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Design of PWM based Buck converter for Low Power Application

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ABSTRACT: Now a day's dc-dc switching converters are widely used for sophisticated application. By using these converters with given dc input voltage a stabilized output voltage can be obtained by using Buck (lower), Boost (higher) or Buck –Boost (generic) topology which improves the efficiency of dc-dc converter as compared to linear regulators. Most used technique to control switching power supply is pulse width modulation (PWM). In this way a particular dc-dc converter is designed by keeping the typical application in mind. A properly designed dc-dc converter provide low ripple, better noise rejection, reliable and efficient converter. For some typical application like powering LED needs constant current supply for constant illumination, hence feedback based closed loop converters becomes better choice. In the present thesis for low power application a PWM based closed loop dc-dc buck converter has been designed, analyzed and simulated. A MOSEFET has been used as switching device and components has been designed for low ripple and low noise. With variation in load and variation in input power supply output supply voltage has been obtained as constant value by using PID controller. The performance of PID controller and switching frequency has been adjusted such that the output voltage maintain at 8 V. By rigorous simulation procedure it has been obtained that for load resistance in the range of 10Ω to 35Ω and with the value of P = 8, I = 20 and at a switching frequency of 100 KHz, the output voltage provides a constant value at 7.995 V approximately. The maximum ripple value obtained is 4%. MATLAB has been used as a tool for simulation. The performance of converter has been analyzed by controlling PID controller.

KEYWORDS: Linear Regulator, Switching Regulator, Ripple/Noise, Converter, transistor switch, capacitor, diode, inductor, pulse-width modulating controller etc.

I. INTRODUCTION

A linear regulator works by taking the difference between the input and output voltages, and just burning it up as waste heat. The larger the difference between the input and output voltage, the more heat is produced. In most cases, a linear regulator wastes more power stepping down the voltage than it actually ends up delivering to the target device. With typical efficiencies of 40%, and reaching as low as 14%, linear voltage regulation generates a lot of waste heat which must be dissipated with bulky and expensive heat sinks. This also means reduced battery life for your projects. A switching regulator works by taking small chunks of energy, bit by bit, from the input voltage source, and moving them to the output. This is accomplished with the help of an electrical switch and a controller which regulates the rate at which energy is transferred to the output. The energy losses involved in moving chunks of energy around in this way are relatively small, and the result is that a switching regulator can typically have 85% efficiency. Since their efficiency is less dependent on input voltage, they can power useful loads from higher voltage sources.

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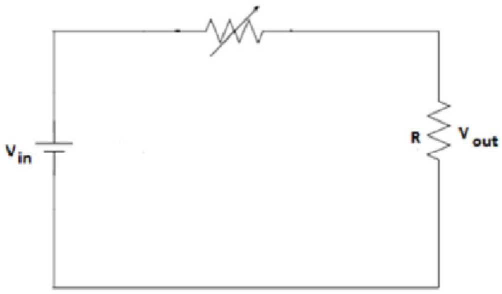
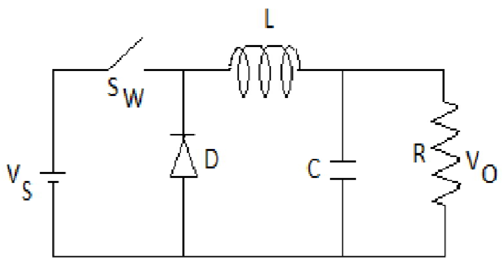


Linear Regulator

A simple Linear Regulator. If we consider an example, where V_{in}= 12V and we want to have a V_{out}= 8V. In this case we need to drop 4 volts across the regulator.
Using standard power equation: P = V*I
If the output current = 10A, this will result in 10 A * 4 V = 40 W.

Figure 2 is a very basic switching regulator. The switching regulator is a simple switch (and hence ideally no resistance or very low resistance). This switch goes on and off at a fixed rate (usually between 50 KHz to 100 KHz) as show



Switching Regulator

The time that the switch remains closed during each switch cycle is varied to maintain a constant output voltage. The switching regulator is much more efficient than the linear regulator achieving efficiencies as high as 80% to 95% in some circuits. In contrast, the linear regulator usually exhibits only 50% to 60% efficiency. With higher efficiency smaller heat sinks will be required because lesser heat is dissipated.

