Implementation of Two Mode Control Scheme of Synchronous Buck Boost DC-DC Converter

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Abstract— The paper titled "Implementation of Two Mode Control Scheme of Synchronous Buck Boost Dc-Dc Converter" aimed at the ability of both voltage step-up and step-down and to achieve high efficiency over the entire voltage range. For the converter in the applications with wide input voltage variation, input voltage feed-forward (IVFF) compensation is an attractive approach for improving the transient response of the converter, for it can eliminate the effect of the input voltage disturbance on the output voltage .The proprietary switching algorithm, which allows its output voltage to be regulated above,below, or equal to the input voltage.Synchronous switch provide high efficiency, pulse width modulation control.

Key words: IVFF, Buck Boost Converter, Pulse Width Modulation

I. Introduction

This topology eliminates diode drop occurring in the existing system.In this systemswitching algorithm provides transition between operating modes and eliminates discontinuities in average inductor current,inductor ripple current and loop transfer function throughout. Besides, nearly smooth switching between buck and boost modes is also guaranteed.To maintain constant output voltage for wide range of input voltage by using synchronous buck boost dc-dc converter.By replacing the diodes by switches we obtain synchronous operation in order to eliminate the diode drop .

A. *Existing System:*

The two-mode control scheme with IVFF compensationis thenproposed for the TSBB converter, which realizesautomatic selections of operating modes and the correspondingIVFF functions. Besides, nearly smooth switching between buckand boost modes is also guaranteed.

B. *Proposed System:*

This topology eliminates diode drop occurring in the existing system.In this systemswitching algorithm provides transition between operating modes and eliminates discontinuities in average inductor current,inductor ripple current and loop transfer function throughout. Besides, nearly smooth switching between buck and boost modes is also guaranteed.

II. Module description

The module consists of the following

- Buck boost converter
- Pulse width modulation(PWM)
- Dc-dc converter
- Synchronous converter
- Phase shift
- Feed forward method
- Voltage regulation
- Switching losses
- Microcontroller

A. *Buck Boost Converter:*

The buck–boost converter is a type of DC-DC converter hat has an output voltage magnitude that is either greater than or less than the input voltage magnitude. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, from an output voltage much larger (in absolute magnitude) than the input voltage, down to almost zero.

The output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. Neither drawback is of any consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. The switch can be on either the ground side or the supply side.

The output voltage is of the same polarity of the input, and can be lower or higher than the input. Such a non-inverting buck-boost converter may use a single inductor which is used for both the buck inductor and the boost inductor.It was created to allow an output voltage level greater or smaller than the input, depending of duty cycle.

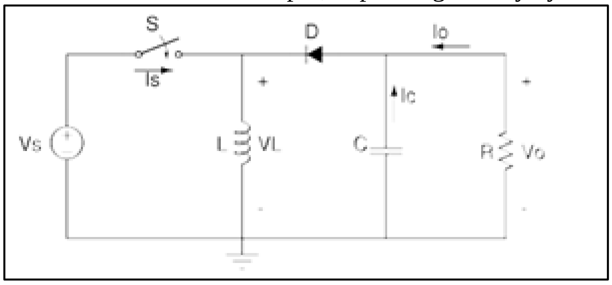

Fig. 1: Buck Boost Converter

B. *Pulse Width Modulation:*

Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a technique used to encode a message into a pulsing signal It is a type of modulation. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. In addition, PWM is one of the two principal algorithms used in photovoltaic solar battery chargers,the other being MPPT.The average value of voltage and current is fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load.

The PWM switching frequency has to be much higher than what would affect the load (the device that uses the power), which is to say that the resultant waveform perceived by the load must be as smooth as possible. Typically switching has to be done several times a minute in an electric stove, 120 Hz in a lamp dimmer, from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies.

The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time; a low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on.

