BUCK CONVERTER

(DC TO DC STEP DOWN CONVERTER)

PROJECT REPORT SUBMITTED IN PARTIAL FULFULLMENT OF THE REQUIREMENT FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING,

BY

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<u>RECOMMENDATION</u>

I hereby recommend that the project report titled "Buck Converter (DC to DC Step Down Converter)" prepared by **Debolina Majumder** (Roll No-11707675016); **Muskan Mehta** (Roll No-11701615024); **Sayani Mukherjee** (Roll No-11701615045); **Shovondev Mondal** (Roll No-11701615048); accepted in partial fulfullment of the requirement for the Degree of Bachelor of Technology in Electrical Engineering, RCC Institute of Information Technology.

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Full Signature of the Student

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CERTIFICATE

To whom it may concern

This is to certify that the project work entitled **"Buck Converter(DC to DC Step Down Converter)"** is the bona fide work carried out by ***DEBOLINA MAJUMDER*** *(ROLL NO-11701615016);* ***MUSKAN MEHTA*** *(ROLL NO-11701615024);* ***SAYANI MUKHERJEE****(ROLL-11701615045);* ***SHOVONDEV MONDAL****(ROLL-11701615048)* , a student of B.Tech in the Dept. of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India, during the academic year **2018-19**, in partial fulfillment of the requirements for the degree of Bachelor of Technology in Electrical Engineering and that this project has not submitted previously for the award of any other degree, diploma and fellowship.

Signature of the Guide	**Signature of the HOD**
Name:	**Name:**
Designation	**Designation**

Signature of the External Examiner

Name:

Designation:

: Table of Contents:

[It is standard practice, not to use serial number for ***Nomenclature, Acronyms, List of Tables, List of Figures, Abstract, Reference.*** *For* ***Appendix*** *follow serial no. as* ***A.1, A.2*** *or* ***B.1, B.2*** *....etc.]*

ABSTRACT

A Buck Converter is the basic switched-mode power supply topology. Buck converter is a DC-DC converter which will step down a higher voltage to a lower voltage level ,that means output voltage magnitude is less than the input voltage magnitude. Digital control design is done with use of Arduino Uno microcontroller. This microcontroller is used to produce Pulse Width Modulation (PWM) signal with constant duty cycle to drive the switch of the converter. The switch then will alternate turn the converter on and off to produce regulated voltage.

The Buck Converter produces voltage ranging from the input voltage to down to Zero voltage. It is widely used throughout the industry to convert higher DC input voltage into lower DC output voltage.

CHAPTER 1
INTRODUCTION

In this project we are going to make a Buck Converter Circuit using Arduino and P-Channel MOSFET(9540) with a maximum current capacity of 6amps. We are going to step down 12v DC to any value between 0 and 10v DC. We can control the output voltage value by rotating the potentiometer. **A buck converter is a DC to DC converter, which steps down DC voltage**. It is just like a transformer with one difference; whereas transformer steps down AC voltage buck converter steps down DC voltage. Efficiency of buck converter is lower than a transformer.

Key components of buck converter are mosfet; either n-channel or p-channel and high frequency Square Pulse Generator (either a timer IC or microcontroller). Arduino is used here as Pulse Generator. Here we have demonstrated this Buck converter by **controlling DC-Motor speed with Potentiometer**.

However the output power is equal to input power by assuming no power loss in the converter i.e. input power(Pin) =output power(Pout). Since Vin>Vout in this converter, obviously output current should be greater than the input current in order to have Pin=Pout to support law of conservation of energy.In buck converter, there are two filter components i.e. inductor and capacitor which are responsible for smoothening the output signal. Here inductor opposes sudden changes in input current. When switch is ON in buck converter, ihe Inductor stores the energy by the virtue of current flowing through it and it stores the energy in the form of magnetic energy and it discharges the energy when the switch goes OFF. The size of the capacitor assumed to be high in order to have high RC time constant in the output stage of the circuit. When the time constant is high compare to time period of the switch, output voltage Vo(t)=Vo constant

The output voltage is controlled by controlling the switch duty cycle. The rario of output voltage to input voltage is-

$$V_o/V_{in}=D(1/1-D)=I_{in}/I_o$$

Where, Vo and Vin are the output and input voltages, repectively. The term Io and Iin are the output and input currents,repectively.

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$$Vo/Vin=D(1/1-D)=Iin/Io$$

Where, Vo and Vin are the output and input voltages, repectively. The term Io and Iin are the output and input currents,repectively. The term D is the duty ratio and defined as the ratio of the on time of the switch to the total switching period. This shows the output voltage to be higher or lower than the input voltage, based on the duty ratio D. The dc-dc converter inputs an unregulated dc voltage input and ontput a constant or regulated voltage. Regulators can be mainly into linear and switching regulators. The regulator have a power transfer stage and a control circuitry to sense the output voltage and adjust the power transfer stage to maintain the constant output voltage.

As usually known, the conventional buck converter is widely used in the industry. DC–DC converters have been effectively controlled for many years using analog integrated circuit technology and linear system design techniques

CHAPTER 2
LITERATURE REVIEW

BUCK CONVERTER:

A buck converter is a step-down DC to DC converter. For a DC–DC converter, input and output voltages are both DC. It uses a power semiconductor device as a switch to turn on and off the DC supply to the load. The switching action can be implemented by a BJT, a MOSFET, or an IGBT. Figure 1 shows a simplified block diagram of a buck converter that accepts a DC input and uses pulse-width modulation (PWM) of switching frequency to control the switch. An external diode, together with external inductor and output capacitor, produces the regulated dc output. Buck, or step down converters produce an average output voltage lower than the input source voltage.

