Experiment No : 5

Buck, Boost and Buck Boost converter

Aim : Design of Buck ,Boost and Buck Boost converter and verify the simulation results of input voltage, output voltage, load current, voltage across inductor

a) Buck converter

Circuit Diagram

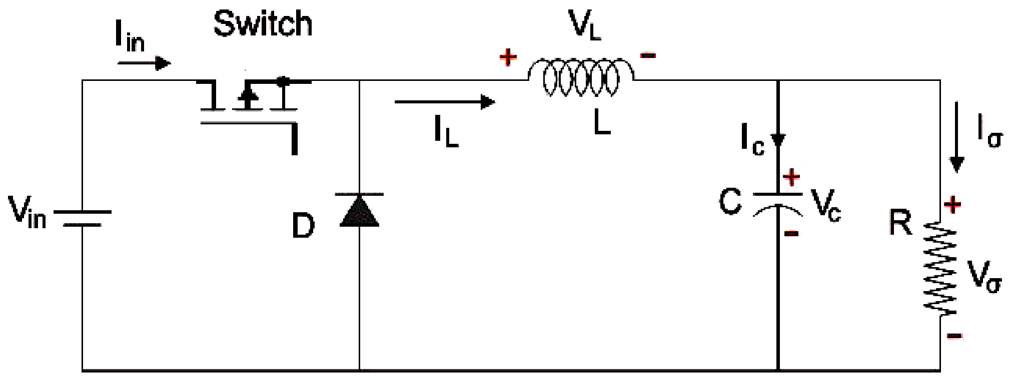

Figure 11.1 Circuit Diagram of Buck converters

Theory

Buck converter which reduces the input DC voltage to a specified DC output voltage. The input voltage source is connected to a controllable solid-state device which operates as a switch. The solid-state device can be a Power MOSFET or IGBT. Thyristors are not used generally for DC-DC converters because to turn off a Thyristor in a DC-DC circuit requires another commutation which involves using another Thyristor, where as Power MOSFET and IGBT can be turned off by simply having the voltage between the GATE and SOURCE terminals of a Power MOSFET, or, the GATE and COLLECTOR terminals of the IGBT go to zero. The second switch used is a diode. The switch and the diode are connected to a low-pass LC filter which is appropriately designed to reduce the current and voltage ripples. The load is a purely resistive load. The input voltage is constant and the current through load is also constant. The load can be seen as current source.

The controlled switch is turned on and off by using Pulse Width Modulation (PWM). PWM can be time based or frequency based. Frequency based modulation has disadvantages like a wide range of frequencies to achieve the desired control of the switch which in turn will give the desired output voltage. This leads to a complicated design for the low-pass LC filter which would be required to handle a large range of frequencies. Time based Modulation is mostly used for DC-DC converters. It is simple to construct and use. The frequency remains constant in this type of PWM modulation. The Buck converter has two modes of operation. The first mode is when the switch is on and conducting.