The main advantage of PWM is that power loss in the switching devices is very low. When a switch is off there is practically no current, and when it is on and power is being transferred to the load, there is almost no voltage drop across the switch. Power loss, being the product of voltage and current, is thus in both cases close to zero. PWM also works well with digital controls, which, because of their on/off nature, can easily set the needed duty cycle.PWM has also been used in certain communication systems where its duty cycle has been used to convey information over a communications channel.

C. DC-DC Converter:

DC-DC converters are electronic devices used whenever we want to change DC electrical power efficiently from one voltage level to another. They are needed because unlike AC, DC can't simply be stepped up or down using a Transformer. In many ways, a DC-DC converter is the DC equivalent of a transformer. All DC-DC converters is that like a transformer, they essentially just change the input energy into a different impedance level. So whatever the output voltage level, the output power always comes from the input, there is no energy manufactured inside the converter. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing.

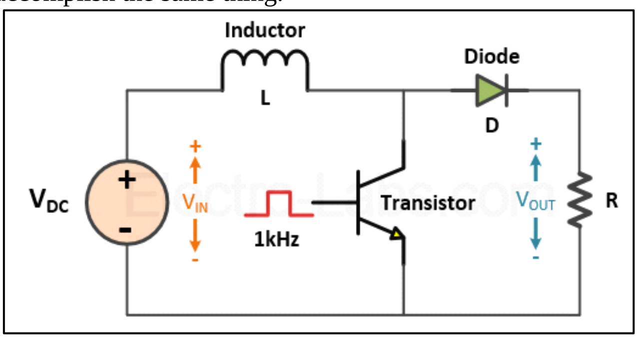

Fig. 2: DC-DC Converter

D. Synchronous Converter:

For even higher efficiency, some converters drop the diodes altogether and use extra MOSFET switches instead driven by the same circuitry used to drive the main switching MOSFETs, so they are turned on at just the right time for efficient gating or rectification of the output.This is known as synchronous rectification.Synchronous rectification can be used in virtually any of the DC-DC converters we have looked at here. All that involved is replacing each diode or diodes used in the basic converter with a suitable MOSFET, driven with a control signal that turns it on during the same part of the converters cycle that the diode would normally conduct. As a conducting MOSFET has much lower voltage drop than a conducting diode this achieves a very worthwhile further increase in converter efficiency. Even buck-type step down converters with 2-3V output can use synchronous rectification to achieve efficiencies as high as 94%.In the synchronous topology the low-side MOSFET's lower resistance from drain to source (RDSON) helps reduce losses significantly and therefore optimizes the overall conversion efficiency. However, all of this demands a more complicated MOSFET drive circuitry to control both the switches. Care has to be taken to ensure both MOSFETs are not turned on at the same time. If both MOSFETs are turned on at the same time a direct short from VIN to ground is created and causes a catastrophic failure. Ensuring this direct short, which is also called cross-conduction or shoot-through, does not occur requires more complexity and cost within the IC.

E. Phase Shift:

Phase shift is any change that occurs in the phase of one quantity, or in the phase difference between two or more quantities. With regard to wave motion, a phase shift represents the amount a wave has shifted horizontally from the original wave. Phase shifts are typically measured in degrees where a complete cycle is 360 degrees. In the diagram below, the second wave is shifted by the specified amount from the original wave:

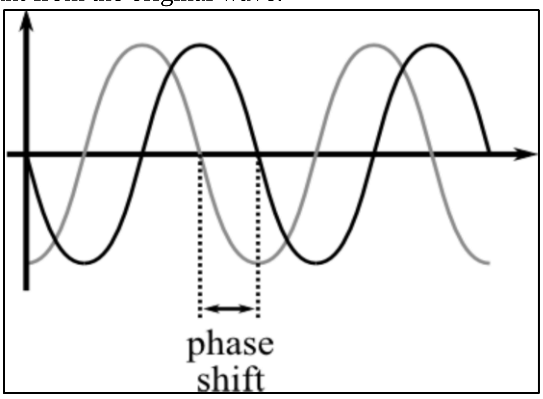

Fig. 3: DC-DC Converter

Because the horizontal axis denotes time, a phase shift represents a shift in time from the original wave. The signal in a circuit, for example, will have some phase shift between the input and the output. When designing an operational amplifier, for example, engineers prefer to minimize the phase shift as much as possible to avoid unwanted oscillations.

