Design and Analysis of a DC -DC Buck converter and Boost Converter to Achieve High Efficiency by altering duty cycle and input voltage

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Abstract- This paper explains DC to DC buck convertor and boost converter which cites the dependency of duty cycle and input voltage on output voltage. It consists of elements like switch/mosfet, transistor, inductor, resistors. A NGSpice simulation has been conducted to analyze the efficiency of the DC-DC buck converter and boost converter. The result shows the efficiency of the DC-DC buck and boost converter increases as we increase the duty cycle and the input voltage.

Index Terms- DC-DC buck and boost converter, ,efficiency , input voltage , duty cycle

I. INTRODUCTION

While doing literature survey, we came across that DC- DC buck and boost converter was not designed with the help of switches, instead it was designed with the transistors. So, in order to form a novel project we decided to design this DC to DC convertor with the help of a switch. As we know that, to change the values of MOSFETs we had to alter the values of gate in order to get the output response. But in our case switch is used in place of MOSFET. This was the difficulty and the challenge which we incurred during our project simulation. As a solution to this we decided to give different voltages at the switch so that we can observe different ON and OFF time as per our desire which will fetch us buck or boost converter. This entire project simulation is done on NGSpice which is widely used for the simulation purpose. It consists of a very simple yet efficient interface. We can design very interesting circuits on this platform which can be a problem while trying to attempt all those circuits on some other platform.

A DC power offer is employed in most of the appliances wherever a relentless voltage is needed. DC stands for electrical energy, during which the present flow is one-way. the method of DC conversion are often done by DC Converters. The charge carriers in DC offer travel in a very single direction. star cells, batteries and thermocouples square measure the sources of DC offer.. In AC offer the charge carriers modification their direction sporadically. AC offer is employed as utility current for home desires.

A DC to DC device takes the voltage from a DC supply and converts the voltage of offer into another DC voltage level. they're wont to increase or decrease the voltage level. this is often unremarkably used cars, moveable chargers and moveable optical disk players. Some devices want an exact quantity of voltage to run the device. an excessive amount of of power will destroy the device or less power might not be ready to run the device. The device takes the ability from the battery and cuts down the voltage level, equally a device change of magnitude the voltage level. for instance, it would be necessary to step down the ability of an oversized battery of 24V to 12V to run a radio.

The device takes the ability from the battery and cuts down the voltage level, equally a device change of magnitude the voltage level. for instance, it would be necessary to step down the ability of an oversized battery of 24V to 12V to run a radio.The Buck device represented in Power provides Module three.1 produces a DC output in an exceedingly vary from 0V to simply but the input voltage. The boost device can turn out associate output voltage starting from identical voltage because the input, to grade abundant over the input.There square measure several applications but, like powered systems, wherever the input voltage will vary wide, beginning at full charge and bit by bit decreasing because the battery charge is employed up. At full charge, wherever the battery voltage is also over truly required by the circuit being supercharged, a buck regulator would be ideal to stay the availability voltage steady. but because the charge diminishes the input voltage falls below the extent needed by the circuit, and either the battery should be discarded or re-charged.

II. OPERATION

i. DC-DC buck converter

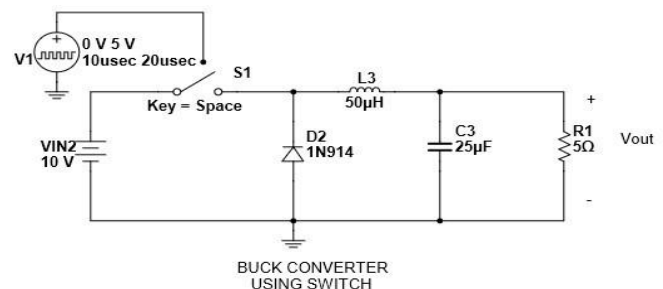Circuit configuration of a DC-DC buck converter using switch.

