BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

Department of Electrical and Computer Engineering

ENGINEERING SIMULATION LAB

(ENEE4104)

Experiment 6

“Power Electronics Converters In ORCAD”

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Abstract

The purpose of the experiment is to simulate many DC-to-DC converters using OrCAD software. The switching duty cycle, the output filter size, and the load were among the important factors that were altered. This led to a thorough examination of how each parameter affected the converters' performance.

Theory

Buck Converter (Step Down Converter)

A buck converter, sometimes called a step-down converter, is a straightforward device used in power electronics that lowers an input voltage. It is frequently seen in gadgets like portable electronics that need lower voltage levels.

The buck converter is efficient and easy to use since it only needs a few components, as shown in Figure 1. This converter regulates the energy flow from the input to the output using a switch, an inductor, and a capacitor. Switches of many kinds, including MOSFETs and IGBTs, are feasible. The duty cycle, or the amount of time the switch is on as opposed to off, determines how much the converter steps down the input.

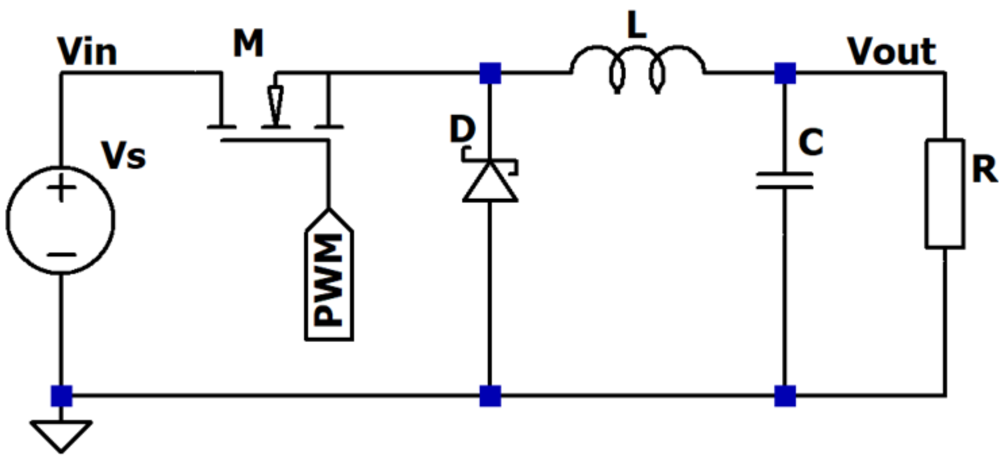

Figure 1 buck converter

Situation 1: The switch is activated

As seen in Figure 2, the diode (D) is reverse biased and the MOSFET is on. When the MOSFET is turned off, the circuit initially has no current flowing through it. Current passes through the inductor (L) when the MOSFET is turned on, charging it. According to the following formula, the inductor's current grows linearly:

$$\mathbf{iL(on)} = \frac{\mathbf{(Vin - Vout) \cdot ton}}{L} + \mathbf{i}_{init}$$

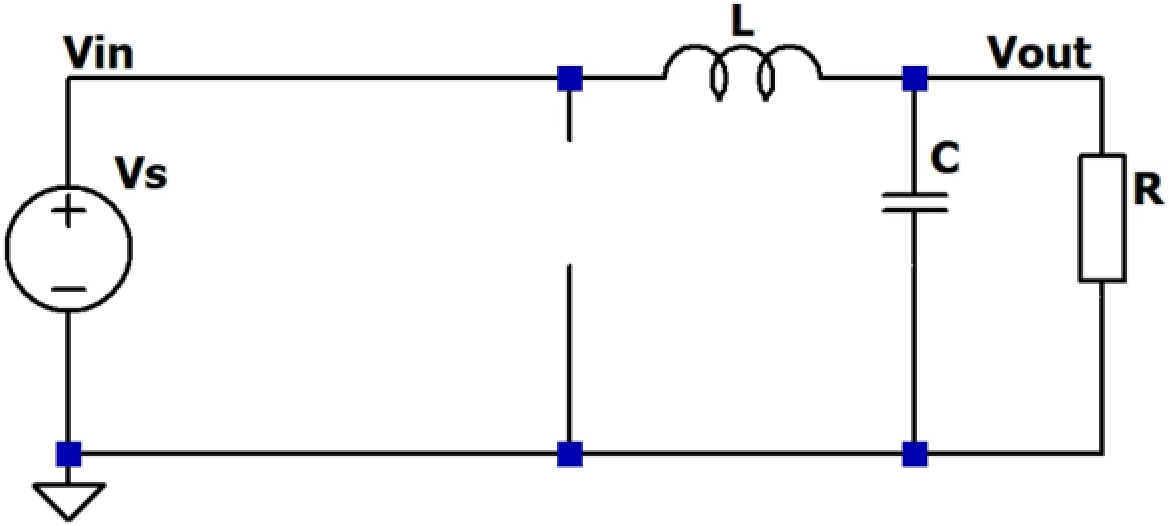

Figure 2 buck conv with and activated switch

As the current increases, the inductor's magnetic field opposes the input voltage, causing the voltage across the load to fall. However, the voltage drop across the inductor likewise reduces as the current gradually rises, raising the voltage across the load.

During this process, the flyback diode remains reverse-biased and inactive, the inductor stores energy in its magnetic field, and the total energy stored in the inductor and output capacitor (C) is calculated using the following formula:

$$\mathbf{E = (1/2) \cdot L \cdot (ipk - imin)^{\wedge}2}$$

Situation 2: The switch is not in use.

When the MOSFET (M) is turned off, the diode (D) conducts, as shown in Figure 3. If the MOSFET is turned off while the current is still flowing, a voltage drop across the inductor causes the voltage at the load (R) to be lower than the input voltage. Energy can return to the circuit through the inductor's magnetic field, which releases previously stored energy. The flyback diode (D), which is now in operation, gives the current flowing through the inductor a channel.

Because of the energy release, the load is powered by a steadily decreasing current during this phase, making the inductor the primary source of power. Less current passes through the inductor as its energy level does, and this process is continued when the MOSFET is turned back on.

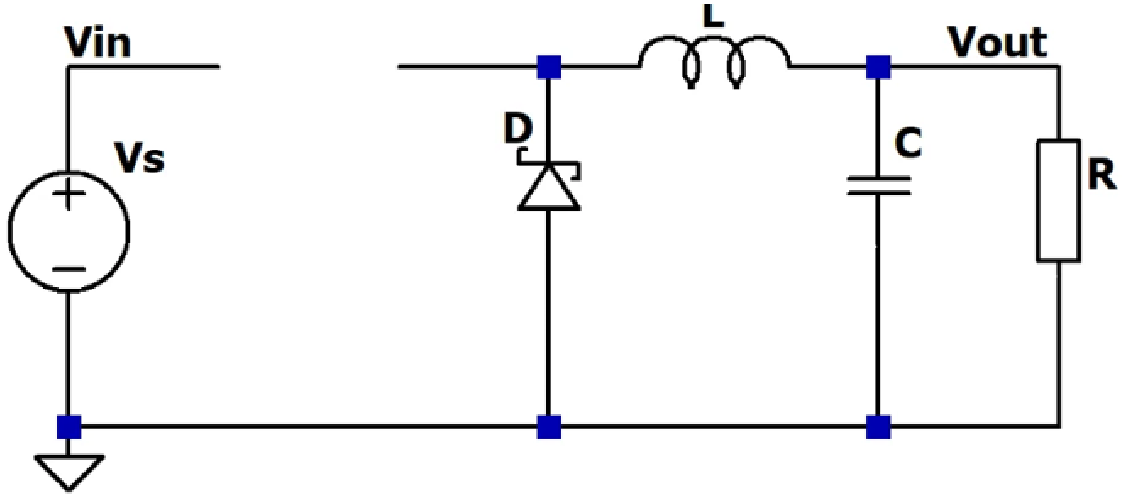

Figure 3 The Buck converter with the switch not active

Boost Converter (Step up Converter)

The boost converter functions by storing energy in an inductor, which responds to variations in the current flowing through it by adjusting its voltage. The arrangement depicted in Figure shows that a diode is connected to the load and the capacitor in the circuit, while a power MOSFET acts as a switch that is connected to the power source. With this setup, a high and steady DC output voltage is guaranteed to reach the load.