F. Feed Forward Control:

Feedforward control is a conceptually simple, highly effective and extremely robust, but not very well known or appreciated, technique for improving the dynamic regulation of switching regulators. Feedforward control is also used for stabilizing the switching frequency or the loop gain of free-running converters.Input-voltage feed-forward improves efficiency and dynamic performance over a wide range of input voltages.

G. Voltage Regulator:

A voltage regulator is designed to automatically maintain a constant voltage level. A voltage regulator may be a simple "feed forward" design or may include negative feedback control loop.

It may use an electromechanical mechanism, or electronic components. Depending on the design, it may be used to regulate one or more ACor DC voltages.

Electronic voltage regulators are found in devices such as computer power supplies where they stabilize the DC voltages used by the processor and other elements. In automobile alternators and central power station generator plants, voltage regulators control the output of the plant. In an electric power distribution system, voltage regulators may be installed at a substation or along distribution lines so that all customers receive steady voltage independent of how much power is drawn from the line. A simple voltage regulator can be made from a resistor in series with a diode (or series of diodes). Due to the logarithmic shape of diode V-I curves, the voltage across the diode changes only slightly due to changes in current drawn or changes in the input. When precise voltage control and efficiency are not important, this design may work fine.

Feedback voltage regulators operate by comparing the actual output voltage to some fixed reference voltage. Any difference is amplified and used to control the regulation element in such a way as to reduce the voltage error.

H. Switching Losses:

As the devices voltage waveforms in the switching transitions have been obtained, switching losses can be directly calculated by means of using a piecewise switch-off current model, where the switch-off current is defined for IGBT devices by means of the tail factor β, and fall and tail intervals.

I. Microcontroller:

A microcontroller is a small computeron a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form ofFrroelectric RAM,OTP/RAM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocesors and personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes

Some microcontrollers may use four-bit words and operate at clock rate frequencies as low as 4 kHz, for low power consumption (single-digit milliwatts or microwatts). They will generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping (CPU clock and most peripherals off) may be just nanowatts, making many of them well suited for long lasting battery applications. Other microcontrollers may serve performance-critical roles, where they may need to act more like a Digital Signal Processor (DSP), with higher clock speeds and power consumption.

III. CIRCUIT EXPLANATION

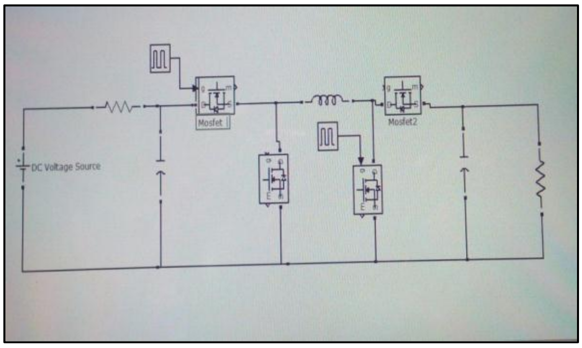

Fig. 4: Synchronous Buck Boost Converter

A. Operating Modes:

The new topology can be effectively broken down into four distinct operating modes, shown in schematic form in.

1) STATE 1:

The basic operation of the synchronous buck boost converter is explained. The circuit operating as a Buck Converter. In this mode Mosfet2 is turned off, and Mosfet 1 is switched on and off by a high frequency square wave from the control unit. When the gate of Mosfet1 is high, current flows though L, charging its magnetic field, charging C and supplying the load. The Schottky diode Mosfet3 is turned off due to the positive voltage on its cathode. The circuit shows the current flow during the buck operation of the circuit when the control unit switches Mosfet1 off. The initial source of current is now the inductor L. Its magnetic field is collapsing, the back e.m.f. generated by the collapsing field reverses the polarity of the voltage across L, which turns on Mosfet3 and current flows through Mosfet4 and the load.