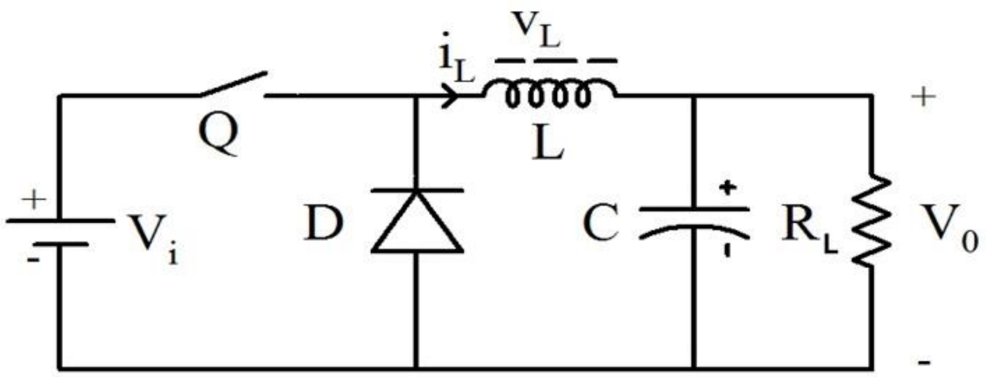


Figure 1: Buck Converter

BUCK CONVERTER OPERATION:

The operation of a buck converter happens in two modes. The first mode is when switch Q close, and the second one is when switch Q open. When switch Q closes, current flows from the supply voltage Vi through the inductor and into the load, charging the inductor by increasing its magnetic field and increasing Vo. Diode D will be on reverse bias, thus blocking the path for current.

An inductor reduces ripple in current passing through it and the output voltage would contain less ripple content since the current through the load resistor is the same as that of the inductor. At the same time, the current through the inductor increases and the energy stored in the inductor increases. When Vo reaches the desired value, switch Q is open and diode D is turned on. Figure 2 shows this mode.

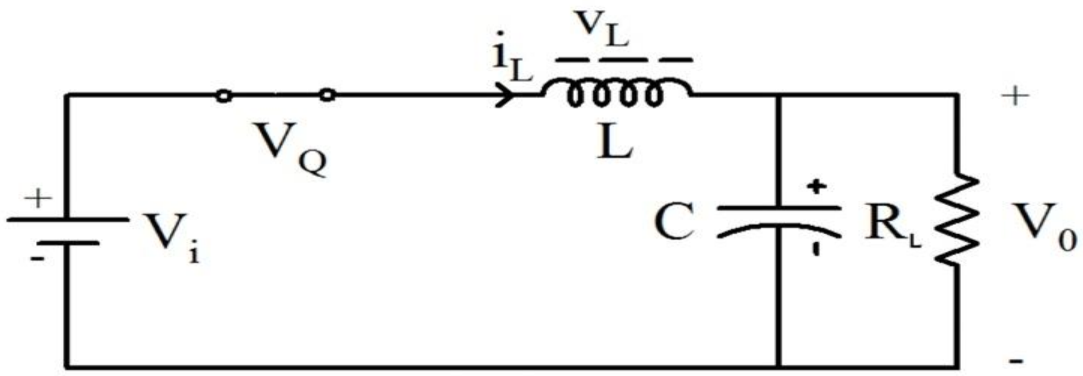


Figure 2: Switch Q closed

When the switch Q opens, the inductor acts as a source and maintains the current through the load resistor. During this period, the energy stored in the inductor decreases and its current falls. Current continues to flow in the inductor through the diode D as the magnetic field collapses and the inductor discharges. Before the inductor completely discharges, diode D is open and Q is closed and the cycle repeats. It is important that there is continuous conduction through the load for this circuit. Figure 3 shows this mode.

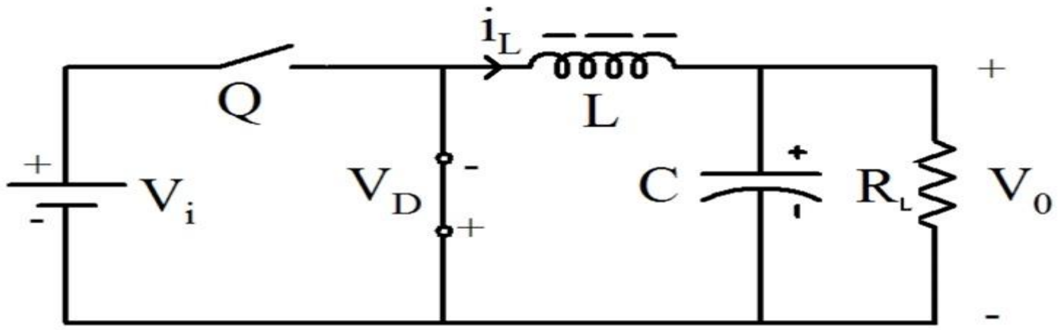


Figure 3: Switch Q open

CCM and DCM:

The buck converter can operate in two different modes; continuous conduction mode (CCM) and discontinuous conduction mode (DCM). The difference between the two is that in CCM the current in the inductor does not fall to zero.

A buck converter operates in continuous mode if the current through the inductor never falls to zero during the commutation cycle. In DCM, the current through the inductor falls to zero during part of the period. Practically, converter can operated in either operation modes. Figure 4 shows CCM and DCM mode.

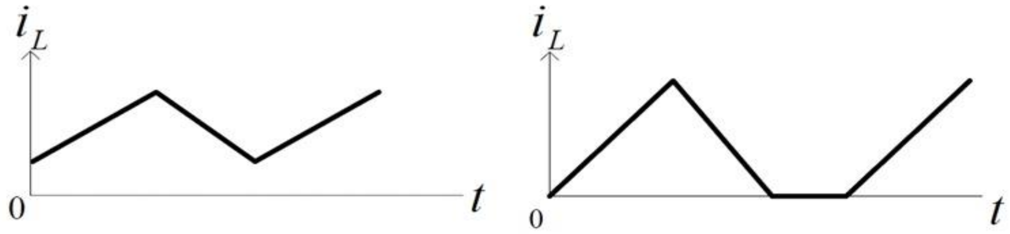


Figure 4: (a)CCM (b)DCM

.BUCK CONVERTER DUTY CYCLE:

The ratio of output voltage, Vout to input voltage, Vin can be adjusted by varying the duty cycle of switch Q. The longer Q is turned on, the greater Vout will be. The duty cycle of Q is usually called the converter's duty cycle. If the switches and the inductor are lossless, Vin is converted to Vout with no loss of power and the conversion is 100% efficient. Figure 5 shows variation of duty cycle. Duty cycle is always being presented in percentage value. A 60% duty cycle means the power is on 60% of the time and off 40% of the time.