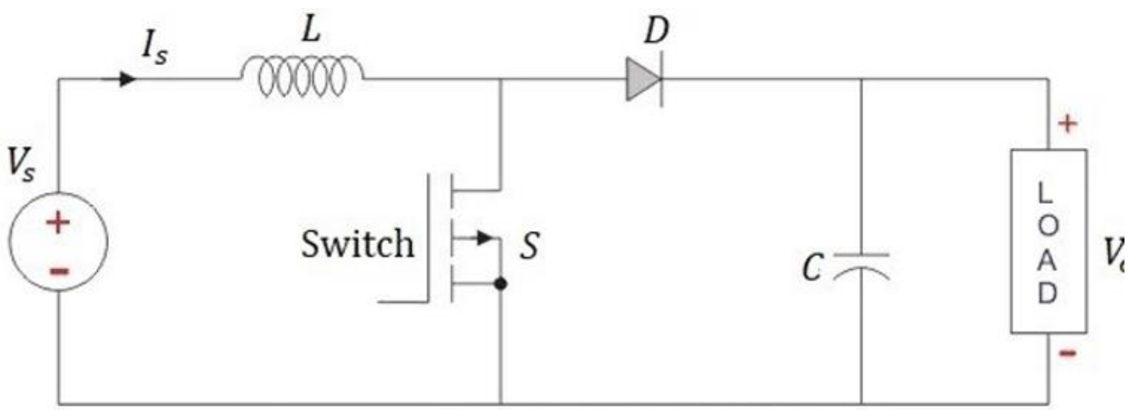

Figure 4 Boost converter

There are two ways that the Boost converter can function. They are:

Mode I: Diode D is off while Switch S is on.

Mode II: Diode D is ON and Switch S is OFF

Mode I:

behavior of the circuit in the first mode that was specified. MOSFET functions as a short circuit during this time. As a result, the inductor stores energy in its magnetic field as current runs through it.

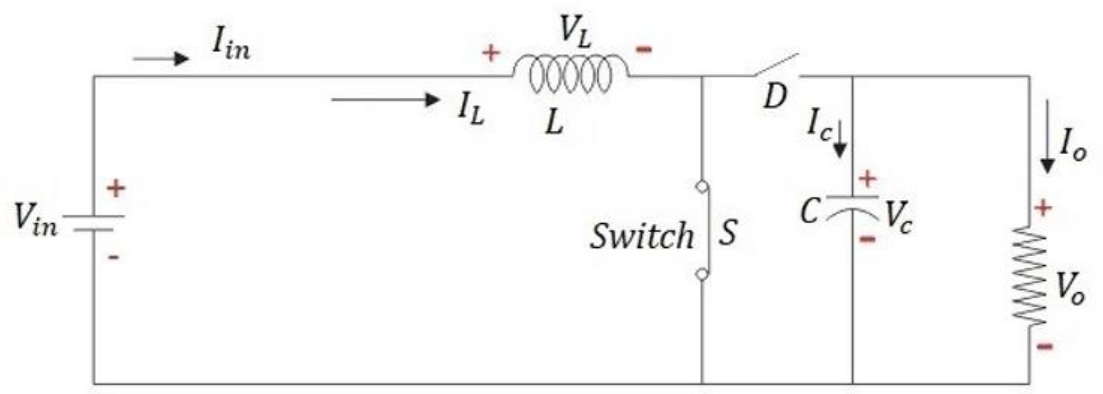

Figure 5 The Boost converter with the switch on

Mode II:

In this state, as shown in Figure 6, the switch S is off, but the diode D is on, permitting current to flow. The inductor acts as the energy source when the switch is open, storing energy as a magnetic field when the switch was closed. The inductor's polarity is reversed, the diode D becomes forward biased, and current passes through it when this stored energy is released. The energy produced by the inductor is absorbed by the load resistance.

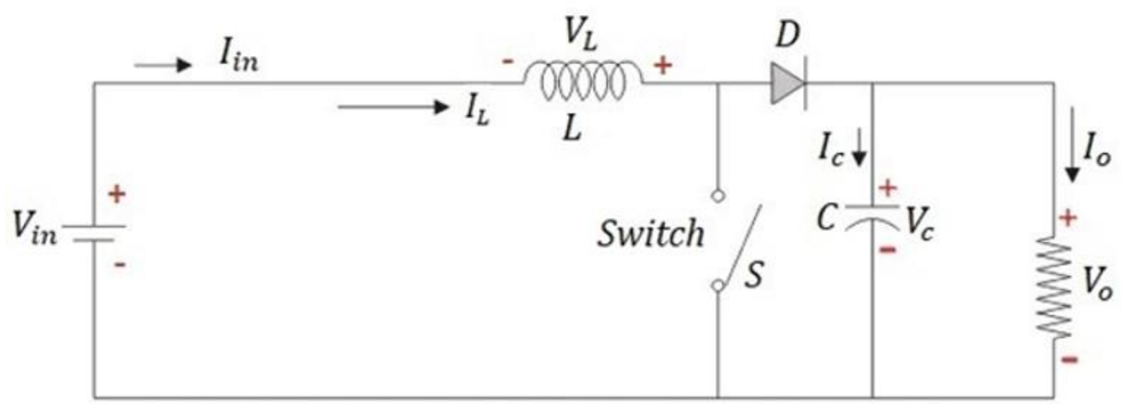

Figure 6 boost converter with the switch off

Buck-Boost Converter

The Buck-Boost Converter, sometimes referred to as a chopper, is an example of a DC-to-DC converter. A magnitude difference between the input and output voltages is possible due to the modification of the output voltage. The magnitude of the output voltage can be altered by altering the duty cycle of the switch. In this sense, this converter is similar to transformers since it enables voltage step-up or step-down operations.

The components of the traditional Buck-Boost Converter are a voltage source, a switch, an inductor, a diode, and a capacitor connected in parallel with the load, as shown in Figure 7. GaNs, BJTs, IGBTs, and MOSFETs could all be utilized as switches. The pulse width modulation (PWM) approach is used to turn the controlled switch on and off.

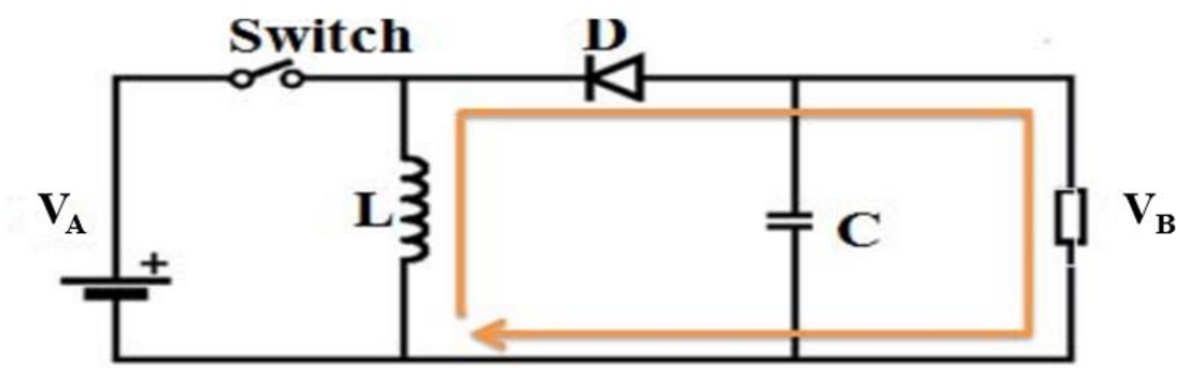

Figure 7 buck-boost converter

Procedure:

Buck Converter (Step Down Converter):

The circuit in the figure below was drawn in OrCAD.