II. DC-DC CONVERTER

DC-DC converters are electronic devices that are used whenever we want to change DC electrical power efficiently from one voltage level to another. In the previous chapter we mentioned the drawbacks of doing this with a linear regulator.

Types of Converters
Currently, dc/dc converters can be divided into two broad categories:
- Non-isolated dc/dc converters
- Isolated dc/dc converters

Non-Isolated DC/DC Converters
The non-isolated converter usually employs an inductor, and there is no dc voltage isolation between the input and the output. The vast majority of applications do not require dc isolation between input and output voltages. The non-isolated dc-dc converter has a dc path between its input and output. Battery-based systems that don't use the ac

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power line represent a major application for non-isolated dc-dc converters. Point-of-load dc-dc converters that draw input power from an isolated dc-dc converter, such as a bus converter, represent another widely used non-isolated application. Most of these dc-dc converter ICs use either an internal or external synchronous rectifier. Their only magnetic component is usually an output inductor and thus less susceptible to generating electromagnetic interference. For the same power and voltage levels, it usually has lower cost and fewer components while requiring less pc-board area than an isolated dc-dc converter. For lower voltages (12V) non-isolated buck converters can be used.

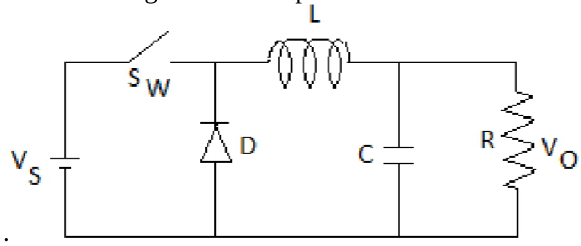
Isolated DC/DC Converters

For safety considerations, there must be isolation between an electronic system's ac input and dc output. Isolation requirements cover all systems operating from the ac power line, which can include an isolated front-end ac-dc power supply followed by an isolated "brick" dc-dc converter, followed by a non-isolated pointof-load converter. Typical isolation voltages for ac-dc and dc-dc power supplies run from 1500 to 4000V, depending on the application. An isolated converter employs a transformer to provide dc isolation between the input and output voltage which eliminates the dc path between the two.

Isolated dc-dc converters use a switching transformer whose secondary is either diode-or synchronousrectified to produce a dc output voltage using an inductor capacitor output filter. This configuration has the advantage of producing multiple output voltages by adding secondary transformer windings. For higher input voltages (48V) transformer isolated converters are more viable

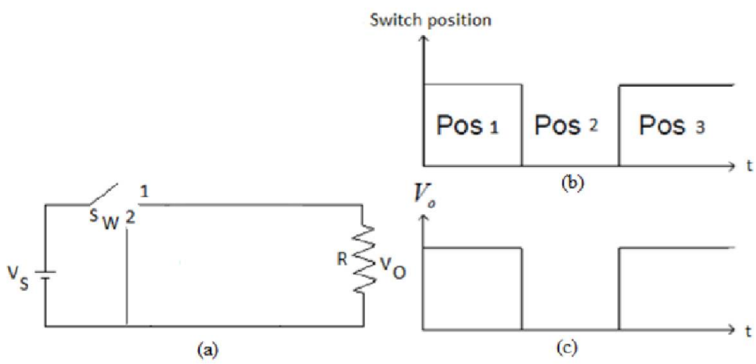
Buck Converter – Theory of Operation

The name "Buck Converter" presumably evolves from the fact that the input voltage is bucked/chopped or attenuated, in amplitude and a lower amplitude voltage appears at the output. A buck converter, or step-down voltage regulator, provides non-isolated, switch-mode dc-dc conversion with the advantages of simplicity and low cost. Figure 3 shows a simplified non-isolated buck converter that accepts a dc input and uses pulse-width modulation (PWM) of switching frequency to control the output of an internal power MOSFET. An external diode, together with external inductor and output capacitor, produces the regulated dc output.



Non isolated Buck Regulator

The buck converter here onwards is introduced using the evolutionary approach. Let us consider the circuit in Figure 4(a), containing a single pole double-throw switch.



