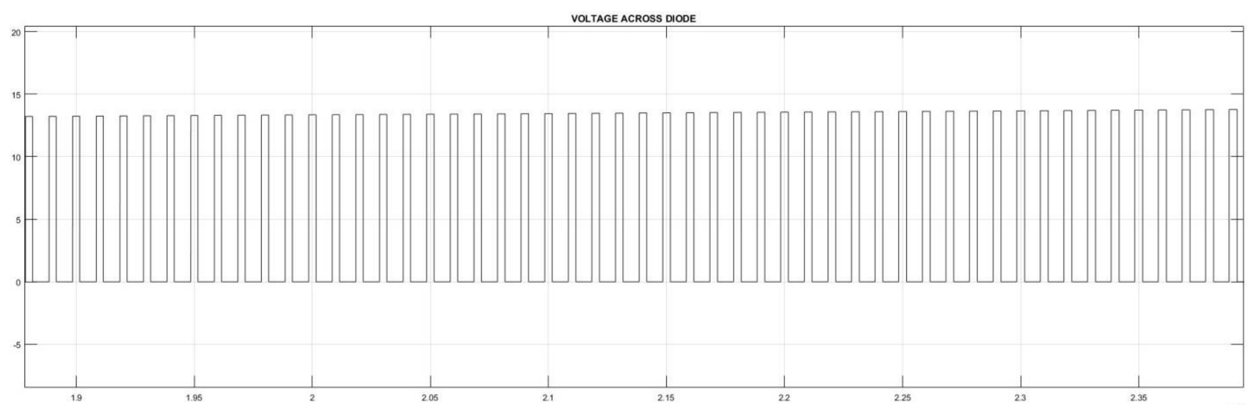


0.25

<u>Fig 26 : Output voltage for 20% Duty</u>



<u>Fig 27 : I through Inductor for 75% Duty</u>



<u>Fig 28 : V across diode for 75% duty</u>

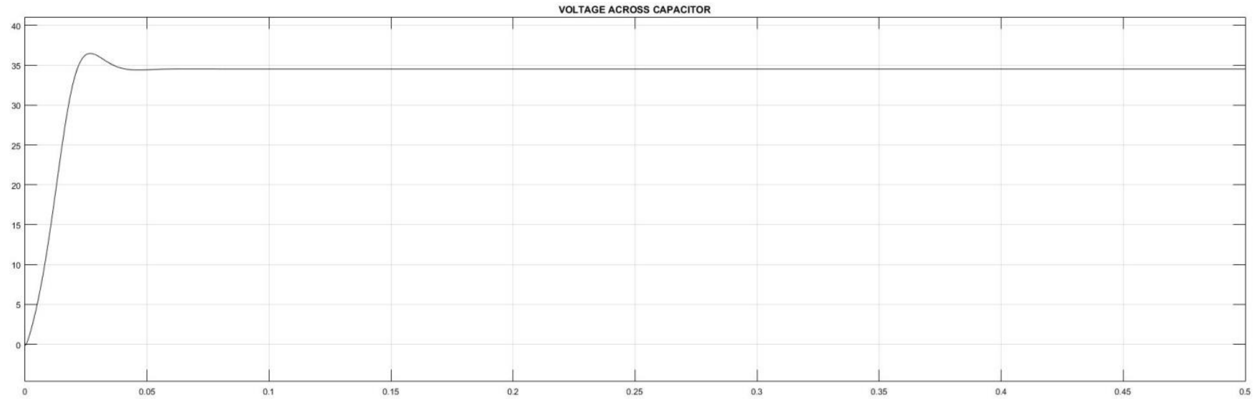


Fig 29 : V across C for 75% duty

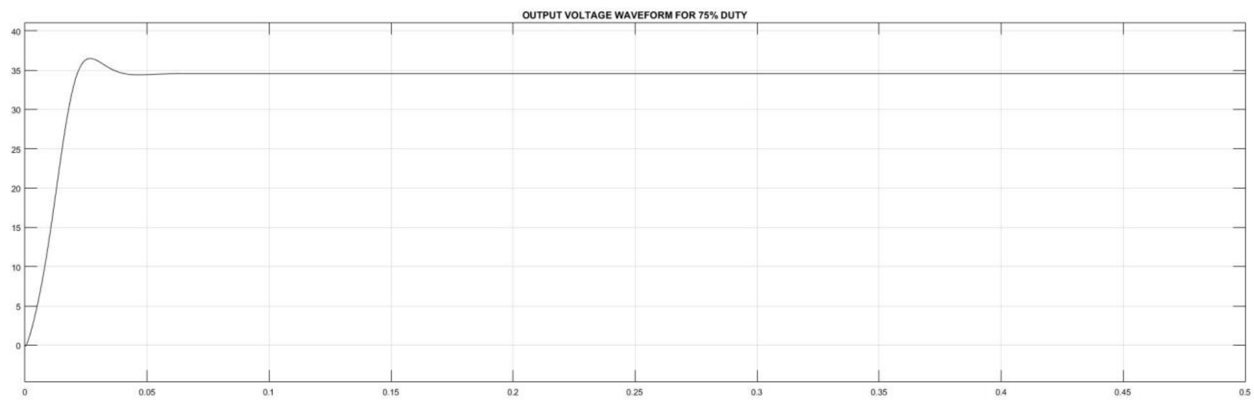


Fig 30 : Output voltage for 75% duty

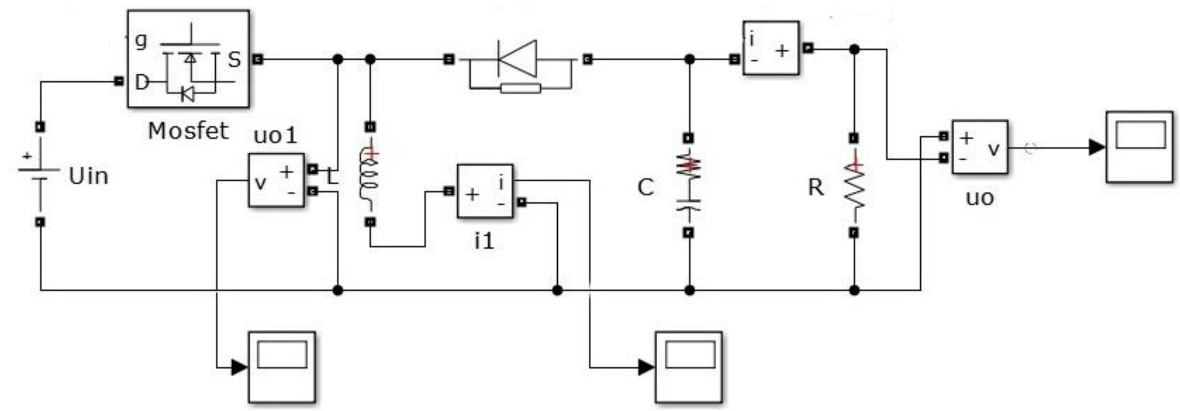


Fig 31:Circuit for Buck Converter.