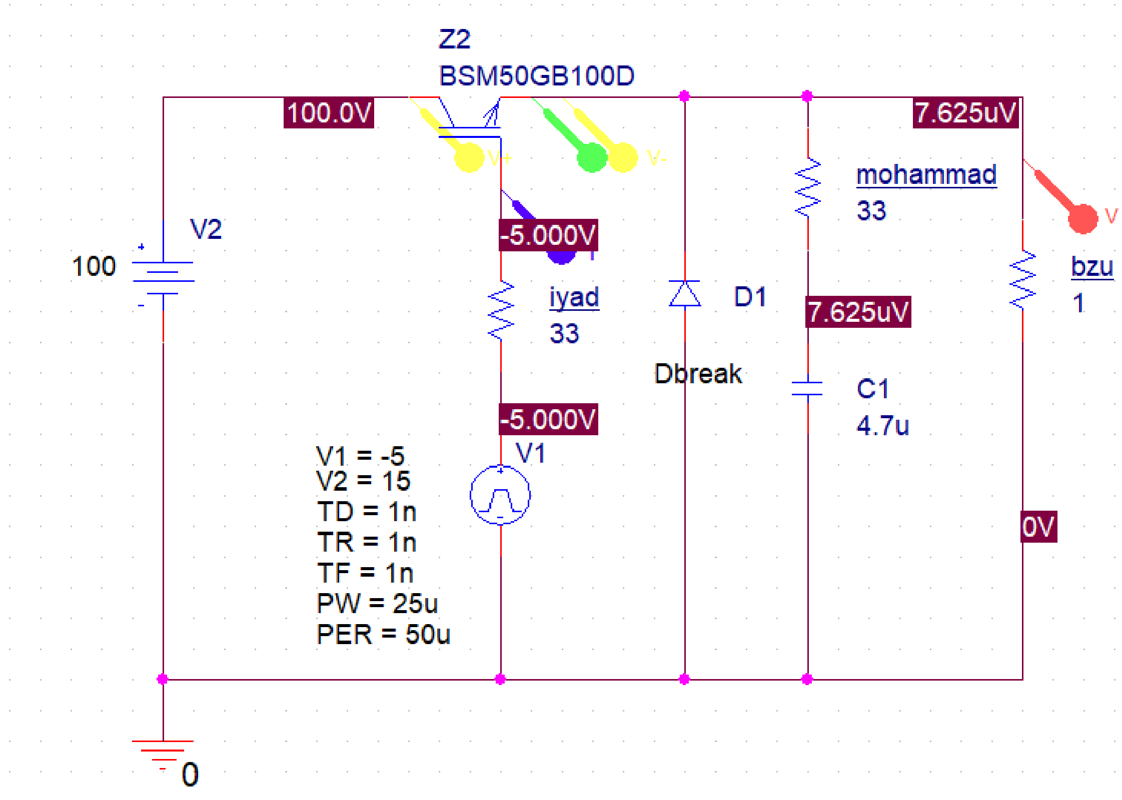

Figure 8 buck converter

The figure below shows the output voltage and it's average of the buck converter on the same plot using a suitable time. The output resistance was 1 ohm.

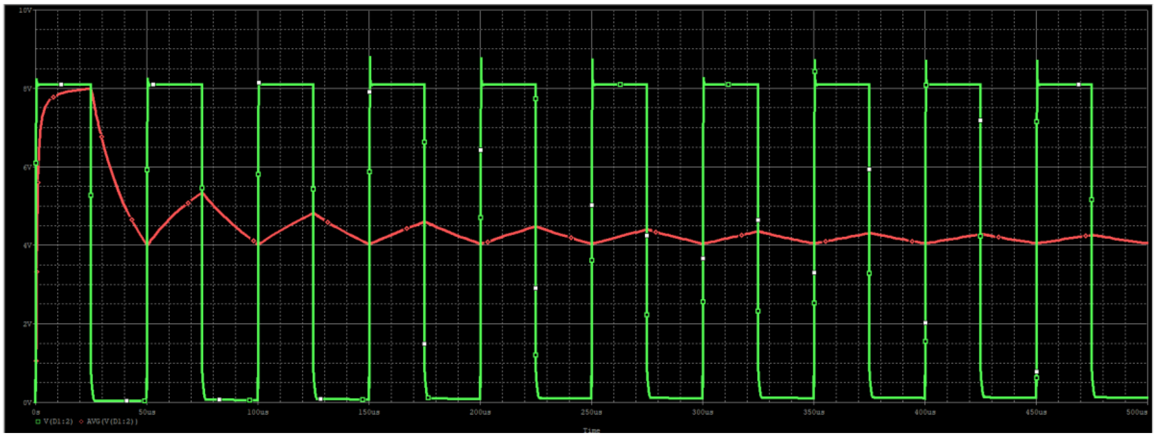

Figure 9 Vout and Vavg R=1

Figure 10 shows the IGBT current and the gate current and the voltage across the IGBT.

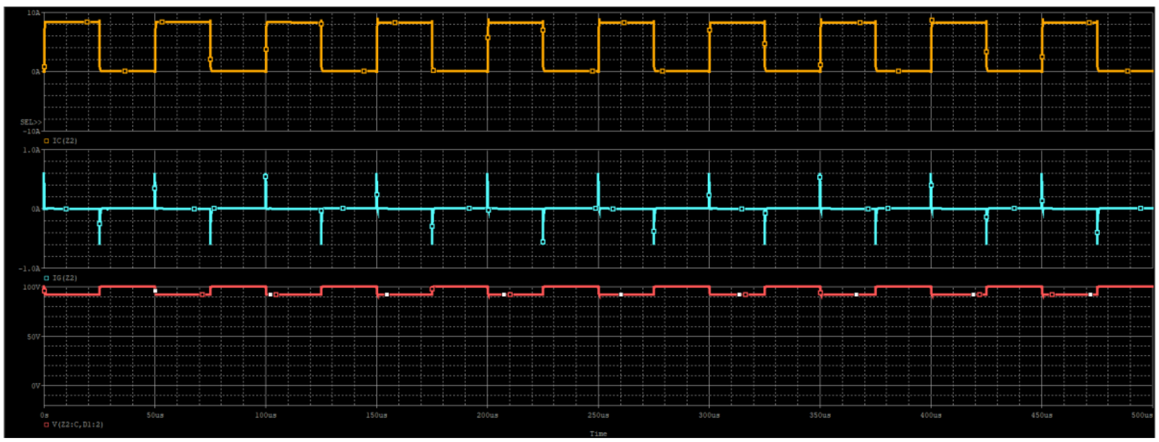

Figure 10 Igate ,Vce ,Ice

Then it was measured for k=20%,50% and 70%

By changing the PW which changes the duty cycle.