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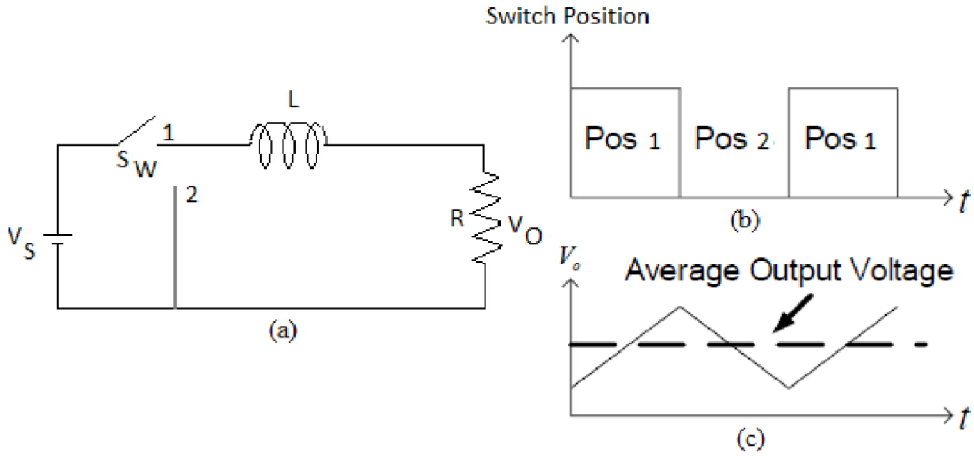
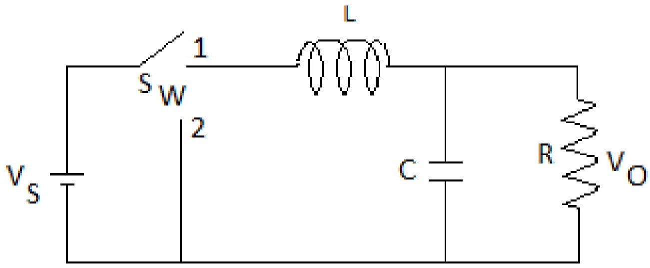
Buck Converter

The output voltage equals the input voltage when the switch is in position 1 and it is zero when the switch is in position 2. By varying the duration for which the switch is in position 1 and 2, it can be seen that the average output voltage can be varied, but the output voltage is not pure dc. The circuit in (a) can be modified as shown in belwo by adding an inductor in series with the load resistor. An inductor reduces ripple in current passing through it and the output voltage would contain less ripple content since the current through the load resistor is the same as that of the inductor. When the switch is in position A, the current through the inductor increases and the energy stored in the inductor increases. When the switch is in position 2, the inductor acts as a source and maintains the current through the load resistor. During this period, the energy stored in the inductor decreases and its current falls. It is important to note that there is continuous conduction through the load for this circuit. If the time constant due to the inductor and load resistor is relatively large compared with the period for which the switch is in position 1 or 2, then the rise and fall of current through inductor is more or less linear, as shown in Figure 5.



Effect of an Inductor

A capacitor reduces the ripple content in voltage across it, whereas an inductor smoothes the current passing through it. The combined action of LC filter reduces the ripple in output to a very low level.



III. STEP DOWN BUCK CONVERTER WITH FEEDBACK

The PWM Controller above figure compares a portion of the rectified dc output with a voltage reference (V_{ref}) and varies the PWM duty cycle to maintain a constant dc output voltage. If the output voltage wants to increase, the PWM lowers its duty cycle to reduce the regulated output, keeping it at its proper voltage level. Conversely, if the output voltage tends to go down, the feedback causes the PWM duty cycle to increase and maintain the proper output. A buck converter or step-down switch mode power supply can also be called a switch mode regulator