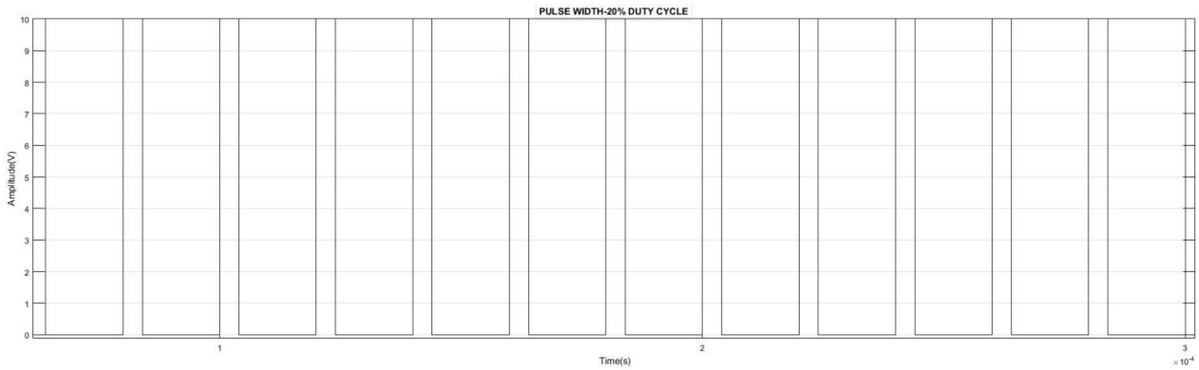


Fig 32 : Pulse Width of 20% Duty Cycle

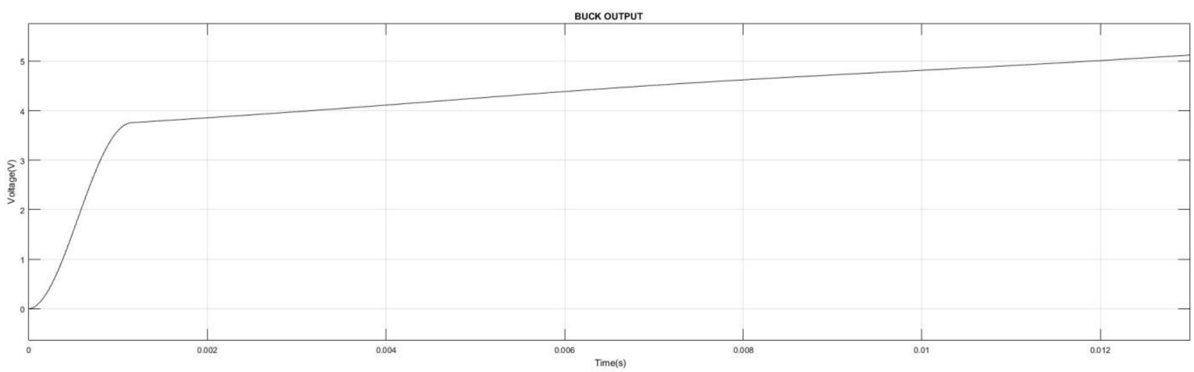


Fig 33 : Output waveform of buck converter

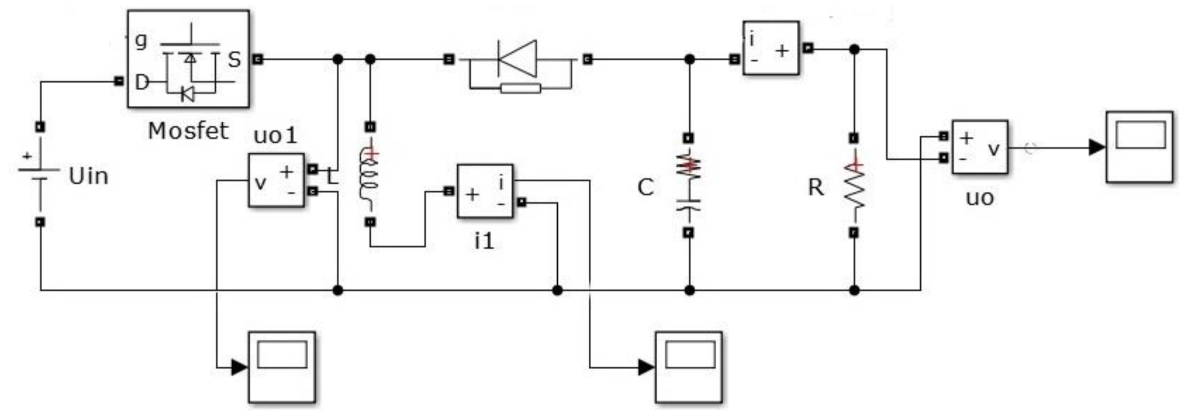


Fig 34 : Circuit for Boost Converter.

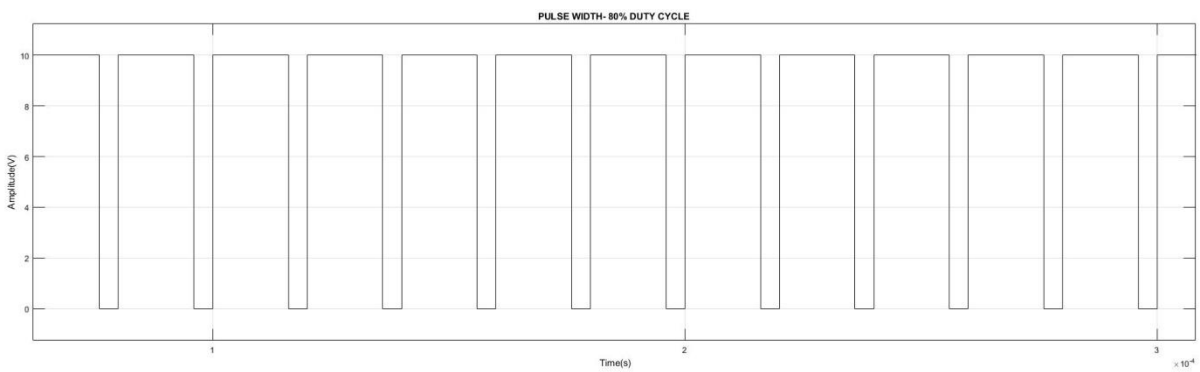


Fig 35 : Pulse Width of 80% Duty Cycle

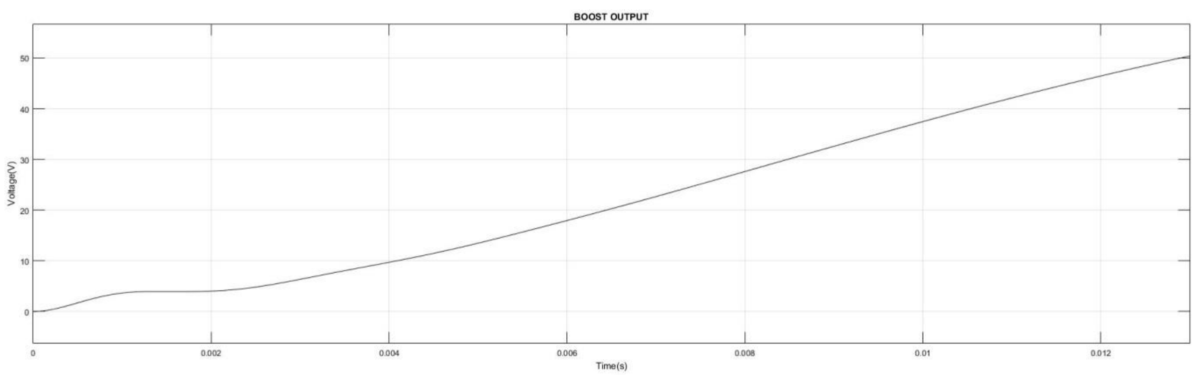
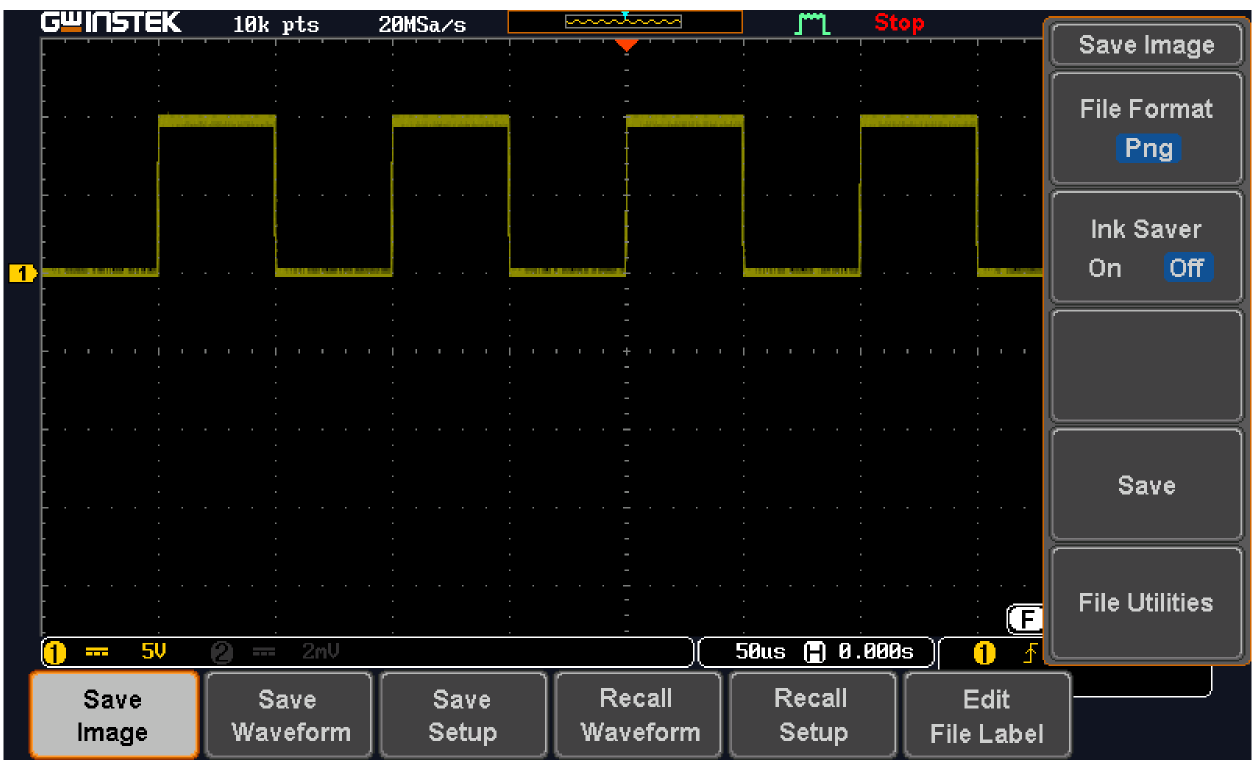


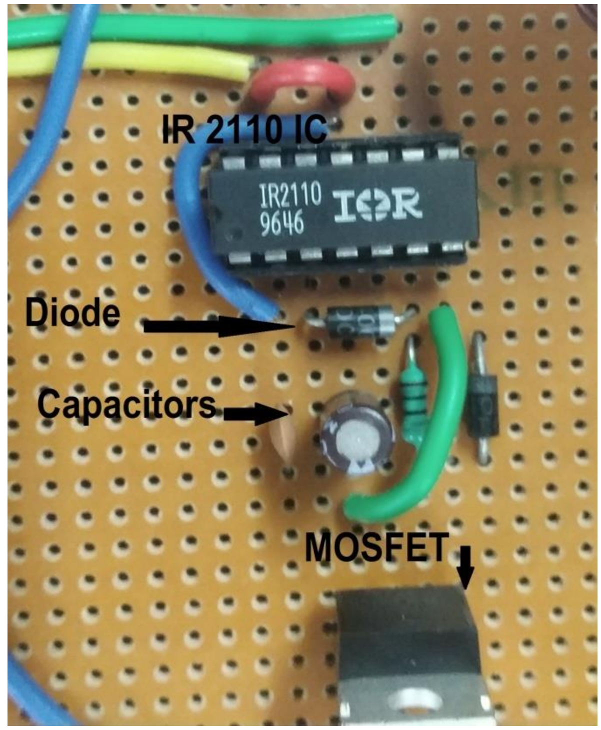
Fig 36 : Output waveform of boost converter

Fig 38 : Output of 1kHz received from D-space



<u>**HARDWARE CIRCUITS:**</u>

Fig 39 : Top view of IR2110 IC circuit



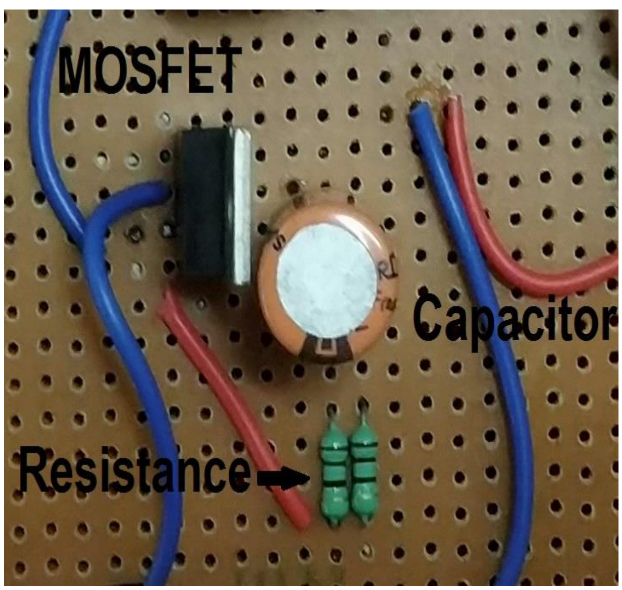


Fig 40 : MosFET IRF 540 Along with its Snubber Circuit.

