

**A Project report**  
**On**  
**“BOOST CONVERTER USING ARDUINO”**

**A Major-project report submitted in partial fulfillment of the  
Requirements for the award of the degree of**

**Bachelor of Technology**  
**In**  
**Electrical and Electronics Engineering**

**Submitted by**

**S.RUPESH KUMAR (10241A0253)**  
**BUDIGE RAJU (10241A0211)**  
**M.CHINA RAGHAVA REDDY (10241A0235)**



**Under the esteemed guidance of**

**V.HIMA BINDU**

**Assistant Professor**

**Department of Electrical and Electronics Engineering**

**GOKARAJU RANGARAJU INSTITUTE OF  
ENGINEERING AND TECHNOLOGY**

**Bachupally, Kukatpally. (Affiliated to JNTU, Hyderabad)**

**2013-2014.**

# GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY

Bachupally, Kukatpally, Hyderabad, 500090, A.P

(Approved by AICTE, New Delhi & Affiliated to JNTU, Hyderabad)

## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

### CERTIFICATE

*This is to certify that the Major-Project Work entitled **BOOST CONVERTER USING ARDUINO** is being submitted by following students during the Academic Year 2013-14 in partial fulfillment of the requirements for the award of the **B.TECH Degree in ELECTRICAL AND ELECTRONICS ENGINEERING** Specialization affiliated to JNTU, Hyderabad.*

**S.RUPESH KUMAR** (10241A0253)

**BUDIGE RAJU** (10241A0211)

**M.CHINA RAGHAVA REDDY** (10241A0235)

*This record is a Bonafide work carried out by them under my guidance & supervision. The Result(s) embodied have not been submitted to any other University/Institution for the award of any Degree/Diploma.*

**Guide**

**HOD**

**Major-Project Viva-Voice Exam Held on Dated** \_\_\_\_\_

**External Examiner**

## **ACKNOWLEDGEMENTS**

The satisfaction that accompanies the successful completion of any task would be incomplete without the mention of the people who made it possible and whose encouragement and guidance has been a source of inspiration throughout the course of the project.

We are obliged and grateful to **Mr. P. S. Raju, Director**, GRIET, for allowing us to carry out our project work. Our special thanks to **Principal Dr. Jandhyala N Murthy**, GRIET, for his encouragement shown towards us to complete the project.

We would like to express our gratitude to **Dr. M. Chakravarthy, Head of the Department**, E.E.E., GRIET for having been kind enough to arrange for the necessary facilities for executing the project in the college.

We are immensely thankful to our internal guide **V.HimaBindu, Assistant Prof**, GRIET for her valuable guidance in each and every stage throughout the course of the project which helped us in completing this project work successfully.

We express our gratitude to our project coordinator **Mr. E. Venkateshwarlu, Associate Professor**, GRIET for his valuable recommendations and for accepting this project report.

Last but not the least we would like to thank our parents for arranging necessary facilities for our course. We are thankful to one and all that co-operated us to complete our project successfully.

**By/-**

**PROJECT ASSOCIATES.**

# ABSTRACT

As the size, utility and complexity of today's most modern electronic devices increases, new techniques must be developed to effectively power them up and create very useful devices quickly through software interfacing.

The purpose of this project is to model a boost converter which is used to step-up DC voltages. The pulses given to power switches by PWM technique are generated by utilizing Arduino package which is a single-board microcontroller whose hardware has a simple open source hardware board. The software has a standard programming language compiler and a boot loader that executes on the microcontroller. The programming is done using C language. This package reduces the complexity of generating PWM triggering signals. Depending on the application, effective feedback system is implemented to get the desired DC voltages rather than going for conventional methods.

Though we have the simplest way to regulate the dc supply voltage with a linear regulator, they have less efficiency regarding power consumption and limited applications. The DC converters which use Arduino with appropriate feedback have high efficiency (95%).

## TABLE OF CONTENTS

1 . INTRODUCTION.....	01
1.1. TYPES OF CONVERTERS.....	01
2 . BOOST CONVERTER.....	06
2.1. DEFINITION.....	06
2.2. WHY BOOST CONVERTER.....	06
2.3. BOOST CONVERTER CIRCUIT TOPOLOGY.....	07
2.3.1. SWITCH.....	08
2.3.2. INDUCTOR.....	11
2.3.3. CAPACITOR.....	12
2.3.4. RESISTOR.....	13
2.3.5. DIODE.....	14
2.4 BLOCK DIAGRAM.....	15
2.5 TWO STATES OF OPERATION OF BOOST CONVERTER.....	16
2.5.1. ON STATE.....	16
2.5.2 OFF STATE.....	17
3. ANALYSIS OF TYPICAL BOOST CONVERTER.....	21
3.1. CIRCUIT DIAGRAM .....	22
3.2. WAVEFORM.....	22
4. ARDUINO.....	24
4.1. ARDUINO UNO.....	26
4.1.1. OVERVIEW .....	26

4.1.2. PIN DESCRIPTION.....	27
5. INTERFACING WITH ARDUINO.....	32
6. SOFTWARE DEVELOPMENT.....	33
7. DESIGN SPECIFICATIONS.....	34
7.1. INDUCTOR VALUE.....	34
7.2. CAPACITOR VALUE.....	34
7.3. DUTY CYCLE.....	34
8. RESULTS.....	35
9. CONCLUSION.....	36
10. FUTURE SCOPE.....	37
11. REFERENCES.....	37
12. APPENDIX.....	37
12.1. APPENDIX-A.....	40
12.2. APPENDIX-B.....	42

## FIGURE OF CONTENTS

FIGURE 1: Circuit diagram of a Linear Regulator.....	06
FIGURE 2 : Boost converter.....	08
FIGURE 3 : Switch.....	08
FIGURE 4 : Mosfet.....	10
FIGURE 5 : Inductor.....	11
FIGURE 6 : Capacitor.....	12
FIGURE 7: Resistor.....	13
FIGURE 8 : Diode.....	14
FIGURE 9 : Block Diagram.....	15
FIGURE 10 : On state of boost converter.....	17
FIGURE 11 : Off state of boost converter.....	17
FIGURE 12 : Boost converter wave forms.....	18
FIGURE 13 : Representation of duty cycle.....	19
FIGURE 14 : Circuit Diagram& waveforms.....	21
FIGURE 15 : Arduino uno.....	25
FIGURE 16 : Arduino schematic diagram .....	26
FIGURE 17 : Megunolink serial monitor .....	30
FIGURE 18 : Interfacing with Arduino.....	33
FIGURE 18 : Serial Monitor Display.....	35
FIGURE 19 : Megunolink Graphs.....	36

# 1.Introduction

---

Over the years as the portable electronics industry progressed, different requirements evolved such as increased battery lifetime, small and cheap systems, brighter, full-color displays and a demand for increased talk-time in cellular phones. An ever increasing demand from power systems has placed power consumption at a premium. To keep up with these demands engineers have worked towards developing efficient conversion techniques and also has resulted in the subsequent formal growth of an interdisciplinary field of Power Electronics. However it comes as no surprise that this new field has offered challenges owing to the unique combination of three major disciplines of electrical engineering: electronics, power and control. These multi-discipline technologies have involved control theory, filter synthesis, signal processing, thermal control, and magnetic components design

In this section the Motivation and Background work done for the thesis, as well as our contribution and outline of the thesis are summarized.

## **TYPES OF CONVERTERS**

- **AC-AC converter**
- **DC-DC converter**
- **AC-DC converter**
- **DC-AC converter**

## **AC-AC CONVERTER :-**

An AC-AC converter converts an AC waveform such as the mains supply, to another AC waveform, where the output voltage and frequency can be set arbitrarily. It is also called as cycloconverter.

The input to the cycloconverter is normally single phase or three phase Ac mains supply. It is fixed voltage and fixed frequency. The cycloconverter provide the output which has variable voltage and variable frequency. The output frequency is lower than the input frequency. The Cycloconverter are used mainly for AC traction drives.



## **DC-AC CONVERTER:-**

A DC-AC converter is also called as an INVERTER. An inverter is an electrical device that converts direct current (DC) to alternating current (AC); the converted .

AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. The inverter performs the opposite function of a rectifier. There are two main types of inverter.

- Modified sine wave.
- Pure sine wave.

The output of a modified sine wave inverter is similar to a square wave output except that the output goes to zero volts for a time before switching positive or negative. A pure sine wave inverter produces a nearly perfect sine wave output that is essentially the same as utility-supplied grid power.

## **AC-DC CONVERTER:-**

A converter which converts AC voltage to DC voltage is called as rectifier. It is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which is in only one direction, a process known as rectification.

## **DC-DC CONVERTER:-**

A DC-to-DC converter is an electronic circuit which converts a source of direct current (DC) from one voltage level to another. It is also called as Chopper. It is a class of power converter.

DC to DC converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. Most DC to DC converters also regulate the output voltage. Some exceptions include high-efficiency LED power sources, which are a kind of DC to DC converter that regulates the current through the LEDs, and simple charge pumps which double or triple the input voltage.

DC- DC converters are the power supply that output a fixed voltage efficiently, converting the input voltage. There are three types of DC- DC converters.

- Step-up DC/DC converters
- Step-down DC/DC converters
- Step-up/down DC/DC converters.

Currently, dc/dc converters can be divided into two broad categories:

- Non-isolated dc/dc converters
- Isolated dc/dc converters

### ✓ NON-ISOLATED DC/DC CONVERTERS

The non-isolated converter usually employs an inductor, and there is no dc voltage isolation between the input and the output. The vast majority of applications do not require dc isolation between input and output voltages. The non-isolated dc-dc converter has a dc path between its input and output. Battery-based systems that don't use the ac power line represent a major application for non-isolated dc-dc converters. Point-of-load dc-dc converters that draw input power from an isolated dc-dc converter, such as a bus converter, represent another widely used non-isolated application.

Most of these dc-dc converter ICs use either an internal or external synchronous rectifier. Their only magnetic component is usually an output inductor and thus less susceptible to generating electromagnetic interference. For the same power and voltage levels, it usually has lower cost and fewer components while requiring less pc-board area than an isolated dc-dc converter. For lower voltages (12V) non-isolated buck converters can be used.

### ✓ ISOLATED DC/DC CONVERTERS

For safety considerations, there must be isolation between an electronic system's ac input and dc output. Isolation requirements cover all systems operating from the ac power line, which can include an isolated front-end ac-dc power supply followed by an isolated "brick" dc-dc converter, followed by a

non-isolated point-of-load converter. Typical isolation voltages for ac-dc and dc-dc power supplies run from 1500 to 4000V, depending on the application. An isolated converter employs a transformer to provide dc isolation between the input and output voltage which eliminates the dc path between the two. Isolated dc-dc converters use a switching transformer whose secondary is either diode-or synchronous-rectified to produce a dc output voltage using an inductor capacitor output filter. This configuration has the advantage of producing multiple output voltages by adding secondary transformer windings.

Modern electronic devices require efficient, high quality, light weight power supplies. We have linear power regulators, whose principle of operation depends on current or voltage division which is inefficient. The main area of application is at low power levels. When it comes to high power levels switching regulators are used where switch operates in on and off states. Latest power electronic switches can operate at high frequencies. Therefore, faster dynamic response to rapid changes in the load current is possible with high operating frequencies. These High frequency electronic power processors are used in dc-dc power conversion.