FOR K = 20%:

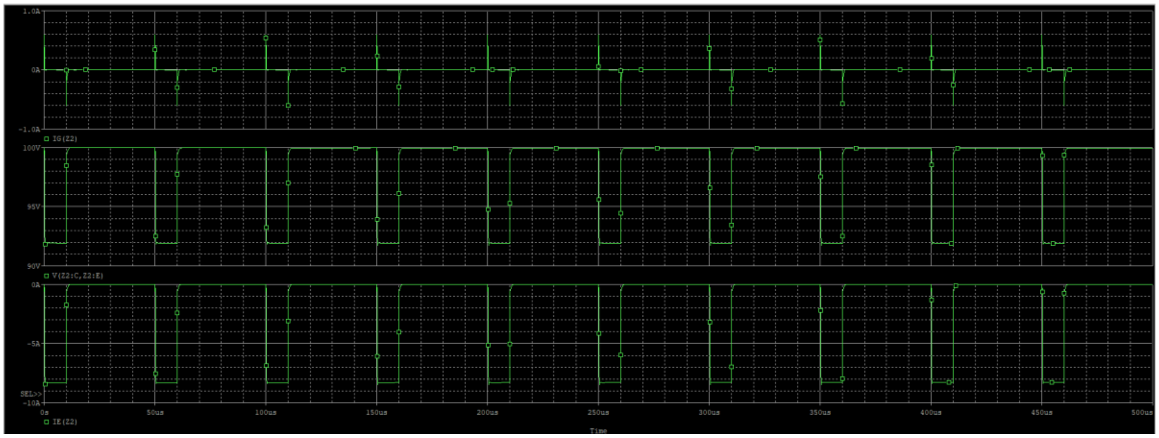

Figure 11 Igate ,Vce ,Ice k=20%

FOR K= 50%:

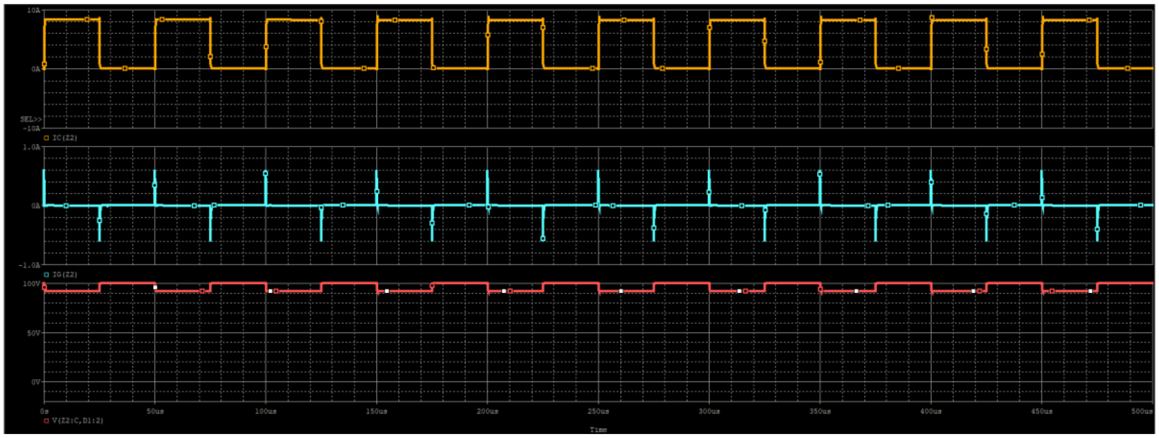

Figure 12 Igate ,Vce ,Ice k=50%

FOR K=70%:

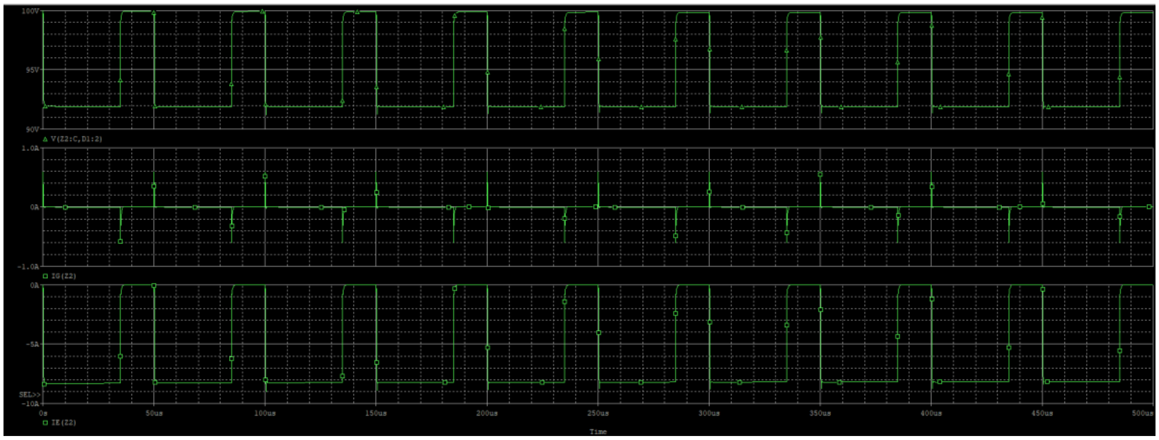

Figure 13 Igate ,Vce ,Ice k=70%

The same concept was done as the current passes through the IGBT 70% of the time period.

FFT analysis was used to show the frequency spectrum of the output voltage for the 70% case only.

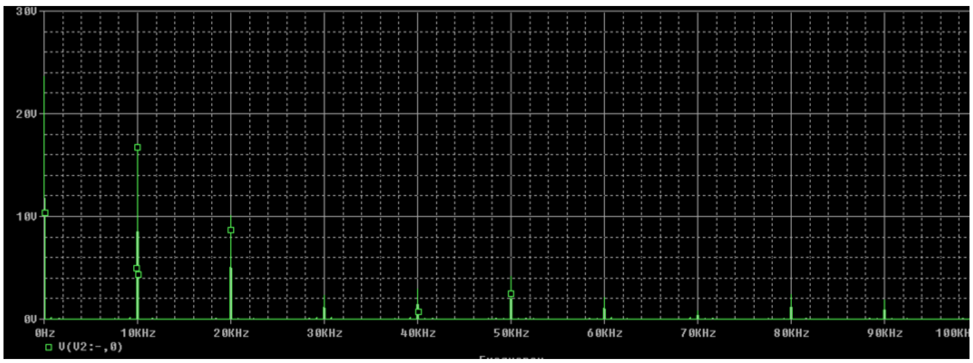

Figure 14 spectrum of Vout at duty=70%

Then a low pass filter was added

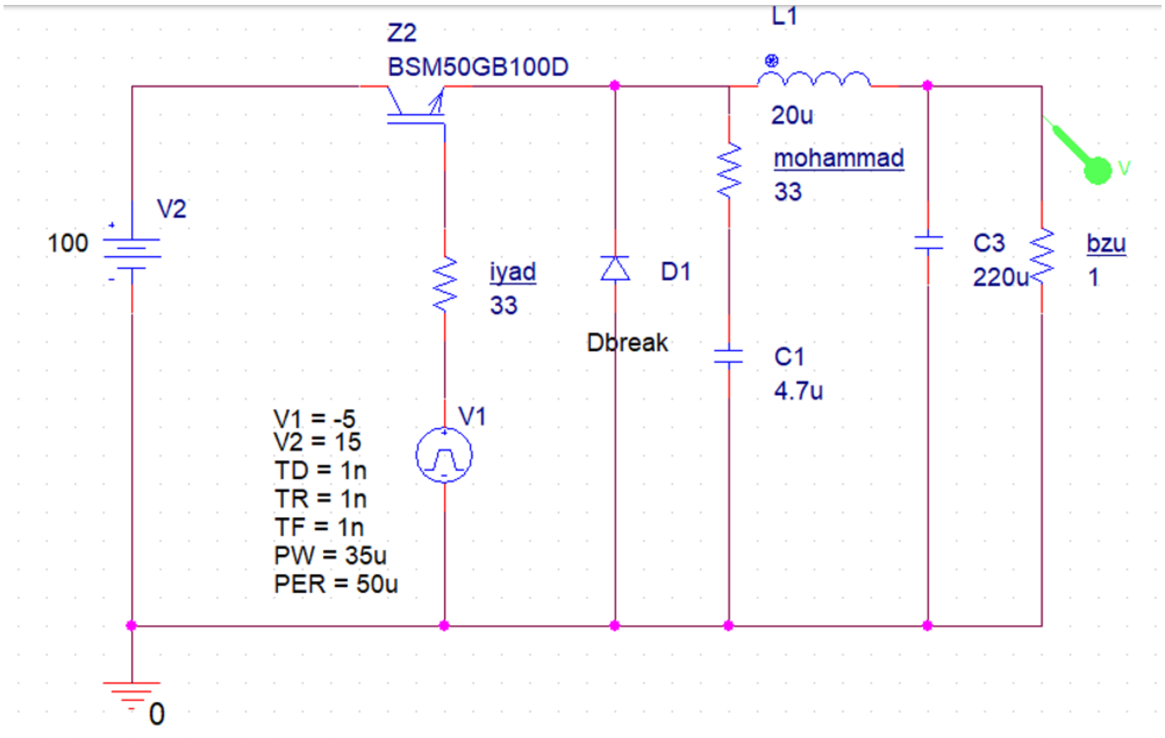

Figure 15 buck converter with a low pass filter

The figure below shows the output voltage of the buck converter after adding a low pass filter.

