CONSTANT DC OUTPUT BOOST CONVERTER FOR SOLAR SYSTEM SOURACE MODEL

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Abstract

A Neural network controller of DC-DC boost converter is designed and presented in this project. In order to control the output voltage of the boost converter, the controller is designed to change the duty cycle of the converter. The mathematical model of boost converter and neural network controller are derived to design simulation model. The simulation is developed on Matlab simulation program. To verity the effectiveness of the simulation model, an experimental set up is developed. The boost circuit with mosfet as a switching component is developed. The neural network controller to generate duty cycle of PWM signal is programmed. The simulation and experimental results show that the output voltage of the boost converter can be controlled according to the value of duty cycle.

ABSTRAK

Sebuah pengawal alat peranti neural boost DC-DC direka dan dihasilkan dalam projek ini. Untuk mengendalikan tegangan output dari alat peranti boost, alat pengawal direka untuk menukar kerja-kerja kitaran dari alat peranti. Model matematik dari peranti boost dan pengawal neural network yang diperolehi dan direka digunakan sebagai model simulasi. Simulasi dibangunkan dalam program Matlab. Untuk menunjukkan hasil keberkesanan yang sebenar, sebuah peranti eksperimental dibangunkan. Rangakaian buck-boost beserta dengan mosfed dibangunkan sebagai komponen pertukaran pengawal neuralnetwork untuk menghasilkan kerja-kerja kitaran dari isyarat PWM yang telah diprogramkan. Simulasi dan hasil percubaan menunjukkan bahawa voltan keluaran dari peranti boost boleh dikawal sesuai dengan nilai kitaran kerja.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

DC	-	Direct Current
D	-	Duty cycle
MATLAB	-	Matrix Laboratory
DSP	-	Digital signal Processes
PI	-	Proportional plus Integral
PMSG	-	Permanent Magnet Synchronous Generator
DFIG	-	Doubly Fed Induction Generator
PWM	-	Pulse Width Modulation
SIMULINK	-	Simulation and Link
IGBT	-	Insulated Gate Bipolar Transistor
MOSFET	-	Metal Oxide Semiconductor Field-Effect Transistor
S	-	Switch
VDC	-	Voltage Direct Current
Vr	-	Voltage Reference
Vo	-	Voltage output
Fr	-	Frequency Reference
Vc	-	Voltage Carrier
Fc	-	Frequency Carrier
MF	-	Modulation Frequency

MI	-	Modulation Index
MLP	-	Multilayer Perceptron
BPNN	-	Backpropagation Neural Network
PCB	-	Printed Circuit Board

CHAPTER 1

INTRODUCTION

1.1 Project Background

The solar energy is one of the resources renewable energy, clean, plentiful and thanks to today's technologies, easy to get it. Every single day enough solar energy strikes the planet to meet the world's energy needs for four to five years. Solar energy can become an incredibly valuable solution for helping to protect our planet [1].

The solar energy is one of the resources renewable energy, clean, plentiful and thanks to today's technologies, easy to get it. Every single day enough solar energy strikes the planet to meet the world's energy needs for four to five years. Solar energy can become an incredibly valuable solution for helping to protect our planet.

Solar cells, which are the foundation of Photovoltaic PV systems, convert the energy in sunlight directly into electricity. A number of solar cells electrically connected to each other and mounted in a support structure or frame is called a photovoltaic module. Modules are designed to supply electricity at a certain voltage, such as common (12V) system. Multiple modules can be wired together to form an array. In general, the larger the area of a module or array, the more electricity that will be produced. Photovoltaic modules and arrays produce DC current electricity. The current produced is directly dependent on how much light strikes the module.

There are two different types of solar energy systems that will convert the solar resource into electricity; the first type is by collecting solar energy as heat and converting it into electricity using a typical power plant or engine; the second type is by using photovoltaic PV cells to convert solar energy directly into electricity.

The solar energy conversion systems can be connecting to a large electrical transmission grid, or to the storage or auxiliary energy supply. Auxiliary energy may be supplied either as heat before the power conversion system, or as electricity after it. If the photovoltaic route is chosen, extra electricity may be stored, usually in storage batteries, thereby extending the operating time of the system, the (typical 12V) storage batteries are ordinary used in the home solar conversion systems to satisfy its operation and maximize power tracking purpose. The objective is to collect the maximum possible power from solar panels at all times, regardless of the load.

The DC-DC converter is an electrical circuit that transfers energy from a DC voltage source to a load. The energy is first transferred via electronic switches to energy storage devices and then subsequently switched from storage into the load. The switches are transistors and diodes; the storage devices are inductors and capacitors. This process of energy transfer results in an output voltage that is related to the input voltage by the duty ratios of the switches.

There are many types of dc-dc converter which is buck (step down converter, boost (step-up) converter, and buck-boost (step up- step-down) convertor.

Boost converter is an intriguing subject from the control point of view, due to its intrinsic non-linearity. Common control approaches like voltage control and current injected control, require a good knowledge of the system and accurate tuning in order to obtain performances.

Nowadays, neural network controllers have been used in many industrial applications and also power electronic drives in order to improve performance without having to develop mathematical model of the system. The main feature of a neural network is that it can convert the linguistic control rules based on expert knowledge into automatic control strategy. So it can be applied to control systems with unknown or unmodelled dynamics. [2]

General idea of dc-dc converter to convert a fixed voltage dc source into a variable voltage dc source.The output voltage of the dc-dc converter can be higher or lower than the input. Dc-Dc Converter widely used for traction motor in electric automobiles, trolley cars, marine hoists, and forklift trucks. They provide smooth acceleration control, high efficiency, and fast dynamic response. Dc converter can be used in regenerative braking of dc motor to return energy bake into the supply, and this feature results in energy saving for transportation system with frequent stop and also are used, in dc voltage regulation.

1.2 Problem Statements

In this project the problem statements are how to develop simulation model of boost converter and neural network controller to control duty cycle of PWM signal generator to ensure the output voltage of converter be constant with change in input voltage.

1.3 Objectives of the Project

The major objectives of this research are.

1. To develop modelling DC Converter input voltage using MATLAB
2. To develop neural network control for DC Converter to get constant output from variable input.

1.4 Scopes of the project

Simulation consists of -:

a) Modelling DC to DC boost converter.

b) Modelling neural network controller

c) Development of modelling of boost converter by using MATLAB SIMULINK software

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter includes the study of dc-dc converter and its system it also focus on controller used in this project.