- <u>ModeI: Switch is ON, Diode is OFF</u>

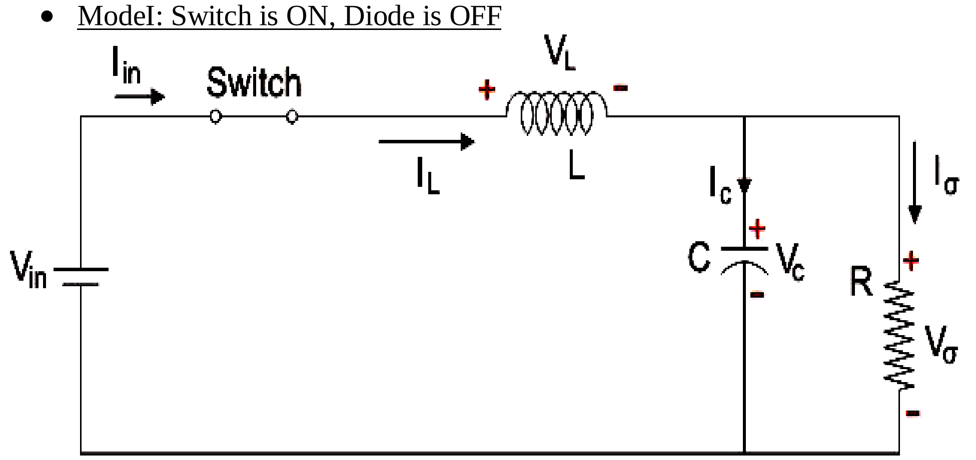

Figure 11.2 Circuit Diagram of Buck converter when switch is ON

- <u>ModeII: Switch is OFF, Diode is ON</u>

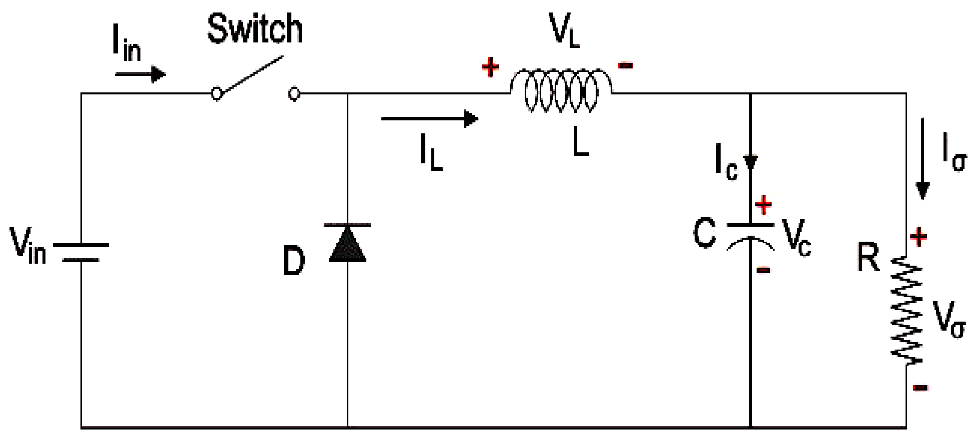

Figure 11.3 Circuit Diagram of Buck converter when switch is OFF

Design

Buck convertor switching frequency

Switching frequency is a designer´s choice, normally f_s>20KHz. Since 20KHz is the audible limit of human ear.

Let f_s=40 KHz

Buck Convertor (Duty Cycle)

Vs=48 V

Vo =18V

$$V_O = DV_S$$

Therefore, Duty ratio D=0.375V

Inductor Capacitor and Resistor

Choose a standard power resistor of 100 ohm , 10W

$$L_{min} = \frac{(1-D)R}{2f_s} = 78\mu H$$

$$1.25L_{min} = 97.5\mu H$$

Voltage ripple ΔV_o =0.5 V

$$\frac{\Delta V_o}{V_o} = \frac{(1-D)}{8LCf_s^2}$$

Therefore C=100µH

Procedure

1.Setup the circuit in bread board as per the circuit diagram using connection wires and components

2. Connect PWM signal
3. Check the circuit connections according to the schematics.
4. Set the duty cycle at 45%, and switching frequencyat40kHz.
5. Observe and measure the output voltage. Compare with the calculated value.
6. Vary the duty cycle to 37.5%
7. Measure the output voltage V_o for each of the duty cycle. Compare the

measurement with theoretical calculation.