The main functions of dc-dc converters are:

1. It converts DC input voltage into DC output voltage.
2. It provides isolation between source and load.
3. It can regulate the output voltage against load.
4. It can reduce the ac voltage ripple on the dc output voltage.

The dc-dc converters are mainly divided into two types:

1. Hard switching pulse width modulated (PWM) converters and
2. Resonant and soft switching converters.

In this thesis we deal with PWM dc to dc converters which are very popular for the last few decades and can be used at all power levels.

Some applications have additional technical constraints. Consider the power supplies used in battery powered electronics, such as laptop computers or mobile phones have a requirement of maintaining high efficiency over a wide range of loads. In desktop computers and servers, the microprocessor supplies must include the capabilities of digitally programmed output voltage. The

output must depend on the load as well the dynamic response must be faster even for large load transients. Voltage Regulator Modules have multi phase architectures consisting of several buck or similar converter modules which operate in parallel to share the load current in order to improve dynamic response.

So because of the wide range of applications in industries, telecom sector and in medical field given rise to the development of “Digital Power” which leads to computerizing the DC to DC converters, hence the main focus of the DC to DC converters area today. We can obtain the better performance by modeling and simulation of the system. The modeling depends on the internal structure of the system and system dynamics are influenced by the load of the system. If we have insufficient information about the system parameters it cause to error in designing the controller. So, better control can be obtained by using experimental data to determine the load information. System identification can be done in two ways, Parametric and Non-parametric identification. In Non-parametric method we use spectral analysis and correlation analysis to estimate frequency response or impulse response of the system. The behavior of the system is then estimated from the obtained frequency response. Where as in parametric estimation, a model structure is proposed and the parameter of the model is identified using information extracted from the system . In this paper we are working with Non-parametric system identification method.

## 2.Boost Converter

---

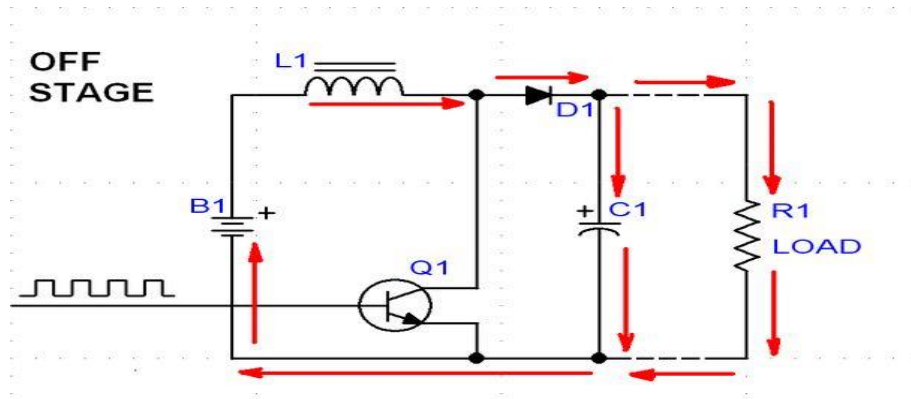
### 2.1 BOOST CONVERTER

In this section we summarized the brief introduction of boost converter and purpose why we choose the boost converter as well the circuit topology and the brief explanation of the components used in the construction of boost converter.

There has been an incredible development in the field of electrical components in recent years. The competition is to make things portable and flexible so that the usage will be more with less effort. As stated for electrical components to run, the power consumption is the major factor. For the optimum usage of electronic components, dc to dc converter plays a major role. The dc to dc converter can be used for many electronic components and it is widely used in telephone components and many other electronic devices. The purpose of dc to dc converter is to convert (i.e. to step up) the voltage from one value to the other and to perform regulation for the electronic circuit.

### 2.2 Why Boost Converter?

In general the boost converter is the simplest way to increase the voltage of a DC supply is which is not possible with the help of the transformers and promises high efficiency. Consider the linear regulator as shown in Figure 1. Here, the source voltage  $V_s$  is which is to be step down to voltage  $V_L$  across the resistor  $R_1$  which means the voltage across  $R_L$  must be dropped which intern results in waste of power in the form of heat. This problem can be overcome by using Boost Converter as it uses switch (Diode) to operate in ON and OFF state



**Figure 01. Circuit diagram of a Linear Regulator**

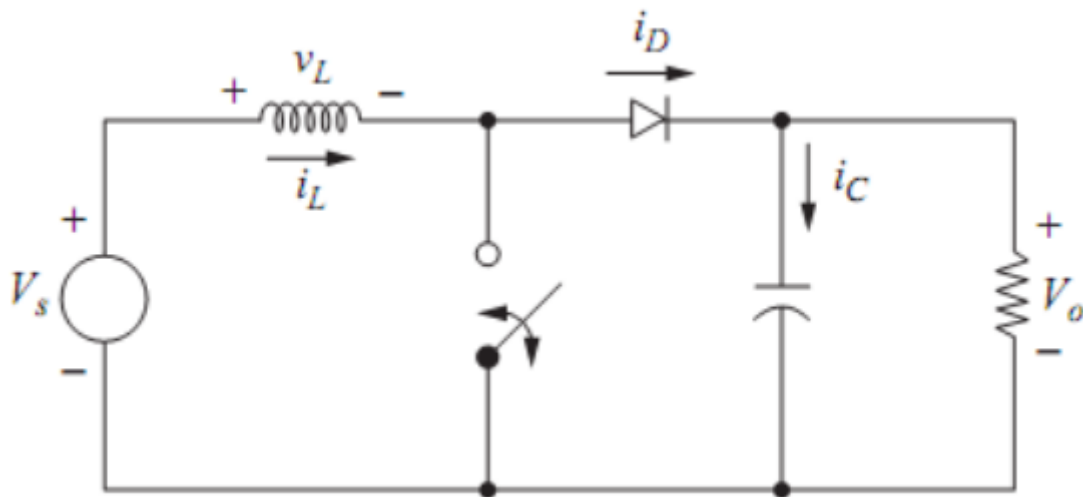
The dc-dc boost converter topology is most widely used power management and microprocessor voltage-regulator applications. These applications require high frequency and transient response over a wide load current range. They can convert high voltage into low regulated voltage. Boost converter can be used in computers, where we need voltage to be stepped down. Boost converter provides long battery life for mobile phones which spend most of the time in stand-by state.

When the switch is ON the inductor gets charged to its maximum level, because of its flexibility of ON and OFF states it can be switched to OFF state when inductor charges to its maximum capacity. With this feature the usage of heat sinks and cooling agents can be avoided. Hence, because of its advantage we opt for buck converter rather than a linear regulator.

### 2.3 Boost Converter Circuit topology

The name “Boost Converter” itself indicates that the input voltage is boosted or increased and high voltage appears at the output. A boost converter or step up voltage regulator provides non isolated, switch mode dc-dc conversion with the advantage of simplicity and low cost. Figure 2, shows a simplified dc-dc boost converter that accepts a dc input and uses pulse width modulation of switching frequency to control the output voltage. The buck converter consists of Source Voltage ‘ $V_s$ ’, Diode, Inductor ‘ $L$ ’, Inductor Resistance ‘ $R_L$ ’, Capacitor ‘ $C$ ’, and Capacitive Resistance ‘ $R_c$ ’ all connected to a Load.

Switch mode power supply is generally used to provide the output voltage which is higher than the input voltage to the load from an intermediate DC input voltage bus or a battery source. A simplified boost converter point of load which has power supply from a switch mode buck converter is shown in Figure.3. The buck converter consists of main power switch, a diode, a low-pass filter (L and C) and a load. The basic boost converter operates in ON and OFF states. In ON state i.e. when the switch is closed the current flows through inductor from the voltage source, where inductor gets charged to its peak level. Where as in OFF state i.e. when switch is open the inductor acts as additional voltage source to the supply thus boosting its voltage to the load.



**Figure 02. Boost Converter**

**Circuit components used:**

**2.3.1 Switch**



**Figure 03. Switch**

The most familiar form of switch is a manually operated electromechanical device with one or more sets of electrical contacts, which are connected to external circuits. Each set of contacts can be in one of

two states: either "closed" meaning the contacts are touching and electricity can flow between them, or "open", meaning the contacts are separated and the switch is nonconducting. The mechanism actuating the transition between these two states (open or closed) can be either a "*toggle*" (flip switch for continuous "on" or "off") or "*momentary*" (push-for "on" or push-for "off") type.

## **Electronic switch :**

An electronic switch is an electronic component or device that can switch an electrical circuit, interrupting the current or diverting it from one conductor to another.

## **MOSFET :**

The metal–oxide–semiconductor field-effect transistor (MOSFET, MOSFET, or MOS FET) is a transistor used for amplifying or switching electronic signals. Although the MOSFET is a four-terminal device with source (S), gate (G), drain (D), and body (B) terminals, the body (or substrate) of the MOSFET often is connected to the source terminal, making it a three-terminal device like other field-effect transistors. Because these two terminals are normally connected to each other (short-circuited) internally, only three terminals appear in electrical diagrams.

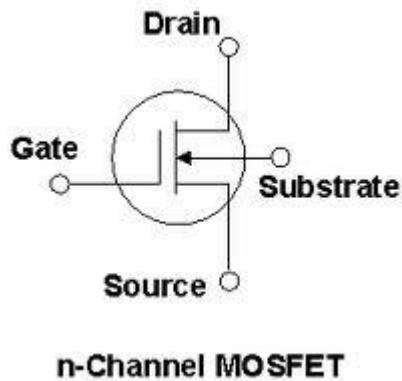
The MOSFET is by far the most common transistor in both digital and analog circuits, though the bipolar junction transistor was at one time much more common.

In *enhancement mode* MOSFETs, a voltage drop across the oxide induces a conducting channel between the source and drain contacts *via* the field effect. The term "enhancement mode" refers to the increase of conductivity with increase in oxide field that adds carriers to the channel, also referred to as the *inversion layer*. The channel can contain electrons (called an nMOSFET or nMOS), or holes (called a pMOSFET or pMOS), opposite in type to the substrate, so nMOS is made with a p-type substrate, and pMOS with an n-type substrate (see article on semiconductor devices). In the less common *depletion mode* MOSFET, detailed later on, the channel consists of carriers in a surface impurity layer of opposite type to the substrate, and

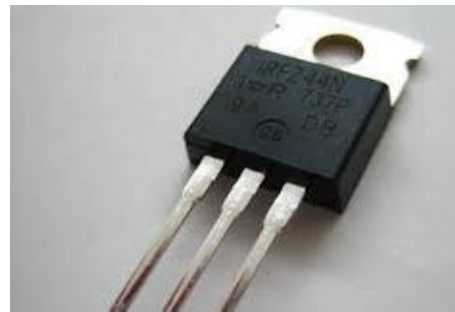


conductivity is decreased by application of a field that depletes carriers from this surface layer.

symbol :



actual photo :



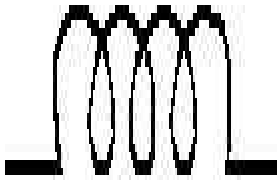
**Figure 04: Mosfet**

In order to overcome the increase in power consumption due to gate current leakage, a high- $\kappa$  dielectric is used instead of silicon dioxide for the gate insulator, while polysilicon is replaced by metal gates. When a voltage is applied between the gate and body terminals, the electric field generated penetrates through the oxide and creates an "inversion layer" or "channel" at the semiconductor-insulator interface. The inversion channel is of the same type, p-type or n-type, as the source and drain, thus it provides a channel through which current can pass. Varying the voltage between the gate and body modulates the conductivity of this layer and thereby controls the current flow between drain and source. The Mosfet is used for low voltage, low current and high frequency applications.