2.2 Controller Development

Switching control techniques of the nonlinear DC-DC converter has been great issues in power conversion system. Usually, the control problem consists in defining the desired nominal operating conditions and regulating the circuit so that it stays close to the nominal, when the system is subject to external disturbances and internal variations. Modeling errors also can cause its operation to deviate from the nominal value. Many approaches for designing controller for boost converter has been deeply studied and conducted to obtain high quality and reliable power conversion system.

In the past decade, basically switching control enlightened towards the applications of Proportional-Integral (PI); enhanced to Proportional-Integral-Derivative (PID) controllers. A study [3] shows that these classical control methods are very efficient when the converter model is well-known; the working-point of the load is well defined. If the dynamics of the whole converter is more complex, varying and/or uncertain, advanced control laws have to be introduced.

The controller must keep the DC-DC converter within a certain percentage of the specified nominal operating points in the presence of disturbances and modeling errors.

Unfortunately, PID controller does not always full fill the above mentioned control specifications, especially when disturbance rejection and transient response time requirements are concerned, due to the highly nonlinear characteristics of the converter. PID will suffer from dynamic transient time response; higher overshoot and longer rise time reported by Loic Michel, I. [4].

A large number of possible intelligence controllers among others, fuzzy logic control, neural network control and hybrid neuro-fuzzy control have been reported in M. Milanovic and D. Gleich (2005). Many types of controllers have been proposed on the previous papers.

By referring to the (K.H. Cheng, et al., 2007), the research focused on an efficient simulation model of Cuk converter by applying the fuzzy-neural sliding mode control (FNSM) as the controller. The simulation model of FNSM developed improved the dynamic characteristics of boost converter. The fuzzy logic controller is designed purposely to ensure the converter system is able to reach the steady state condition in a short time. The result obtained from fuzzy logic controller will compared with the PID controller. The result shows that the fuzzy logic controller is better performance compared with PID controller.

Development of Proportional-Derivative and Integral (PD-I) type Fuzzy-Neural Network Controller (FNNC) based on Takagi-Sugeno fuzzy model is proposed for boost converter to achieve satisfied performance under steady state and transients conditions presented in [5]. The PD-FNNC is activated during transient states and the PI-FNNC is activates in steady state region.

After the pioneering studies done by [6], a great deal of research has been directed at developing techniques for averaged modeling of different classes of switching converters [7] and for an automatic generation of the averaged models. The motivation of such studies was the simplest possible selection of continuous models adequate to capture all the main features of the switching converters in term of stability, dynamic characteristics, and effectiveness of the design.

Rapid technologies discover intelligent controls of neural network controllers (NNC) has great capability to adapt by updating its learning process using back propagation and sensitivity adjustment. Therefore it is suitable for nonlinear control system. NNC found to be improving the dynamic characteristic of the converter compared with the conventional method. Voltage tracking of boost converter using NNC demonstrates the results in achieving the minimum error between regulated DC output voltage and reference voltage injected to the system. This has been verified in [8]. From the simulation results, it shows that when the proposed NNC is trained with back propagation algorithm, the overshoot has been greatly decreased and the boost converter output voltage can reach its steady state faster. In the case of load disturbances, the NNC can shorten the settling time compared with ordinary PID control with a better tracking performance.

2.3 Types of photovoltaic

Photovoltaic power systems are generally classified according to their functional and operational requirements, their component configurations, and how the equipment is connected to other power sources and electrical loads. The two principal classifications are grid-connected or utility-interactive systems and stand-alone systems. Photovoltaic systems can be designed to provide DC and/or AC power service, can operate interconnected with or independent of the utility grid, and can be connected with other energy sources and energy storage systems.

There are 3 basic types of construction of PV panels as following:

1. Monocrystalline cells are cut from a single crystal of silicon- they are effectively a slice from a crystal. In appearance, it will have a smooth texture and you will be able to see the thickness of the slice. These are the most efficient and the most expensive to produce. They are also rigid and must be

2. Mounted in a rigid frame to protect them. The efficiency of this type is between 11%-16%.

3. Multicrystalline cells are effectively a slice cut from a block of silicon, consisting of a large number of crystals. They have a speckled reflective appearance and again you can you see the thickness of the slice. These cells are slightly less efficient and

slightly less expensive than monocrystalline cells and again need to be mounted in a rigid frame. The efficiency of this type is between 9%-13%

4. Amorphous cells are manufactured by placing a thin film of amorphous (non crystalline) silicon onto a wide choice of surfaces. These are the least efficient and least expensive to produce of the three types. Due to the amorphous nature of the thin layer, it is flexible, and if manufactured on a flexible surface, the whole solar panel can be flexible. One characteristic of amorphous solar cells is that their power output reduces over time, particularly during the first few months, after which time they are basically stable. The quoted output of an amorphous panel should be that produced after this stabilization. The efficiency of this type is between 3%-6%.

2.4 Why silicone materials excel in solar applications?

1. Silicones are renowned for their UV stability and moisture resistance.
2. Silicones are durable and solar radiation resistant.
3. Silicones have excellent electrical insulating properties –excellent dielectric strength and high volume resistivity.
4. Silicones have low ionic impurities, low moisture absorption, and low dielectric constant.
5. Silicone encapsulates perform over a wide operating temperature range – from -40 to 150°C (-40 to 302°F).
6. Silicones are optically transparent over a wide spectrum.
7. Silicones offer excellent adhesion to glass and photovoltaic cell substrates.

2.5 How does photovoltaic work?

PV cells convert sunlight directly into electricity without creating any air or water pollution. PV cells are made of at least two layers of semiconductor material. One layer has a positive charge, the other negative. When light enters the cell, some of the photons from the light are absorbed by the semiconductor atoms, freeing electrons from the cell's negative layer to flow through an external circuit and back into the positive layer. This flow of electrons produces electric current. To increase their utility, dozens of individual PV cells are interconnected together in a sealed, weatherproof package called a module. When two modules are wired together in series, their voltage is doubled while the current stays constant. When two modules are wired in parallel, their current is doubled while the voltage stays constant. To achieve the desired voltage and current, modules are wired in series and parallel into what is called a PV array. The flexibility of the modular PV system allows designers to create solar power systems that can meet a wide variety of electrical needs, no matter how large or small