Fig. 1.1 DC-DC buck converter circuit configuration

In a DC to DC buck converter the output voltage is lower than the input voltage i.e**. step down chopper.**

Vout = K x Vin where **k= (TON/T)**

When the switch is turned off, a free wheeling diode is used to allow the load current to flow through it,. Due to the load inductance, the load current must be allowed a path, which is provided by the diode .In the absence of the diode it may cause damage to the switching device like MOSFET due to the high induced emf of the inductance. During the ON period (TON ≥ t ≥ 0), the output voltage is same as the input voltage i.e. v0 = Vs. (The ON period is TON).During the OFF period (T ≥ t ≥ TON), the output voltage is zero i.e. v0 = 0 and diode DF starts conducting. (The OFF period is TOFF = T-TON).The total time period is T = TON +TOFF and the frequency is f= 1/T. The duty ratio is k= (TON/T) = [TON/(TON/(TON+TOFF))], its range being 1.0≥k≥0.0.

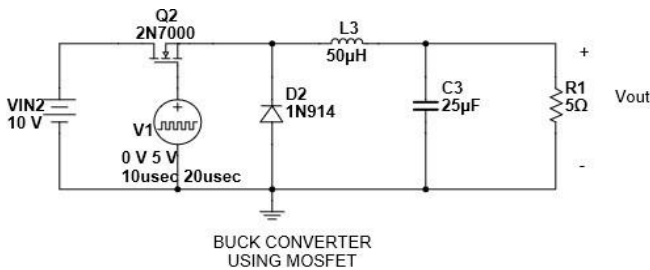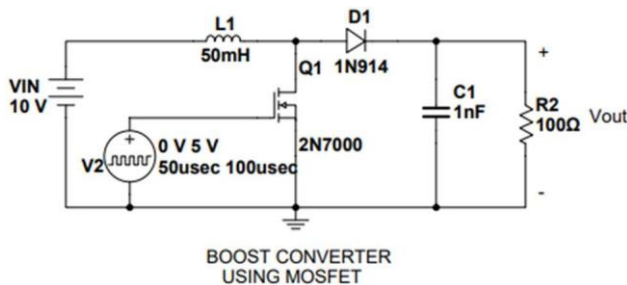Circuit configuration of a DC-DC buck converter using MOSFET.

Fig. 1.2 DC-DC buck converter circuit configuration

A variable dc output voltage is obtained from a constant dc input voltage. A buck converter (dc-dc) is shown in Fig. 1.1 Only a switch is shown, for which a device as described earlier belonging to transistor family is used. The load is inductive (R-L) one. Resistor is connected in parallel with capacitor to discharge it. Due to the load inductance, the current across load must be allowed a path, which is provided by the diode; otherwise, i.e., in the absence of the above diode, due to the high induced emf of the inductance load current decrease, may cause damage to the switching device.

ii.   **DC-DC boost converter**
Circuit configuration of a DC-DC boost converter using MOSFET.

Fig.   2.1   DC-DC boost   converter   circuit

The load is resistive and inductive (R-L) type, in which the inductance of the load is small.. Initially during the ON period (TON ≥ t ≥ 0), The output voltage is zero (V0=0). The switch S is kept OFF during the period T ≥ t ≥ TON, where the OFF period is TOFF = T – TON . A boost converter (dc-dc) is shown in Fig. Normally transistor is used as a switch. Also, a diode is used in series with the load. The load is of the same type as given earlier. An inductance, L is assumed in series with the input supply. The position of the switch and diode is different as compared to their position in the buck converter.

The operation of the circuit is explained as follows. Firstly, the switch, S (i.e., the device) is put ON (or turned ON) during the period . If no battery (back emf) is connected in series with the load,output voltage is zero and also as stated earlier. The current from the source flows in the inductance L. The value of current increases linearly with time in this interval, with being positive. As the current through L increases, the polarity of the induced emf is taken as positive.