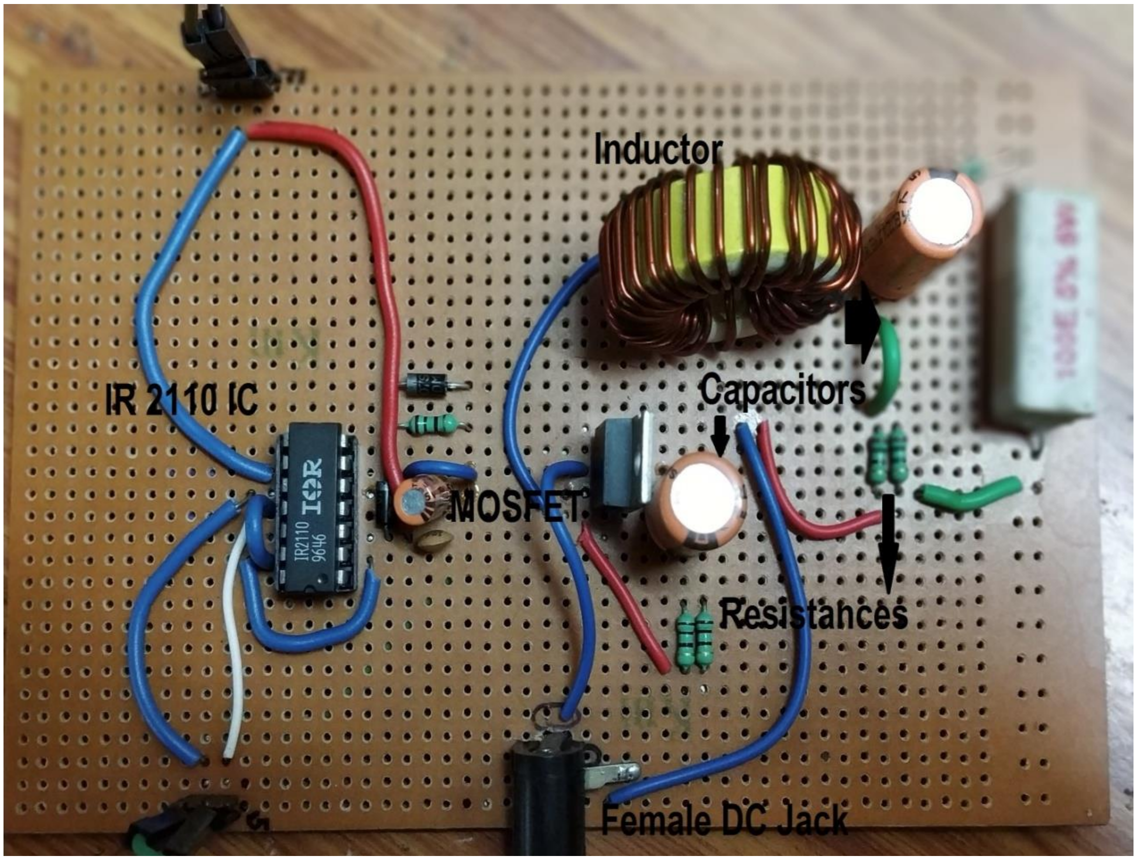


Fig 41 : TOP view of the complete Hard ware circuit

HARDWARE OUTPUT RESULTS:

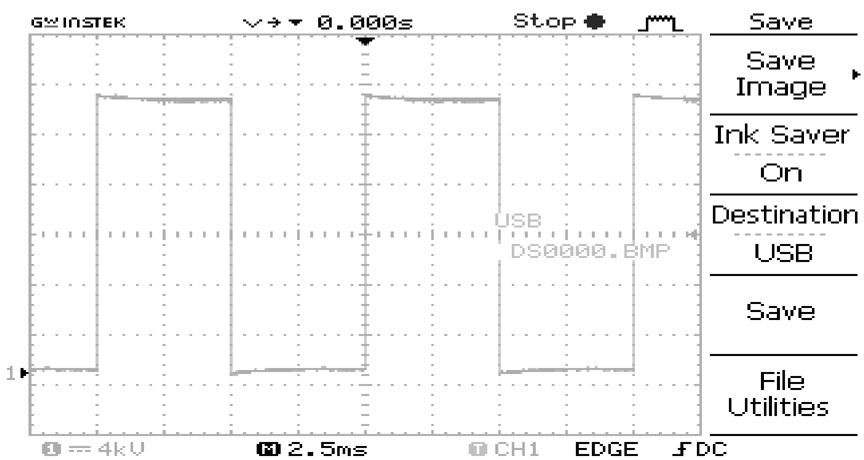


Fig 42 : 1kHz of Input Pulse applied to the IR 2110

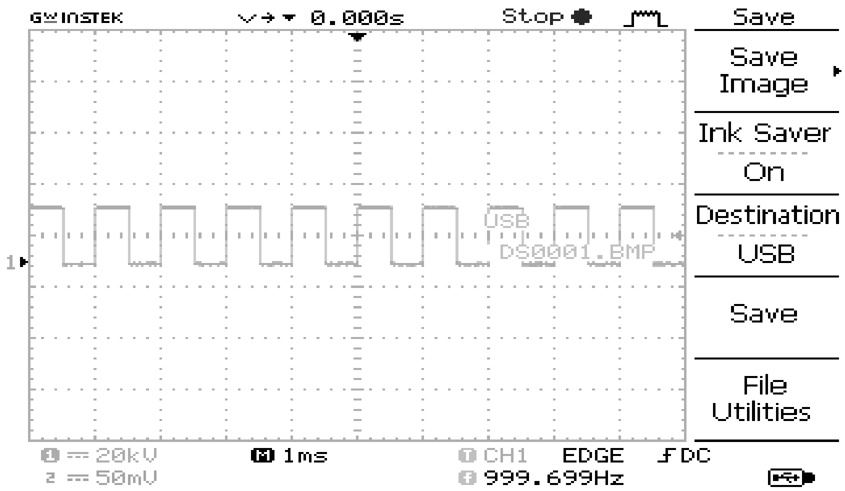


Fig 43 : Output Pulse received from IR 2110 (80% width)

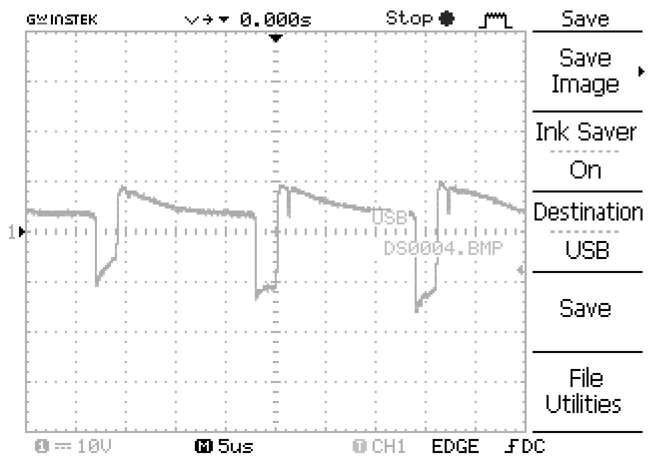


Fig 44 : Output pulse received across load(80% pulse width)

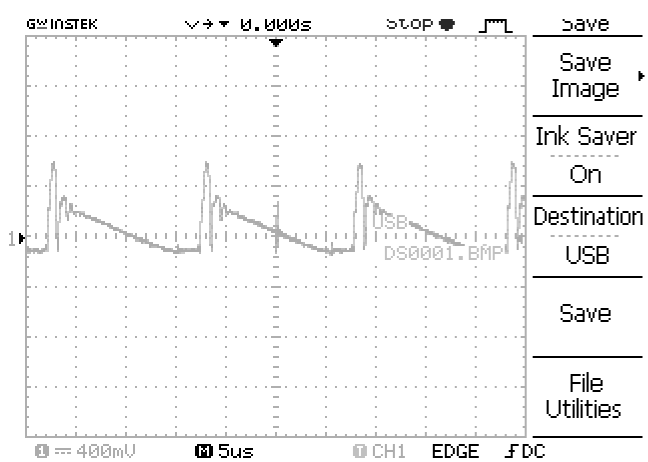


Fig. 45 Output pulse received across capacitor(80% pulse width)

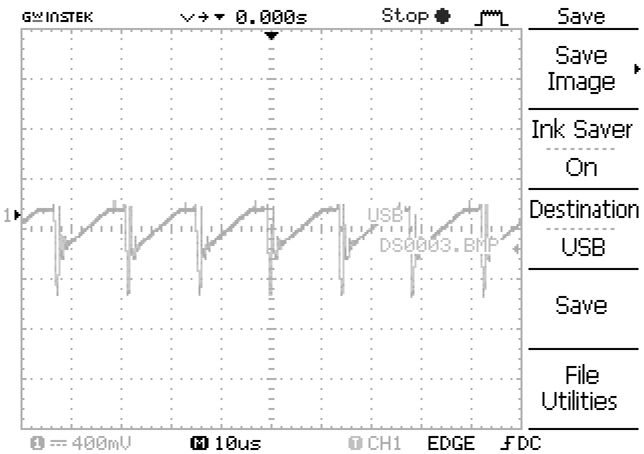


Fig. 46 Output pulse received across inductor showing charging And discharging(80% pulse width)