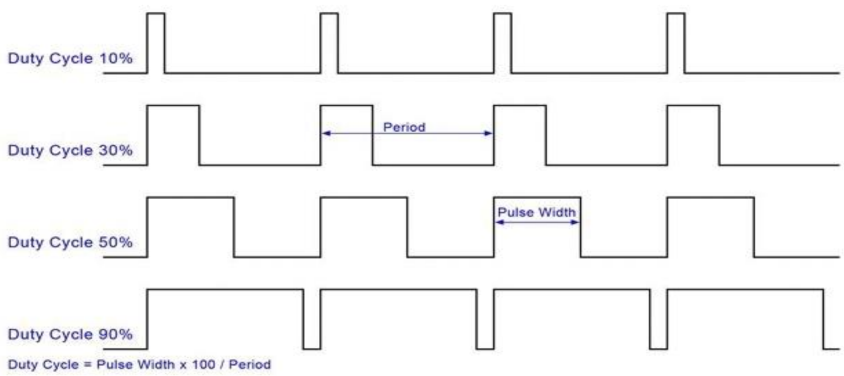
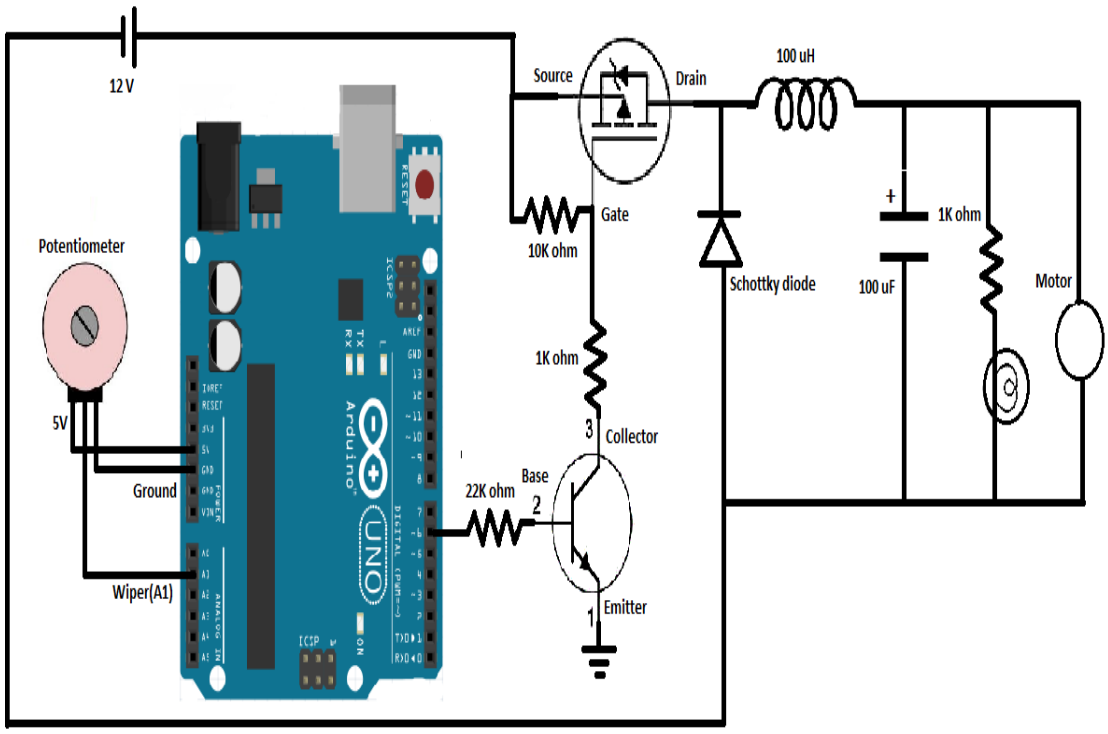


Figure 5: Duty Cycle

CIRCUIT DIAGRAM:



CHAPTER 3
MATHEMATICAL MODEL

3.1 MATHEMATICAL MODEL ANALYSIS:

Two state of operation is considered. First, switch Q turn on and D turn off. After steady state condition has been reached, switch Q will turn off and D turn on. Figure 6 shows these two operations.