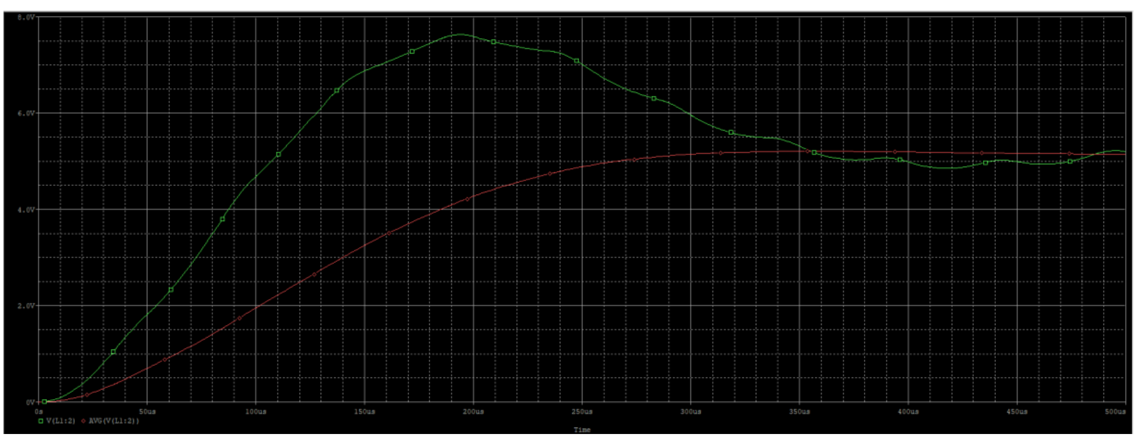

Figure 16 Vout and Vavg

Adding a filter to the output has reduced the output voltage ripple

Then the same things were measured as the previous part.

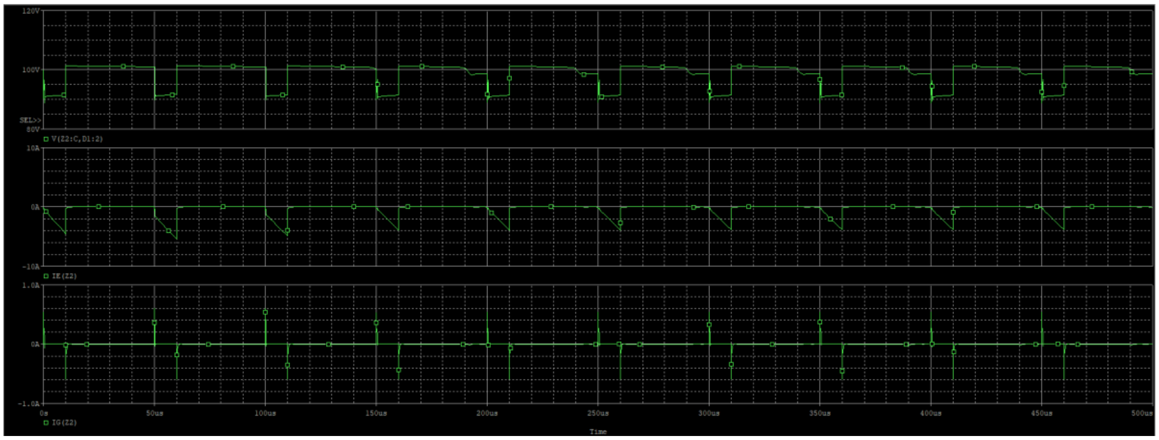

Figure 17 Igate ,Vce ,Ice k=20%

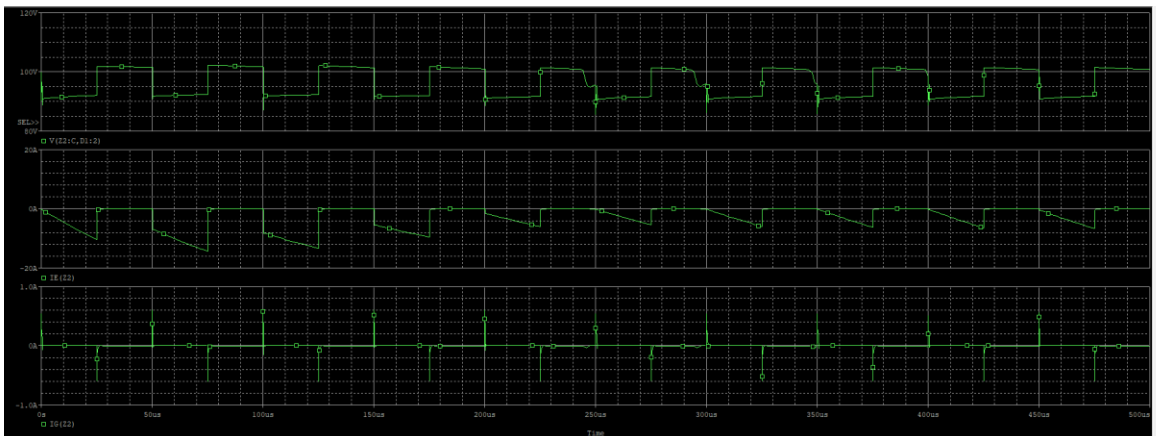

Figure 18 Igate ,Vce ,Ice k=50%

Figure 19 Igate ,Vce ,Ice k=70%

FFT analysis was used to show the frequency spectrum of the output voltage for the 70% case only as seen in the figure below.