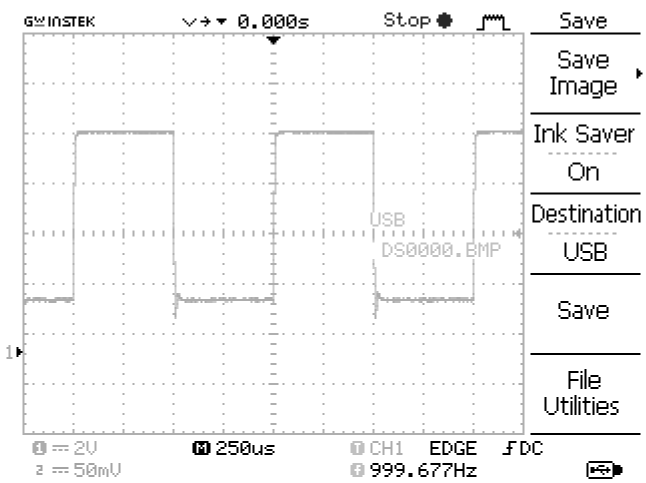


Fig 47: Output Pulse received from IR 2110 (50% width)

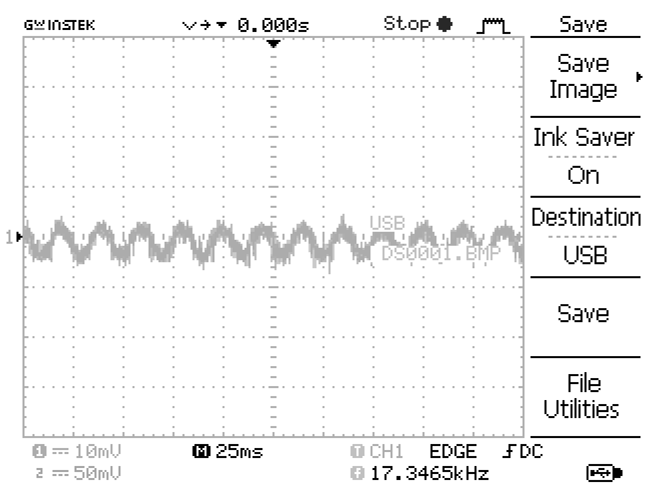


Fig 48 : Output pulse received across load(50% pulse width)

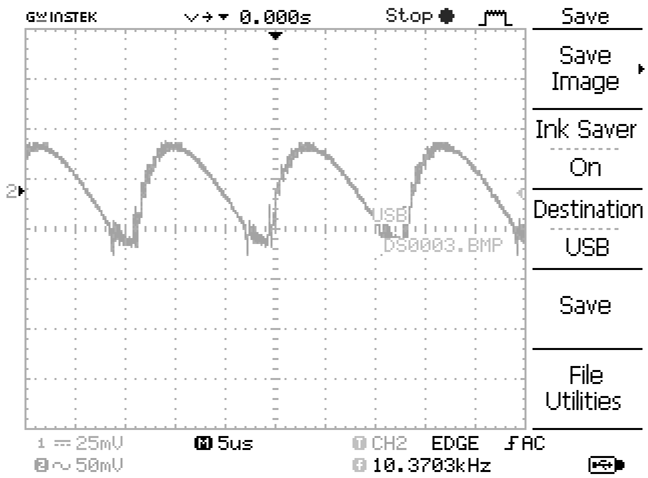


Fig. 49 Output pulse received across inductor showing charging And discharging (50% pulse width)

8.RESULT ANALYSIS

From the project report it is understood that we got all the output curves as expected as it was in case of software simulations.

- From fig. 44 we can see that the output curve across the load is almost 10 volts and it functions properly for its given 80% pulse width.
- From fig. 45 we noted that the capacitor is working properly and showing its charging-discharging the nature across its terminals.
- From fig. 46 we vereified as per the simulation graphs that the pulse received across inductor is similar in nsture.
- Form fig. 48 we noted the output across the load for 50% of pulse width is as expected almost of 10 volts.
- Form fig. 49 we noted the reqired pulse and it was as expected.

8. CONCLUSION

DC-DC converters are electronic devices used to change DC electrical powerefficiently from one voltage level to another. The advantages over AC because DCcan simply be stepped up or down. They provide smooth acceleration control, highefficiency, and fast dynamic response. DC converter can be used in regenerativebraking of DC motor to return energy back into the supply, and this feature results inenergy saving for transportation system with frequent stop; and also are used, in DCvoltage regulation.In many ways, a DC-DC converter is the DC equivalent of atransformer. There are FOUR main types of converter usually called the buck, boost,buck-boost and Boost converters. The buck converter is used for voltage stepdown/reduction, while the boost converter is used for voltage step-up. The buckboostand Cuk converters can be used for either step-down or step-up.Basically, the DC-DC converter consists of the power semiconductor deviceswhich are operated as electronic switches and classified as switched-mode DC-DCconverters. Operation of the switching devices causes the inherently nonlinearcharacteristic of the DC-DC converters. Due to this unwanted nonlinearcharacteristics, the converters requires a controller with a high degree of dynamicresponse. Pulse Width Modulation (PWM) is the most frequently consider methodamong the various switching control method**.** In DC-DC voltage regulators, it isimportant to supply a constant output voltage, regardless of disturbances on the inputvoltage.

FUTUTURE SCOPES:

In this project we have successfully completed the design of a buck-boost converter which can easily be used to get the output as required for the load to run properly.

For the upcoming future the converter can be further improved and its output voltage can be varied to see that which of the loads are easily used. Now as of now the converter is used for conversion of voltages from 5 volts to 18 volts. To make this project viable and for further use we can use it to change the range of conversion and use it for more practical purposes and real world expertise.

9. REFERENCES

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ANNEXURE

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

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.

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

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

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)

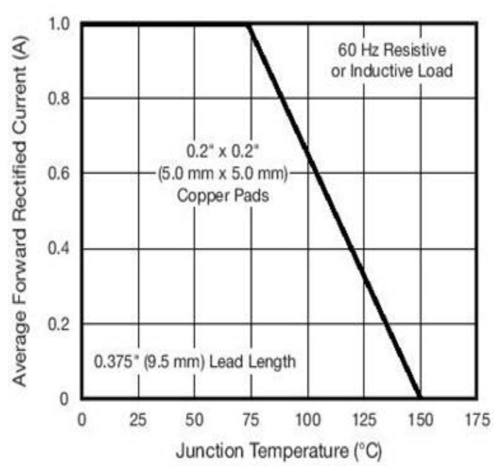


Fig. 1 - Forward Current Derating Curve

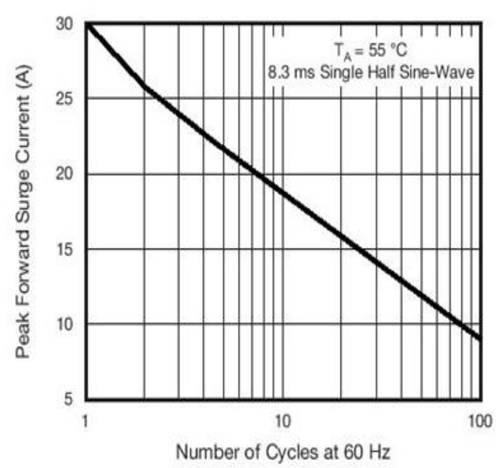
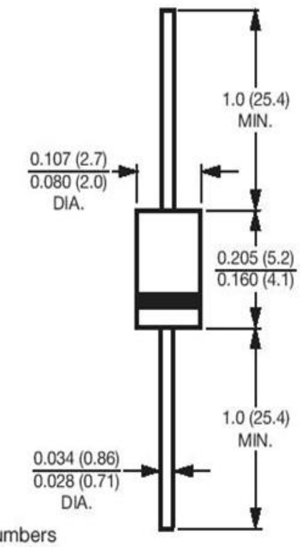


Fig. 2 - Maximum Non-repetitive Peak Forward Surge Current

PACKAGE OUTLINE DIMENSIONS in inches (millimeters)

DO-204AL (DO-41)



Note

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

For technical questions within your region, please contact one of the following:
DiodesAmericas@vishay.com, DiodesAsia@vishay.com, DiodesEurope@vishay.com

International 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

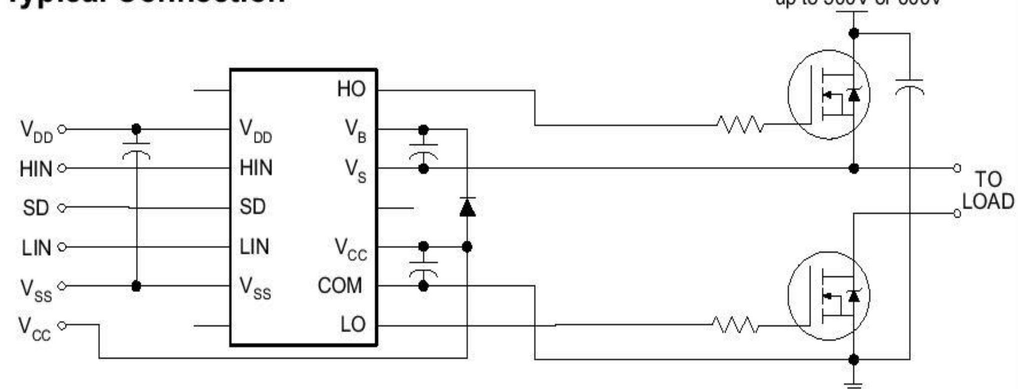
14-Lead PDIP
IR2110/IR2113

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 @ $T_A \leq$ +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.