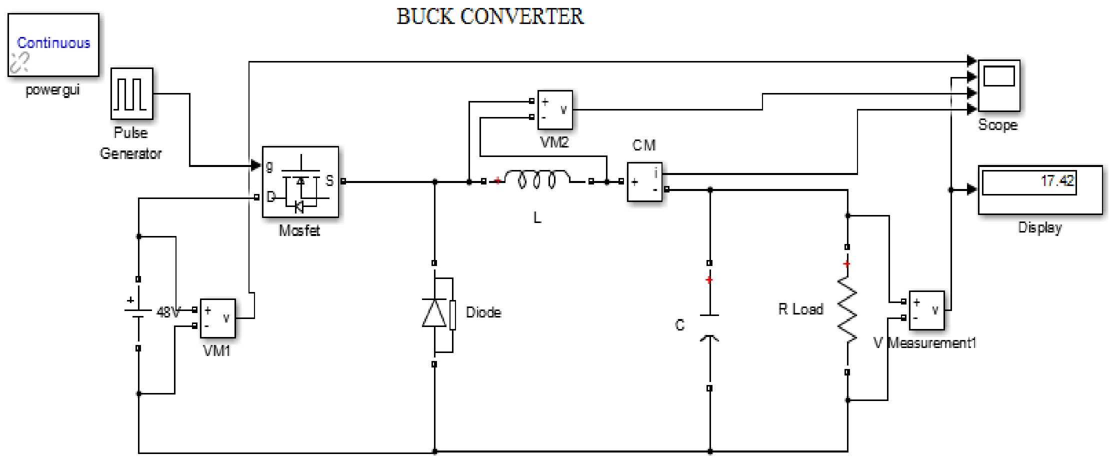

Figure 11.4 Simulation Diagram of Buck converter

Simulink Blocks Used:-

R,L,C – series RLC branch

PG – Pulse Generator (Amplitude 1, period 2.5x10^{-5}, pulse width 25%)

MOSFET, DIODE (from Simpower systems – Power Electronics)

48V - Dc voltage source

Voltage measurement, current measurement

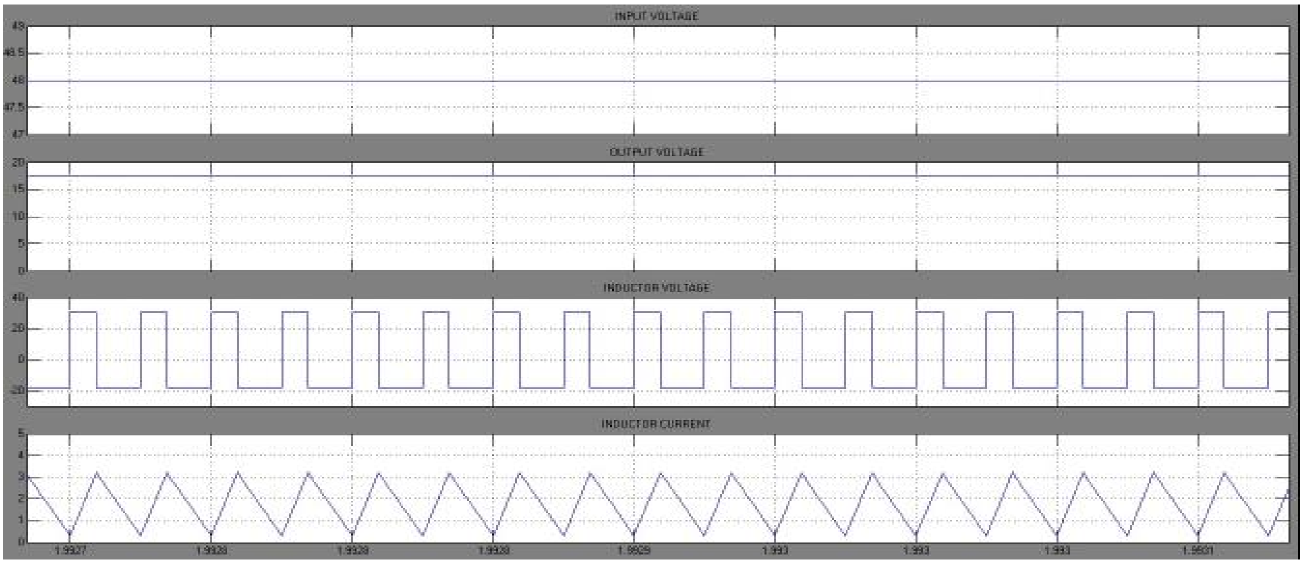

Figure 11.5 Load voltage, inductor current and load current waveforms

Result

Designed and setup a buck b convertor and observed its outputs. Regulated output voltage between18V from 48V DC supply