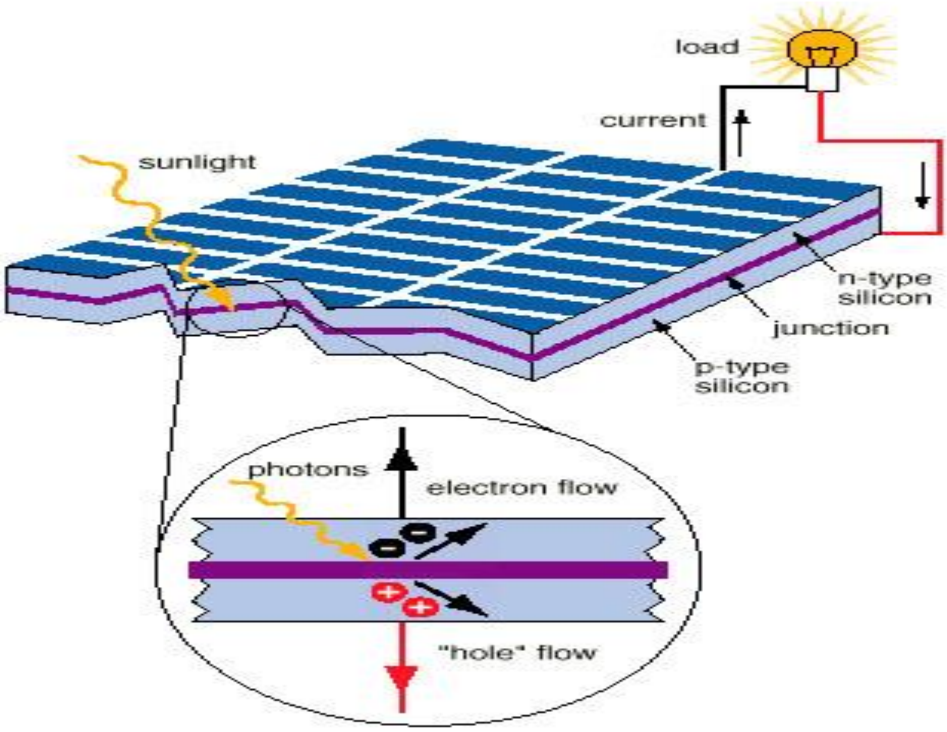


Figure 2-1 show how the photovoltaic produce current

2.6 DC-DC converters

The DC-DC converter is an electrical circuit that transfers energy from a DC voltage source to a load. The energy is first transferred via electronic switches to energy storage devices and then subsequently switched from storage into the load. The switches are transistors and diodes; the storage devices are inductors and capacitors. This process of energy transfer results in an output voltage that is related to the input voltage by the duty ratios of the switches.

DC conversion is of great importance in many applications, starting from low power applications to high power applications. The goal of any system is to emphasize and achieve the efficiency to meet the system needs and requirements. Several topologies have been developed in this area, but all these topologies can be considered as apart or a combination of the basic topologies which are buck, boost and flyback [9]

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

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

In recent pass, DC power supplies are extensively utilized in many areas compromising of simple electronic devices such as notebook computers, till even more advance application such as electric vehicle and also the aerospace applications. Hence, the DC- DC converter is widely used by convert a DC voltage to a different DC voltage level in order to provide the DC voltage source level requirements of the load to the DC power supply, In addition, the DC-DC converter is also an important application for the power conditioning of the alternative electrical energy such as photovoltaic, wind generator and fuel cell system. Due to these reasons, the DC-DC converter application will head to a more potential market in the future.

Basically, the DC-DC converter consists of the power semiconductor devices which are operated as electronic switches and classified as switched-mode DC-DC converters or normally refers as Switched mode power supply [SMPS]. Operation of the switching devices causes the inherently nonlinear characteristic of the Buck-Boost converters. Due to this unwanted nonlinear characteristics, the converters requires a controller with a high degree of dynamic response. Recently, the research on the switching control techniques has been highlighted in order to achieve a high-quality power system. Pulse Width Modulation (PWM) is the most frequently consider method among the various switching control method [1].

In the past decade, the controller for the PWM switching control is restraining to Proportional-Integral-Differential (PID) controller. This controller often applied to the converters because of their simplicity. However, implementations of this control method to the nonlinear plants such as the power converters will undergo from dynamic response of the converter output voltage regulation. In general, PID controller produces long rise time when the overshoot in output voltage decreases [2].

In order to tackle this problem and improve the dynamic response of DC-DC converters, several intelligence controllers such as fuzzy logic control, neural network control and hybrid neuro-fuzzy control methods for DC-DC converter have been reported in [3]-[8]. The purpose and utilization of the fuzzy controller for dc-dc converter has been developed in [5]. Implementations of the fuzzy logic control to dc-dc converter using micro controller have been verified in [6]. Inherently, the relatively simple fuzzy controller has a good performance for those systems where linear control technique fail and can apply to any dc-dc converter topologies.

Due to lack of formal analysis and synthesis technique [4] it has not been viewed as a rigorous science, even though many practical successes has been achieved by the fuzzy logic controllers, hence, a lot of research has been carried out to improve the control system. A fuzzy-neural sliding-mode (FNSM) control system is one of the approaches that develop to control power electronic converters [3] for a PWM-based power electronic system. The FNSM control system consists of a compensation controller and a neural controller where the compensation robust controller is designed to recover the residual of the approximation error, while the neural controller is designed to approximate an ideal controller. An Adapt recurrent fuzzy neural network (ARFNN) control system is proposed in [4] in order to achieve good regulation performances. With the on-line learning algorithm is applied, the ARFNN control scheme is suitable to control the dc-dc converter.

2.7 Functions of DC-DC converters

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

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

ii. Regulate the DC output voltage against load and line variations.

iii. Reduce the AC voltage ripple on the DC output voltage below the required level.

iv. Provide isolation between the input source and the load (if required).

v. Protect the supplied system and the input source from electromagnetic interference

The DC-DC converter is considered as the heart of the power supply, thus it will affect the overall performance of the power supply system. The converter accepts DC and produces a controlled DC output.

2.8 Boost converter

The boost converter is capable of producing a dc output voltage greater inmagnitude than the dc input voltage. The circuit topology for a boost converter is a shown in figure 2.1.