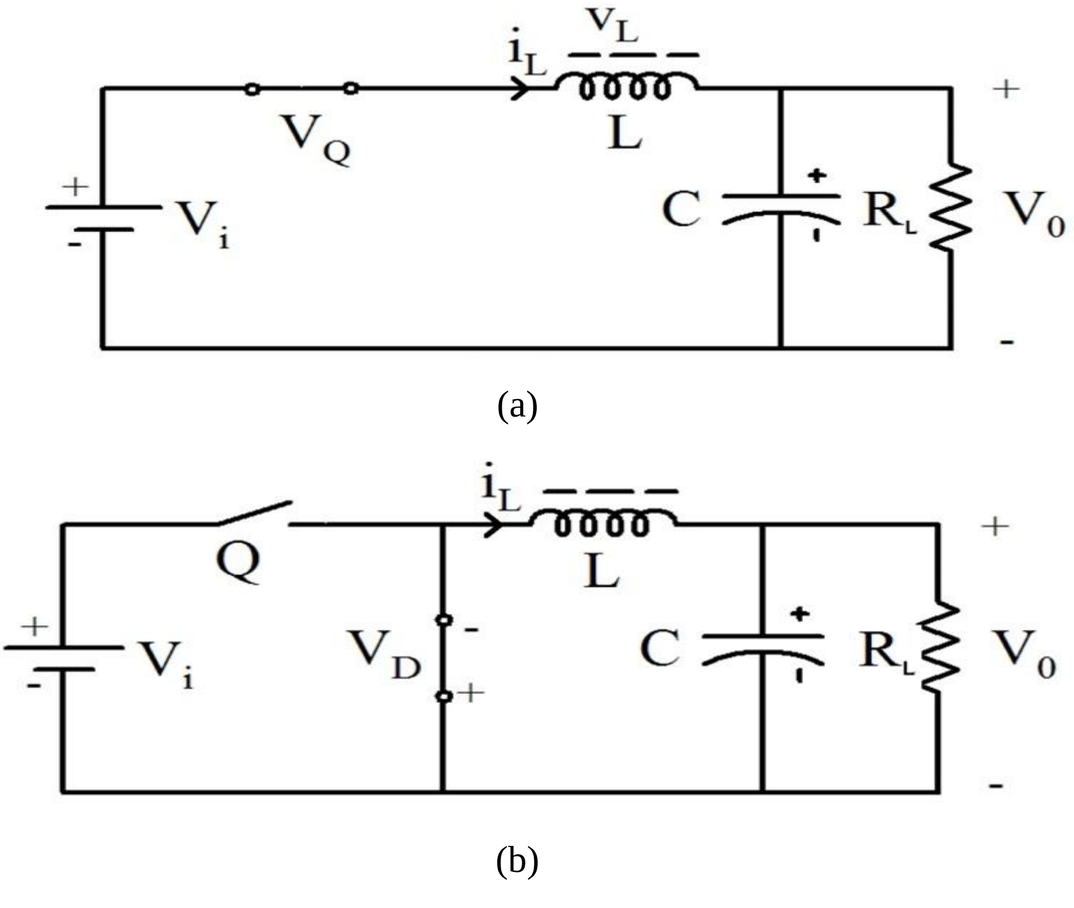


Figure 6: Buck converter operation (a) Q turn on (b) Q turn off

By using Kirchhoff's Voltage Law (KVL), the voltage across the inductor when switch Q is closed is –

$$V_L = V_i - V_Q - V_O \tag{1.0}$$

At the same time, the voltage V_L across the inductor is related to the change in current flowing through it is –

$$V_L = L(di_L / dt) \quad (1.1)$$

Put the V_L value in equation (1.0) will result in

$$L(di_L / dt) = V_i – V_Q - V_O$$

So the amount of inductor current is:

$$di_L / dt = (V_i – V_Q - V_O) / L \quad (1.2)$$

The duty cycle of the buck converter is defined as:

$$D = T_{ON} / (T_{ON} + T_{OFF}) = T_{ON} / T \quad (1.3)$$

When switch Q open, the voltage across inductor is:

$$V_L = V_O + V_D \quad (1.4)$$

Now $V_L = L(di_L / dt)$, we get

$$L(di_L / dt) = V_O + V_D$$

$$di_L / dt = (V_O + V_D) / L \quad (1.5)$$

These two equations can be equated and solved for V_O to obtain the continuous conduction mode buck voltage conversion relationship.

$$[(V_i – V_Q - V_O) / L] T_{ON} = [(V_O + V_D) / L] T_{OFF}$$

$$V_iT_{ON} - V_QT_{ON} – V_OT_{ON} = V_OT_{OFF} + V_DT_{OFF}$$

$$V_OT_{ON} + V_OT_{OFF} = V_iT_{ON} – V_QT_{ON} - V_DT_{OFF}$$

$$V_O (T_{ON} + T_{OFF}) = V_iT_{ON} – V_QT_{ON} - V_DT_{OFF}$$

$$V_OT = T_{ON} (V_i – V_Q) - V_DT_{OFF}$$

$$V_O = [T_{ON} (V_i – V_Q) - V_DT_{OFF}] / T$$

$$V_O = (V_i – V_Q)D - V_DT_{OFF} / T \quad (1.6)$$

Add using

$$(1-D) = T_{OFF} / T \tag{1.7}$$

$$V_O = (V_i - V_Q)D - V_D (1-D) \tag{1.8}$$

The steady-state equation for V_O is:

$$V_O = (V_i - V_Q)D - V_D (1-D)$$

This equation demonstrates the fact that, output voltage V_O is defined with the duty cycle, D for the converter. For this explanation, the buck converter output voltage is lower than input voltage because D is a number between 0 and 1. To generalize, V_Q and V_D are neglected because they are small enough to ignore. Simplified output voltage can be calculated by:

$$V_O = V_i D \tag{1.9}$$

In a steady state, inductor current is given by:

$$I_L = I_C + I_O \tag{1.10}$$

Since IC = 0 in steady state condition, we have:

$$I_L = I_O \tag{1.11}$$

Ohm's law required that

$$I_O = V_O / R_L \tag{1.12}$$

So the average value of I_L is:

$$I_L = I_O = V_O / R_L$$

From Figure 5 we can write:

$$I_{L(\max)} = I_L + \frac{|\Delta I_L|}{2} \tag{1.13}$$

Now we can write in equation 1.12 :

$$I_{L(\max)} = \frac{V_O}{R_L} + \frac{V_O}{2L}(1-D)T \tag{1.14}$$

Similarly from Figure 5 we can write

$$I_{L(\min)} = I_L - \frac{|\Delta I_L|}{2} \tag{1.15}$$

Or

$$I_{L(\min)} = \frac{V_O}{R_L} - \frac{V_O}{2L}(1-D)T \tag{1.16}$$

To guarantee an uninterrupted flow of IL through the inductor, we need I_L (min) > 0. So we need