b) <u>Boost converter</u>

Circuit Diagram

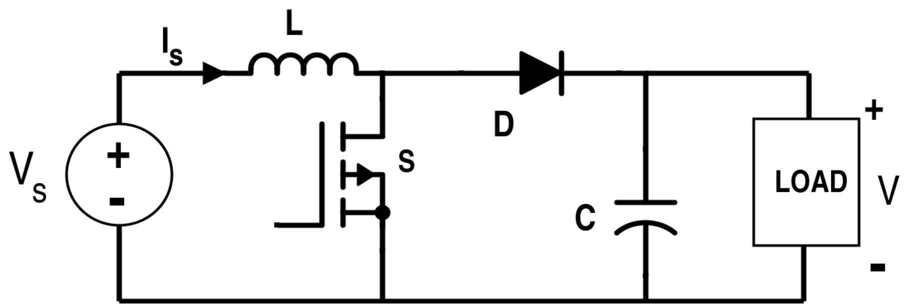

Figure 11.6 Circuit Diagram of Boost converter

Theory

A boost converterõs output voltage is always higher than the input voltage. Figure11.6 shows the schematics of a boost converter. It has a dc input voltage, a transistor working as switch, an inductor and a capacitor forming a low pass filter to smooth out the output voltage, and a load resistor. The diode provides a path for the inductor current when the switch is opened and is reverse biased when the switch is closed.

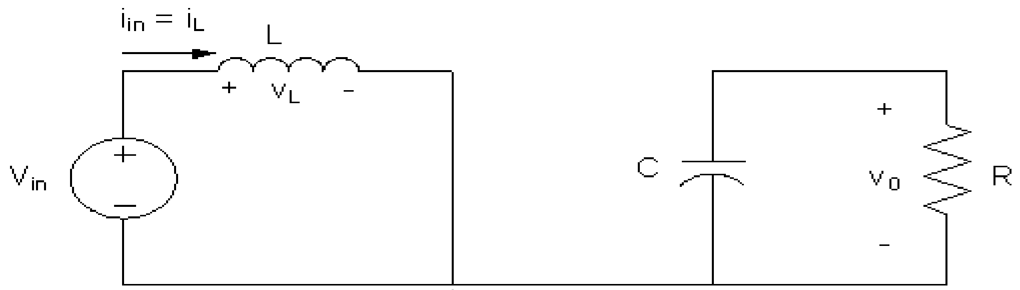

Figure 11.7 Equivalent circuit when the switch is closed

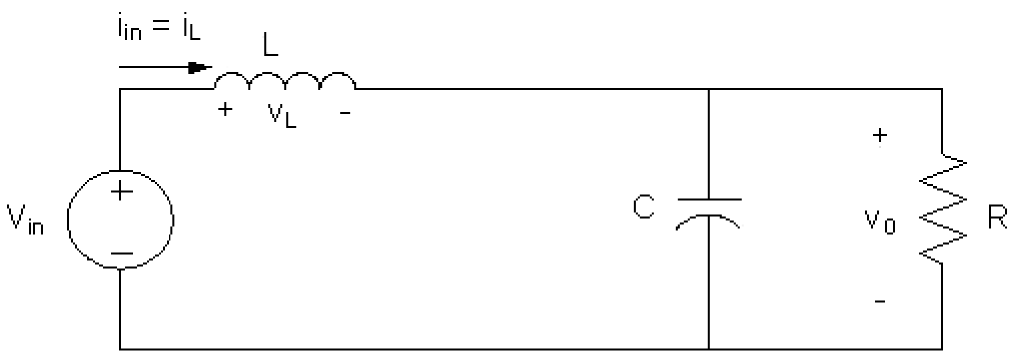

Figure 11.8 Equivalent circuit when the switch is open

Output voltage of a boost converter is controlled by a pulse width modulated (PWM)signal generated by TL 494 IC. The duty cycle is the ratio between the on time and the switching period. By adjusting the duty cycle, we can obtain desired output voltage.