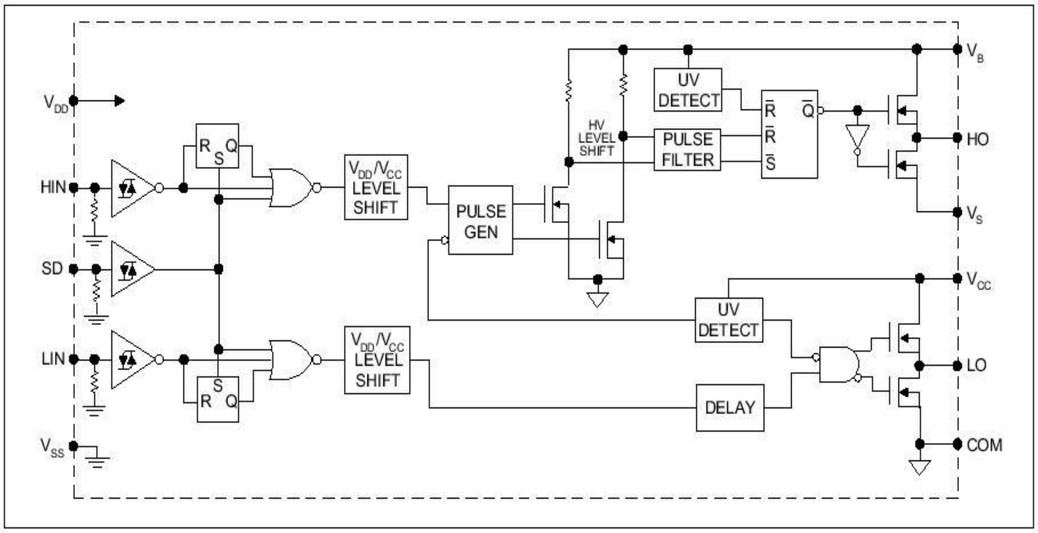
Symbol	Definition	Figure	Min.	Typ.	Max.	Units	Test Conditions
t_{on}	Turn-on propagation delay	7	—	120	150	ns	V_S = 0V
t_{off}	Turn-off propagation delay	8	—	94	125		V_S = 500V/600V
t_{sd}	Shutdown propagation delay	9	—	110	140		V_S = 500V/600V
t_r	Turn-on rise time	10	—	25	35		
t_f	Turn-off fall time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