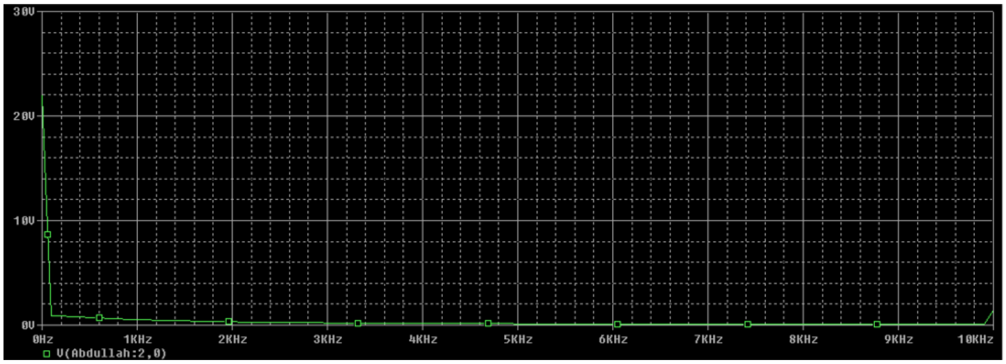

Figure 20 spectrum of Vout at duty=70% with low pass filter

Then the filter capacitance was changed to 22µF

And the same measurement were taken

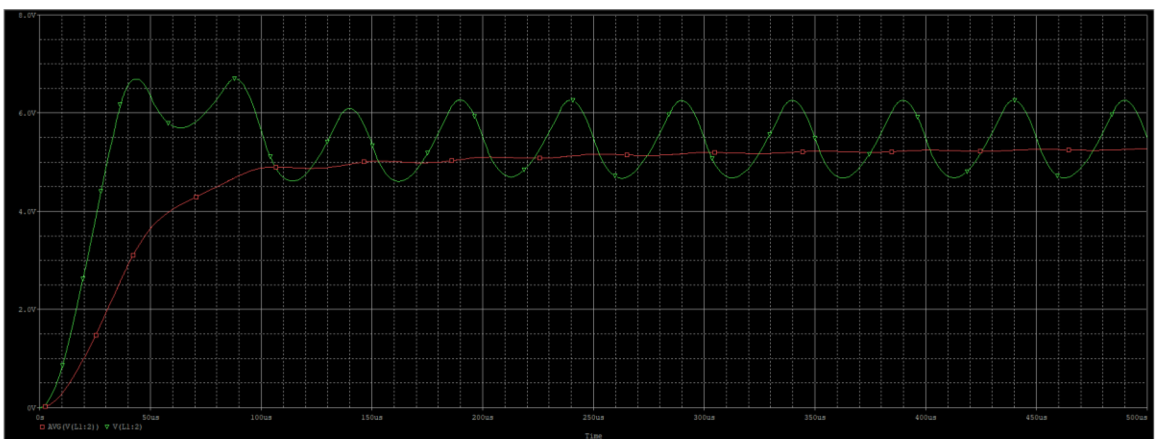

Figure 21 Vout and Vavg C=22

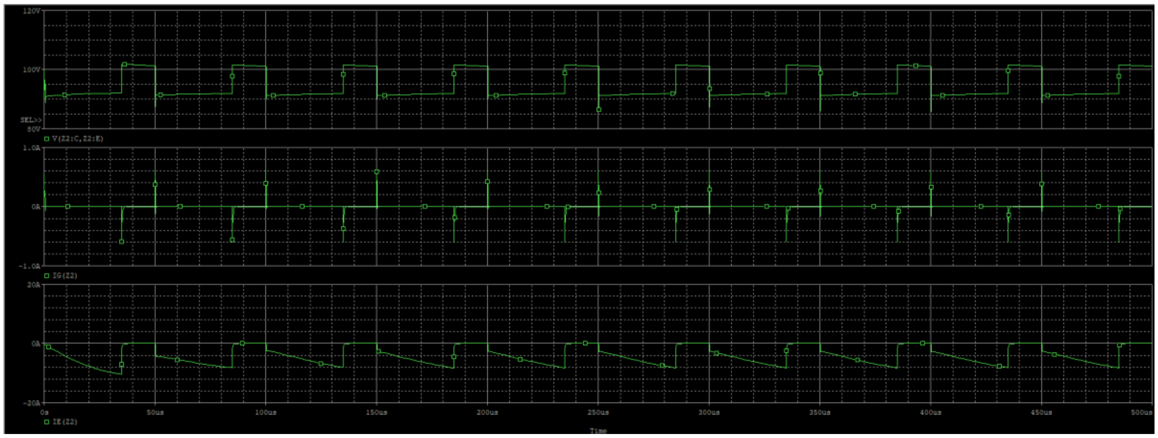

Figure 22 Igate ,Vce ,Ice k=20% C=22

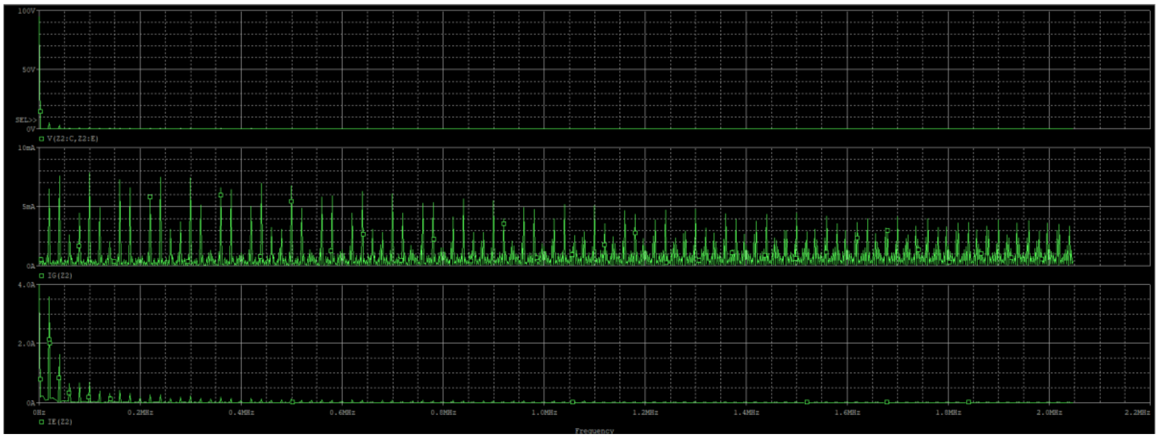

Figure 23 FFT spectrums of all signals

Buck-Boost Converter

The circuit in the figure below was drawn in OrCAD.

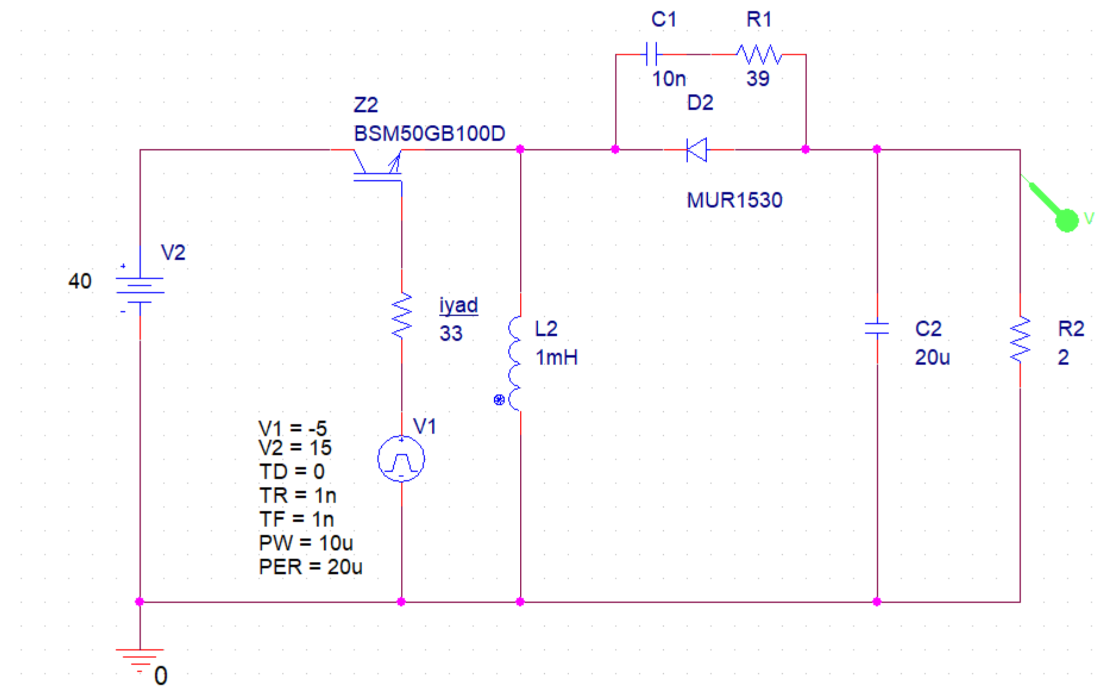

Figure 24 Buck boost converter in ORCAD

The Figure below shown the output voltage along the average voltage.