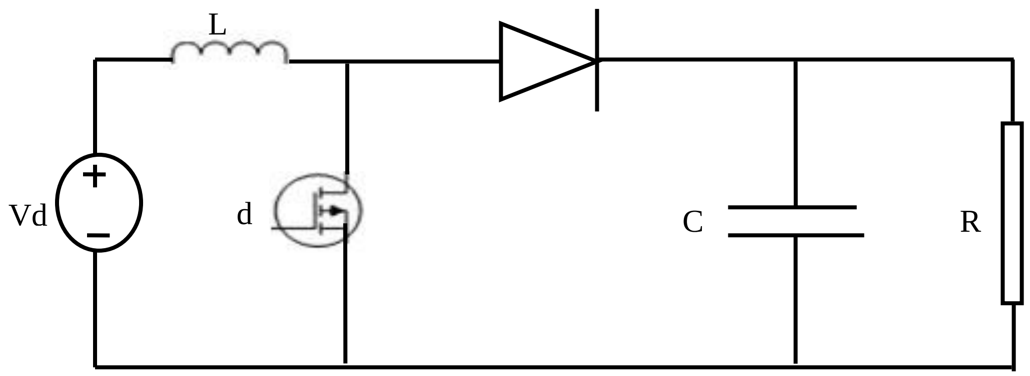
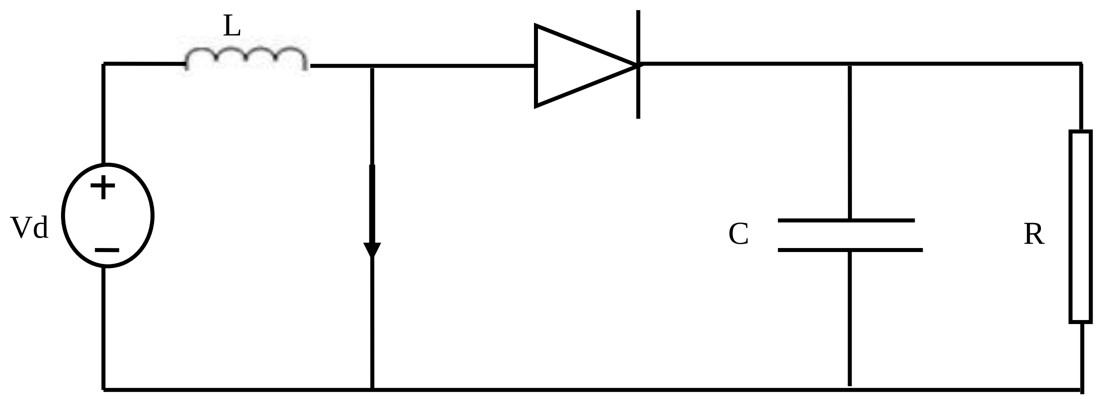
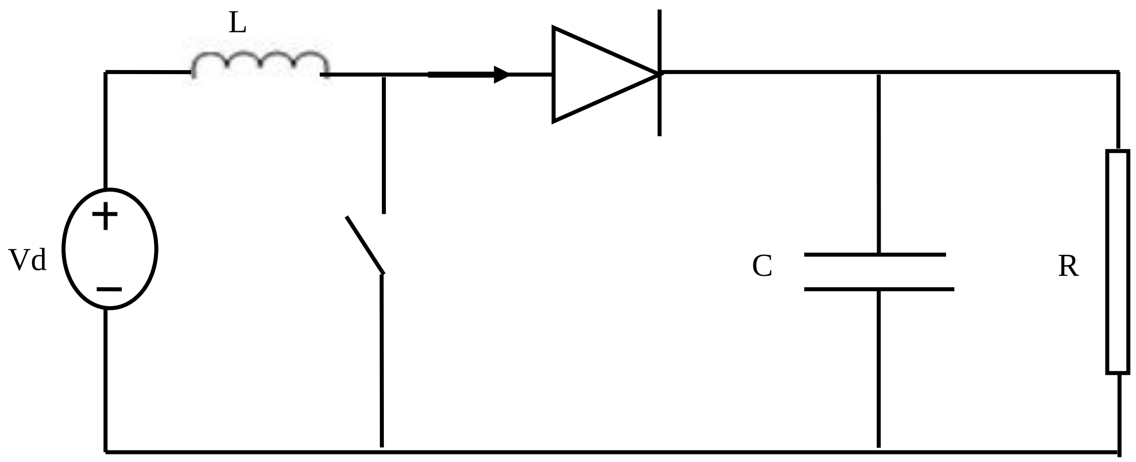


Figure 2.1: Boost Converter



Mode 1(circuit when switch is closed)



Mode 2(circuit when switch is closed)

Figure 2.2: equivalent circuits of boost converter

The circuit operation divided into two modes , When the transistor Q1 is on the current in inductor L, rises linearly and at this
time capacitor C, supplies the load current, and it is partially discharged. During the second interval when transistor Q1 is off, the diode D1, is on and the inductor L, supplies
the load and, additionally, recharges the capacitor C. The steady state inductor current
and voltage waveform is shown in figure 2.3.

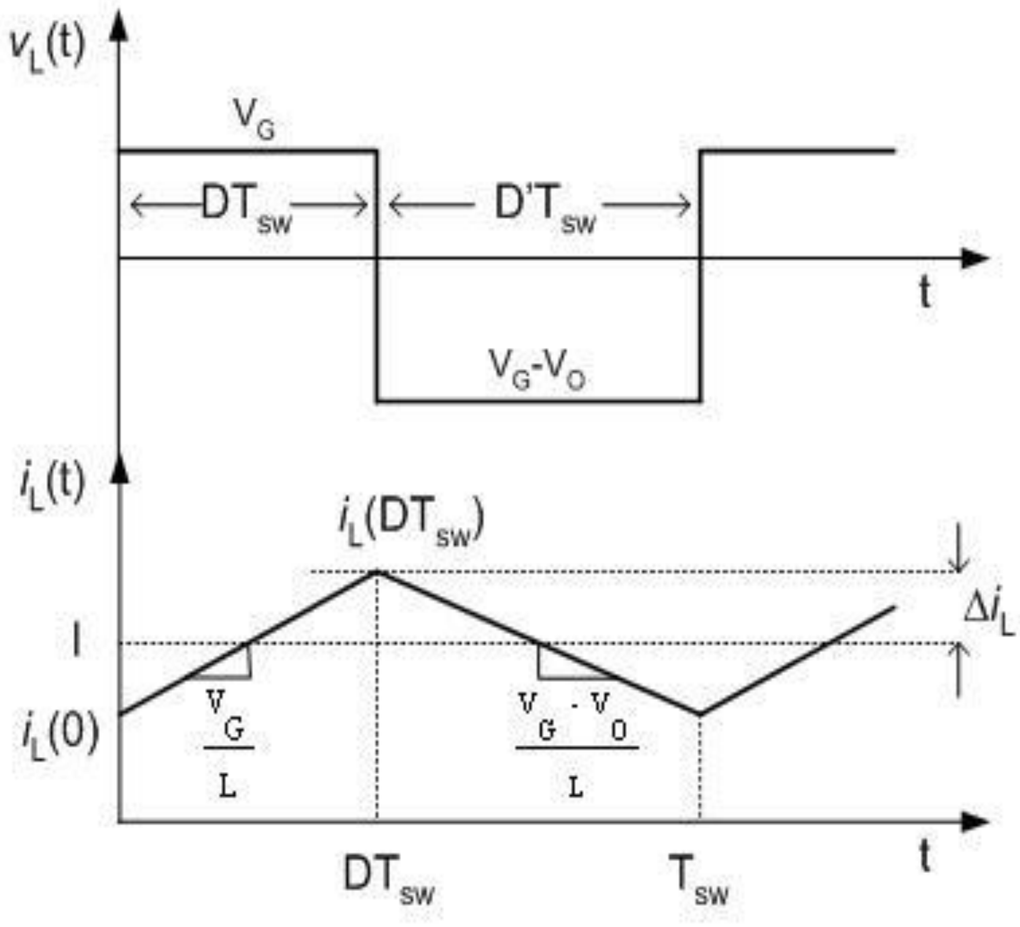


Figure 2.3: waveforms of boost converter

The rate of change of inductor current is a constant, indicating a linearly increasing inductor current. The preceding equation can be expressed as