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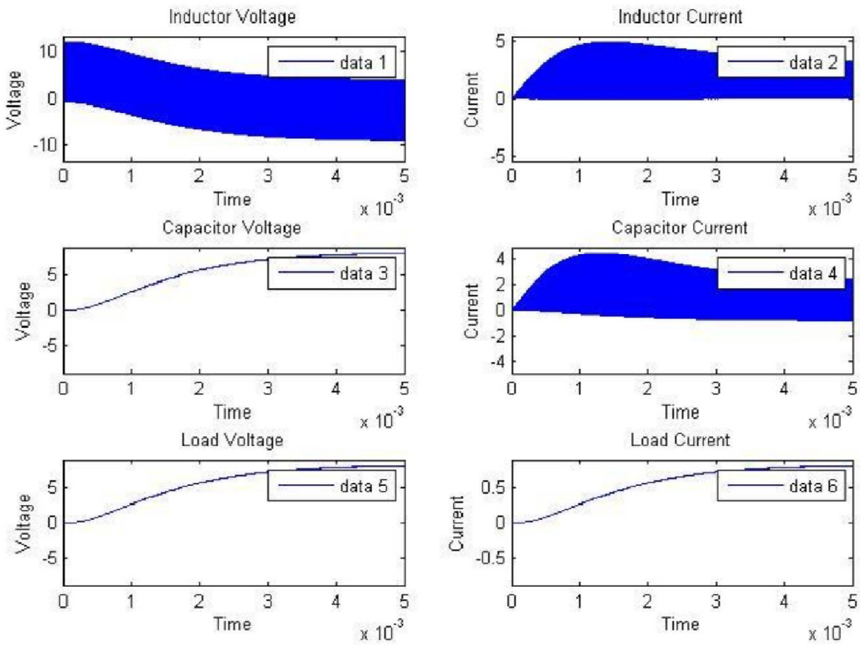
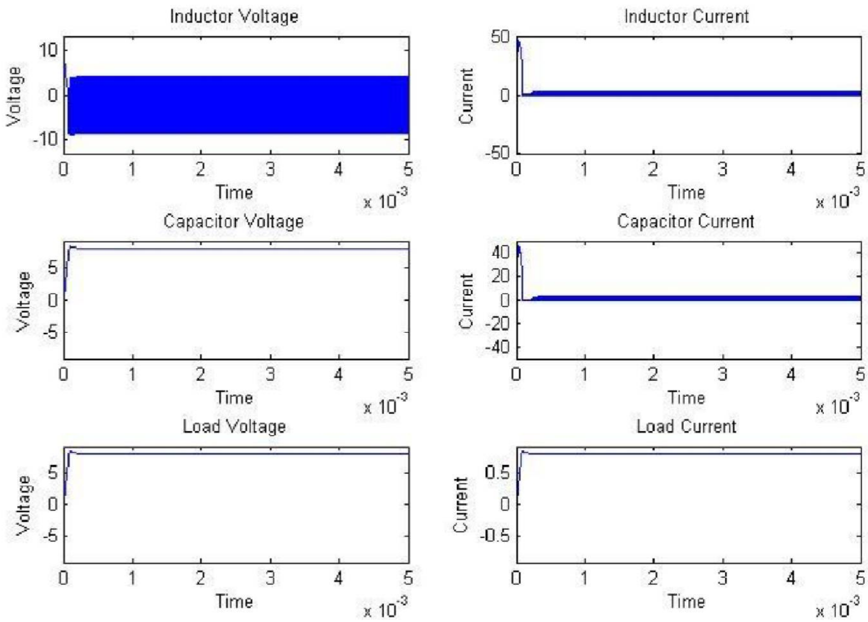