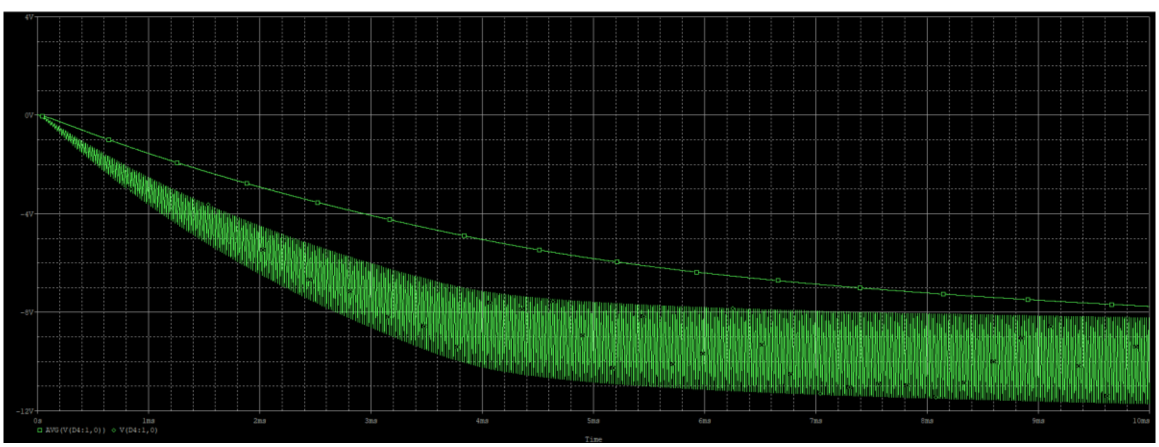

Figure 25 Vout and Vavg

The figure below shows the inductor current and IGBT current for a different duty cycles (20% and 70%)

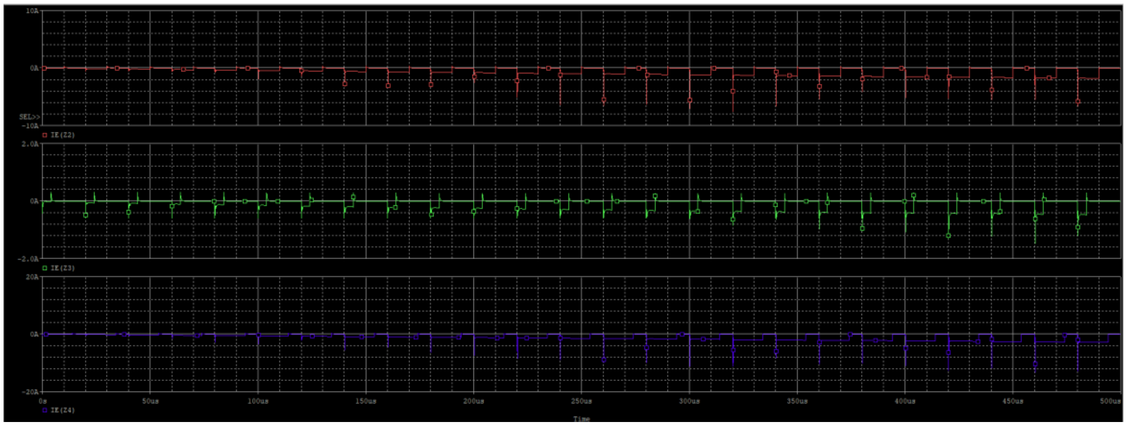

Figure 26 I_ Inductor IG IE dutycylce=20%

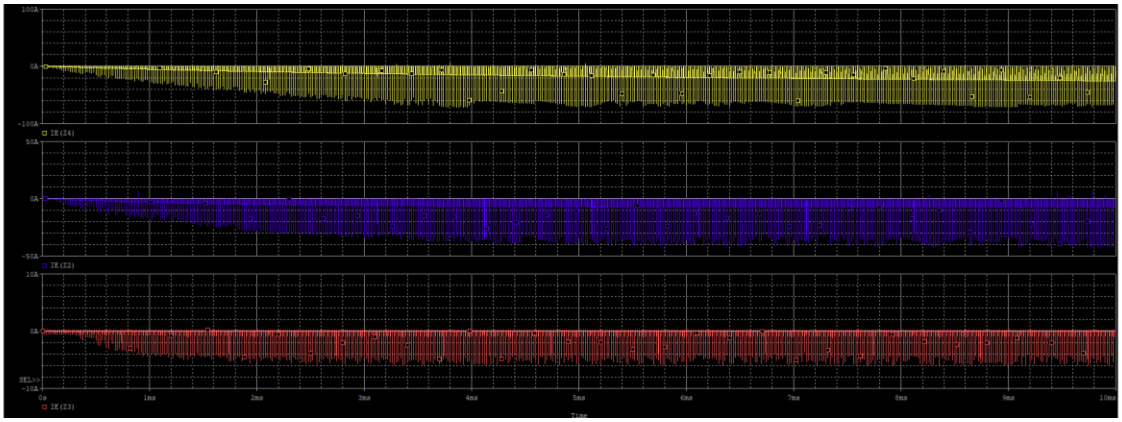

Figure 27 I_ Inductor IG IE dutycylce=70%

The Figure below shows the Buck-Boost Converter output voltage ripple for a 70% duty cycle.

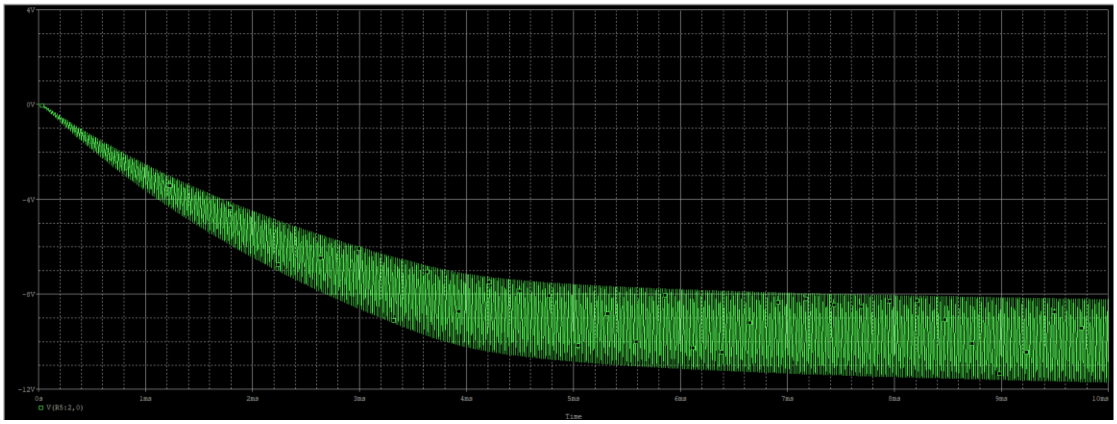

Figure 28 buck-boost Voltage ripple

Frequency spectrum of the output voltage at 70% of the duty cycle.

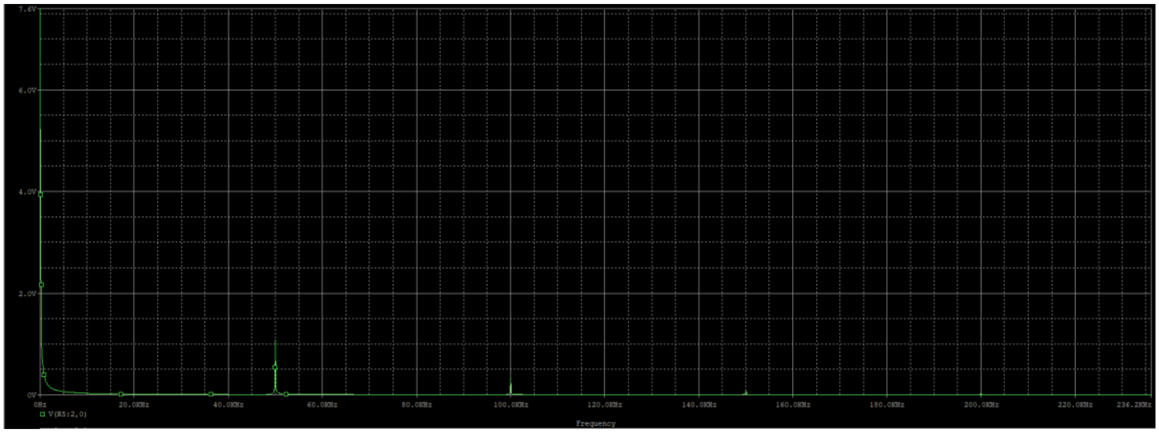

Figure 29 FFT of Vout duty cycle=70%

Then the capacitance was changed to 1uF.