## Various electrical components used in project

### 2.3.2 Inductor

Symbol :



Actual image :



**Figure 05: Inductor**

An **inductor**, also called a **coil** or **reactor**, is a passive two-terminal electrical component which resists changes in electric current passing through it. It consists of a conductor such as a wire, usually wound into a coil. When a current flows through it, energy is stored temporarily in a magnetic field in the coil. When the current flowing through an inductor changes, the time-varying magnetic field induces a voltage in the conductor, according to Faraday's law of electromagnetic induction, which opposes the change in current that created it.

When the current through an inductor tends to fall, the inductor tends to maintain the current by acting as a source. This limits the otherwise high-peak current that would be limited by the switch resistance alone. The key advantage is when the inductor is used to drop voltage, it stores energy. Also the inductor controls the percent of the ripple and determines whether or not the circuit is operating in the continuous mode. Peak current through the inductor determines the inductor's required saturation-current rating, which in turn dictates the approximate size of the inductor.

Saturating the inductor core decreases the converter efficiency, while increasing the temperatures of the inductor, the MOSFET and the diode. The size of the inductor and capacitor can be reduced by the implementation of high switching frequency, multi-phase interleaved topology, and a fast hysteric controller.

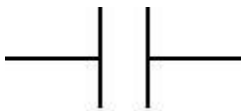
A smaller inductor value enables a faster transient response; it also results in larger current ripple, which causes higher conduction losses in the switches, inductor, and parasitic resistances. The smaller inductor also requires a larger filter capacitor to decrease the output voltage ripple.

Inductors used in switched supplies are sometimes wound on toroidal cores, often made of ferrite or powdered iron core with distributed air-gap to store energy. A DC-DC converter transfers energy at a controlled rate from an input source to an output load, and as the switching frequency increases, the time available for this energy transfer decreases.

For example, consider a buck converter operating at 500 kHz with a 10  $\mu\text{H}$  inductor. For most DC-DC converters, changing the frequency to 1 MHz allows use of exactly one half the inductance, or 5  $\mu\text{H}$ .

### 2.3.3 Capacitor

Symbol :



Actual image :



**Figure 06: Capacitor**

A capacitor (originally known as a condenser) is a passive two-terminal electrical component used to store energy electrostatically in anelectric field. The forms of practical capacitors vary widely, but all contain at least

two electrical conductors (plates) separated by dielectric (i.e., insulator). The conductors can be thin films of metal, aluminum foil or disks, etc. The 'nonconducting' dielectric acts to increase the capacitor's charge capacity. A dielectric can be glass, ceramic, plastic film, air, paper, mica, etc. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, a capacitor does not dissipate energy. Instead, a capacitor stores energy in the form of an electrostatic field between its plates.

Capacitor provides the filtering action by providing a path for the harmonic currents away from the load. Output capacitance (across the load) is required to minimize the voltage overshoot and ripple present at the output of a step-down converter. The capacitor is large enough so that its voltage does not have any noticeable change during the time the switch is off. Large overshoots are caused by insufficient output capacitance, and large voltage ripple is caused by insufficient capacitance as well as a high equivalent-series resistance (ESR) in the output capacitor. The maximum allowed output-voltage overshoot and ripple are usually specified at the time of design. Thus, to meet the ripple specification for a step-down converter circuit, we must include an output capacitor with ample capacitance and low ESR.

Since switched power regulators are usually used in high current, high performance power supplies, the capacitor should be chosen for minimum loss. Loss in a capacitor occurs because of its internal series resistance and inductance. Solid tantalum capacitors are the best in this respect. For very high performance power supplies, sometimes it is necessary to parallel capacitors to get a low enough effective series resistance

#### 2.3.4 Resistor

Symbol :



Actual image :

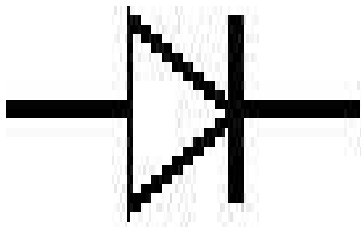


**Figure 07: Resistor**

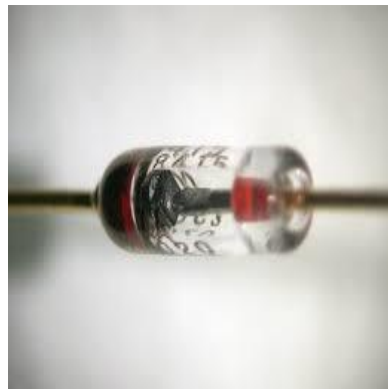
A **resistor** is a passive two-terminal electrical component that implements electrical resistance as a circuit element. Resistors act to reduce current flow, and, at the same time, act to lower voltage levels within circuits. Resistors may have fixed resistances or variable resistances, such as those found in thermistors, varistors, trimmers, photoresistors and potentiometers. Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors can be composed of various compounds and films, as well as resistance wires (wire made of a high-resistivity alloy, such as nickel-chrome). Resistors are also implemented within integrated circuits, particularly analog devices, and can also be integrated into hybrid and printed circuits.

### 2.3.5 Diode

Symbol :



Actual photo :



**Figure 08: Diode**

In electronics, a diode is a two-terminal electronic component with asymmetric conductance; it has low (ideally zero) resistance to current in one direction, and high (ideally infinite) resistance in the other. A semiconductor diode, the most common type today, is a crystalline piece of semiconductor material with a p-n junction connected to two electrical terminals

The most common function of a diode is to allow an electric current to pass in one direction (called the diode's *forward* direction), while blocking current in the opposite direction (the *reverse* direction). Thus, the diode can be

viewed as an electronic version of a check valve. This unidirectional behavior is called rectification, and is used to convert alternating current to direct current, including extraction of modulation from radio signals in radio receivers—these diodes are forms of rectifiers.

However, diodes can have more complicated behavior than this simple on–off action, due to their nonlinear current-voltage characteristics. Semiconductor diodes begin conducting electricity only if a certain threshold voltage or cut-in voltage is present in the forward direction (a state in which the diode is said to be *forward-biased*). The voltage drop across a forward-biased diode varies only a little with the current, and is a function of temperature; this effect can be used as a temperature sensor or voltage reference.

Semiconductor diodes' current–voltage characteristic can be tailored by varying the semiconductor materials and doping, introducing impurities into the materials. These are exploited in special-purpose diodes that perform many different functions. For example, diodes are used to regulate voltage (Zener diodes), to protect circuits from high voltage surges (avalanche diode), to electronically tune radio and TV receivers (varactor diodes), to generate radio frequency oscillations (tunnel diodes, Gunn diodes, IMPATT diodes), and to produce light (light emitting diodes). Tunnel diodes exhibit negative resistance, which makes them useful in some types of circuits.

## **Feedback**

Feedback and control circuitry can be carefully nested around these circuits to regulate the energy transfer and maintain a constant output within normal operating conditions. Control by pulse-width modulation is necessary for regulating the output. The transistor switch is the heart of the switched supply and it controls the power supplied to the load.

## **2.4 Block Diagram:**

The block diagram for the boost converter with arduino is shown below. It consists of a dc supply of 9V, an inductor, a electrolytic capacitor, a n-channel MOSFET, a normal p-n junction diode, a potential or voltage divider circuit and load.

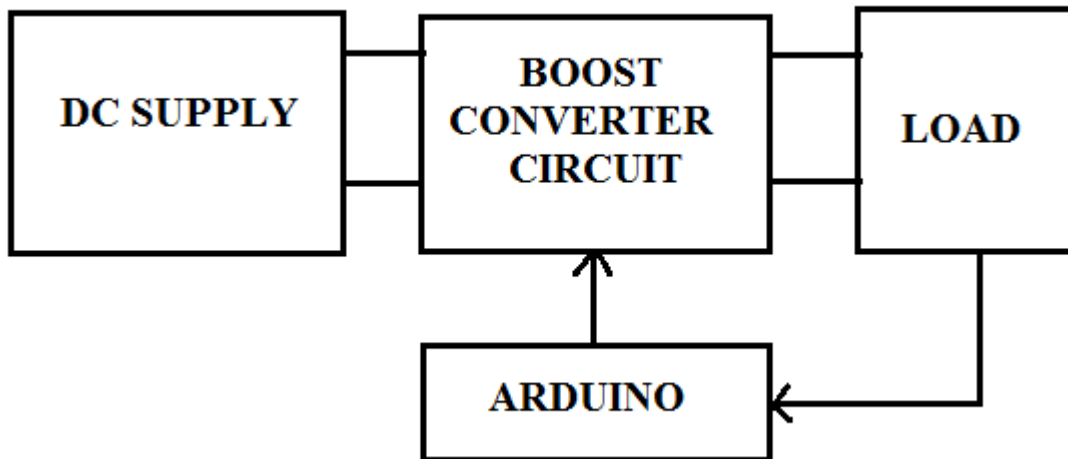


Figure: Block Diagram

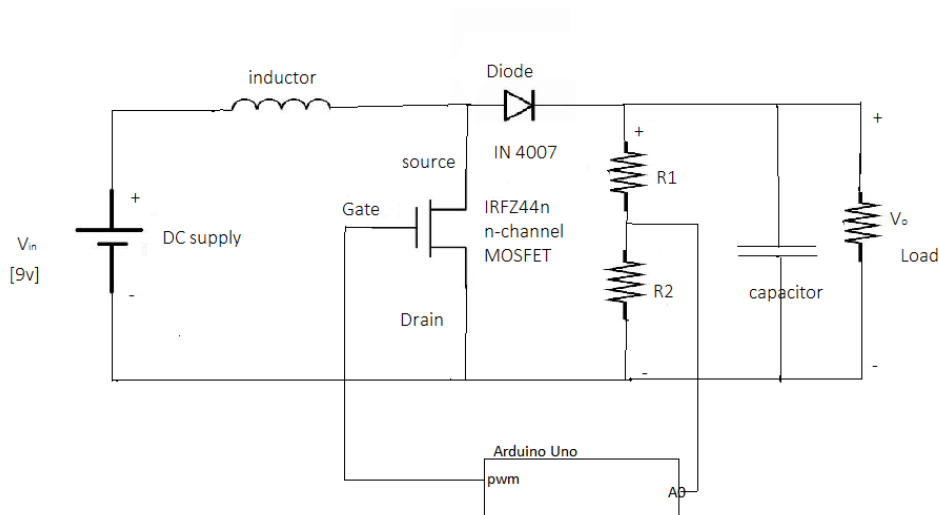
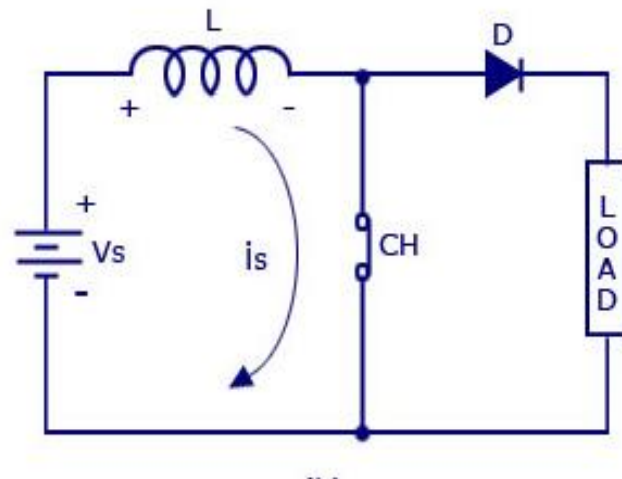