$$I_{L(\min)} = \frac{V_O}{R_L} - \frac{V_O}{2L}(1-D)T > 0$$

$$\frac{V_O}{R_L} > \frac{V_O}{2L}(1-D)T$$

$$L > \frac{(1-D)}{2} T R_L$$

$$L > \frac{(1-D)}{2f} R_L$$

Where f = 1 / T

CHAPTER 4
OVERVIEW OF THE PROJECT

4.1 BLOCK DIAGRAM:

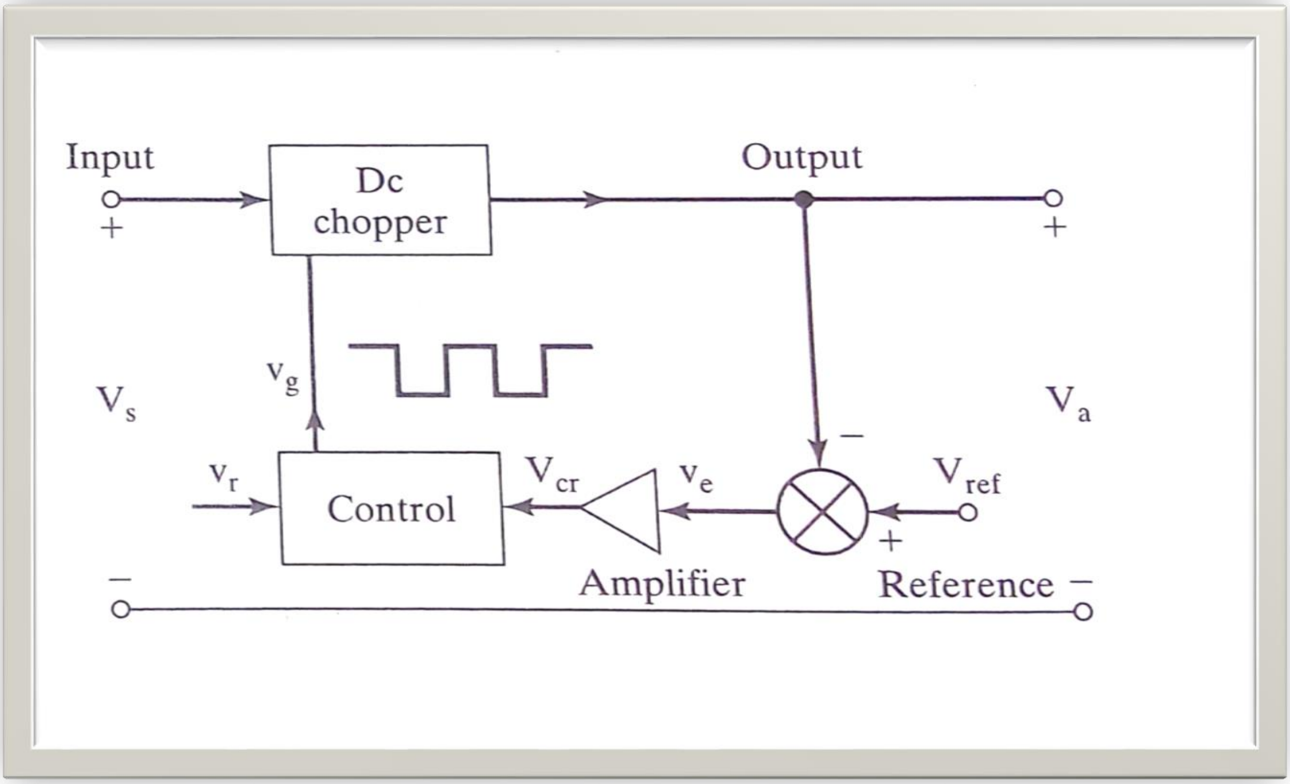


Figure 1: Block diagram of the part of this Project

Description of Project:

In DC-DC switch mode converters, a buck converter is one of the type where the output voltage is scaled down to a voltage level which the output voltage is scaled down to a voltage level which is less than the input voltage. This converter is also known as step down converter.

4.2 COMPONENTS USED, SPECIFICATION, ADVANTAGES, WORKING:

Components	Specification
Arduino Uno	16 MHz crystal oscillator, based on the ATmega328
P channel MOSFET (IRF 9540)	Drain to Source Voltage : 100V Current- Continuous Drain : 19A Input Capacitance : 1400pF Power- Max : 150W Gate Charge : 61nC FET Feature : Standard
BJT (BC 547)	Transistor Type : NPN Voltage- Collector Emitter Breakdown (Max) : 45V Current- Collector(Ic) (Max) : 100mA Power- Max : 625mW Frequency- Transition : 300MHz
Potentiometer	Tolerance : 25% Taper : Linear Operating Voltage : 20VDC or AC RMS, max Resolution : Essentially infinite Weight : 0.11gm Temperature range : -20^{0}C- +85^{0}C
Inductor	100uH

Capacitor	100 uF ,25V
Resistor	Resistor (1k ohm): Power : 0.25W Tolerance : 5% Type : Carbon Film
	Resistor (10k ohm): Power : 0.25W Tolerance : 5% Maximum Working Voltage : 250V
	Resistor (22k ohm): Power : 2W Tolerance : 5% Temperature Coefficient : 300ppm/^{0}C
Schottky diode (1N5819)	Working Peak Reverse Voltage : 40V RMS Reverse Voltage : 28V Average Rectified Forward Current : 1.0A Ambient Temperature : 75^{0}C
LED	Operating Frequency : 50-60Hz

Capacitor	100 uF ,25V
Resistor	<u>Resistor (1k ohm):</u> Power : 0.25W Tolerance : 5% Type : Carbon Film

Motor	12V DC
Bread board	Universal Solderless Breadboard : 172.5mm x 128.5mm (Minimum) DC Power Supply : +5V, +12V,-12-0-12V (variable) with 1A Pulse Generator : square, triangle, sine Frequency Range: 1Hz to 1MHz On board Section : voltmeter, CRO connector

Table 1: components used and their specification

Arduino Uno :

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, 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.. You can tinker with your UNO without warring too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