III.   EXPRESSION FOR THE DC-DC BUCK AND BOOST CONVERTER

i.   DC-DC BUCK CONVERTER the average value of the output voltage is

$$V_0 = \frac{1}{T}\int_0^T v_0\, dt = \frac{1}{T}\int_0^{T_{ON}} V_s\, dt = V_s\left(\frac{T_{ON}}{T}\right) = k\,V_s$$

ii.   DC-DC BOOST CONVERTER
The average value of the output voltage

$$(V_s\,/\,L)\,T_{ON} = [(V_0 - V_s)/\,L]\,T_{OFF}$$

$$V_0 = V_s\left(\frac{T}{T_{OFF}}\right) = V_s\left(\frac{T}{T-T_{ON}}\right) = V_s\left(\frac{1}{1-(T_{ON}/T)}\right) = V_s\left(\frac{1}{1-k}\right)$$

$$k = (T_{ON}/T) = [T_{ON}/(T_{ON}+T_{OFF})].$$

II.   PERFORMANCE OF THE DC-DC Buck AND
Boost CONVERTER

i.   **DC-DC BUCK CONVERTER**
The converter is designed by using NGSPICE. The converter is arranged by 10V input DC source. MOSFET switch which is considered as a switching device where the switching frequency has been set to 50KHz, as well as inductors L1 set at 50uH, load resistance RL 5Ω and output filter capacitor CL at 25µF. Table below represents the specifications of the circuit.
In a DC to DC buck converter the output voltage is higher than the input voltage i.e. **step up chopper.**

Table 1 Specification of the buck converter.

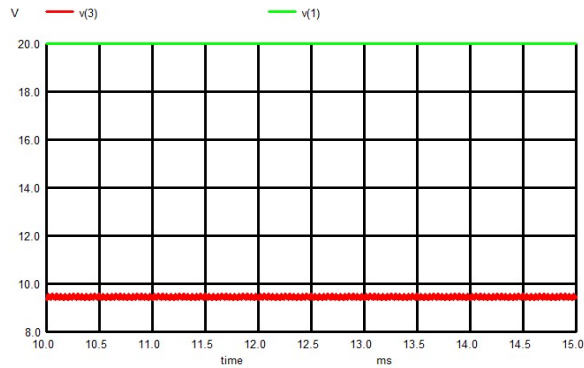| Input DC Voltage	$V_{in} = 10V$
Inductor	$L_1 = 50uH$
Capacitor	$C_L = 50u$
Resistor	$R_L = 5\Omega$

A. Result from ngspice Simulation :

The waveform plot presented in Fig. shows the simulation result of the DC-DC buck converter. Simulation result Fig shows output voltage received from the simulation is significantly smaller than the input signal. The fig containing currents passing through diodes D inductors L capacitor CL and resistor RL respectively. Here the input voltage 10V and the output voltage 8V and efficiency 83.79%
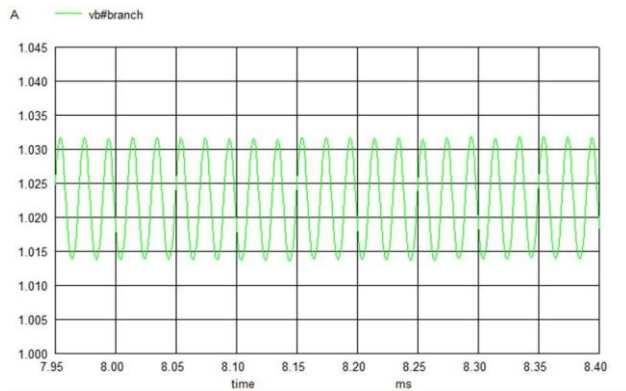
GRAPHS: V(1) Input Voltage V(3) Output Voltage