$V_L = V_d$

$=L\frac{di_L}{dt} \Longrightarrow$

$\frac{di_L}{dt} = \frac{Vd}{L}$

$\frac{di_L}{dt} = \frac{\Delta i_L}{DT} = \frac{V_d}{L}$ (2.1)

Solving for Δi_L when the switch is closed

$(\Delta i_L)closed = \frac{V_d DT}{L}$ (2.2)

When the switch is opened, current will be reduced as the impedance is higher. Therefore, change or reduction in current will be opposed by the inductor. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

$v_L = V_d - V_o$ (2.3)

$= L\frac{di_L}{dt}$

$\Rightarrow \frac{di_L}{dt} = \frac{V_d - V_o}{L}$

$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t}$ (2.4)

$=\frac{\Delta i_L}{(1-D)T}$

$\Rightarrow \frac{di_L}{dt} = \frac{V_d - V_o}{L}$ (2.5)

$\Rightarrow (\Delta i_L)opened = \frac{(V_d - V_o)(1-\mathrm{DT})}{L}$

(2.5)

For steady-state operation, the net change in inductor current must be zero over one period using Equation .2.2 and 2.5

$$(\Delta i_L)closed + (\Delta i_L)opened = 0$$

$$\frac{V_d DT}{L} + \frac{(V_d - V_o)(1-\mathrm{DT})}{L} = 0$$
(2.6)

Solving for Vo,

$$V_o = \frac{V_d}{1-D} \quad (2.7)$$

Equation 2.7 shows 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 produces output voltage that is greater or equal to the input voltage.

• Alternative explanation:

  – when switch is closed, diode is reversed. Thus output is isolated. The input supplies energy to inductor.
  – When switch is opened, the output stage receives energy from the input as well as from the inductor. Hence output is large.
  – Output voltage is maintained constant by virtue of large C.

Power absorbed by the load must be the same as that supplied by the source,

Input=output

$$P_d = P_0$$

$$P_d = V_d I_d \quad (2.8)$$

$$P_o = \frac{V_0^2}{R} \quad (2.9)$$

From equation (2.8) and (2.9)

$$V_d I_d = \frac{V_0^2}{R} \Rightarrow$$

$$V_d I_d = \frac{\left(\frac{V_d}{(1-D)}\right)^2}{R} = \frac{V_d^2}{(1-D)^2 \, R} \quad (2.10)$$

Average inductor current,

Substituting for VO using Eqe 2.7 and solving for

$$I_l = \frac{V_d}{(1-D)^2 \, R} \quad (2.11)$$

Maximum inductor current,

$$I_{max} = I_l + \frac{\Delta i_L}{2} = \frac{V_d}{(1-D)^2 \, R} + \frac{V_d DT}{2L} \quad (2.12)$$

Minimum inductor current,

$$I_{max} = I_l - \frac{\Delta i_L}{2} = \frac{V_d}{(1-D)^2 \, R} - \frac{V_d DT}{2L} \quad (2.12)$$

Output voltage ripple

The output voltage ripple for the buck boost converter is computed from the capacitor current waveform

$$|\Delta Q| = \left(\frac{V_0}{R}\right) DT = C \Delta V_O$$

(2.13)

Solving for ΔV_O,

$$\Delta V_O = \frac{V_O D}{RCf}$$

$$r = \frac{\Delta V_O}{V_O} = \frac{D}{RCf}$$
(2.14)

2.9 MOSFET Transistor

The word MOSFET actually stands for Metal Oxide Semiconductor Field-Effect Transistor. This particular device, which is used to amplify or switch electronic signals,
is by far the most common field-effect transistor in both digital and analog circuits .
There are two types of MOSFETs which are N-channel type and P channel type.
When voltage to the gate is not supplied, the electric current doesn't flow between drain and source. When positive voltage is applied to the gate of the N-channel MOSFET, the electrons of N-channel of source and drain are attracted to the gate and go into the P-channel semiconductor among both .With the move of these electrons, it 15 becomes the condition which spans a bridge for electrons between drain and source. The size of this bridge is controlled by the voltage to apply to the gate. The following Figure 2.4 show symbol of MOSFET transistor.

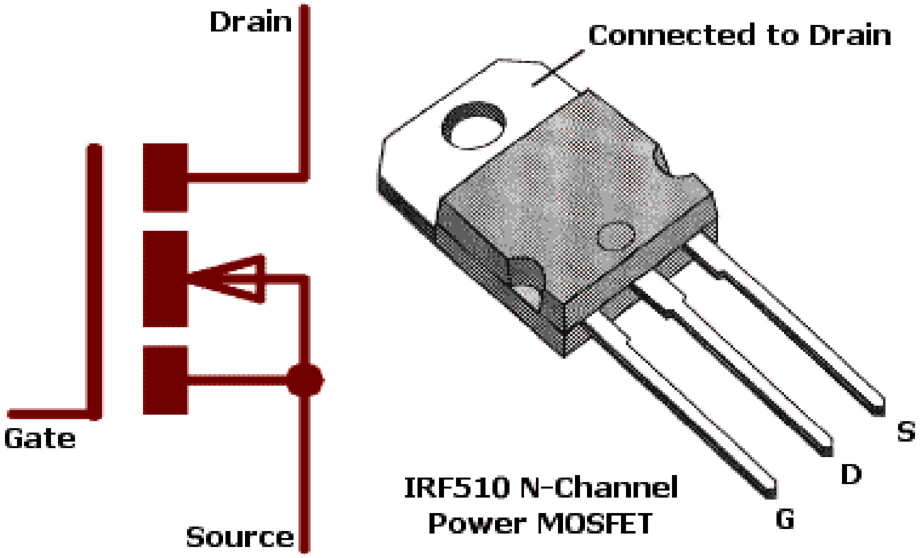


Figure 2.4: symbol of MOSFET Transistor

2.10 A neural network

A neural network is a powerful data modelling tool that is able to capture and represent complex input/output relationships. The motivation for the development of neural network technology stemmed from the desire to develop an artificial system that could perform "intelligent" tasks similar to those performed by the human brain.