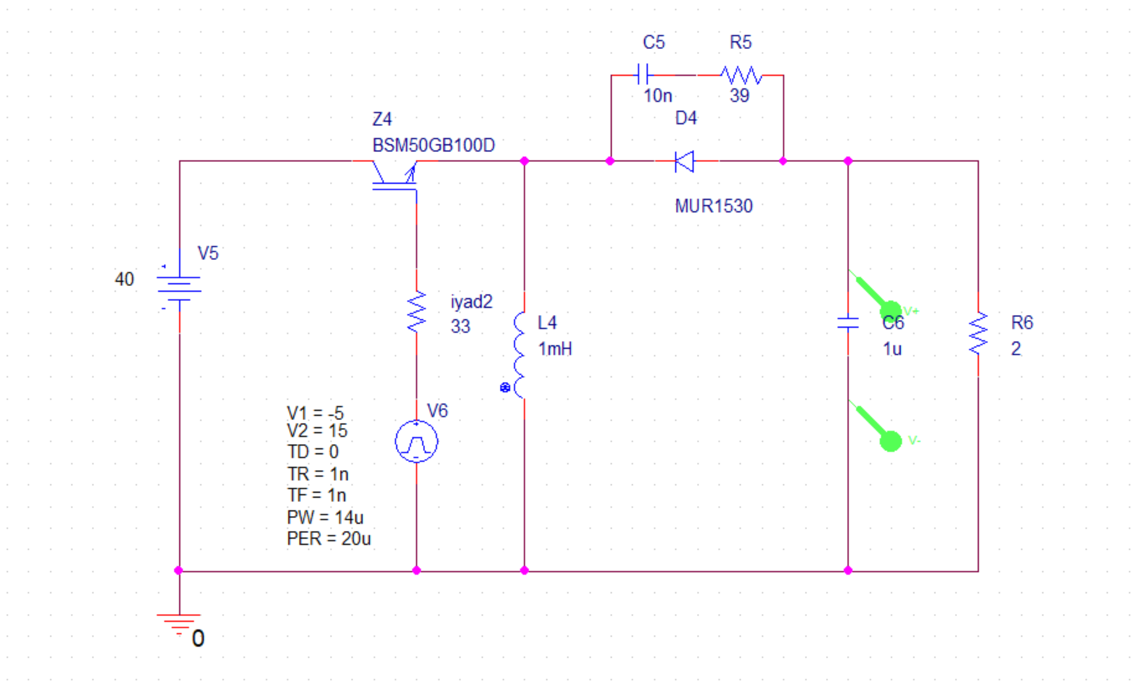

Figure 30 Buck-Boost C=1uF

and the new ripple voltage on the output voltage for a 70% duty cycle was plotted as seen

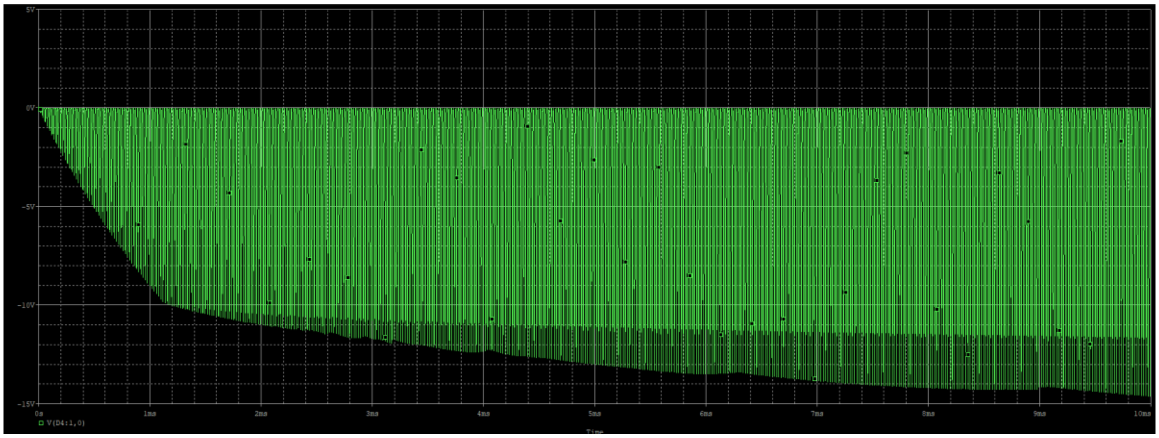

Figure 31 new Vout ripple

FFT analysis was used to show the frequency spectrum of the output voltage for the new capacitor value.

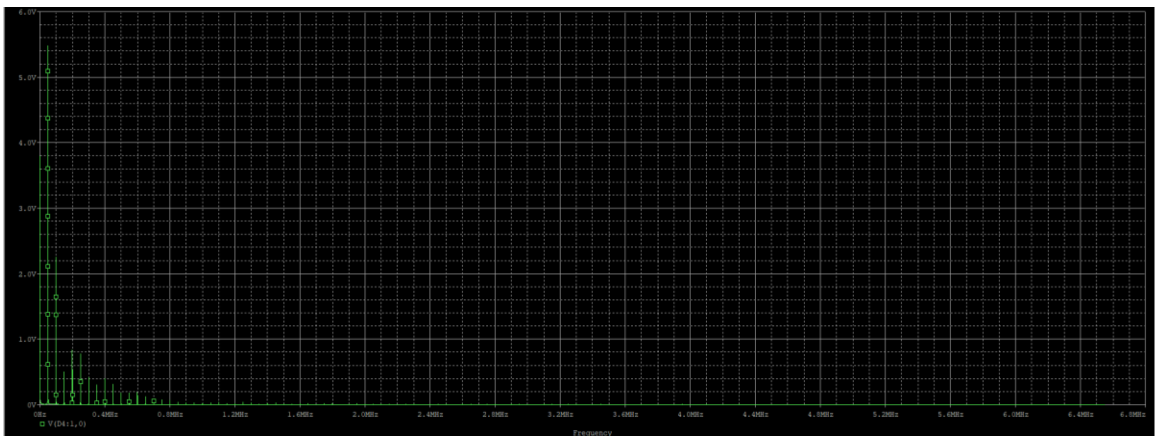

Figure 32 spectrum for Vout

Conclusion

To sum up, OrCAD is a helpful tool for modeling different converters since it helps with output prediction and assesses the influence of important variables like load value, duty cycle, and filters. Buck, Boost, and Buck-Boost converters were among the basic power electronics converters that were thoroughly investigated in this experiment. It also illustrates how converter performance may be optimized using these simulations in a variety of operating scenarios.

References

[1] Dr.M.Abu-Khaizaran Power Electronics ENEE3308 Lecture Notes.

[2]https://www.monolithicpower.com/en/power-electronics/dc-dc-converters/buck-converters

accessed at (12/3/2024 8:13 PM)

[3] https://www.monolithicpower.com/en/power-electronics/dc-dc-converters/buck-converters

accessed at (12/3/2024 8:39 PM)

[4] ENEE4104 Lab Manual.