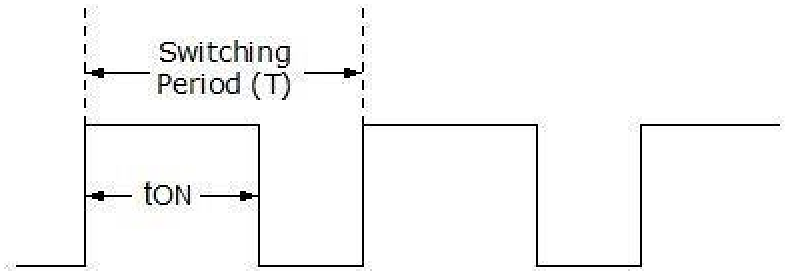

Figure 11.9 switching Scheme

Design

Let f_s=40KHz

Vs=12 V

Vo=24 V

$$V_0 = \frac{V_s}{1-D}$$

Therefore, Duty ratio D=0.5V

<u>Inductor Capacitor and Resistor</u>

Choose a standard power resistor of 10ohm , 10W

$$L_{min} = \frac{D(1-D)R}{2f_s} = 15.635\mu\ H$$

$$1.25L_{min} = 19.53\mu H$$

Voltage ripple ΔV_o =0.5 V

$$\frac{\Delta V_o}{V_o} = \frac{D}{RCf_s}$$

Therefore C=25μH

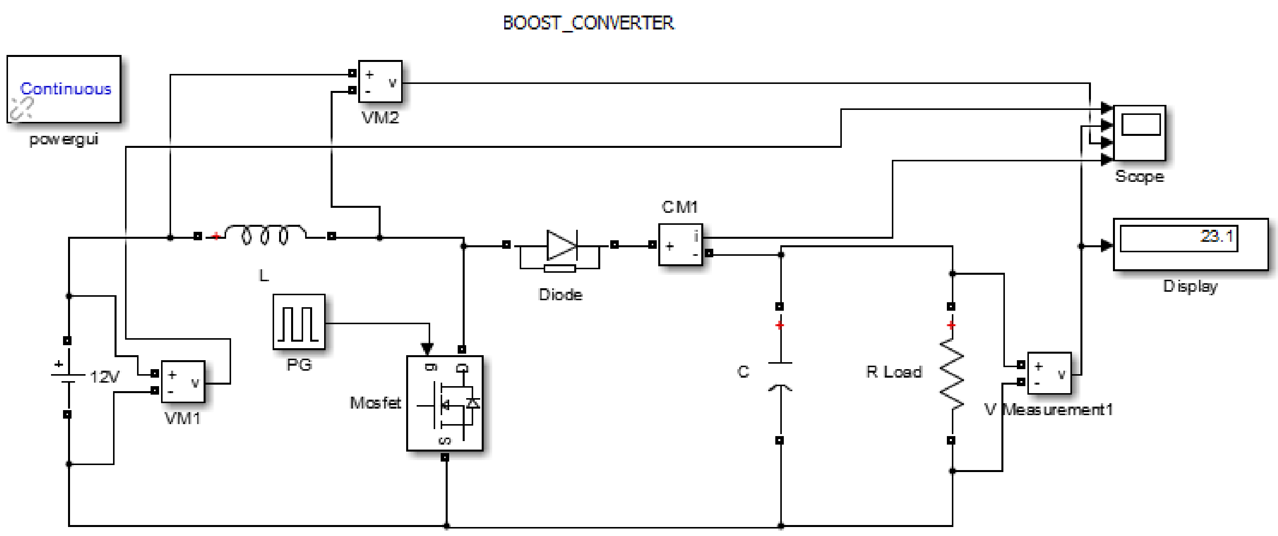

Figure 11.10 Simulation Diagram of Boost converter

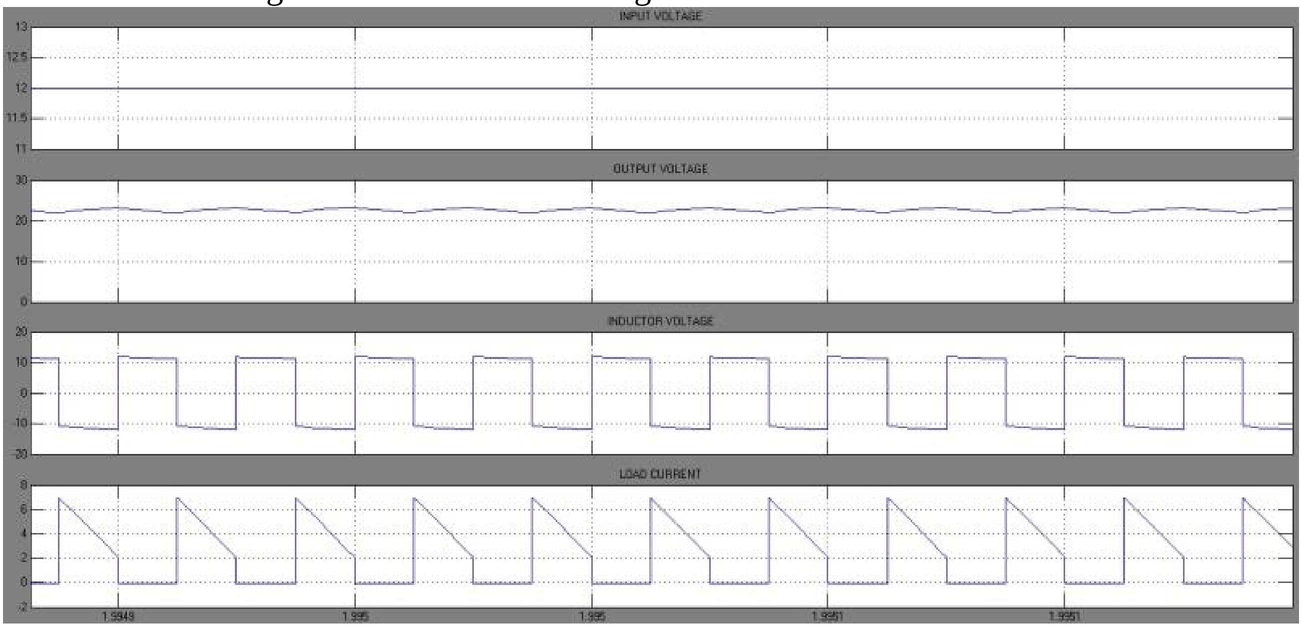

Figure 11.11 Load voltage, inductor current and load current waveforms

Result

Designed and setup a boost convertor and observed its outputs. Regulated output voltage 24V from 12V DC supply is obtained

c) <u>Buck Boost converter</u>

PRINCIPLE:

In buck-boost converters, the output voltage is either higher or lower than the input voltage; but the polarity of the output voltage is reversed with respect to the input voltage.

When the switch is ON, the diode is reverse biased and input provides energy to the inductor. When the switch is OFF, the energy stored in the inductor is transferred to the output. No energy is supplied by the input during this interval.