Output current

Current across inductor

B. Quantitative Comparison

Variation of Voltage gain and efficiency with respect to duty cycle

Table 1 below shows the comparative analysis between DC-DC buck converter under duty cycle and voltage gain variation, where circuits are switched at 50kHz means total time is 20us. When circuits are performing under duty variation, the switching frequency 50kHz fixed for buck circuit and other paramters also fixed. The comparison analysis between efficiency verses duty cycle variation of DC-DC buck converter shows that as we increases the duty cycle the efficiency increases. We get maximum efficiency of 83.93 at 100% duty cycle.
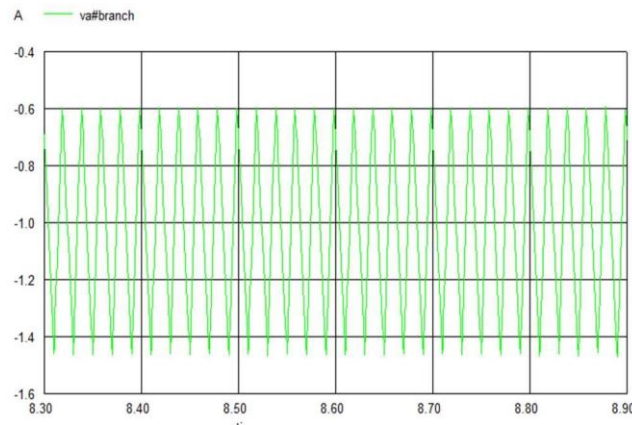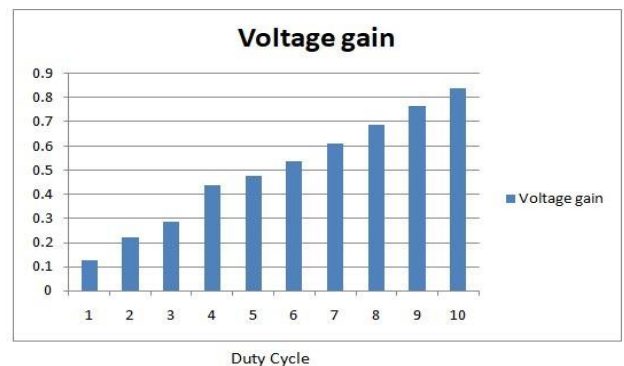
Table 1 Performance Comparison under Duty Cycle

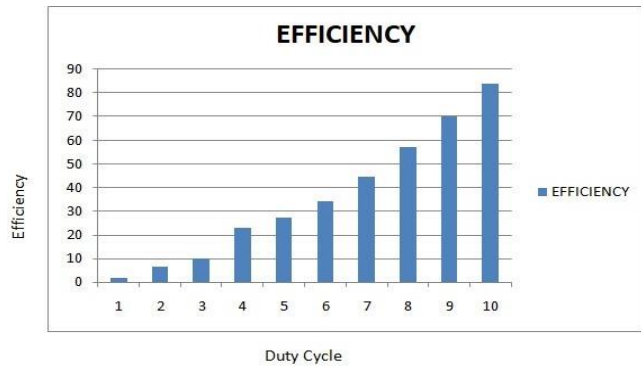| DUTY CYCLE (percentage)	INPUT CURRENT (amperes)	OUTPUT CURRENT (amperes)	OUTPUT VOLTAGE (PRACTICAL) (volts)	OUTPUT VOLTAGE (EXPECTED) (volts)	INPUT POWER (watts)	OUTPUT POWER (watts)	EFFICIENCY (percentage)
100	3.33	3.33	16.8	20	66.6	55.944	83.93
90	3.33	3.05	15.3	18	66.6	46.665	70.11
80	3.33	2.76	13.8	16	66.6	38.08	57.12
70	3.33	2.45	12.18	14	66.6	29.610	44.41
60	3.33	2.13	10.69	12	66.6	22.769	34.15
50	3.33	1.91	9.54	10	66.6	18.221	27.33
40	3.33	1.77	8.7	8	66.6	15.399	23.10
30	3.33	1.17	5.674	6	66.6	6.633	9.950
20	3.33	0.95	4.4	4	66.6	4.18	6.276
10	3.33	0.52	2.5	2	66.6	1.03	1.545