Waveform of V_L, I_L, V_C, I_C, V_O, I_O when P=0 and I=30



Waveform of V_L, I_L, V_C, I_C, V_O, I_O when P=3 and I=0

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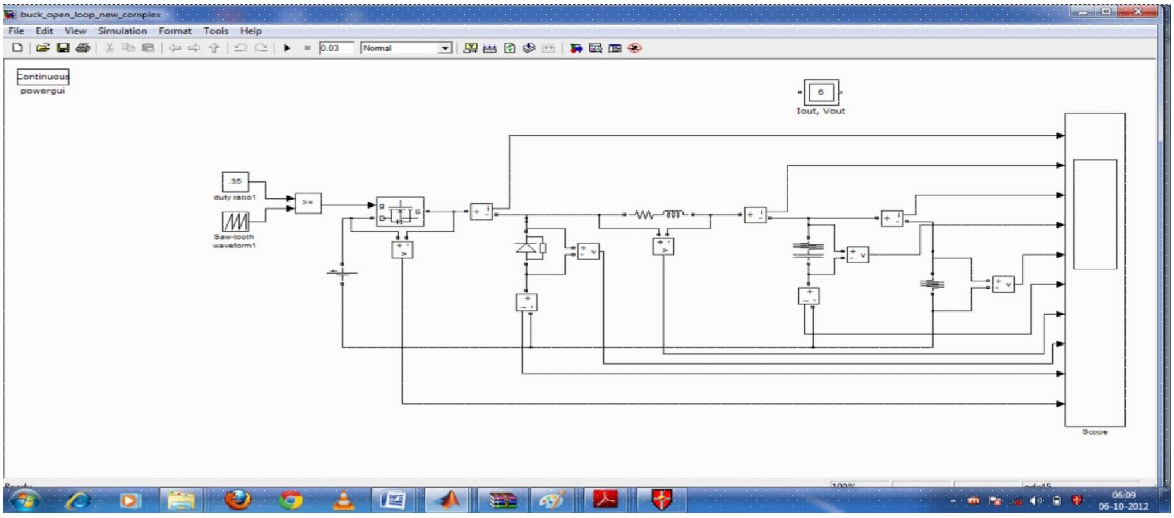
Different Values of V_L, I_L, V_C, I_C, V_O, I_O when P=0 and I=10 to 40

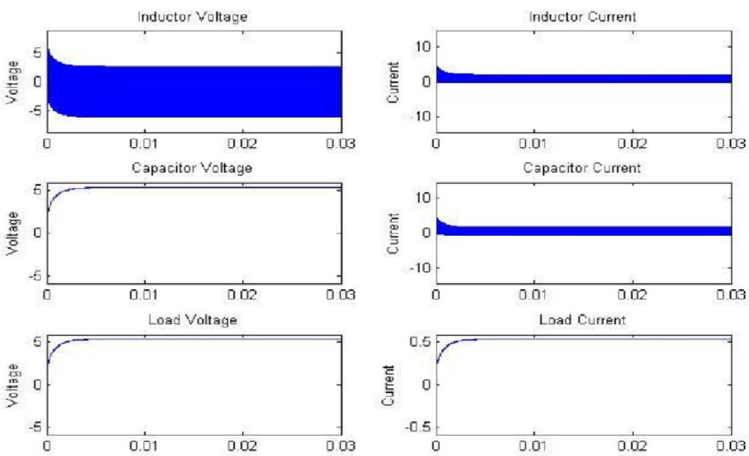
I	VO	IO	VL	IL	VC	IC
10	7.298	0.7298	0.8606	0.2055	7.298	0.5243
20	7.699	0.7699	1.05	0.213	7.699	0.5569
30	7.833	0.7833	0.7386	0.2154	7.833	0.5679
40	7.896	0.7896	1.205	0.2183	7.896	0.5714

IV. SIMULATION OF DC-DC BUCK CONVERTER FOR OPEN LOOP

Simulate the open loop dc-dc buck converter and getting the output response.first we vary the load resistance keeping the supply voltage constant and then vary the supply voltage by keeping the load resistance constant.the output response is show.