As the current due to the discharge of L decreases, the charge accumulated in C during the on period ofMosfet1 now also adds to the current flowing through the load, keeping V_{OUT} reasonably constant during the off period. This helps keep the ripple amplitude to a minimum and V_{OUT} close to the value of V_S.

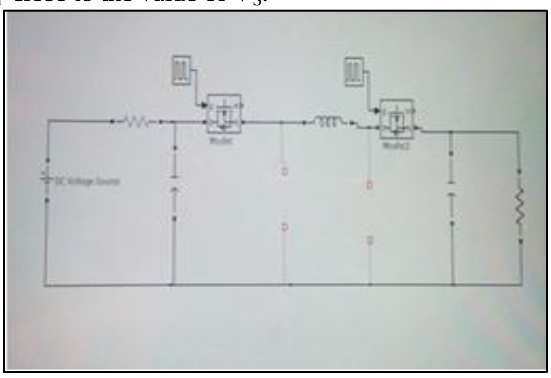

Fig. 5: Buck Operation during Mosfet1ON Period

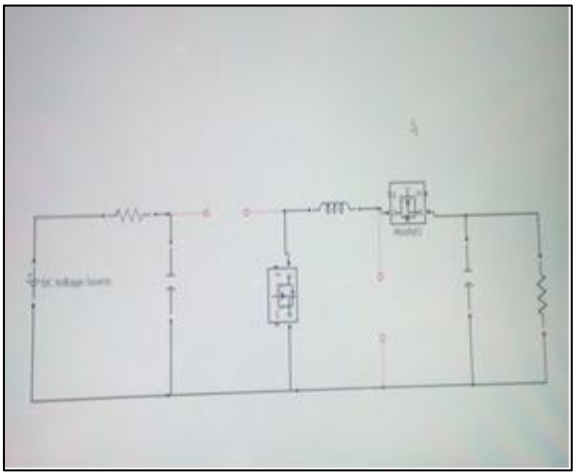

Fig. 6: Buck Operation during Mosfet1OFF Period

2) *STATE 2:*

In Boost Converter mode, Mosfet1 is turned on continually and the high frequency square wave applied to Mosfet2 gate. During the on periods when Mosfet2 is conducting, the input current flows through the inductor L and via Mosfet2, directly back to the supply negative terminal charging up the magnetic field around L. Whilstthis is happening Mosfet4 cannot conduct as its anode is being held at ground potential by the heavily conducting Mosfet2. For the duration of the on period, the load is being supplied entirely by the charge on the capacitor C, built up on previous oscillator cycles.

Frequency ripple on the output voltage, which is at a potential of approximately $V_S + V_L$.

At the start of the off period ofMosfet2, L is charged and C is partially discharged. The inductor L now generates a back e.m.f. and its value that depends on the rate of change of current as Mosfet2 switches of and on the amount of inductance the coil possesses; therefore the back e.m.f can be any voltage over a wide range, depending on the design of the circuit. Notice particularly that the polarity of the voltage across L has now reversed, and so adds to the input voltage V_S giving an output voltage that is at least equal to or greater than the input voltage. Mosfet4 is now forward biased and so the circuit current supplies the load current, and at the same time re-charges the capacitor to V_S+ V_L ready for the next on period of Mosfet4.