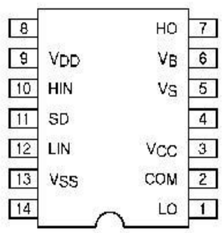
Functional Block Diagram



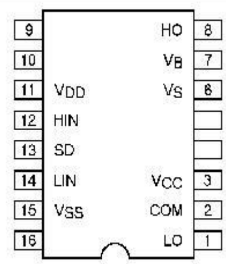
Lead Definitions

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

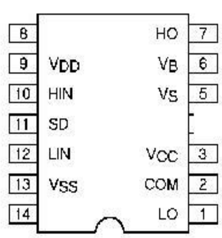
Lead Assignments



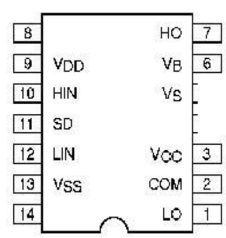
14 Lead PDIP
IR2110/IR2113



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

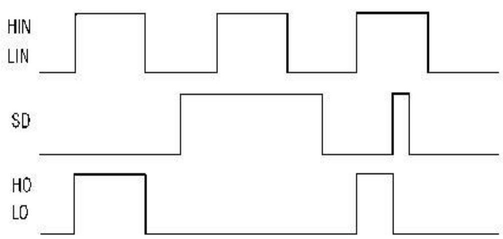


Figure 1. Input/Output Timing Diagram

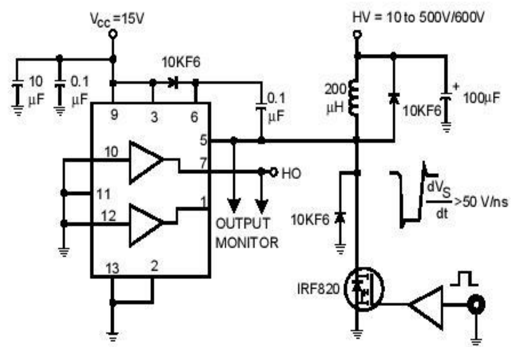


Figure 2. Floating Supply Voltage Transient Test Circuit

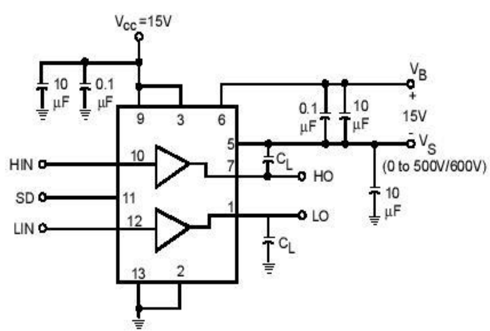


Figure 3. Switching Time Test Circuit

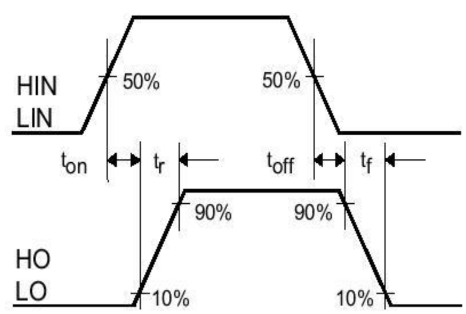


Figure 4. Switching Time Waveform Definition

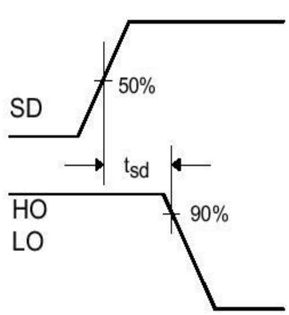


Figure 5. Shutdown Waveform Definitions

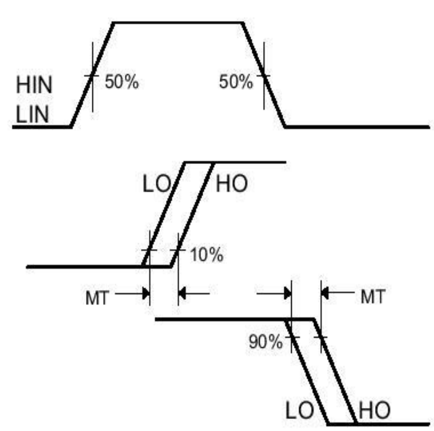


Figure 6. Delay Matching Waveform Definitions

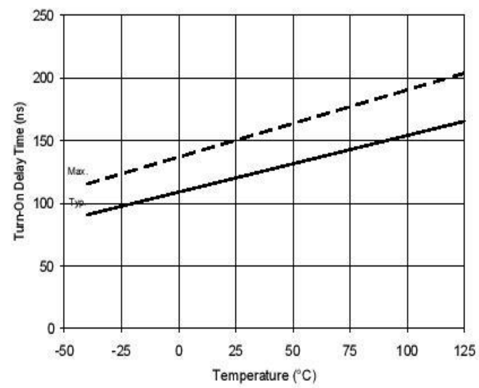


Figure 7A. Turn-On Time vs. Temperature

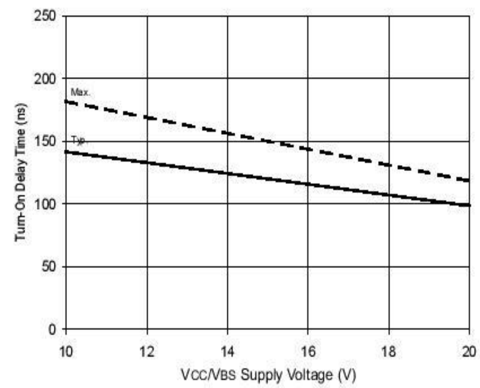


Figure 7B. Turn-On Time vs. VCC/VBS Supply Voltage

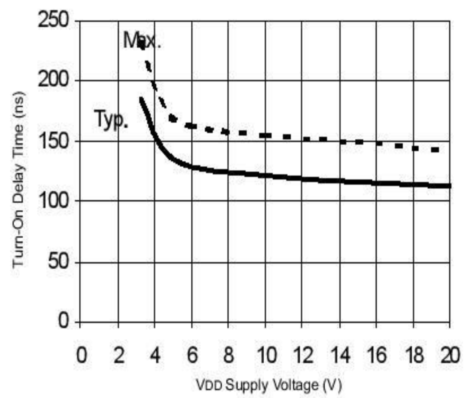


Figure 7C. Turn-On Time vs. VDD Supply Voltage

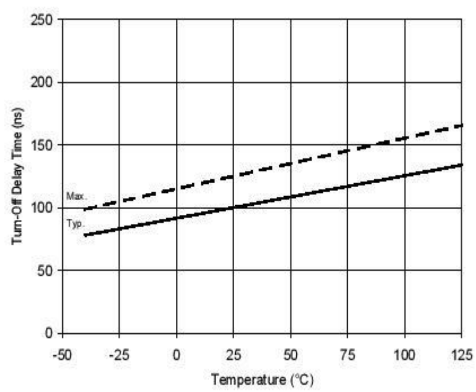


Figure 8A. Turn-Off Time vs. Temperature

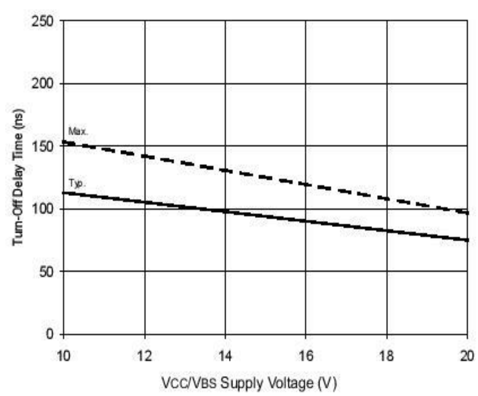


Figure 8B. Turn-Off Time vs. VCC/VBS Supply Voltage

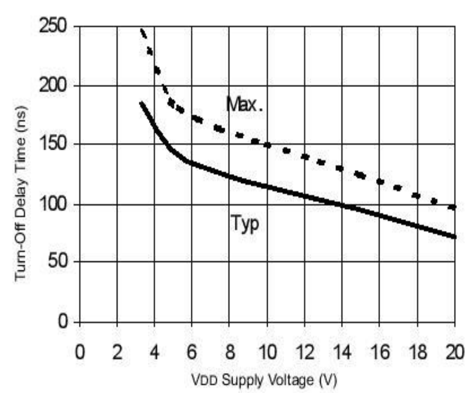


Figure 8C. Turn-Off Time vs. VDD Supply Voltage

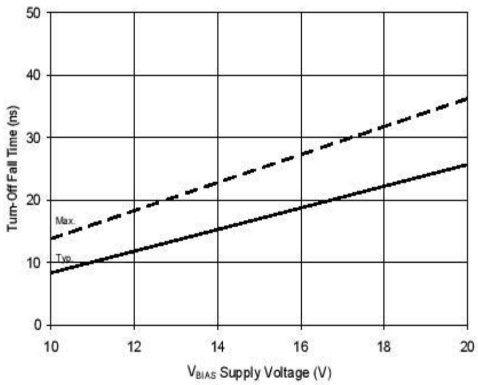


Figure 11B. Turn-Off Fall Time vs. Voltage

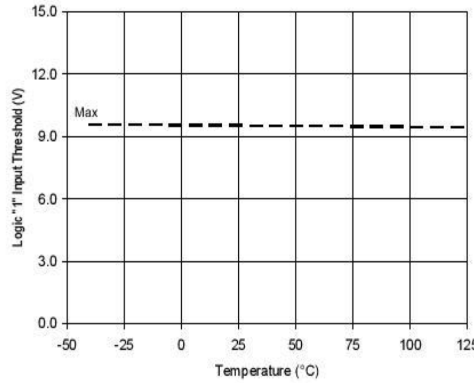


Figure 12A. Logic "1" Input Threshold vs. Temperature

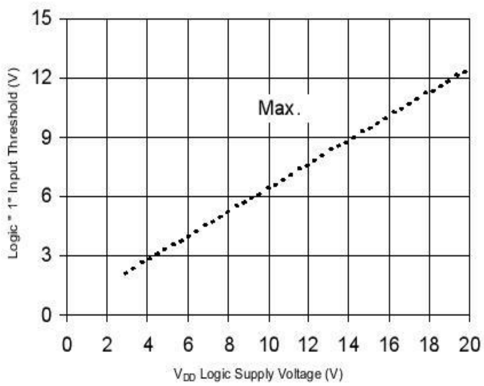


Figure 12B. Logic "1" Input Threshold vs. Voltage

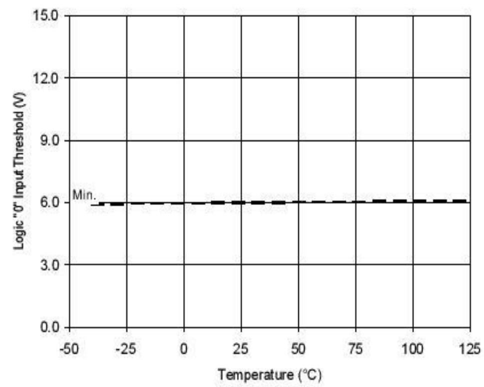


Figure 13A. Logic "0" Input Threshold vs. Temperature

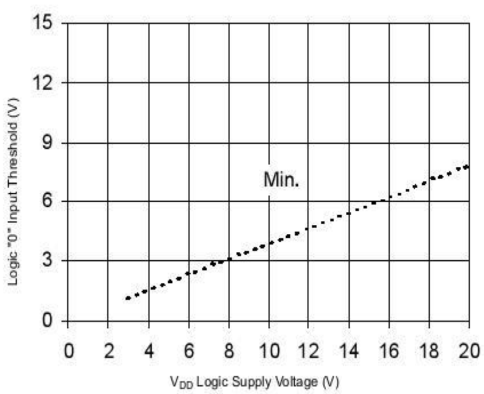


Figure 13B. Logic "0" Input Threshold vs. Voltage

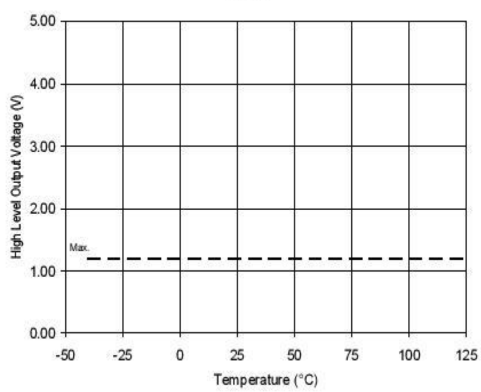


Figure 14A. High Level Output vs. Temperature

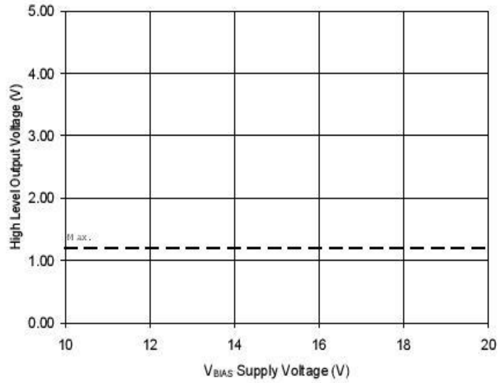


Figure 14B. High Level Output vs. Voltage

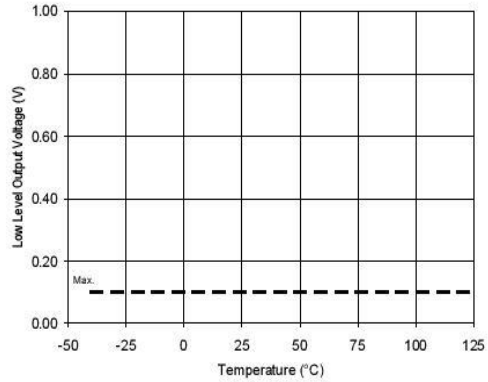


Figure 15A. Low Level Output vs. Temperature

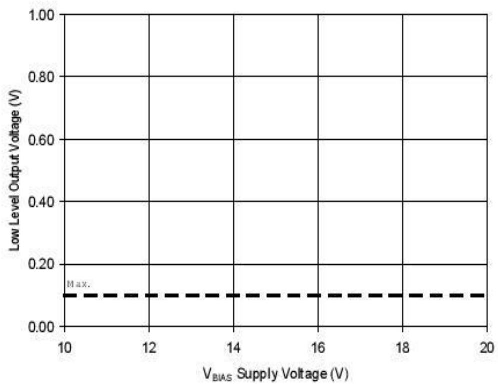


Figure 15B. Low Level Output vs. Voltage

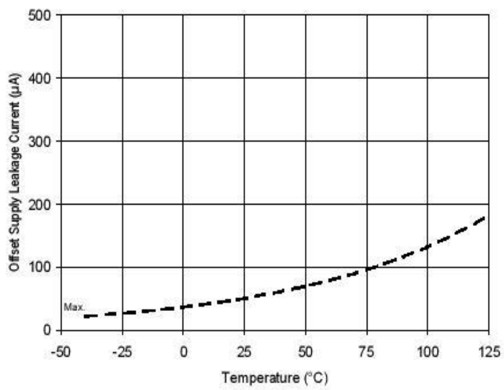


Figure 16A. Offset Supply Current vs. Temperature

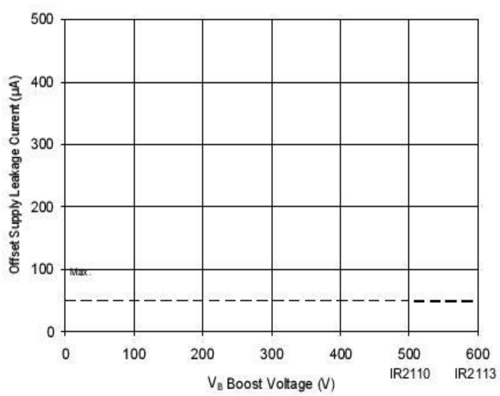


Figure 16B. Offset Supply Current vs. Voltage

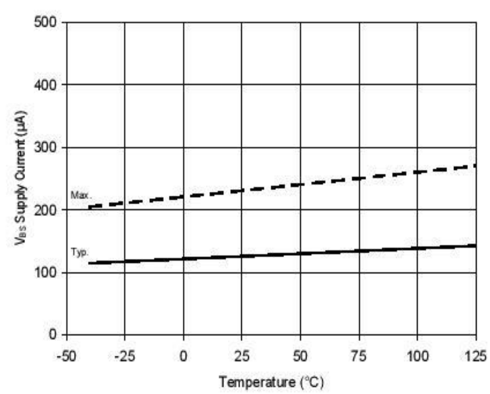


Figure 17A. V_{BS} Supply Current vs. Temperature

THERMAL RESISTANCE RATINGS				
PARAMETER	SYMBOL	TYP.	MAX.	UNIT
Maximum Junction-to-Ambient	R_{thJA}	-	62	°C/W
Case-to-Sink, Flat, Greased Surface	R_{thCS}	0.50	-	
Maximum Junction-to-Case (Drain)	R_{thJC}	-	1.0	