Figure 09:Detailed Diagram

## 2.5 Two States of operation of Boost Converter

### 2.5.1 ON State

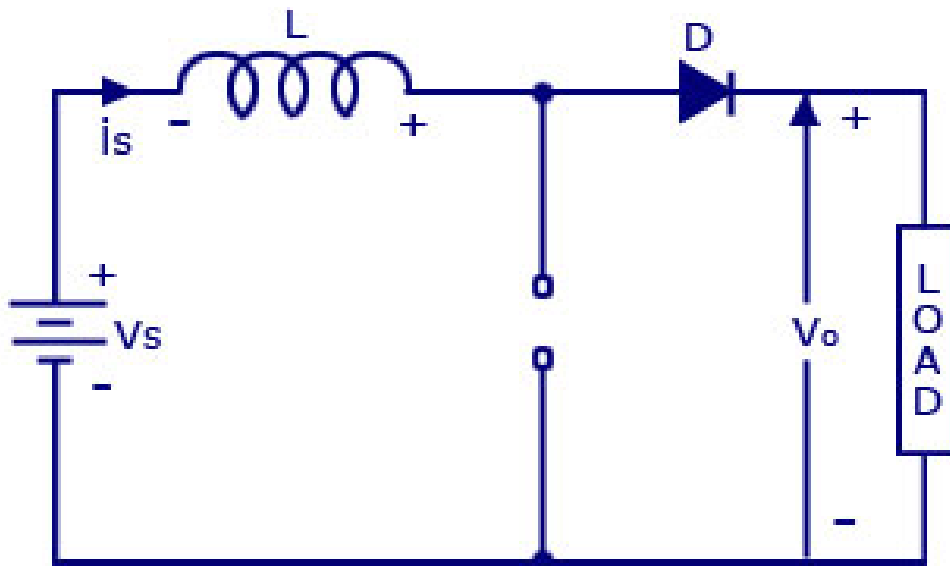
Below figure , shows the boost converter operating in on state. In this state of operation the switch will be in closed state so that  $V_s$  will be the source voltage applied across inductor. The current flows through the inductor rising its voltage for the certain amount of time.



**Fig 10: step up chopper in ON position**

### 2.5.2 OFF State

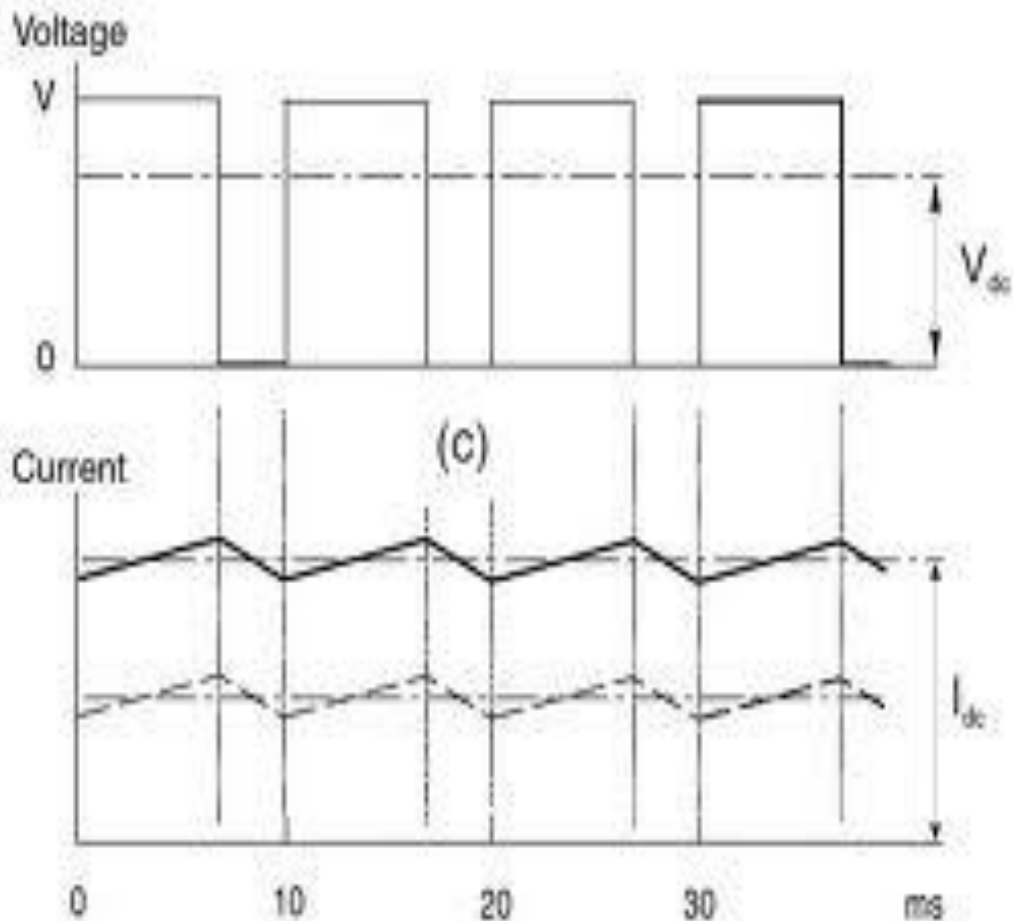
Below figure , shows the boost converter operating in off state. In this state of operation the switch will be in open position and inductor starts discharging and aid the supply voltage to boost the voltage.



**Figure 11 : Off State of Boost Converter**



Below waveforms , shows the boost converter wave forms i.e. ‘VL’ shows the voltage across the inductor, ‘iS’ shows the switch modes during the time T and ‘iL’ shows the current flow during on and off states.



**Figure 12: Boost converter wave forms**

The relationship between input voltage, output voltage and the switch duty cycle ‘D’ can be derived from VL waveform. According to Faraday’s law, the inductor volt second product over a period of steady state operation is zero.

**For Boost Converter :**

During the On-state, the switch S is closed, which makes the input voltage ( $V_i$ ) appear across the inductor, which causes a change in current ( $i_L$ ) flowing through the inductor during a time period ( $t$ ) by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L}$$

At the end of the On-state, the increase of  $I_L$  is therefore:

$$\Delta I_{L_{On}} = \frac{1}{L} \int_0^{DT} V_i dt = \frac{DT}{L} V_i$$

$D$  is the duty cycle. It represents the fraction of the commutation period  $T$  during which the switch is on. Therefore  $D$  ranges between 0 ( $S$  is never on) and 1 ( $S$  is always on).

During the Off-state, the switch  $S$  is open, so the inductor current flows through the load. If we consider zero voltage drops in the diode, and a capacitor large enough for its voltage to remain constant, the evolution of  $I_L$  is:

$$V_i - V_o = L \frac{dI_L}{dt}$$

Therefore, the variation of  $I_L$  during the off position is

$$\Delta I_{L_{Off}} = \int_0^{(1-D)T} \frac{(V_i - V_o)}{L} dt = \frac{(V_i - V_o)(1-D)T}{L}$$

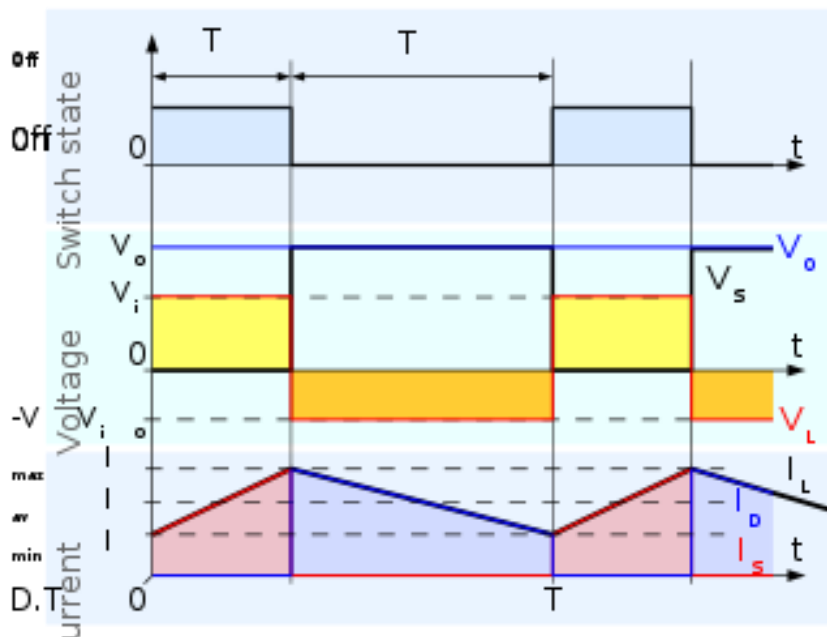


Figure 13: Representation of duty cycle

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by:

$$E = \frac{1}{2}LI_L^2$$

So, the inductor current has to be the same at the start and end of the commutation cycle. This means the overall change in the current (the sum of the changes) is zero:

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = 0$$

Substituting  $\Delta I_{L_{On}}$  and  $\Delta I_{L_{Off}}$  by their expressions yields:

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = \frac{V_i DT}{L} + \frac{(V_i - V_o)(1 - D)T}{L} = 0$$

This can be written as:

$$\frac{V_o}{V_i} = \frac{1}{1 - D}$$

$$D = 1 - \frac{V_i}{V_o}$$

From the above expression it can be seen that the output voltage is always higher than the input voltage (as the duty cycle goes from 0 to 1), and that it increases with D, theoretically to infinity as D approaches 1. This is why this converter is sometimes referred to as a step-up converter.

Boost converter can operate in two modes of operation, Continuous mode and Discontinuous mode. In continuous mode, current at inductor never falls to zero. Where as in discontinuous mode at one point of time the current in inductor falls to zero due to consumption of energy by the load.

### 3. Analysis of a Typical Boost Converter

---

One might ask a question, as the Boost converter involves the conversion of direct voltage to direct voltage. So, how can it be termed a conversion? The answer is that a fixed direct voltage is converted into a variable direct voltage source without changing the power level (neglecting power losses in the switch). Hence, it is also called as a DC Transformer.