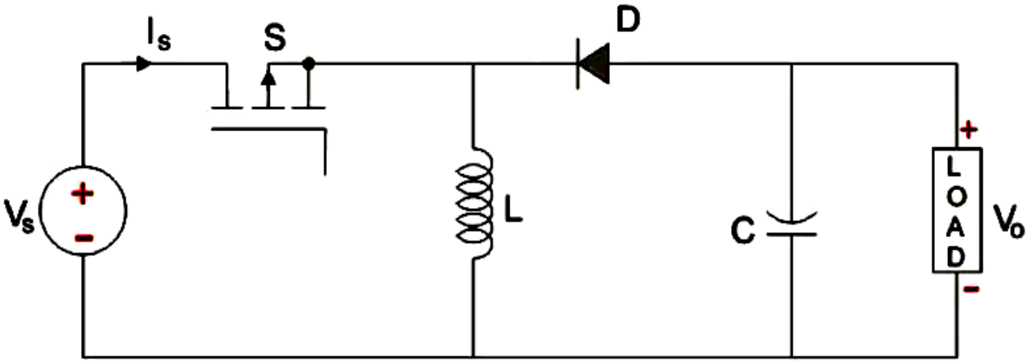

Figure 11.12 Circuit diagram of Buck boost converter

Two modes of operation

Mode I : Switch is ON, Diode is OFF

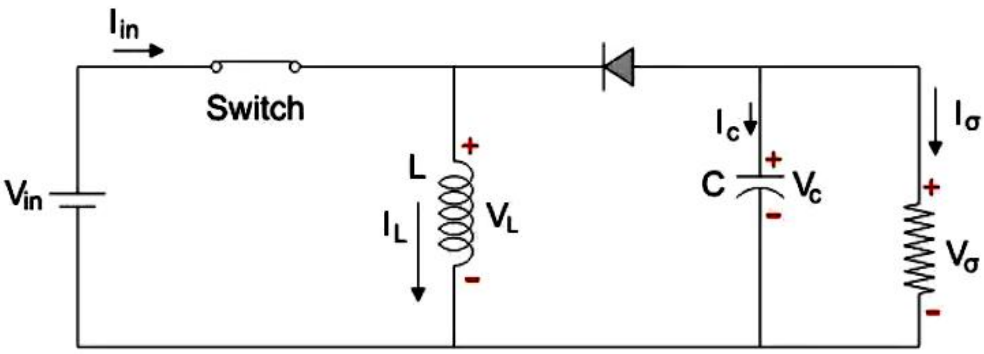

Figure 11.12 Equivalent circuit when the switch is closed

Mode II : Switch is OFF, Diode is ON

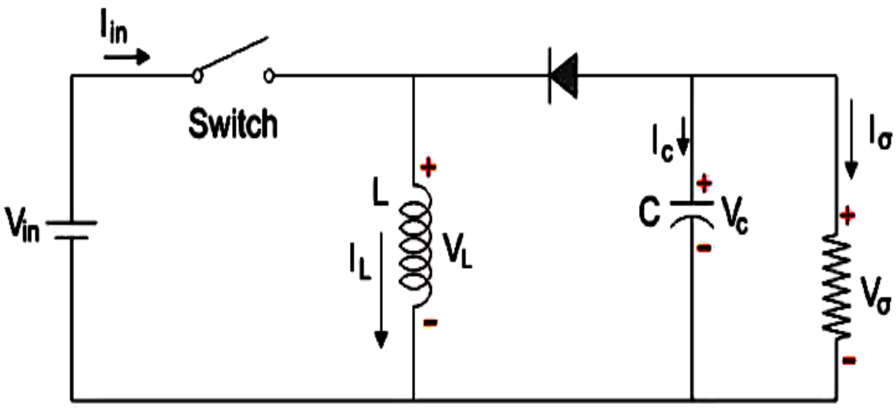

Figure 11.13 Equivalent circuit when the switch is opened

Design

Let f_s=40 kHz

Buck operation

Vs=18V

Vo=12 V

$$V_0 = \frac{DV_s}{1-D}$$

Therefore, Duty ratio D=0.4

Boost operation

Vs=18 V

Vo =25V

Therefore, Duty ratio D=0.6

Inductor, Capacitor and Resistor

Choose a standard power resistor of 10ohm ,10W