The true power and advantage of neural networks lies in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modeled. Traditional linear models are simply inadequate when it comes to modeling data that contains non-linear characteristic [11].

The most common neural network model is the multilayer perceptron (MLP). This type of neural network is known as a supervised network because it requires a desired output in order to learn. The goal of this type of network is to create a model that correctly maps the input to the output using historical data so that the model can then be used to produce the output when the desired output is unknown. A graphical representation of an MLP is shown in figure: 2.5 below.

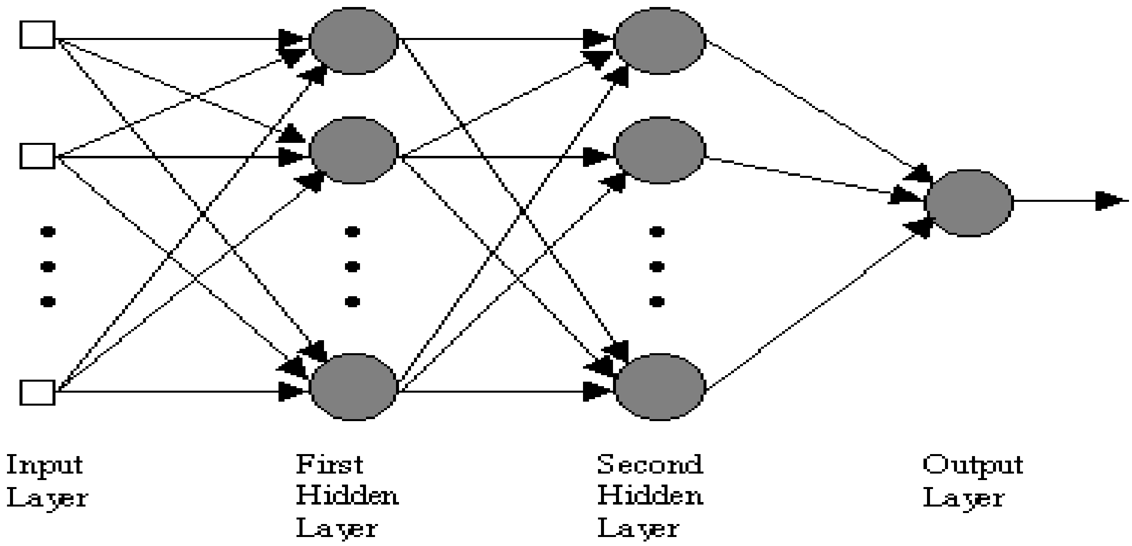


Figure: 2.5: Block diagram of a two hidden layer Multiplayer perceptron (MLP).

The inputs are fed into the input layer and get multiplied by interconnection weights as they are passed from the input layer to the first hidden layer. Within the first hidden layer, they get summed then processed by a nonlinear function. As the processed data leaves the first hidden layer, again it gets multiplied by interconnection weights, then summed and processed by the second hidden layer. Finally the data is multiplied by interconnection weights then processed one last time within the output layer to produce the neural network output.

2.11 Pulse Width Modulation (PWM)

The fundamental principle involved in making a boost converter is creating a square pulse to control the switching of the MOSFET. This square pulse is called the duty cycle and this duty cycle (D) controls the output voltage. The transfer function is derived by the following set of equations. Figure 2.6 is the ideal gate voltage to be able to switch the MOSFET and create a boosted output voltage. The y-axis shows VGS (V) and the x-axis shows the time interval of the signal.

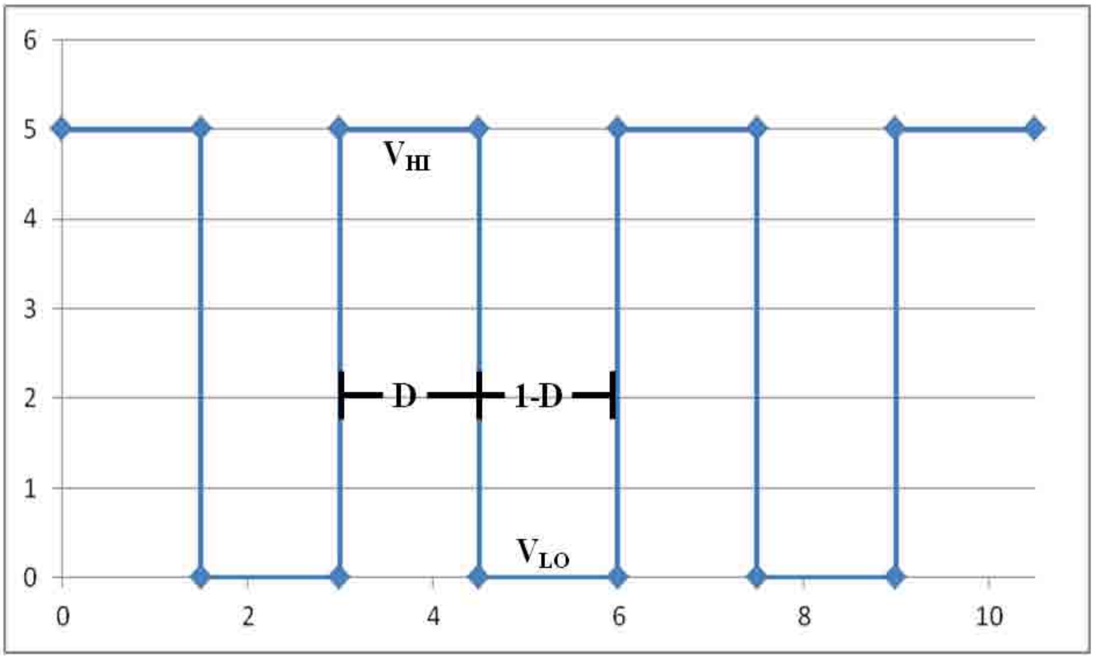


Figure 2.6: Gate Voltage on MOSFET

As the MOSFET gate switches to 0V, current is no longer sourced directly to ground,
thus forcing current to the output. Conversely, when the gate is switched to 5V, the current in the inductor flows directly from the drain to the source which is connected to ground creating different voltages across the inductor. The voltage across the inductor is shown in Figure 2.7 and the voltage changes with the duty cycle.