Open loop Buck Converter SimPower Simulation Diagram



Waveform of V_L, I_L, V_C, I_C, V_O, I_O when Load=10Ω

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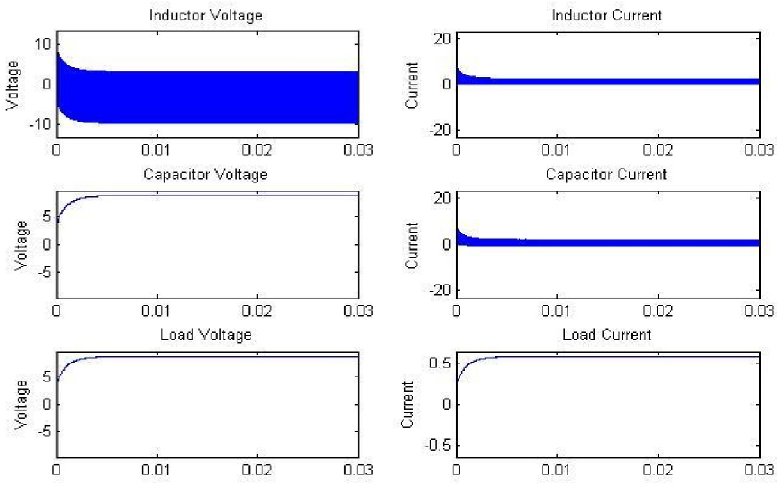
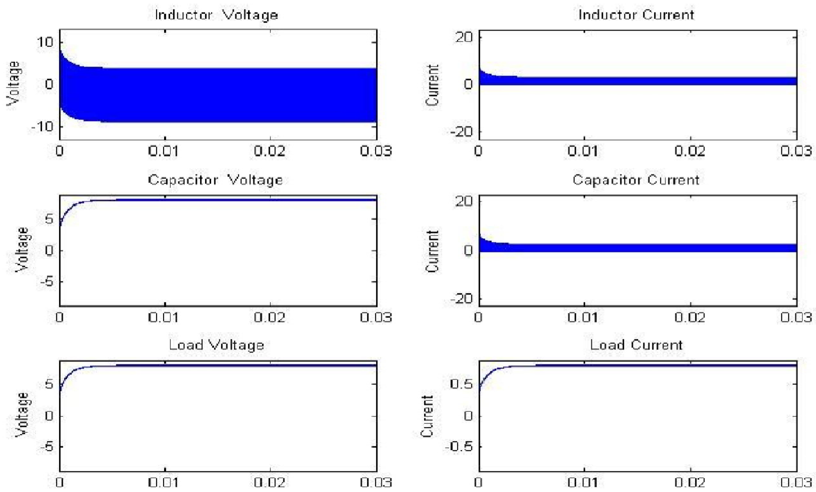


Waveform of $V_L, I_L, V_C, I_C, V_O, I_O$ when Load =15Ω



Waveform of $V_L, I_L, V_C, I_C, V_O, I_O$ when Supply Voltage V_S=12V

Open loop Buck Converter Simulated Values vs. Load Resistance R

R	VO	IO	VL	IL	VC	IC
10	5.232	0.5233	1.879	0.09876	5.232	0.4244
15	8.662	0.5775	1.26	0.09143	8.662	0.4861
20	9.108	0.4554	4.013	0.1036	9.108	0.3518
25	9.433	0.3773	3.969	0.09374	9.433	0.2836
30	9.677	0.3226	4.046	0.08731	9.677	0.2352
35	9.863	0.2818	3.859	0.08169	9.863	0.2001
40	10.03	0.2508	3.756	0.07387	10.03	0.1769
45	10.15	0.2256	3.828	0.06937	10.15	0.1562
50	10.24	0.2047	3.871	0.06758	10.24	0.1371

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Open loop Buck Converter Simulated Values vs. Supply Voltage V_S

V_S	VO	IO	VL	IL	VC	IC
8	5.232	0.5232	1.879	0.09876	5.232	0.4244
8.5	5.566	0.5566	1.101	0.09785	5.566	0.4588
9	5.91	0.591	0.1577	0.08391	5.91	0.5071
9.5	6.239	0.6239	0.5234	0.0916	6.239	0.5323
10	6.568	0.6568	0.4543	0.09439	6.568	0.5625

Closed loop Buck Converter Sims Power Simulation Diagram

Closed loop Buck Converter Simulated Values v/s. Load Resistance R

R	VO	IO	VL	IL	VC	IC
10	7.955	0.7955	1.188	0.04656	7.955	0.7489
15	7.969	0.5312	1.262	0.03165	7.969	0.4996
20	7.978	0.3989	1.093	0.02438	7.978	0.3745
25	7.986	0.3194	1.236	0.02064	7.986	0.2988
30	7.992	0.2664	1.316	0.01675	7.992	0.2496
35	7.998	0.2285	1.299	0.01505	7.998	0.2135
40	8.003	0.2001	1.294	0.01318	8.003	0.1869
45	8.007	0.1779	1.257	0.01227	8.007	0.1657
50	8.012	0.1602	1.332	0.01127	8.012	0.140