The analysis of the boost converter is as shown in figure , and the corresponding waveforms are as shown in figure . Assuming that the current flow in the inductor is continuous, we are now analyzing the boost converter in Continuous Conduction Mode. From the basic principles, we know that,

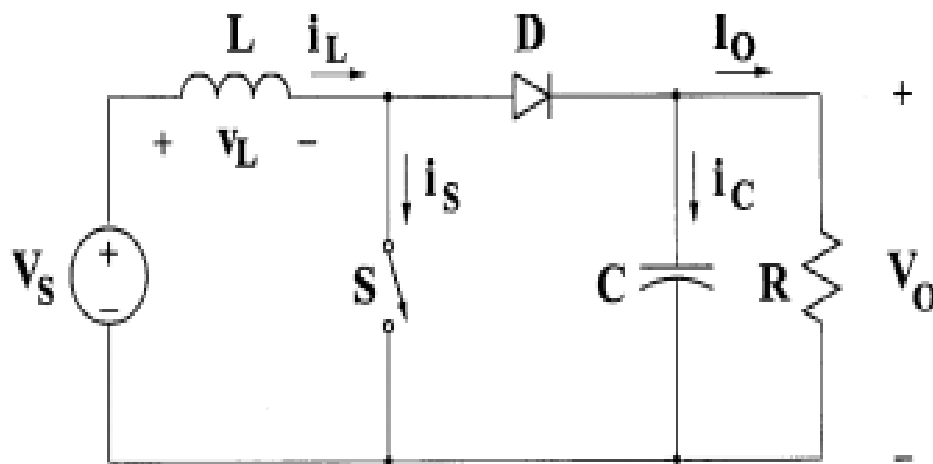
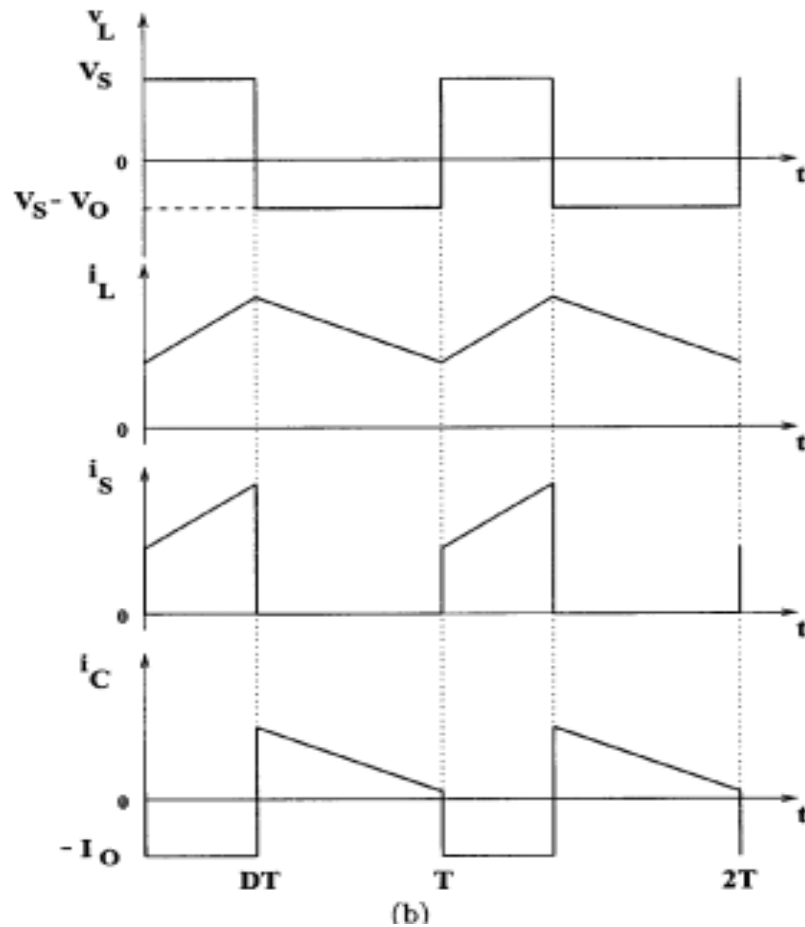


Figure 14 :Circuit Diagram

step-up or a PWM boost converter consists of dc input voltage source  $V_S$ , boost inductor  $L$ , controlled switch  $S$ , diode  $D$ , filter capacitor  $C$ , and load resistance  $R$ . The converter waveforms in the CCM are



When the switch S is in the on state , the current in the boost inductor increases linearly and the diode D is off at that time. When the switch S is turned off, the energy stored in the inductor is released through the diode to the output RC circuit

Using faraday's law of boost inductor

$$V_S D T = (V_O - V_S) * (1-D) T$$

from which the dc voltage transfer turns out to be

$$M_v = V_O / V_S = 1 / (1 - D)$$

As the name of the converter suggests, the output voltage is always greater than the input voltage.

The boost converter operates in the CCM for  $L > L_b$

Where  $L_b = (1 - D)^2 \cdot D R / 2f$

For  $D = 0.5$ ,  $R = 22\text{k ohm}$ , and  $f = 31.25\text{ kHz}$ , the boundary value of the inductance is  $L_b = 6.25\text{ mH}$ . The current supplied to the output RC circuit is discontinuous. Thus, a larger filter capacitor is required in comparison to that in the boost-derived converters to limit the output voltage ripple. The filter capacitor must provide the output dc current to the load when the diode D is off. The minimum value of the filter capacitance that results in the voltage ripple  $V_r$  is given by

$$C_{\min} = DV_o/V_rRf$$

At  $D = 0.5$ ,  $V_r/V_o = 1\%$ ,  $R = 10\text{ ohm}$ , and  $f = 31.25\text{ kHz}$ , the minimum capacitance for the boost converter is  $C_{\min} = 220\text{ microF}$

## 4.ARDUINO

---

An open-source hardware platform based on an Atmel AVR 8-bit microcontroller which is RISC architecture micro controller, designed for higher languages developed in Trondheim, Norway in 1996. **Reduced instruction set computing**, or **RISC** , is a CPU design strategy based on the insight that simplified (as opposed to complex) instructions can provide higher performance if this simplicity enables much faster execution of each instruction. A computer based on this strategy is a reduced instruction set computer, also called *RISC*

An Arduino board has complementary components to facilitate programming and incorporation into other circuits. An important aspect of the Arduino is the standard way that connectors are exposed, allowing the CPU board to be connected to a variety of interchangeable add-on modules known as *shields*. Some shields communicate with the Arduino board directly over various pins, but many shields are individually addressable via an I<sup>2</sup>C serial bus, allowing many shields to be stacked and used in parallel. Official Arduino's have used the mega AVR series of chips, specifically the ATmega8, ATmega168, ATmega328, ATmega1280, and ATmega2560. A handful of other processors have been used by Arduino compatibles. Most boards include a 5 volt linear regulator and a 16 MHz crystal oscillator (or ceramic resonator in some variants), although some designs such as the LilyPad run at 8 MHz and dispense with the onboard voltage regulator due to specific form-factor restrictions. An Arduino's microcontroller is also pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory, compared with other devices that typically need an external programmer. This makes using an Arduino more straightforward by allowing the use of an ordinary computer as the programmer.

At a conceptual level, when using the Arduino software stack, all boards are programmed over an RS-232 serial connection, but the way this is implemented varies by hardware version. Serial Arduino boards contain a level shifter circuit to convert between RS-232-level and TTL-level signals. Current Arduino boards are programmed via USB, implemented using USB-to-serial adapter chips such as the FTDI FT232. Some variants, such as the Arduino Mini and the unofficial

Boarduino, use a detachable USB-to-serial adapter board or cable, Bluetooth or other methods. (When used with traditional microcontroller tools instead of the Arduino IDE, standard AVR ISP programming is used.)

The Arduino board exposes most of the microcontroller's I/O pins for use by other circuits. The Diecimila, Duemilanove, and current Uno provide 14 digital I/O pins, six of which can produce pulse-width modulated signals, and six analog inputs. These pins are on the top of the board, via female 0.10-inch (2.5 mm) headers. Several plug-in application shields are also commercially available.

The Arduino Nano, and Arduino-compatible Bare Bones Board and Boarduino boards may provide male header pins on the underside of the board to be plugged into solderless breadboards

## Arduino Uno



Figure 15:Arduino

### Overview

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support



the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

1.0 pin out: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, which is reserved for future purposes.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform.

### Summary:

Schematic & Reference Design:

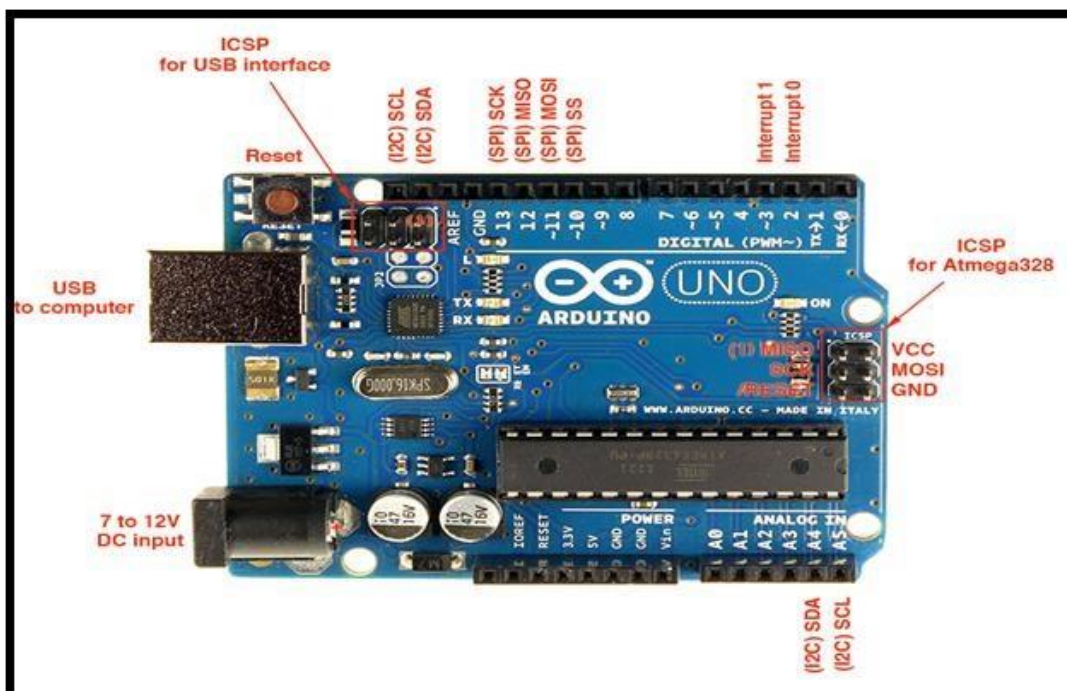


Figure 16: Arduino Schematic Diagram

The Arduino reference design can use an Atmega8, 168, or 328, Current models use an ATmega328, but an Atmega8 is shown in the schematic for reference. The pin configuration is identical on all three processors.

## **Power:**

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

The power pins are as follows:

**VIN:** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

**5V:** This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.

**3V3:** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA

**GND:** Ground pins.

**IOREF:** This pin on the Arduino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage

translators on the outputs for working with the 5V or 3.3V.

## **Memory:**

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM.

## **Input and Output:**

Each of the 14 digital pins on the Uno can be used as an input or output, using `pinMode()`, `digitalWrite()`, and `digitalRead()` functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

**Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.

**External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the `attachInterrupt()` function for details.

**PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the `analogWrite()` function.

**SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication using the SPI library.

**LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off. The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the `analogReference()` function.

Additionally, some pins have specialized functionality:

**TWI: A4 or SDA pin and A5 or SCL pin.** Support TWI communication using the Wire library. There are a couple of other pins on the board:

**AREF.** Reference voltage for the analog inputs. Used with `analogReference()`.

**Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

## **Communication:**

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A Software Serial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus. For SPI communication, use the SPI library.