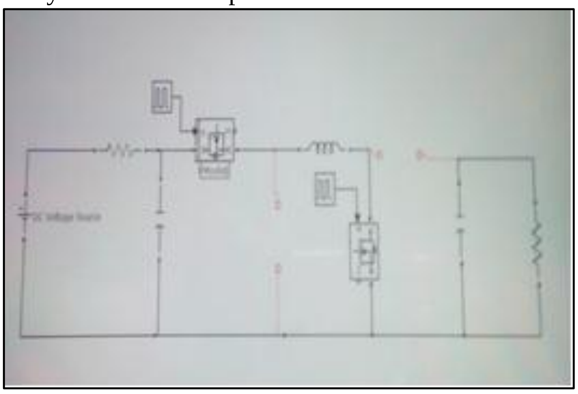

Fig. 7: Boost Operation during Mosfet2ON Period

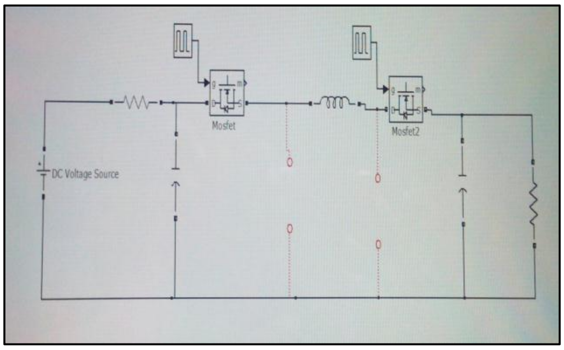

Fig. 8: Boost Operation during Mosfet2 OFF Period

B. *Simulation Results:*

1) *Techniques Used:*

- Synchronous converter
- A Two mode scheme of DC-DC buck boost converter topology

C. *Synchronous Converter:*

The synchronous topology is depicted in the figure above. The bottom side diode 'D' has been replaced with another MOSFET, 'S2.' Since there are two MOSFETs 'S1' is called the high-side MOSFET and 'S2' the low-side MOSFET. The low-side MOSFET is also referred to as the synchronous MOSFET while the high-side MOSFET is called the switching/control MOSFET.

In steady state, the low-side MOSFET is driven such that it is complimentary with respect to the high-side MOSFET. This means whenever one of these switches is ON, the other is OFF. In steady state conditions, this cycle of turning the high-side and low-side MOSFETs ON and OFF complimentary to each other regulates VOUT to its set value.

Observe that the low-side MOSFET will not turn ON automatically. This action needs additional MOSFET drive circuitry within the control IC to turn ON and OFF as needed. Compare this to asynchronous topology where the polarity reversal across the inductor automatically forward biases the diode, completing the circuit

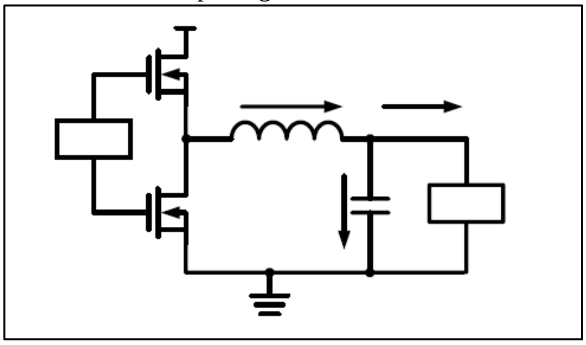

Fig. 9: Synchronous Converter

D. *A Two Mode Control Scheme of Dc-Dc Buck Boost Converter:*

A Buck-Boost converter is a type of switched mode power supply that combines the principles of the Buckconverter and boost converter in a single circuit. Like other SMPS designs, it provides a regulated DC output voltage from either an AC or a DC input.

The Buck converter described in power supplies produces a DC output in a range from 0V to just less than the input voltage. The boost converter will produce an output voltage ranging from the same voltage as the input, to a level much higher than the input.

There are many applications however, such as battery-powered systems, where the input voltage can vary widely, starting at full charge and gradually decreasing as the battery charge is used up. At full charge, where the battery voltage may be higher than actually needed by the circuit being powered, a buck regulator would be ideal to keep the supply voltage steady. However as the charge diminishes the input voltage falls below the level required by the circuit, and either the battery must be discarded or re-charged.