Variation of Voltage gain with respect to duty cycle

Voltage gain=output voltage/input voltage
From above graph,Voltage gain increases with increase in value of duty cycle.
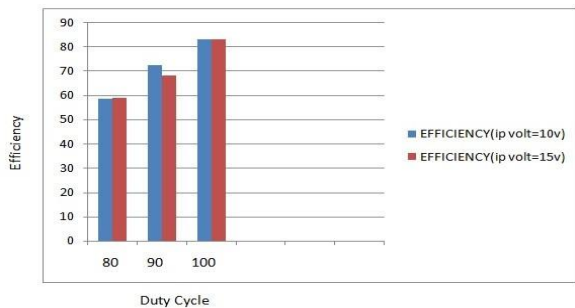
Variation of efficiency with duty cycle

Efficiency of Buck conveter is increases with increase in the value of duty cycle.maximum efficiency is for 100% duty cycle . As for 100% duty cycle output volteg should be equal to that of input voltage.But here output voltage is coming out to be 16.8 V and with 84% efficiency.

Variation of efficiency for different amplitude in different duty cycles

Moreover, Table 2 below shows the comparison between duty cycle and voltage gain for conventional DC-DC boost converter where switching frequency is kept at 10kHz.
Furthermore, the ratio between duty cycle and voltage gain of proposed circuit indicated below.

Table 2 Performance Comparison under input voltage.

DUTY CYCLE (percentage)	INPUT VOLTAGE (volts)	OUTPUT VOLTAGE (PRACTICAL) (volts)	INPUT CURRENT (amperes)	OUTPUT CURRENT (PRACTICAL) (amperes)	INPUT POWER (watts)	OUTPUT POWER (watts)	EFFICIENCY (percentage)
100	10	8.21	1.66	1.66	16.66	13.794	82.79
100	15	12.5	2.5	2.49	37.5	31.125	83
90	10	7.6	1.7	1.52	17	11.552	67.95
90	15	11.4	2.4	2.28	36	25.992	72.2
80	10	6.8	1.6	1.37	16	9.316	58.885
80	15	10.32	2.44	2.058	36.6	21.34	58.30

xiii.   DC-DC BOOST CONVERTER

The converter is designed by using NGSPICE. The converter is arranged by 10V input DC source. MOSFET switch which is considered as a switching device where the switching has been set to 10KHz, as well as inductors L1 set at 0.7mH, and output filter capacitor CL at 1nF. Table below represents the specifications of the circuit.
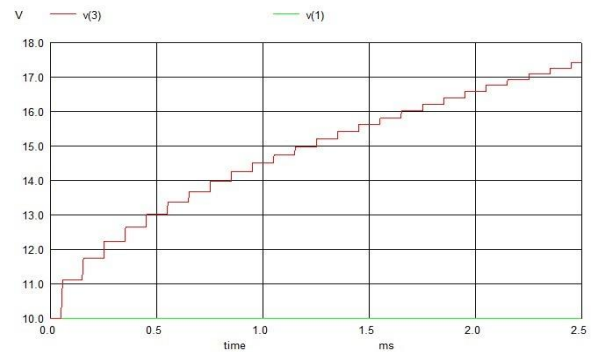
Table 1 Specification of the boost converter.

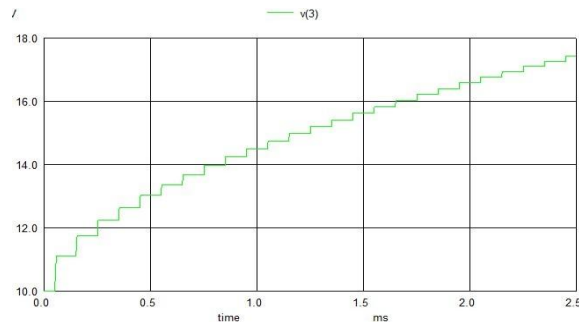| Input DC Voltage	Vin = 10V
Inductor	L1 = L2 = 0.7mHH
Capacitor	CL = 1nF