## **PROGRAMMING**

The Arduino Uno can be programmed with the Arduino software. Select "Arduino Uno from the **Tools > Board** menu (according to the microcontroller on your board). The ATmega328 on the Arduino Uno comes preburned with a boot loader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the boot loader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header. The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available. The ATmega16U2/8U2 is loaded with a DFU boot loader, which can be activated by:

On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2.

On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode.

### USB Overcurrent Protection:

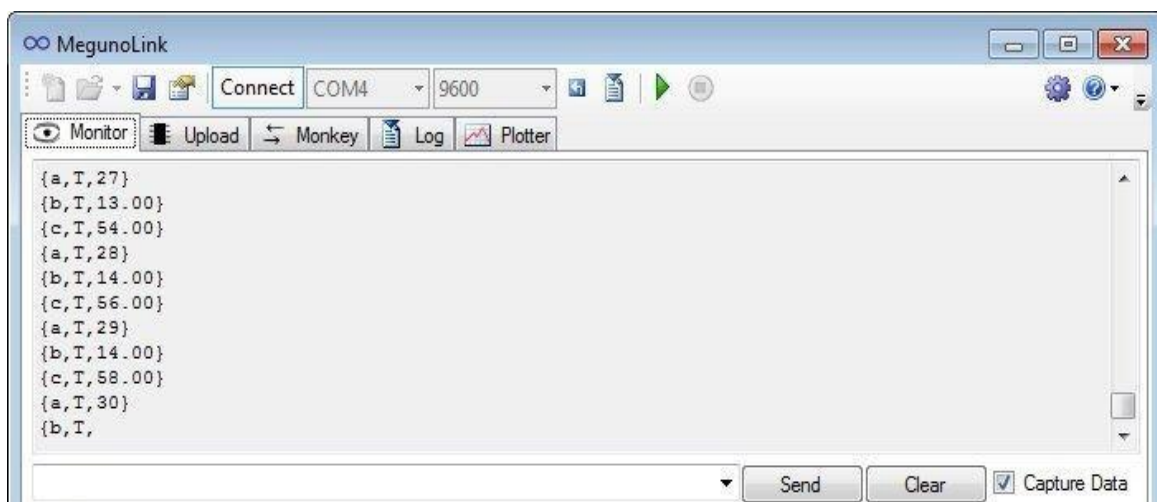
The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

### Physical Characteristics:

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

### Serial Data monitoring:

As with the Serial Monitor in the Arduino IDE, you can monitor the data from the Arduino, and also send it back through the serial line. Just click the „Monitor“ tab and you're set, for example:



**Figure 17: Megunolink Serial Monitor**

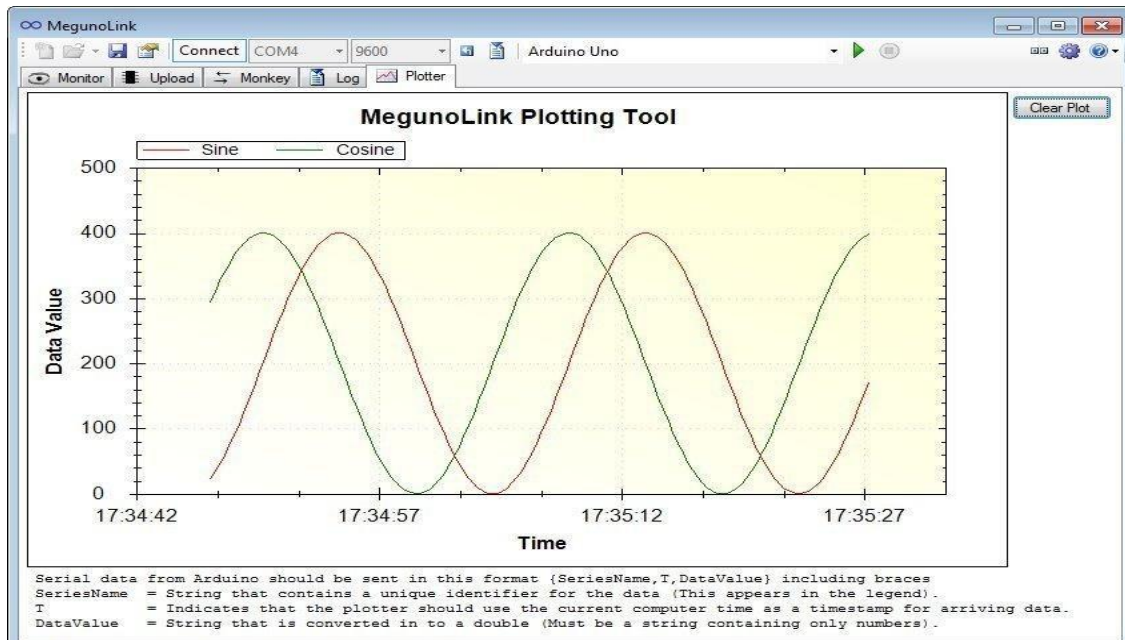
## Capturing Serial Data to a file:

Very useful indeed, much quicker than dumping data to a microSD card and then bringing it back to the PC. Just click the „Log“ tab, specify a file location and name, then click „Enabled“. You can also append data to an existing text file. When creating the output format in your Arduino sketch, be mindful to have separators such as commas or colons – which make it much easier to delimit the data once imported into a spreadsheet or database application.

## Plotting and Graphing Serial Data:

Plotting data to a graph is very simple. You simply format the data you'd like to plot using Serial. Write commands, and Megunolink takes care of the rest – just click the „Plotter“ tab and you're off.

Here is a very simple example, “SendSineCurve” sketch from the Arduino Graphing library:



**Figure. Displaying Sine curve**

You can always save the graph as an image in the usual formats as well as in .emf vector image file format.

## 5.INTERFACING WITH ARDUINO

---

For the boost converter topology , Arduino is used as an effective negative feedback controller circuit. For this purpose , a dc voltage of 9V from battery or ac-dc rectifier with a regulated devices used as an input voltage .In the output or load side of boost converter ,a potential divider circuit is implented to read the voltage on the output side through Arduino using the command “Analogread()”.In arduino ,the analog pins numbering from 0 to 5 ,A0 pin is used to read the voltage across a resistor in potential divider circuit. With this, voltage across the load will be measured.

This load or output voltage will be compared with a reference or required or desired voltage which has to be obtained from the boost converter circuit. The actuating or error signal is amplified or incremented proportionately through a multiplier called proportional controller. From the pwm pins,pin 9 is used to trigger the Mosfet through this actuating signal as Pulse Width Modulated(PWM) from arduino through the command “Analogwrite(pin ,duty cycle)”.The setup used for the sensing of the load voltage and generating pwm pulses for giving them to gate of mosfet is termed as Negative feedback circuit.This is how the arduino is used as feedback controller circuit.

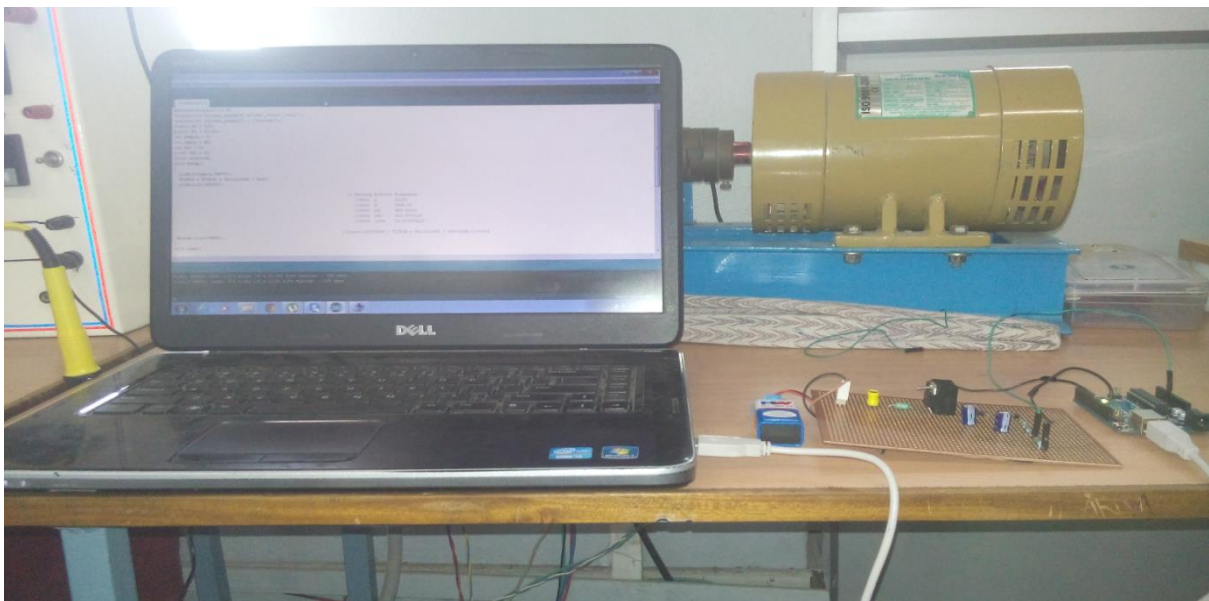
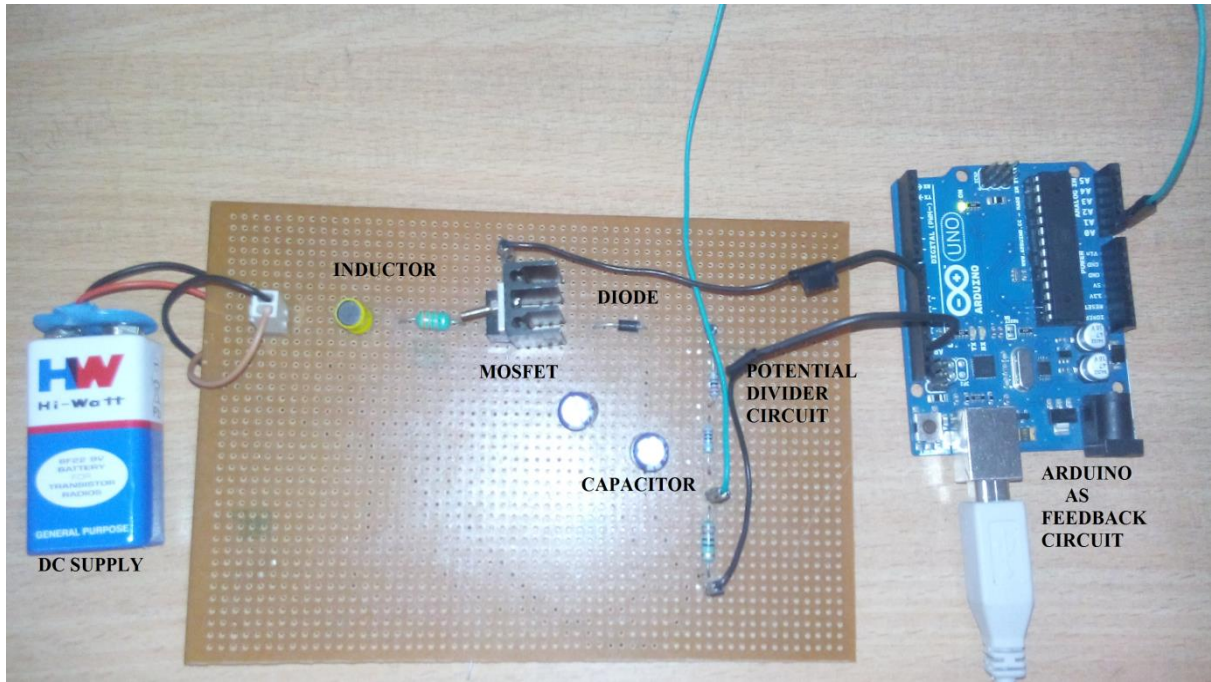


Figure 18: Interfacing with Arduino

## 6. Software Development

This C related program reads the output voltage across load by the analog read pin. This output voltage is compared with the desired output or reference input and calculates the error. This error is multiplied by a proportionality constant which will act as a PI Controller. This error signal is given to the gate terminal of the N-channel Mosfet through the PWM signal generated from Arduino uno. The program code for this circuit is in appendix section.