By combining these two regulator designs it is possible to have a regulator circuit that can cope with a wide range of input voltages both higher or lower than that needed by the circuit. Fortunately both buck and boost converters use very similar components; they just need to be re-arranged, depending on the level of the input voltage.The common components of the buck and boost circuits are combined. A control unit is added, which senses the level of input voltage, then selects the appropriate circuit action. (Note that in the examples in this section the transistors are shown as MOSFETs, commonly used in high frequency power converters, and the diodes shown as Schottky types. These diodes have a low forward junction voltage when conducting, and are able to switch at high speeds)

1) *Simulation Design:*

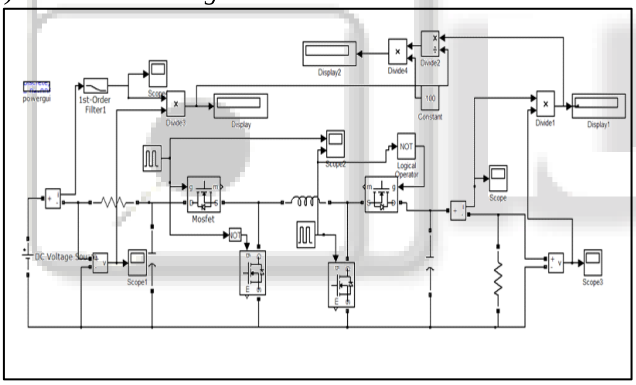