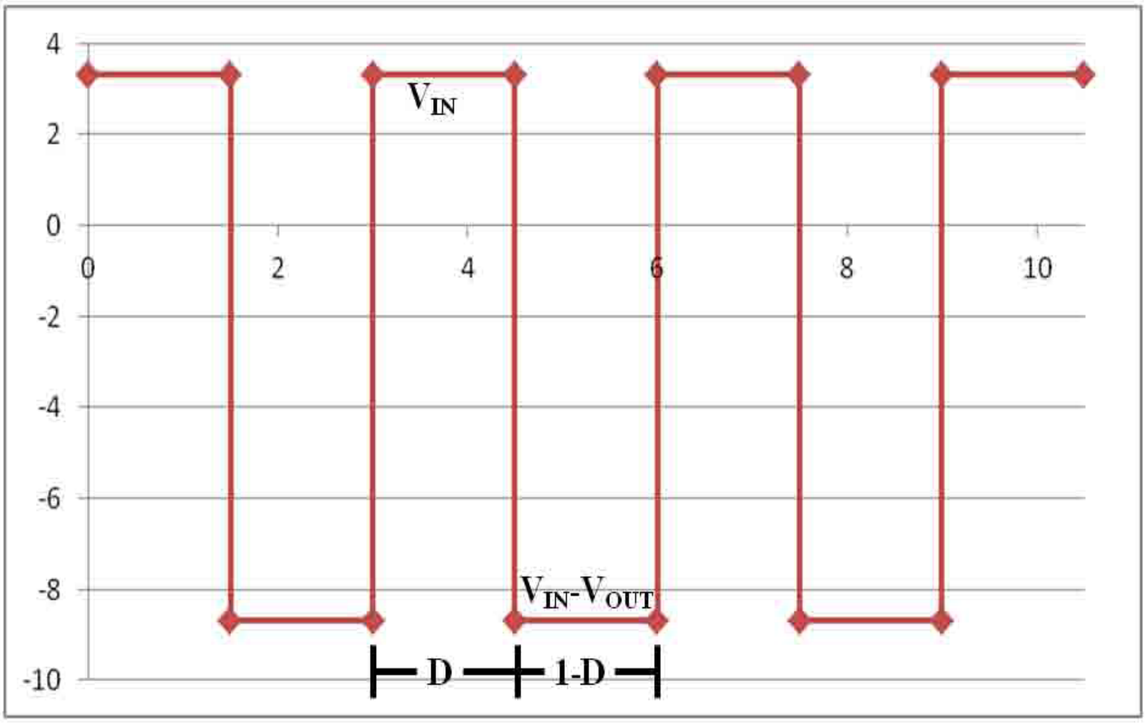


Figure 2.7 Voltage Across the Inductor

The voltage across the inductor while VGS is at 5V is equal to VIN. The voltage across the inductor while VGS is at 0V is equal to VIN-VOUT. Because the constant voltages are applied to the inductor, the current through the inductor ramps up and down linearly with time according to Equation .

$$V_L = L\frac{di}{dt}$$

The rising slope of the current through the inductor is show in Equation

$$\frac{V_{IN}}{L}$$

The falling slope of the current through the inductor is show in Equation.

$$\frac{V_{IN} - V_{OUT}}{L}$$

Based on the slope of the rising and falling slopes of the current through the inductor and the fact that the time duration is a known entity, the transfer function can be computed.

The relationship between the slope and time duration is shown in Figure 2.8 where the y-axis represents an arbitrary current value and the x-axis represents the time interval.

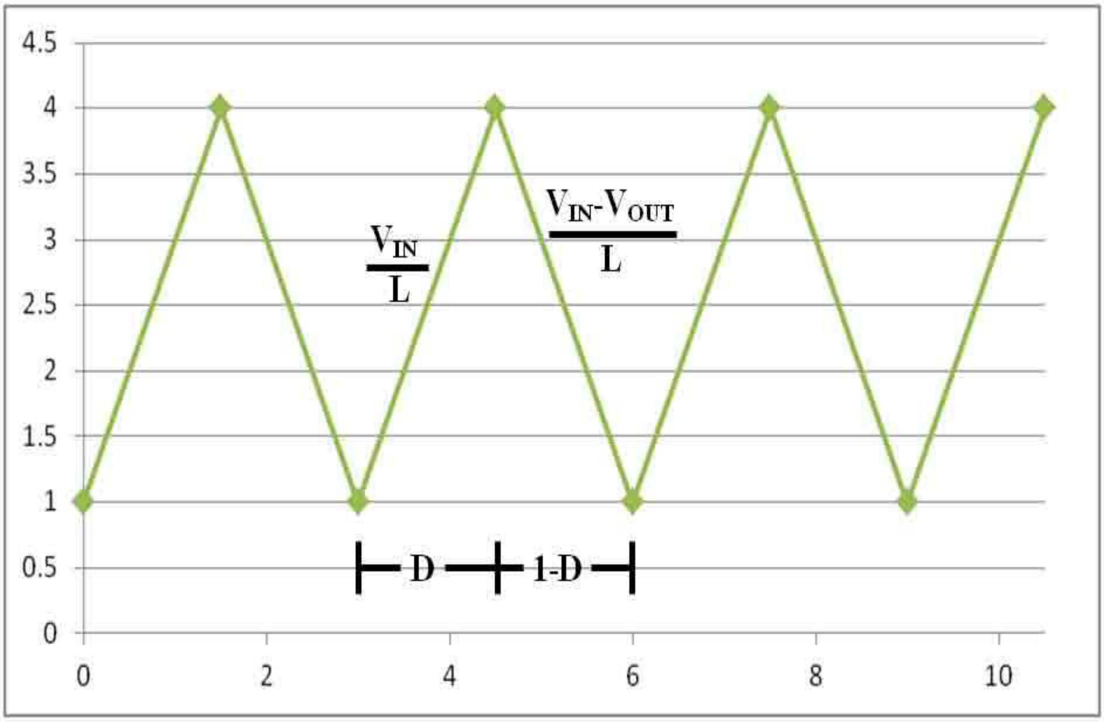


Figure 2.8: Current Through the Inductor

After determining the slope and time interval Equation 2.15 is derived

$$\frac{V_{IN}}{L}(D) + \frac{V_{IN} - V_{OUT}}{L}(1 - D) = 0$$

(2.15)

Algebraic steps were used to isolate V_{OUT} which yields Equation 2.16.

$$V_{OUT} = \frac{V_{IN} D}{1-D} + V_{IN}$$

Lastly, the transfer function of the whole system is shown in Equation 2.17 below.

$$\frac{V_{OUT}}{V_{IN}} = \frac{1}{1-D}$$

The duty cycle of VGS is what allows a boost converter to function. As D increases, the gain also increases. In order to create a duty cycle, a PWM needed to be created. There are several methods of creating a PWM. The first of which is to use a function generator that can output an adjustable duty cycle square wave at a frequency up to 20MHz. However, most function generators cannot produce square waves up to 20MHz. The next method for creating a PWM is to compare a ramp wave to a DC value. As the DC value decreases or increases, the duty cycle increases or decreases respectively. This method is shown in Figure 2.9 below.