SPECIFICATIONS (T_J = 25 °C, unless otherwise noted)						
PARAMETER	SYMBOL	TEST CONDITIONS	MIN.	TYP.	MAX.	UNIT
Static						
Drain-Source Breakdown Voltage	V_{DS}	V_{GS} = 0 V, I_D = 250 μA	100	-	-	V
V_{DS} Temperature Coefficient	$\Delta V_{DS}/T_J$	Reference to 25 °C, I_D = 1 mA	-	0.13	-	V/°C
Gate-Source Threshold Voltage	$V_{GS(th)}$	V_{DS} = V_{GS}, I_D = 250 μA	2.0	-	4.0	V
Gate-Source Leakage	I_{GSS}	V_{GS} = ± 20 V	-	-	± 100	nA
Zero Gate Voltage Drain Current	I_{DSS}	V_{DS} = 100 V, V_{GS} = 0 V	-	-	25	μA
		V_{DS} = 80 V, V_{GS} = 0 V, T_J = 150 °C	-	-	250	
Drain-Source On-State Resistance	$R_{DS(on)}$	V_{GS} = 10 V; I_D = 17 A[b]	-	-	0.077	Ω
Forward Transconductance	g_{fs}	V_{DS} = 50 V, I_D = 17 A[b]	8.7	-	-	S
Dynamic						
Input Capacitance	C_{iss}	V_{GS} = 0 V, V_{DS} = 25 V, f = 1.0 MHz, see fig. 5	-	1700	-	pF
Output Capacitance	C_{oss}		-	560	-	
Reverse Transfer Capacitance	C_{rss}		-	120	-	
Total Gate Charge	Q_g	V_{GS} = 10 V; I_D = 17 A, V_{DS} = 80 V, see fig. 6 and 13[b]	-	-	72	nC
Gate-Source Charge	Q_{gs}		-	-	11	
Gate-Drain Charge	Q_{gd}		-	-	32	
Turn-On Delay Time	$t_{d(on)}$	V_{DD} = 50 V, I_D = 17 A, R_g = 9.1 Ω, R_D = 2.9 Ω, see fig. 10[b]	-	11	-	ns
Rise Time	t_r		-	44	-	
Turn-Off Delay Time	$t_{d(off)}$		-	53	-	
Fall Time	t_f		-	43	-	
Internal Drain Inductance	L_D	Between lead, 6 mm (0.25") from package and center of die contact 	-	4.5	-	nH
Internal Source Inductance	L_S		-	7.5	-	
Drain-Source Body Diode Characteristics						
Continuous Source-Drain Diode Current	I_S	MOSFET symbol showing the integral reverse p - n junction diode 	-	-	28	A
Pulsed Diode Forward Current[a]	I_{SM}		-	-	110	
Body Diode Voltage	V_{SD}	T_J = 25 °C, I_S = 28 A, V_{GS} = 0 V[b]	-	-	2.5	V
Body Diode Reverse Recovery Time	t_{rr}	T_J = 25 °C, I_F = 17 A, dI/dt = 100 A/μs[b]	-	180	360	ns
Body Diode Reverse Recovery Charge	Q_{rr}		-	1.3	2.8	μC
Forward Turn-On Time	t_{on}	Intrinsic turn-on time is negligible (turn-on is dominated by L_S and L_D)				

Notes
a. Repetitive rating; pulse width limited by maximum junction temperature (see fig. 11).
b. Pulse width ≤ 300 μs; duty cycle ≤ 2 %.

TYPICAL CHARACTERISTICS (25 °C, unless otherwise noted)

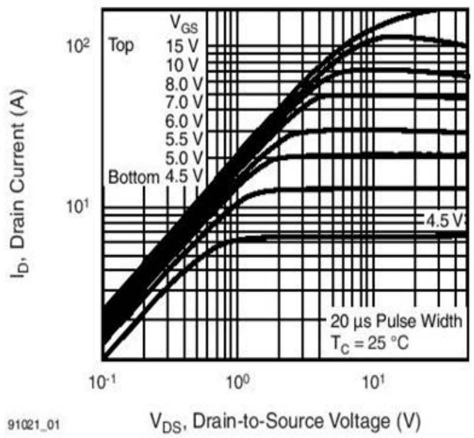


Fig. 1 - Typical Output Characteristics, T_C = 25 °C

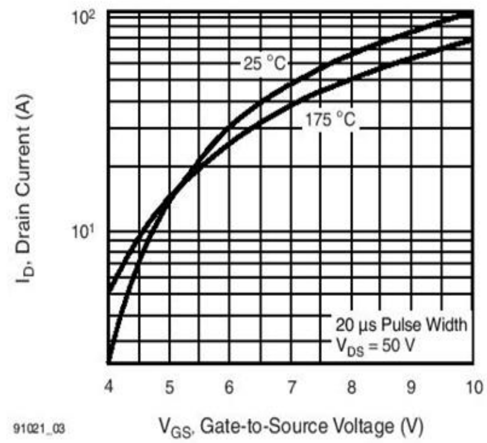


Fig. 3 - Typical Transfer Characteristics

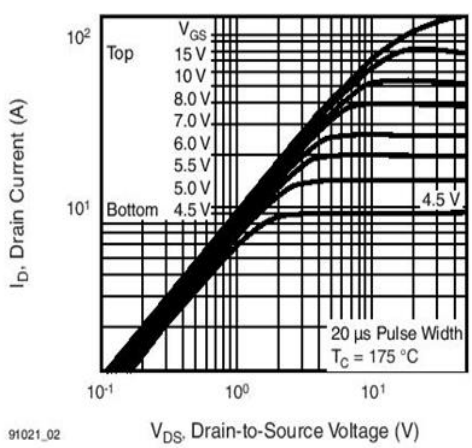


Fig. 2 - Typical Output Characteristics, T_C = 175 °C

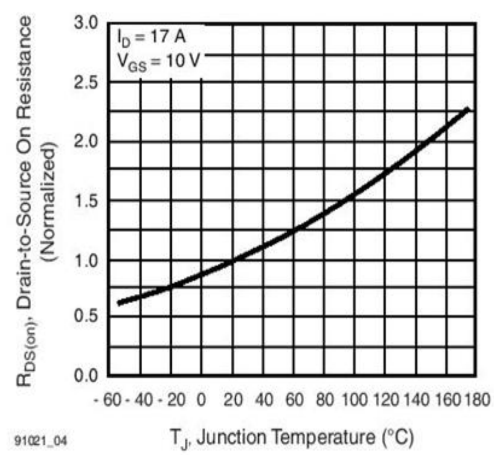


Fig. 4 - Normalized On-Resistance vs. Temperature

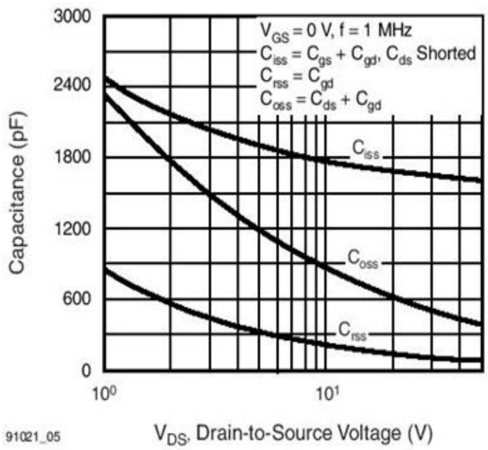


Fig. 5 - Typical Capacitance vs. Drain-to-Source Voltage

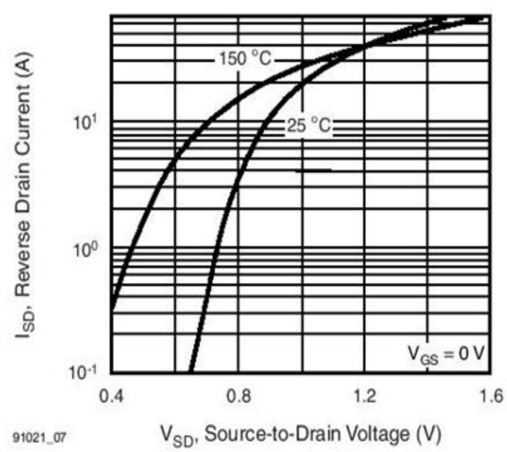


Fig. 7 - Typical Source-Drain Diode Forward Voltage

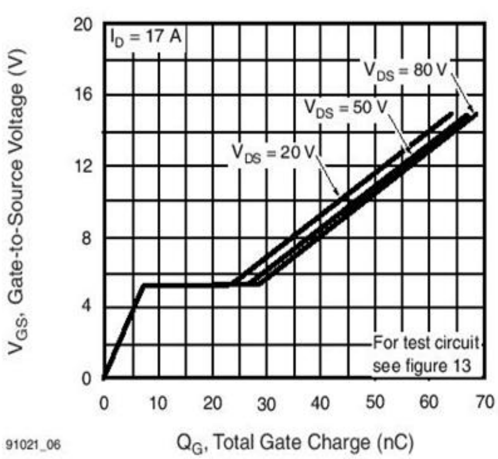


Fig. 6 - Typical Gate Charge vs. Gate-to-Source Voltage

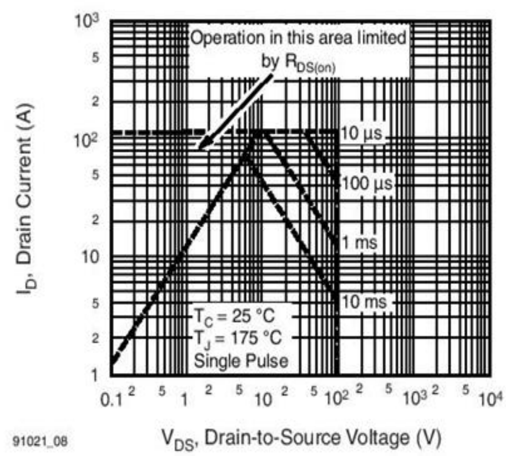
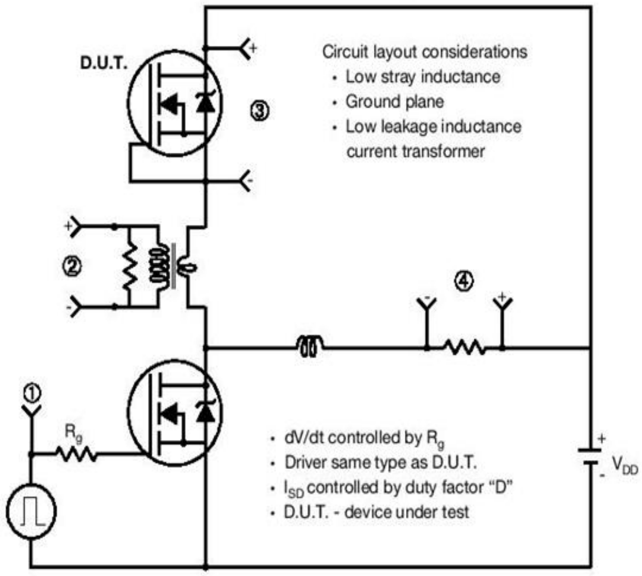
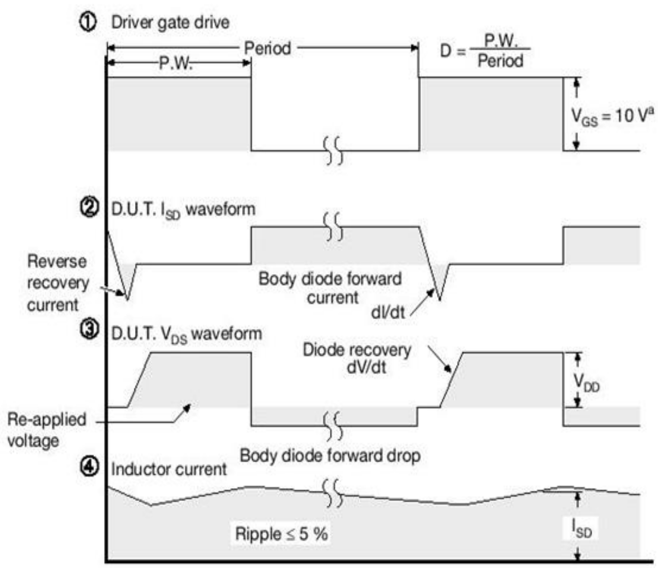