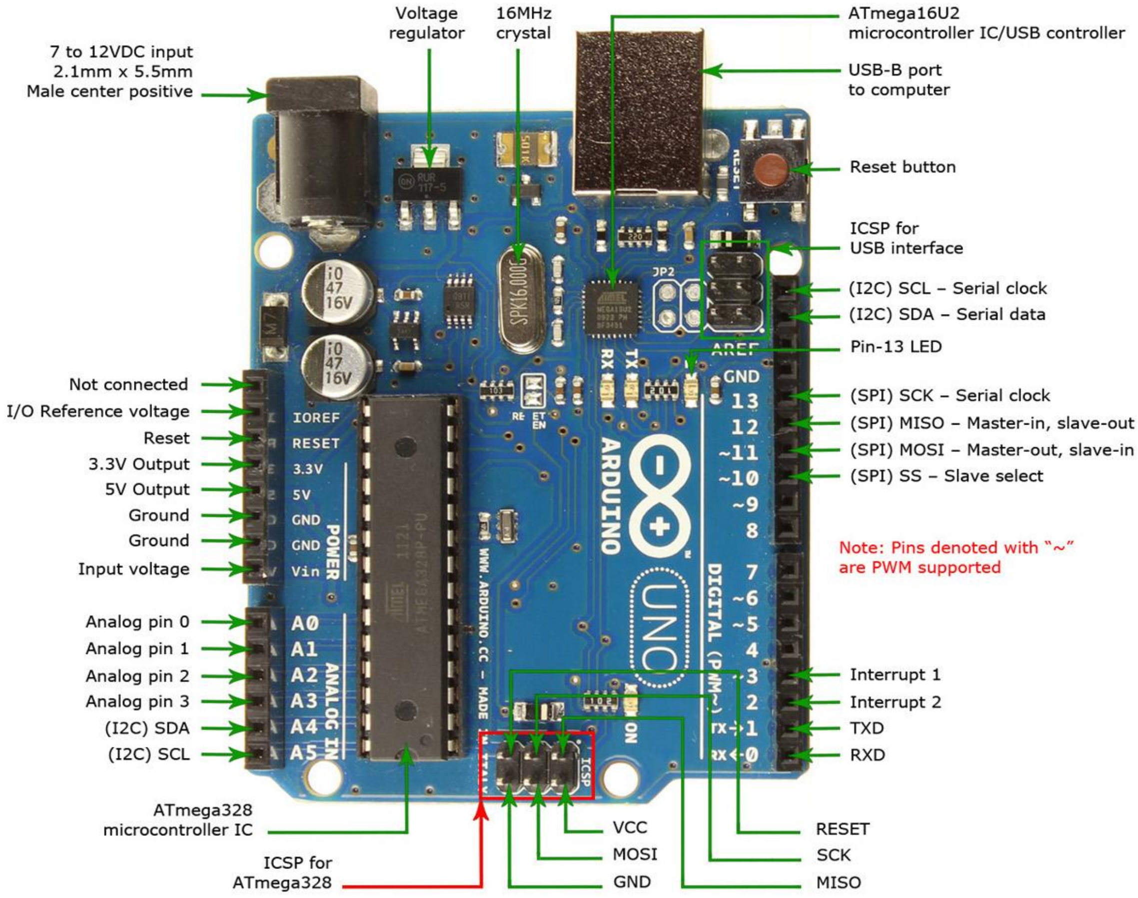


Fig-2: Description of board Arduino Uno

- **<u>Arduino Technical Specifications:</u>**

Microcontroller	ATmega328
Operating Voltage	5V
Supply Voltage (recommended)	7-12V
Maximum supply voltage	20V
Digital I/O Pins	14

Analog Input Pins	6
DC Current per I/O Pin	40mA
DC Current for 3.3V Pin	50mA
Flash Memory	32KB(ATmega328
SRAM	2KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Table- 2: Arduino-uno board Technical Specifications

Inductor:

The magnitude of switching ripple in the output voltage in a properly designed DC supply is much less than the dc component. As a result, the output voltage is approximated by its dc component and the value of inductor can be calculated

by using the defining equation of the inductor

$$V=L\, di_L/dt$$

Referring back to figure 2 for the steady state inductor current wavefom, it can be easily deduced the change in inductor current is its slope times the length of subinterval.

$$\Delta I_L = (V_G - V_O) \cdot \frac{D}{L} \cdot T_{sw}$$

The ripple requirement in inductor current sets the inductor value. Typically del I_L lies in the range of 10-20% of the full load or maximum value of the DC component of IO. The peak inductor current which is equal to the DC component plus the peak to average ripple del I_L/2,flows through the semiconductor switches and is necessary when specifying device ratings.To reduce the peak current a large value of the inductor is required. A secondary benefit in lowering the ripple current is that it reduces core/inductor, ESR and load losses.

Fig-3: Inductor

Capacitor:

The output section of the buck converter is as shown in figure. The only steady state component of output capacitor current is that arising from the inductor current ripple. Here inductor current cannot be neglected when calculating the Output voltage ripple.The inductor current contains both a DC and ripple current component. The DC component must flow entirely through the load resistance R.

While the AC switching ripple divides between the load resistance R and the filter capacitor C.

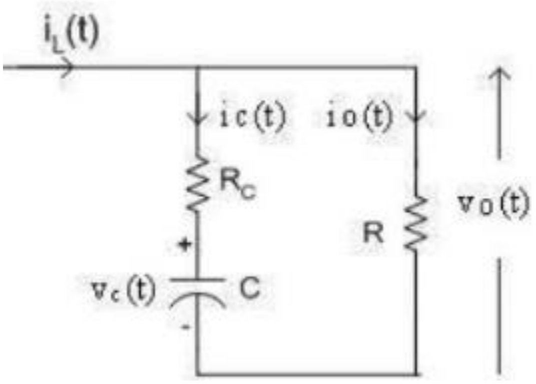


Figure 4: Output filter section-buck converter

The series impedance of R and C at switching frequency is given by

$$Z_{Rc,C} = R_C + \frac{1}{j\omega C}$$

$$\left|Z_{Rc,C}\right| = \sqrt{Rc^2 + \frac{1}{\omega^2 C^2}}$$

To ensure minimum ripple at rated output load, the equivalent condition states that the series R-C branch impedance appear resistive over the frequency band

of switching component. This is the condition of minimum ripple and is a reason for requiring low ESR

$$R_c^2 + \frac{1}{\omega^2 C^2} \ll R$$

$$C \gg \frac{1}{\omega (R^2 - R_c^2)}$$

The output voltage ripple requirement puts an upper bound on capacitor ESR.Thus the voltage ripple peak magnitude is estimated by

$$\Delta V = \Delta I_L \cdot R_c + \frac{\Delta I_L}{8 \cdot C \cdot f_{sw}}$$

$$\Delta V \cong \Delta I_L \cdot R_c$$

With the ESR requirement met, the capacitance value can be selected to achieve adequate filtering. Capacitors are typically paralleled to meet the ESR requirement. An alternate approach to reduce ΔV is to reduce ΔI but this requires a larger value of the inductor.