Fig. 10: Simulation of Synchronous Buck Boost Converter

2) *With Microcontroller:*

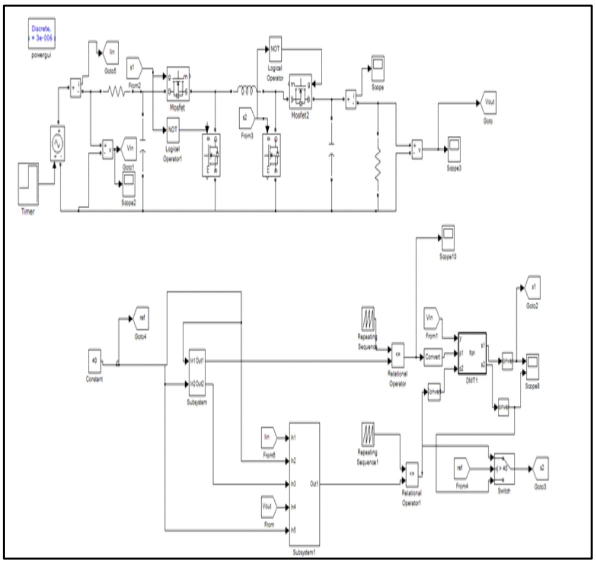

Fig. 11: Simulation of Converter with Microcontroller

3) *Input Voltage:*

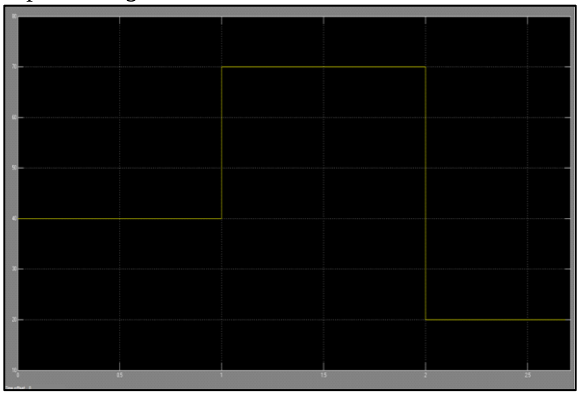

Fig. 12: Input Voltage for Converter

4) *Output Voltage during Buck Mode:*

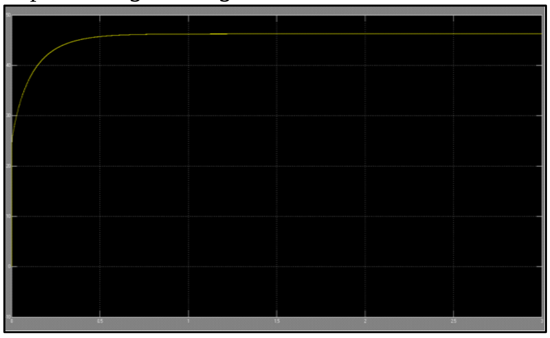

Fig. 13: Output for Buck Mode

5) *During Boost Mode*

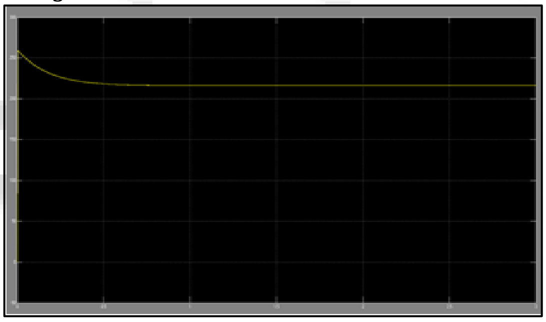

Fig. 14: Output during Boost Mode

6) *Pulses during Boost Mode:*

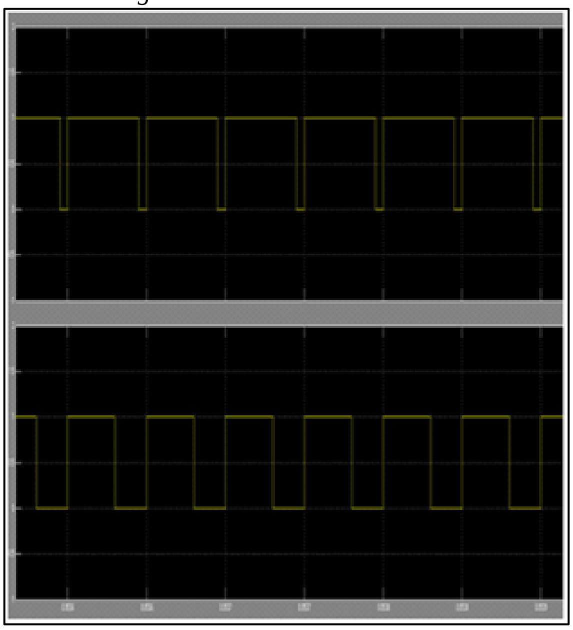

Fig. 15: Pulse for Boost

7) Pulses during Buck Mode:

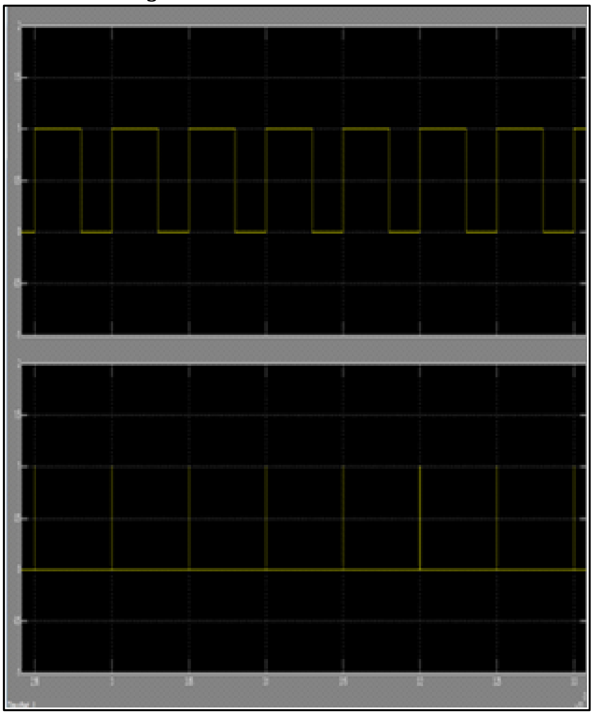

Fig. 16: Pulses for Buck

IV. EXPECTED INPUT AND EXPECTED OUTPUT

Here the Input given to the circuit is upto50V and the output got is 24V

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