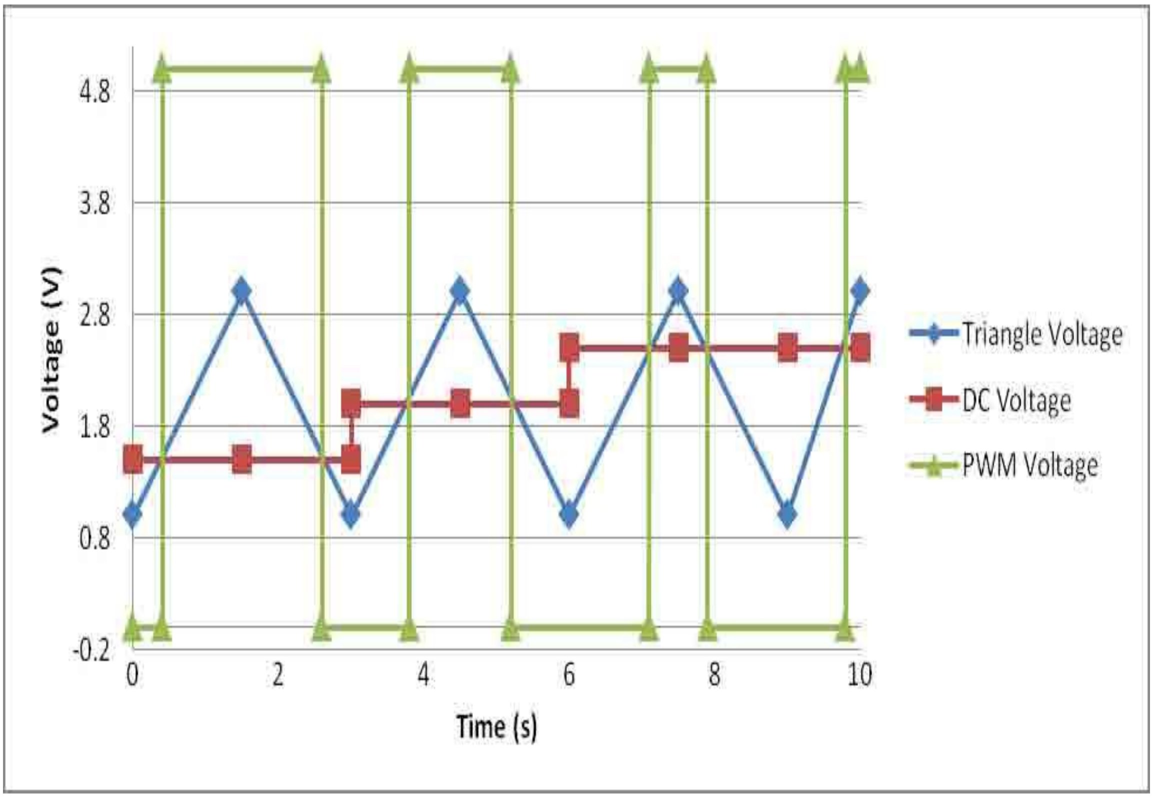


Figure 2.9: Creating a PWM by Comparing Two Waveforms

A triangle waveform is one wave that can be used to create a PWM. The other waveform is a saw tooth wave. The PWM created by using a saw tooth wave is shown in Figure 2.10 below

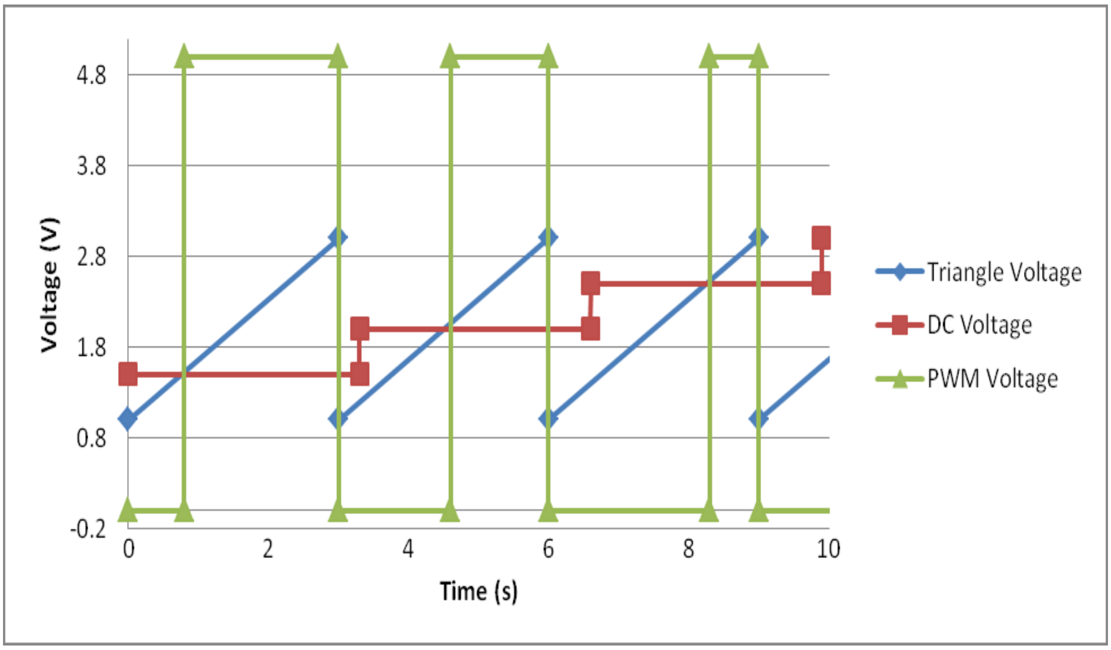


Figure 2.10: Creating a PWM by Comparing Two Waveforms

Either a saw tooth or a triangle wave would work to create a PWM needed for the boost converter, but the triangle is an easier shape to create and the Triangle has a few distinct advantages over the saw tooth. “An intrinsic advantage of modulation using a triangle carrier wave is that the odd harmonic sideband components around odd multiples of the carrier fundamental and even harmonic sideband components around even multiples of the carrier fundamental are eliminated.” [8] Additionally, a small change in the input voltage using the triangle wave will result in a larger change in the PWM than when using a saw tooth.

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