Power MOSFET:

MOSFETs are used as power switches for their near zero DC gate current and fast switching times. Its turn on delay time is proportional to C_{gs} which is illustrated as C_{iss} minus C_{rss} in datasheets. The delay time is equal to the product of C_{gs} and impedance of source driving it ignoring any miller effect. It is a requirement to have delay time much less than switching period. MOSFETs power dissipation impacts converter efficiency. This includes Rdson conduction losses ,leakage losses, turn on-off switching and gate transition losses. To minimize Rdson, the gate signal should be large enough to maintain operation in the linear, triode or ohmic region. MOSFET’s positive temperature coefficients mean conduction loss increases with temperature. A second important consideration when when designing gate drive circuitry is due to C_{gd} ,illustrated as C_{rss} in datasheets. During turn-on and turn-off, the large swing in V_{gd} requires extra current sourcing and sinking capabilities for the gate drive as a direct result of miller effect.

Schottky Diode:

Schottky Diode completes the loop of current when mosfet is switched off and thus ensuring smooth supply of current to load.Apart from this, schottky diode dissipates very low heat and work fine at higher frequency than regular diodes.

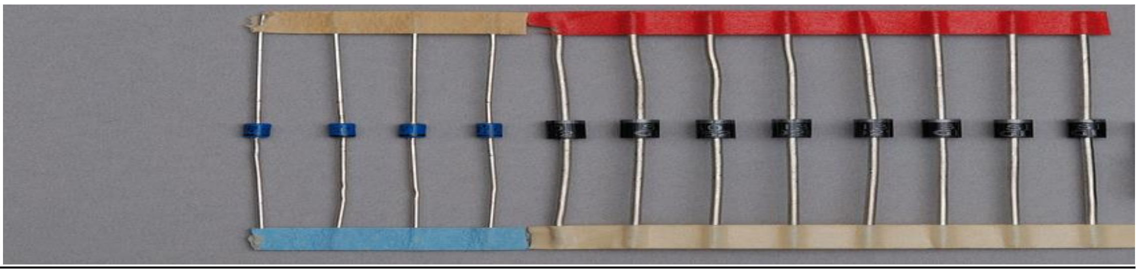


Fig-4: Schottky Diode

LED:

Brightness of LED indicates the step down voltage across load. As we rotate the potentiometer, brightness of LED varies.

Fig-5:LED

Potentiometer:

When wiper terminal of potentiometer is thrown off to different position, voltage between it and ground changes which in turn changes the analog value received by pin A1 of arduino. This new value is then mapped between 0 and 225 and then given to pin 6 of Arduino for PWM.

Fig -6: Potentiometer

BJT (BC547):

The input voltage is applied at its terminal, some amount of current starts to flow from base to the emitter and controls the current at collector. The voltage between the base and the emitter (VBE), is negative at the emitter and positive at the base terminal for its NPN construction.

Fig-7: BJT

CHAPTER 5
ALGORITHM AND SOFTWARE PROGRAM

5.1 PROGRAM OF ARDUINO:

```
int x;

int w;

int TCCROB;

void setup() {

 pinMode(6,OUTPUT);

 pinMode(A1,INPUT);

 TCCROB=TCCROB & B11111000|B00000001;

 Serial.begin(9600);

// put your setup code here, to run once:

}

void loop() {

x=analogRead(A1);

w=map(x,0,1023,0,255);

analogWrite(6,w);

Serial.print("w");

Serial.println(w);

// put your main code here, to run repeatedly: }
```

5.2 EXPLANATION :

Line 6: Normal frequency for PWM for pin 6 is approximately 1K Hz which is not suitable for buck converter, thus it is increased to 65K Hz approximately.

Line 7: Serial communication begins.

Line 11: x is assigned the analog value from pin A1 of UNO

Line 12: w is assigned the mapped value. Between 0 to 255 ADC values of UNO mapped to 2 to 255.

Line 13: Prints the mapped value on screen.

Arduino code is for generating high frequency pulses. As very high frequency, we get average value of pulsed output voltage depending on wiper terminal of potentiometer with respect to 5V terminal. As voltage between wiper terminal and ground increases ,mapped value on PWM pin 6 increases.

Let mapped value=200. Thus pin 6= (200*5)/255=3.921 V

CHAPTER 6
OBSERVATION AND RESULTS

6.1 OBSERVATION:

A buck converter (step down converter) is a class of switched-mode power supply typically containing two semiconductors and energy storage elements like capacitors and inductors. In this project , to reduce voltage ripple, filters made of capacitors are normally added to such a converter's output(load-side filter) and input(supply-side filter).
In this project, we observed different operating frequency and wave form. We also observed led in glowing position and motor (dc) was at running position. The operating frequency determines the performance of the switch. Switching frequency selection is normally determined by efficiency requirements. There is now a rising trend in research work and new power supply designs in increasing the switching frequencies. The higher is the switching frequency, the smaller the physical size and component value.
At higher frequencies the switching losses in the MOSFET increase, and therefore reduce the overall efficiency of the circuit.