A..Result from ngspice Simulation

The classical wave shapes presented in Fig. shows the simulation result of the DC-DC BOOST converter. Simulation result Fig shows output voltage received from the simulation is significantly larger than the input signal. The fig containing currents passing through diodes D inductors L capacitor CL respectively. Here the input voltage 10V and the output voltage 12.8V and efficiency 95.5%
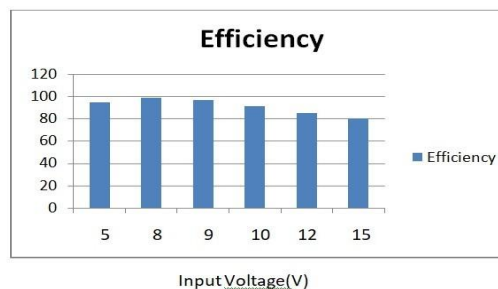
GRAPHS: V(1) Input Voltage V(3) Output Voltage
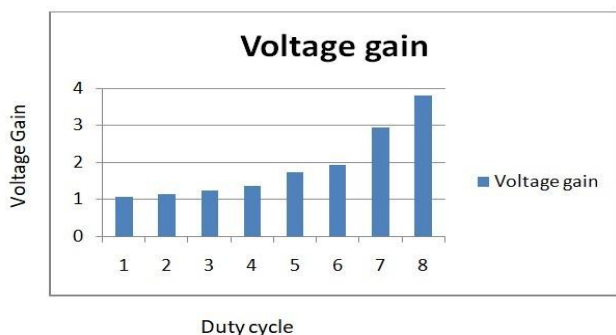

V(3) Output Voltage

B.Quantitative Comparison

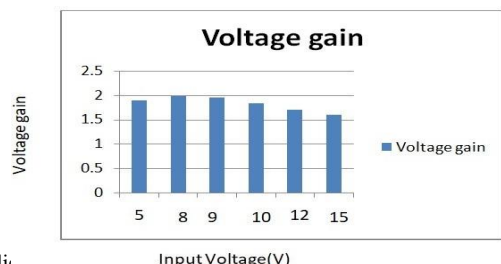| DUTY CYCLE	OUTPUT VOLTAGE(Observed)	OUTPUT VOLTAGE(Theoretical))	EFFICIENCY	Voltage gain
10	10.6122	11.11	95.5	1.06122
20	11.302	12.5	90.41	1.1302
30	12.311	14.28	86.2	1.2311
40	13.52	16.66	81.15	1.352
50	17.32	20	86.6	1.732
60	19.246	25	76.98	2
70	29.5	33.33	88.5	2.95
80	38	50	76	3.8

variation of efficiency with duty cycle:

variation of voltage gain with duty cycle:

variation of input amplitude for 50%duty cycle

input voltage(V)	Output voltage(Observed)	Output Voltage(theoretical)	Voltage gain	Efficiency
5	9.47826	10	1.8955	94.78
8	15.8261	16	1.97826	98.9
9	17.4203	18	1.955	96.7
10	18.2899	20	1.828	91.4
12	20.4058	24	1.7	85
15	24	30	1.6	80

variation of input amplitude for 50%duty cycle

IV.   CONCLUSION

A buck and boost DC to DC converter can be used for the purpose of increasing the output voltage according to the variation in the duty cycle and the input voltage. In this operation, buck boost converter provides step down output voltage and the total circuit has drawn by using the same element of conventional DC-DC buck converter. It can be concluded from the results of DC-DC buck and boost converter output simulations performs better with variation of duty cycle. It is also seen that with increase in duty cycle, there is magnificent increase in efficiency. Not only that, we get a tremendous increase in the voltage gain too. The novelty of this project is we can get high and low voltage as per our application with maximum efficiency. This circuit can efficiently work for DC power supply appliances where a constant voltage is required. There is no such significant increase in output current when we increase the input voltage in Buck converter. This can be surely viewed as a novelty.

The proposed DC-DC buck and boost converter will be suitable to use in audio and instrumentation amplifier, line drivers and receivers.

ACKNOWLEDGMENT

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