$$L_{min} = \frac{D(1-D)R}{2f_s} = 45\,\mu H$$

$$1.25L_{min} = 56.25\,\mu H$$

Voltage ripple ΔV_o =0.5 V

$$\frac{\Delta V_o}{V_o} = \frac{D}{RCf_s}$$

Therefore C=100µH

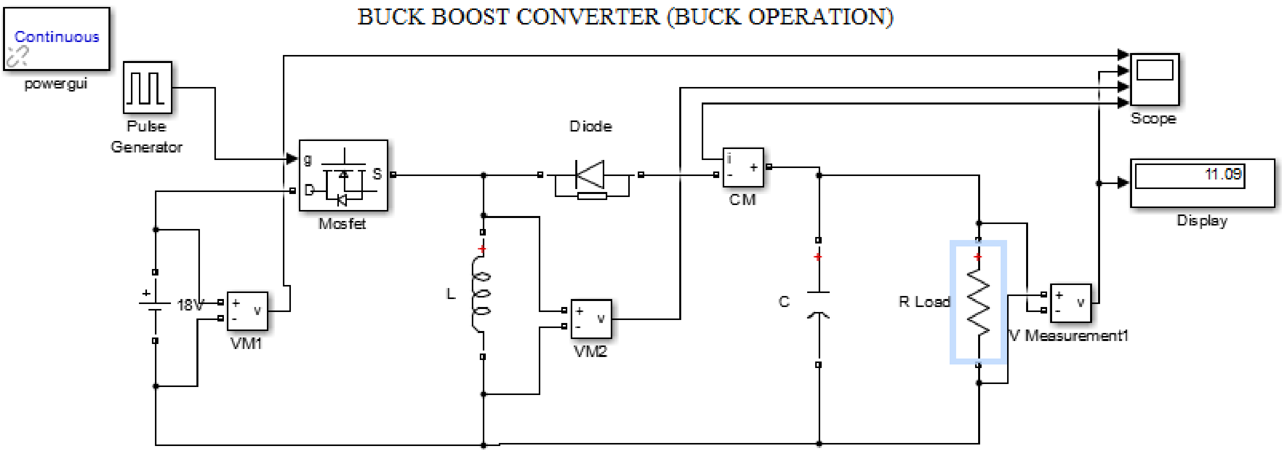

Figure 11.14 Simulation Diagram of Buck boost converter

Figure 11.15 Load voltage, inductor current and load current waveforms for buck operation

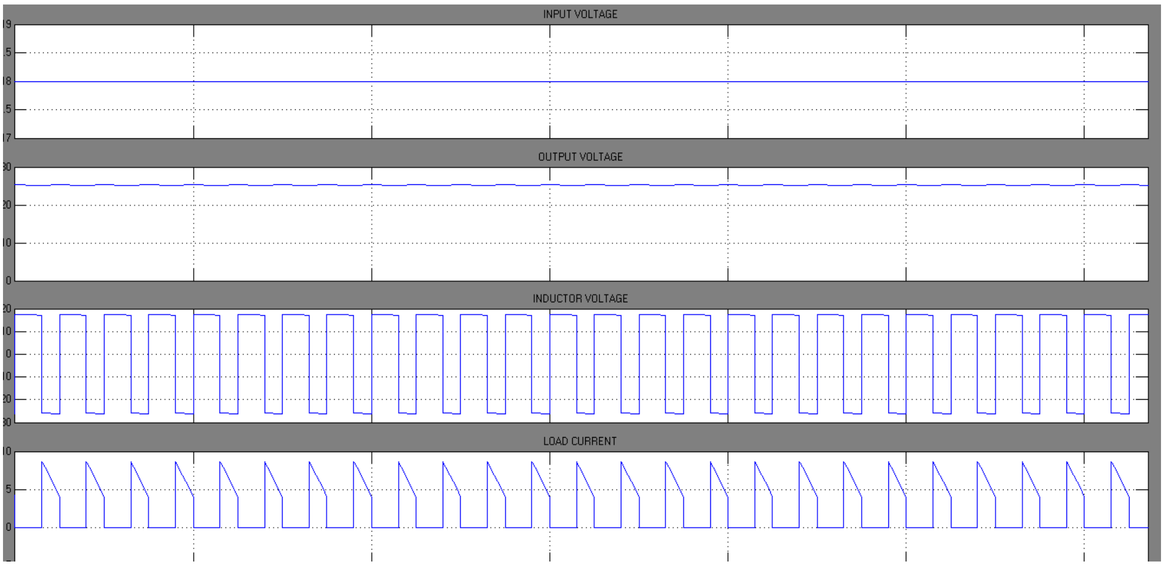

Figure 11.5 Load voltage, inductor current and load current waveforms for boost operation

Result

Designed and setup a buck boost convertor and observed its outputs. Regulated output voltage 18V from 12V for buck operation and 18 V to 25 V boost DC supply is obtained