## 7.DESIGN SPECIFICATIONS

---

### Calculation of Inductor and Capacitor Values :

$$V_{in} = 9 \text{ V}$$

$$V_{OUT} = 10.10 \text{ volts}$$

$$I_{LOAD} = 1 \text{ amps}$$

$$F_{sw} = 31.25 \text{ KHz}$$

$$D = 1 - (V_{in} / V_{out}) = 1 - (9\text{V} / 10.1\text{V}) = 1 - 0.891 = 0.109$$

$$\begin{aligned} L_{min} &= (D \cdot (1-D)^2 \cdot R) / (2 \cdot f) \\ &= (0.109 \cdot 0.891^2 \cdot 14500) / (2 \cdot 31250) \\ &= 0.08007566 \text{ H} \\ &= 80 \text{ mH} \end{aligned}$$

$$\begin{aligned} I_L &= (V_s) / ((1-D)^2 \cdot R) \\ &= (9) / ((1-0.109)^2 \cdot 14500) \\ &= 0.000390093 \\ &= 0.39 \text{ mA} \end{aligned}$$

$$\begin{aligned} \text{Inductor current Ripple} &= (V_s \cdot D \cdot T) / (2 \cdot L) \\ &= (9 \cdot 0.109) / (2 \cdot 0.008 \cdot 31250) \\ &= 0.001962 \text{ A} \\ &= 1.9 \text{ mA} \end{aligned}$$

$$\begin{aligned} \text{Capacitor, } c &= (D \cdot v) / (R \cdot V_o \cdot f) \\ &= (0.109) / (14500 \cdot 0.001 \cdot 31250) = 0.2406181 \text{ F} \\ &= 220 \text{ microF.} \end{aligned}$$

# 8.Results

## In Serial Monitor

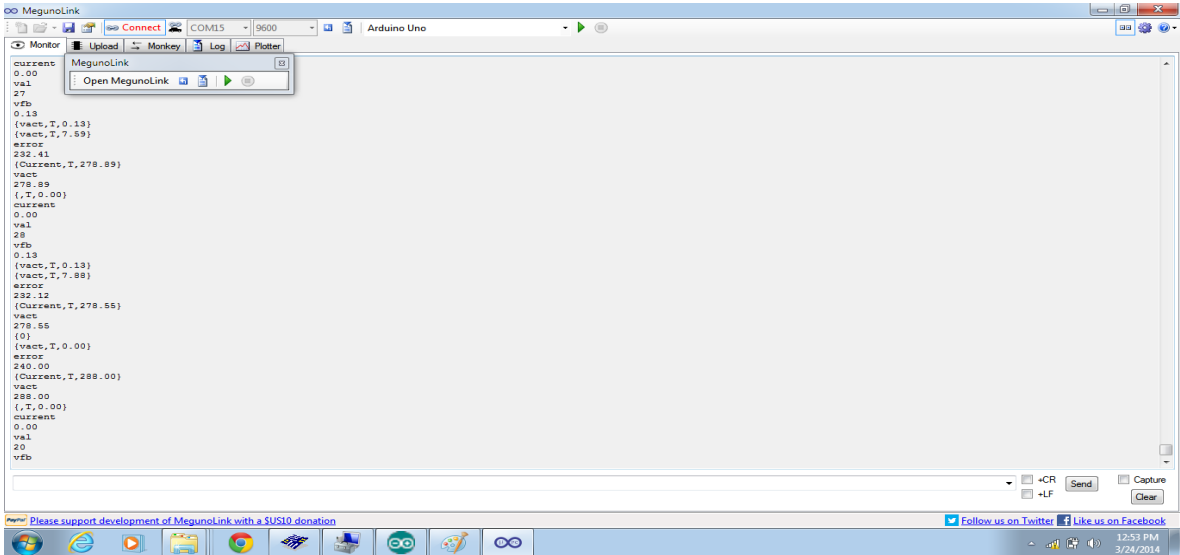


Figure 19: Serial Monitor Display

In Multimeter:



In Meguno Link:

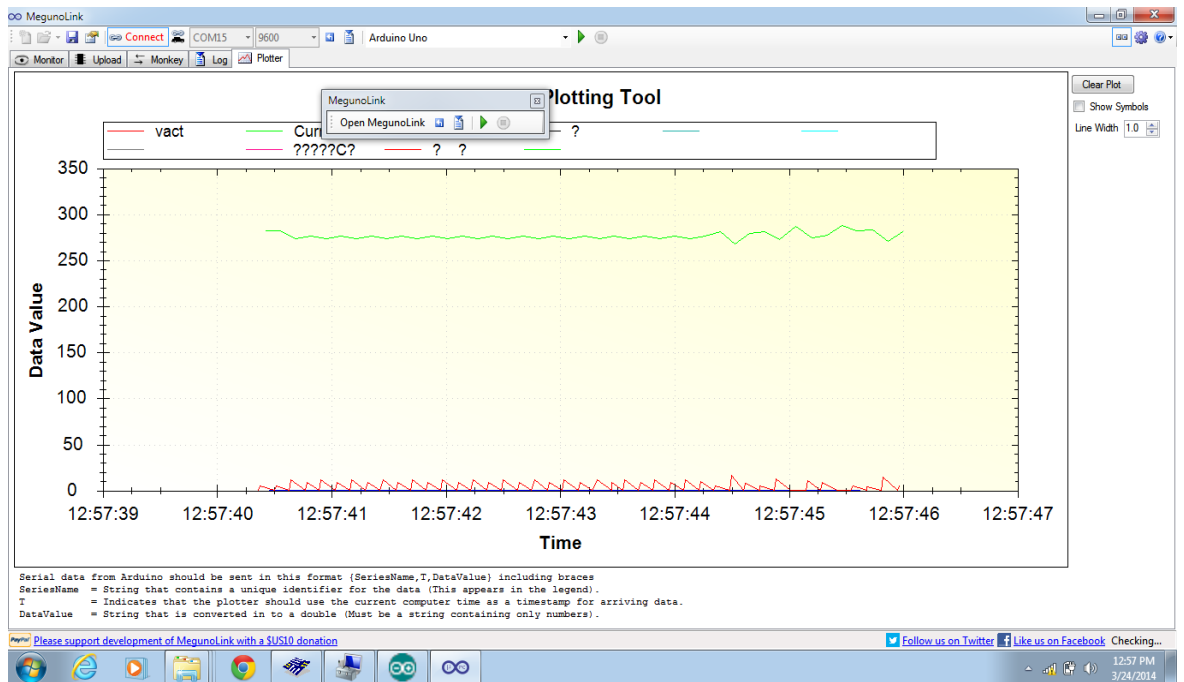


Figure 19 : Megunolink Graphs

In this project ,an input voltage of 9V is given through a battery source. The obtained load voltage is 10.10V,which is boosted by 1.1V.

## **9.Conclusion**

---

BOOST Converter is an efficient step-up DC-DC converter used in numerous electronics devices. It is modeled and simulated using Arduino. A closed loop model is developed and used successfully for simulation. This converter has advantages like reduced hardware, high performance, less weight and accuracy. The simulation results are in line with the predictions.

The same was implemented as a hardware project and an output voltage of 10.10V was obtained with an input of 9V DC supply. Also the waveforms across capacitors and various test points were obtained, studied and compared with the theoretical waveforms. The waveforms were found to be in precise proximity of theoretical waveforms.

## **10.FUTURE SCOPE**

---

As the demand for high-performance, cost-effective systems continues to increase, power system design has become more challenging and complex than ever before. The trend is for DC-DC Converters with higher efficiency, power saving that enable maximum features. Also the minimization in DC-DC converter design for diminishing board sizes and close component density have led to a continuous shrinkage in board space over the past few years.

DC-DC converters are traditionally one of the most dynamic segments of the overall power electronics market. Many of the design, topology and architecture innovations occur in these products, and system-level demands can often be addressed at this level. Although it is a smaller market than ac-dc power supplies, pricing has kept revenues high. This model has slowly been

changing over the past several years, however, as dc-dc converter module and semiconductor products have moved closer and closer together. The applications driving the dc-dc converter market continue to be computer and communications technologies, such as blade servers and Power-over-Ethernet.

The major segments of DC-DC converter are based on the power range - low, medium, and high. To illustrate, telecommunications devices require high input voltage products whereas POS, medical applications, battery charger devices require low input voltage range products. We are witnessing potential growth in end-user markets such as telecommunications, industrial, medical and battery chargers. Increasingly, devices in telecom and medical applications are designed with dependence on electronics to make them compact and portable. As these devices require DC supply to operate, there has been a considerable increase in the demand for point-of-load (POL) converters - which are compact, cost-effective, and more efficient than convenient designs. In addition, it is noted that Point-of-Sale (POS) applications are significantly driving the future of DC-DC converter market. Currently, the telecommunications end-user applications hold the highest share for the DC-DC converter market. This segment is expected to show steady future growth due to the number of applications being developed, fueled by innovations in end-user technology such as design of 3G systems, increasing usage of mobile phones, general packet radio service (GPRS), voice over internet protocol, and power over Ethernet. Medical devices segment has also demonstrated a sturdy growth, driven by the implementation of hand-held devices for diagnostics and medical imaging equipment. Moving forward, the continual expansion and diversification of manufacturing facilities into Asia Pacific regions for the benefit of lower production costs, is likely to further drive this market growth.

## 11.References

- Power Electronics by M.H. Rashid and P.S Bimbhra.
- [www.arduino.cc/](http://www.arduino.cc/)
- [www.microchip.com/smpps](http://www.microchip.com/smpps)
- <http://en.wikipedia.org>
- <http://www.ladyada.net>
- <http://reibot.org>
- <http://electronics.stackexchange.com>

### Appendix-A

Program Code :

```
#include<GraphSeries.h>

GraphSeries voltage_graph[3]=("vfb", "vout", "vact");

GraphSeries current_graph[1] = ("Current");

double R2 = 220;

double R1 = 12700;

int pwmpin = 9;

int inpin = A0;

int val = 0;

float vfb = 0;

float vref=240;

void setup()

{

    pinMode(inpin,INPUT);

    TCCR1B = TCCR1B & 0b11111000 | 0x01;

    pinMode(9,OUTPUT);

    Serial.begin(9600);

}

void loop()
```

```

{
    val=analogRead(inpin);
Serial.println("val");Serial.println(val);

    vfb=(val*4.9)/1023;

    float vout=(vfb*(R2+R1))/R2;
Serial.println("vfb");Serial.println(vfb);

Serial.println("vout");Serial.println(vout);

    voltage_graph[1].SendData(vfb);

    voltage_graph[2].SendData(vout);

    float error=vref-vout;
Serial.println("error");Serial.println(error);

    float kp=1.2;

float vact=error*kp;

    voltage_graph[3].SendData(vact);
Serial.println("vact");Serial.println(vact);

    double current=vfb/R2;

    current_graph[1].SendData(current);
Serial.println("current");Serial.println(current);

    analogWrite(9,255-vact);
}

```

From the above program it was observed that PWM signal has

duration\_on has a range of ( 1960,1965 ) microseconds and

duration\_off has a range of ( 1, 53)microseconds.