Closed loop Buck Converter Simulated Values v/s Supply Voltage

VS	VO	IO	VL	IL	VC	IC
8	7.743	0.7743	0.1186	1.364	7.743	0.5901
8.5	7.888	0.7888	0.4903	0.1228	7.888	0.666
9	7.893	0.7893	0.06857	0.08389	7.893	0.7055
9.5	7.911	0.7911	0.135	0.05655	7.911	0.7345
10	7.922	0.7922	0.2823	0.04702	7.922	0.7452

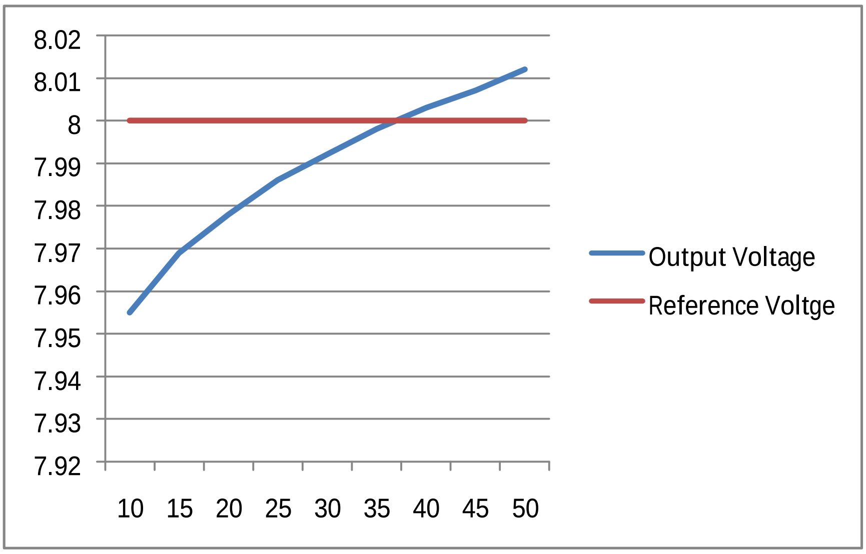

Figure 58 Graph for Output voltage and reference Voltage vs Load

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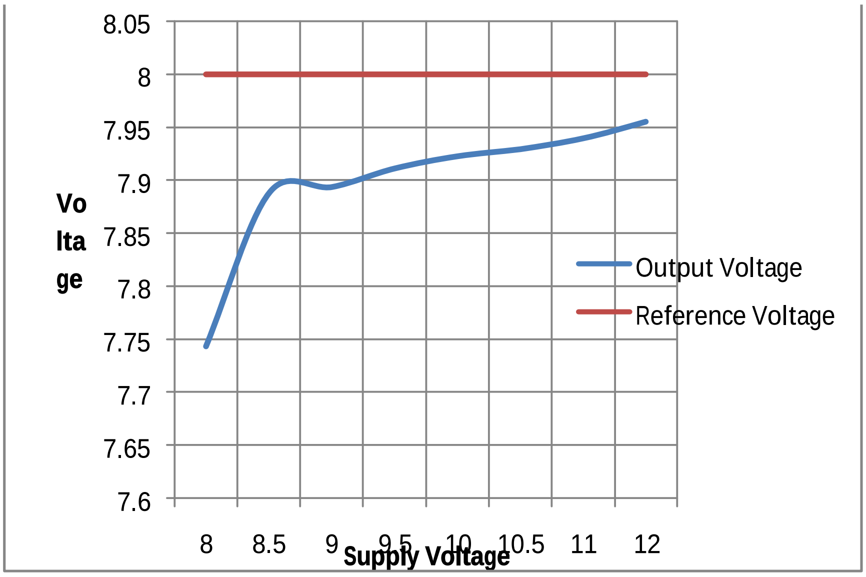

Graph for Output voltage and reference Voltage vs Supply Voltag

V. CONCLUSION

Of variation of load as well as variation in supply voltage. The simulation result shows that the output voltage vary only maximum up to 3% if we vary increase the load resistance by 250% and lower the supply voltage by 66.6%. The converter can be utilized for low power application such as to drive light

FUTURE SCOPE

1. In the present thesis we use asynchronous buck converter, by using the synchronous buck converter efficiency can be improved.
2. Here we design for low power applications, by changing the parameter of buck converter, high power application can be done.
3. By the variation of supply voltage, load and constant parameter (P & I) output voltage can be set for a particular application where it is desired.

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