Fig. 8 - Maximum Safe Operating Area

Peak Diode Recovery dV/dt Test Circuit





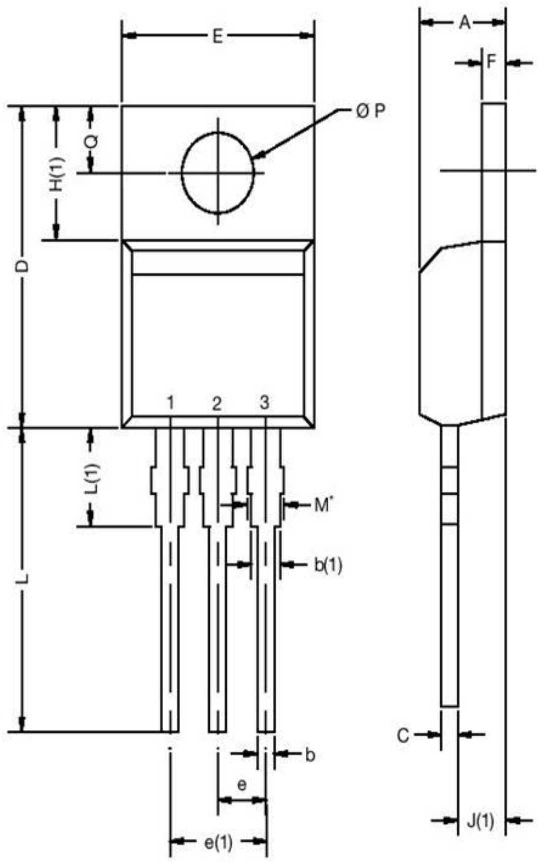
Note

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

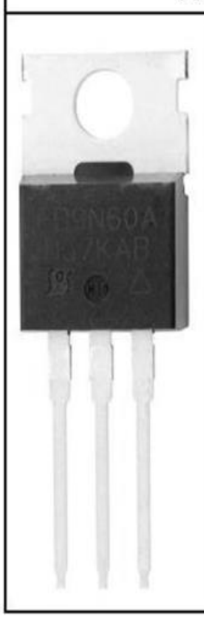
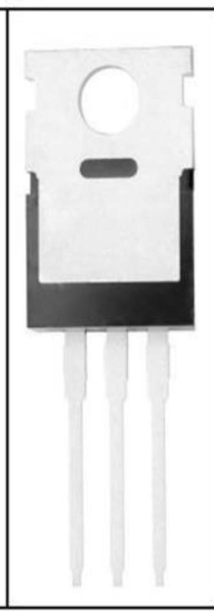
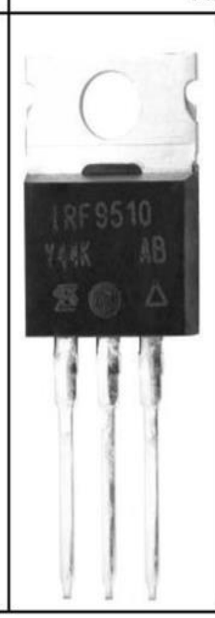
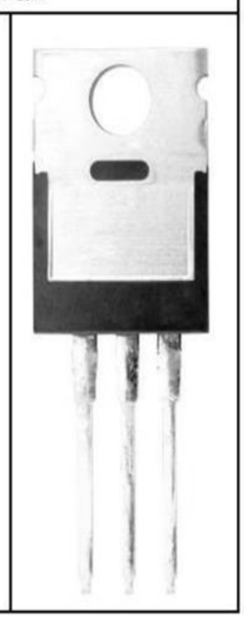


DIM.	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A	4.24	4.65	0.167	0.183
b	0.69	1.02	0.027	0.040
b(1)	1.14	1.78	0.045	0.070
c	0.36	0.61	0.014	0.024
D	14.33	15.85	0.564	0.624
E	9.96	10.52	0.392	0.414
e	2.41	2.67	0.095	0.105
e(1)	4.88	5.28	0.192	0.208
F	1.14	1.40	0.045	0.055
H(1)	6.10	6.71	0.240	0.264
J(1)	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

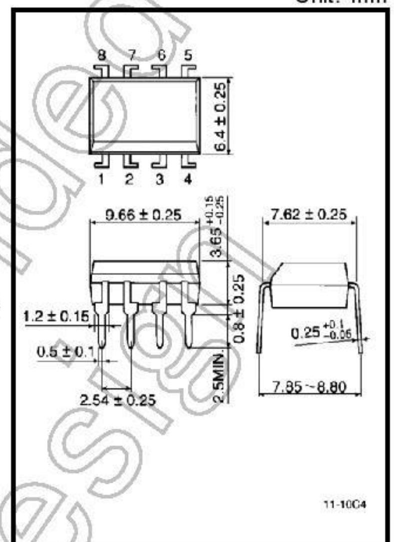
ASE		Xi'an	
			

TOSHIBA Photocoupler GaAℓAs Ired & Photo-IC

TLP250

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

Unit: mm



TOSHIBA 11-10C4

Weight: 0.54 g (typ.)

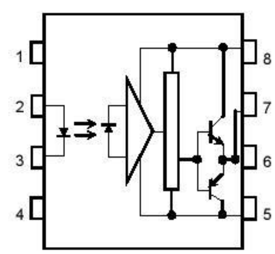
The TOSHIBA TLP250 consists of a GaAlAs light emitting diode and a integrated photodetector.
This unit is 8-lead DIP package.
TLP250 is suitable for gate driving circuit of IGBT or power MOS FET.

- 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)"

Truth Table

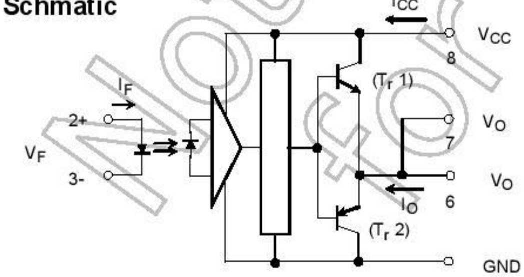
		Tr1	Tr2
Input LED	On	On	Off
	Off	Off	On

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 PW ≤ 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

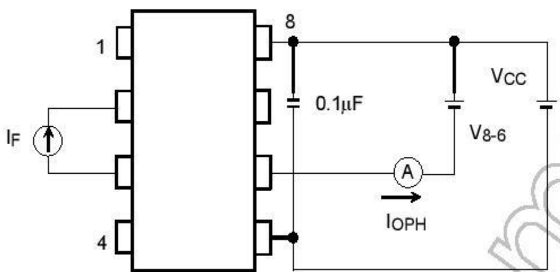
Note 1: Duration of I_O time ≤ 50μs

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

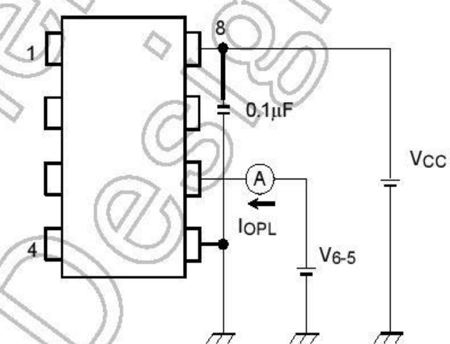
Characteristic		Symbol	Test Circuit	Test Condition	Min	Typ.	Max	Unit
Propagation delay time	L→H	t_{pLH}	5	I_F = 8mA, V_{CC1} = +15V, V_{EE1} = -15V, R_L = 200Ω	—	0.15	0.5	μs
	H→L	t_{pHL}			—	0.15	0.5	
Common mode transient immunity at high level output		CM_H	6	V_{CM} = 600V, I_F = 8mA, V_{CC} = 30V, Ta = 25°C	-5000	—	—	V / μs
Common mode transient immunity at low level output		CM_L		V_{CM} = 600V, I_F = 0mA, V_{CC} = 30V, Ta = 25°C	5000	—	—	V / μs

Note: All typical values are at Ta = 25°C

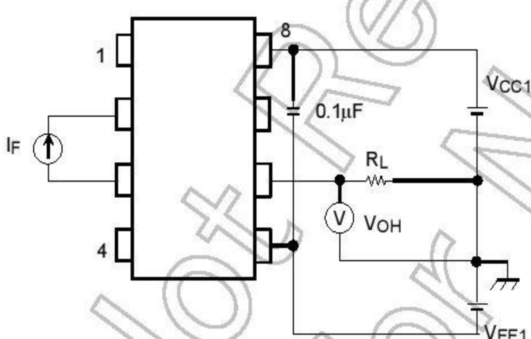
Test Circuit 1 : I_{OPH}



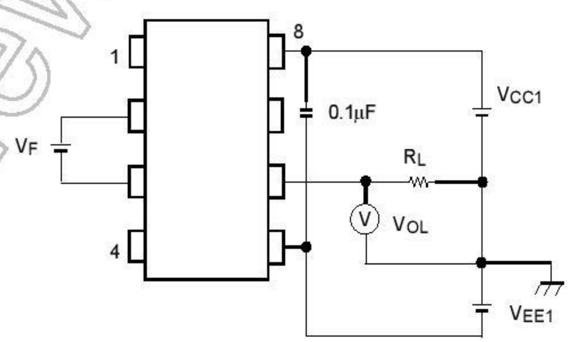
Test Circuit 2 : I_{OPL}



Test Circuit 3 : V_{OH}



Test Circuit 4 : V_{OL}



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.*