6.2 RESULTS:

6.2(a) Inductor waveform:

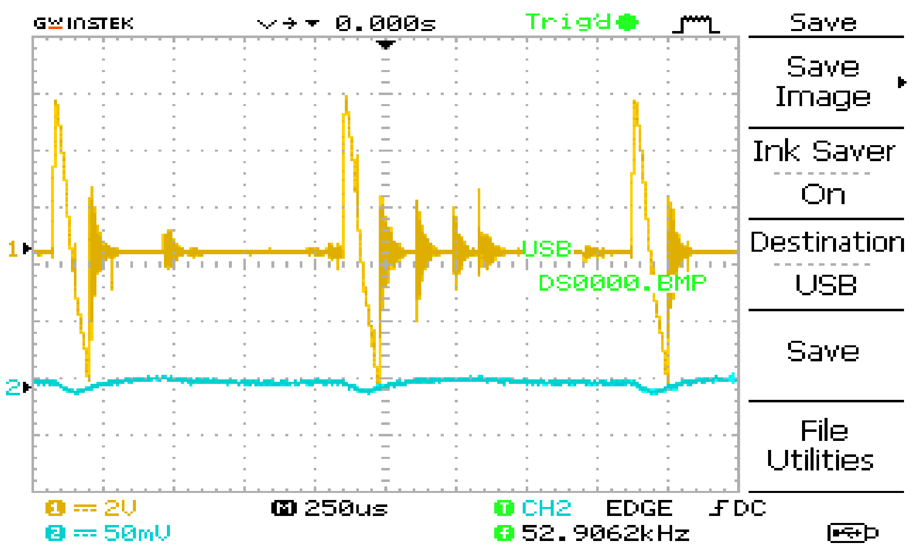


Figure 1: Inductor waveform

6.2(b) Arduino Output:

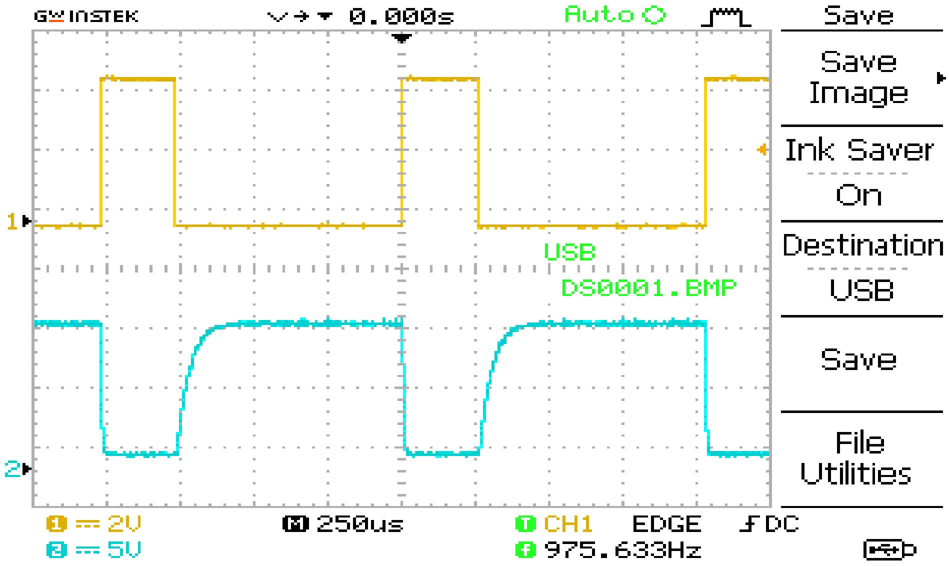


Figure 2: Arduino Output

CHAPTER 7
CONCLUSION

CONCLUSIONS :

From the simulation results it is found that in case of the buck converters, the desired output voltages can be obtained by selecting proper values of inductor, capacitor and switching frequency. All of these individual theories were difficult for anyone to grasp primarily and putting them collectively in the simulator which was extremely puzzling. But it has been done most excellent to formulate an outstanding scheme dissertation with affluent in its contest. At each stage, targets were set to acquire the necessary skills to meet the criteria of the project and design the circuits for implementation into the software and hardware simulation. This final year project gives the opportunity to study new skills and raise valuable knowledge in circuit designing and problem solving skills which has greatly enriched knowledge and understanding through the erudition route which may help one in for the further progression.

Advantages:-

A DC/DC converter is class of power supply that converts a source of direct current (DC) from one voltage level to another. There are two types of DC/DC converters: linear and switched. A linear DC/DC converter uses a resistive voltage drop to create and regulate a given output voltage, a switched-mode DC/DC converts by storing the input energy periodically and then releasing that energy to the output at a different voltage. The storage can be in either a magnetic field component like an inductor or a transformer, or in an electric field component such as a capacitor. Transformer-based converters provide isolation between the input and the output.

Switch mode converters offer three main advantages:

The power conversion efficiency is much higher.

Because the switching frequency is higher, the passive components are smaller and lower losses simplify thermal management.

The energy stored by an inductor in a switching regulator can be transformed to output voltages that can be smaller than the input (step-down or buck), greater than the input (boost), or buck-boost with reverse polarity (inverter).

Unlike a switching converter, a linear converter can only generate a voltage that is lower than the input voltage. While there are many advantages, there are also some disadvantages with switching DC/DC converters. They are noisy as compared to a linear circuit and require energy management in the form of a control loop. Fortunately, modern switching-mode controller chips make the control task easy.

LIMITATIONS:-

A buck converter converts higher voltages to lower. It's more efficient and simpler circuitry than a boost converter, but cannot produce a higher output than input. That's the gist of it.

Appendix A

A.1.

Required Components:-

- Arduino UNO
- P-channel Mosfet(IRF9540)
- Capacitor(100µf)
- Resistor(10kohm,100ohm,4.7kohm,22kohm)
- Inductor(100µh)
- BJT(BC547)
- Load
- CRO
- Bread Board
- LED
- Schottky Diode
- 12V supply
- Potentiometer(100kΩ)
- Connecting Wires

A.2.

Cost Of Implementation:-

Arduino UNO - 390/-

•P-channel Mosfet(IRF9540)-10/-

•Capacitor(100µf) - 4/-

•Resistor(10kohm,100ohm,4.7kohm,22kohm)- 8/-

•BJT(BC547)- 45/-

•Load-25/-

•Bread Board- 80/-

•LED -2/-

•Schottky Diode-4/-

•12V supply - 40/-

•Potentiometer(100kΩ)- 20/-

•Connecting Wires - 45/-

- **TOTAL COST: Rs 750 (approx.)**

References:

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