At any instant of time the time period(T) of the PWM signal is 1963 micro seconds.

The frequency(f) of the signal is given by Inverse of time period(T).

$$f = (1/T);$$



$f = (1/0.001963)$  cycles/sec or Hertz.

$f=31.25\text{kHz}$ .

## APPENDIX-B

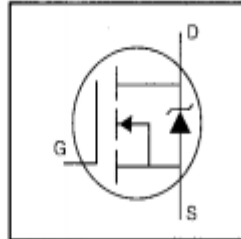
**International  
IR Rectifier**

PD-9.510C

# IRFZ44

HEXFET® Power MOSFET

- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Ease of Paralleling
- Simple Drive Requirements



$$V_{DSS} = 60V$$

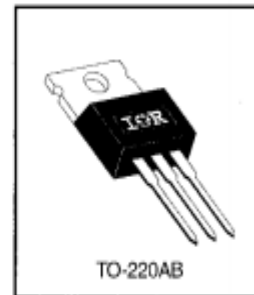
$$R_{DS(on)} = 0.028\Omega$$

$$I_D = 50^*A$$

### Description

Third Generation HEXFETs from International Rectifier provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness.

The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry.



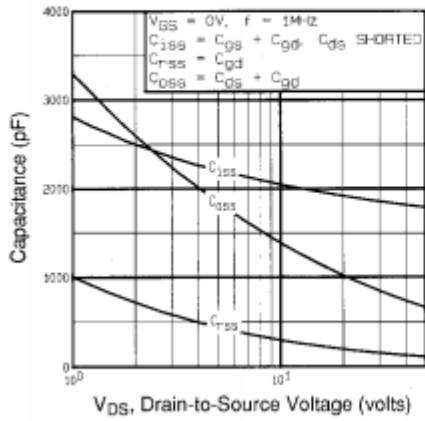
DATA SHEETS

### Absolute Maximum Ratings

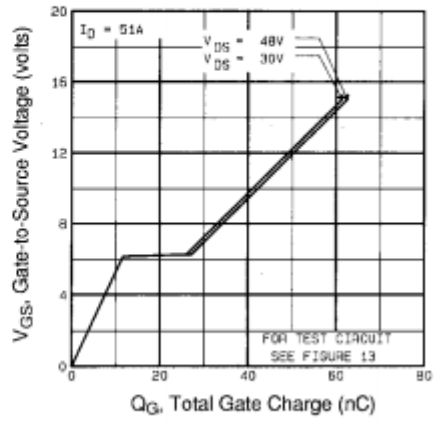
	Parameter	Max.	Units
$I_D$ @ $T_C = 25^\circ C$	Continuous Drain Current, $V_{GS} @ 10V$	50*	A
$I_D$ @ $T_C = 100^\circ C$	Continuous Drain Current, $V_{GS} @ 10V$	36	
$I_{DM}$	Pulsed Drain Current ①	200	
$P_D$ @ $T_C = 25^\circ C$	Power Dissipation	150	W
	Linear Derating Factor	1.0	W/°C
$V_{GS}$	Gate-to-Source Voltage	$\pm 20$	V
$E_{AS}$	Single Pulse Avalanche Energy ②	100	mJ
dv/dt	Peak Diode Recovery dv/dt ③	4.5	V/ns
$T_J$ $T_{STG}$	Operating Junction and Storage Temperature Range	-55 to +175	°C
	Soldering Temperature, for 10 seconds	300 (1.6mm from case)	
	Mounting Torque, 6-32 or M3 screw	10 lbf•in (1.1 N•m)	

### Thermal Resistance

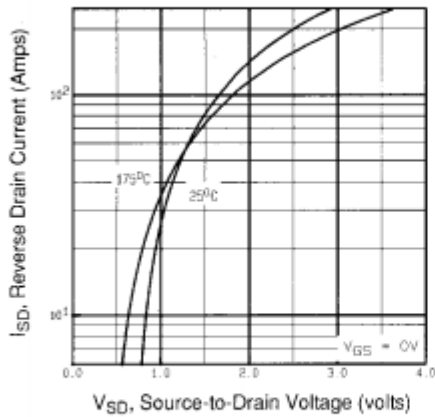
	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	—	—	1.0	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	—	0.50	—	
$R_{\theta JA}$	Junction-to-Ambient	—	—	62	



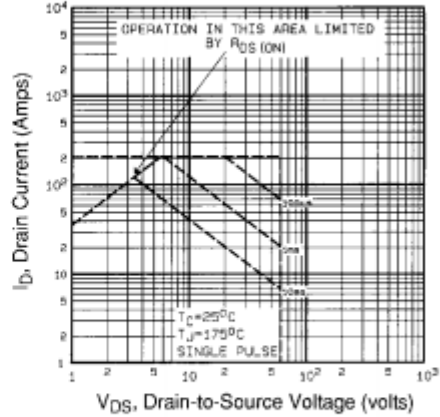
**Fig 5.** Typical Capacitance Vs. Drain-to-Source Voltage



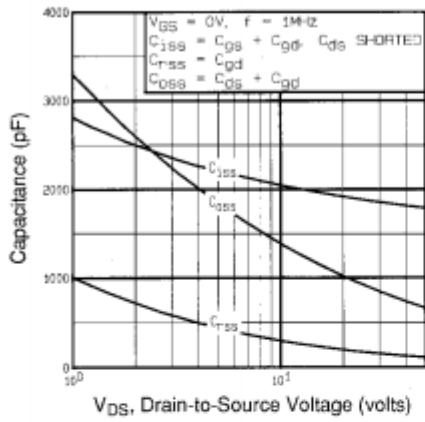
**Fig 6.** Typical Gate Charge Vs. Gate-to-Source Voltage



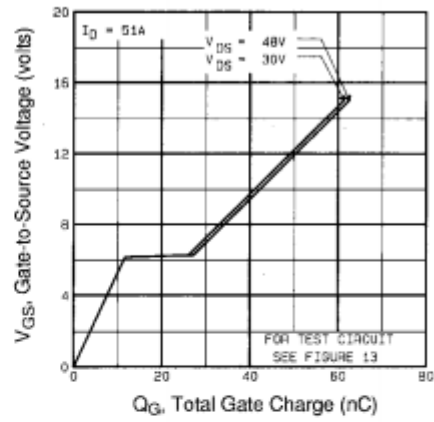
**Fig 7.** Typical Source-Drain Diode Forward Voltage



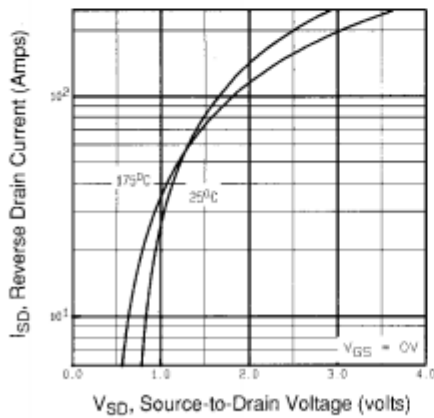
**Fig 8.** Maximum Safe Operating Area



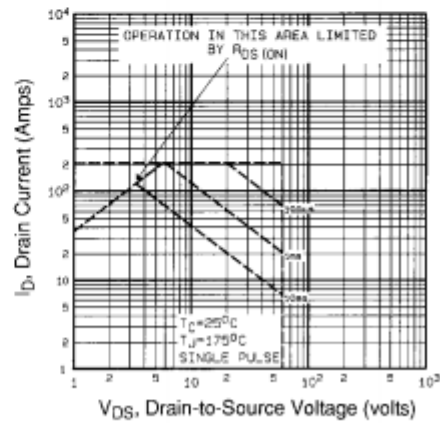
**Fig 5.** Typical Capacitance Vs. Drain-to-Source Voltage



**Fig 6.** Typical Gate Charge Vs. Gate-to-Source Voltage



**Fig 7.** Typical Source-Drain Diode Forward Voltage



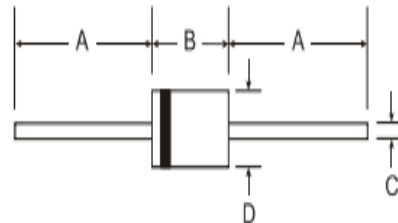
**Fig 8.** Maximum Safe Operating Area

### Features

- Diffused Junction
- High Current Capability and Low Forward Voltage Drop
- Surge Overload Rating to 30A Peak
- Low Reverse Leakage Current
- Lead Free Finish, RoHS Compliant (Note 3)

### Mechanical Data

- Case: DO-41
- Case Material: Molded Plastic. UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020D
- Terminals: Finish - Bright Tin. Plated Leads Solderable per MIL-STD-202, Method 208
- Polarity: Cathode Band
- Mounting Position: Any
- Ordering Information: See Page 2
- Marking: Type Number
- Weight: 0.30 grams (approximate)



Dim	DO-41 Plastic	
	Min	Max
A	25.40	—
B	4.06	5.21
C	0.71	0.864
D	2.00	2.72
All Dimensions in mm		

### Maximum Ratings and Electrical Characteristics @ $T_A = 25^\circ\text{C}$ unless otherwise specified

Single phase, half wave, 60Hz, resistive or inductive load.  
For capacitive load, derate current by 20%.

Characteristic	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak Repetitive Reverse Voltage	$V_{RRM}$								V
Working Peak Reverse Voltage	$V_{RWM}$	50	100	200	400	600	800	1000	V
DC Blocking Voltage	$V_R$								V
RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
Average Rectified Output Current (Note 1) @ $T_A = 75^\circ\text{C}$	$I_O$	1.0							A
Non-Repetitive Peak Forward Surge Current 8.3ms single half sine-wave superimposed on rated load	$I_{FSM}$	30							A
Forward Voltage @ $I_F = 1.0\text{A}$	$V_{FM}$	1.0							V
Peak Reverse Current @ $T_A = 25^\circ\text{C}$	$I_{RM}$	5.0							$\mu\text{A}$
at Rated DC Blocking Voltage @ $T_A = 100^\circ\text{C}$		50							
Typical Junction Capacitance (Note 2)	$C_j$	15				8			pF
Typical Thermal Resistance Junction to Ambient	$R_{\theta JA}$	100							K/W
Maximum DC Blocking Voltage Temperature	$T_A$	+150							$^\circ\text{C}$
Operating and Storage Temperature Range	$T_J, T_{STG}$	-65 to +150							$^\circ\text{C}$

