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# REVIEW PAPER ON DESIGN AND STUDY VOLTAGE CHARACTERISTICS OF BUCK CONVERTER

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**Abstract:-** We have reviewed applied buck converter by the usage of closed loop discrete PI (Proportional Integral) controller. This buck converter will be examined to understand the static and dynamic characteristics. According to static test, there's little or no change in output voltage due to input voltage change and load change of buck converter. According to dynamic test, there is little output voltage fluctuation because of input voltage change and load change. Buck converter control method relies on Voltage Mode Controlled PWM (Pulse width Modulation) with PI (Proportional Integral) Controller. The model is designed by the use of MATLAB Simulink.
**Index Terms:** DC-DC converter, Buck Converter, PWM (Pulse Width Modulation), PI controller (Proportional Integral), MATLAB/Simulink.

## 1. INTRODUCTION

For conversion of one DC voltage level to another DC voltage level DC-DC converter is used. These converters have linear or switch-mode regulators. Linear converters consist of series transistor which operates in active region. Hence it acts as a variable resistor to regulate the output. A high conduction loss is the drawback of linear converter because of which efficiency reduces. In switch-mode converter switching losses are higher but conduction losses are reduced. Thus, high electromagnetic interference generates due to high frequency switching. The principle of DC-DC converter is charging and discharging inductor into load as per the output voltage by switching DC supply ON and OFF at high frequencies.

The main drawback of DC-DC converter is semiconductor losses because of switching transients of finite duration. Another drawback associated is electromagnetic interference due to derivative with respect to time.

Because of High switching Frequency and stability, digitally controlled converters give better results [1] and stable output as compare to analog controlled converter.

In this paper, we proposed to layout buck converter by the usage of PI controller while input voltage and load changes very fast, the output voltage fluctuation peak is small. This also helps in quick recovery towards reference voltage resulting in shorter recovery time. Eventually this method improves dynamic performance of buck converter.

## 2. BUCK CONVERTER

Buck converter is also termed as step-down converter. It is highly efficient and simple to design. It has efficiency more than 90% and also require relatively small output ripple. The input voltage ($V_{IN}$) is greater than the average output voltage ($V_O$) Primary elements of buck converter are controlled switch i.e. MOSFET (switch), an uncontrolled switch i.e. Diode (D), an inductor (L), a capacitor (C), and a load resistance (R). The Buck Converter operates in two conduction modes which are Continuous and Discontinuous i.e. CCM and DCM respectively. When switch is ON and diode D is non- conducting it works in CCM whereas when switch is OFF and diode D is conducting it works in DCM [3]. Fig1 (a) shows Buck converter circuit diagram. Whereas Fig1 (b) and Fig1(c) Consist of waveform of current and voltage in CCM and DCM respectively.

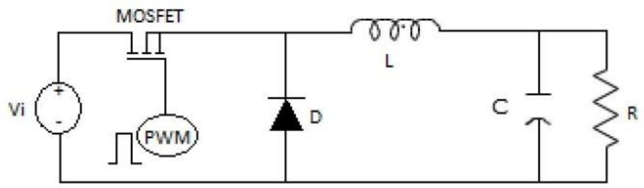


**Fig.1. (a) A Buck converter circuit diagrams**

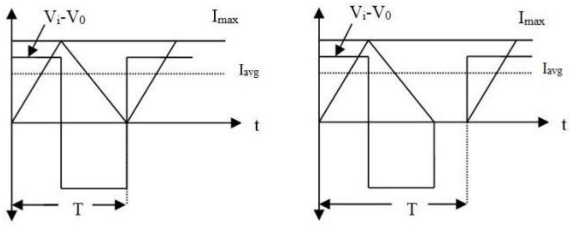


**Fig.1. (b) CCM and (c) DCM mode waveform**

## 3. OPEN LOOP BUCK CONVERTER

Open loop buck converter is a step-down converter which is mainly consists of semiconductor switches like MOSFET and diode and passive elements like inductors, capacitors, resistors.

The gating signal (q) controls the switching of MOSFET. When q value is 1, MOSFET is high and when q value is 0 MOSFET is low.

There is an assumption that current increases and decreases linearly across inductor in open loop converter. The ripple current ($\Delta I$) is inversely proportional to ripple voltage ($V_C$) an d inductor is inversely proportional capacitor. The design parameter of buck converter is stated in table [I]

Mathematically it expressed as,

L= $\frac{VinD(1-\delta)}{f\Delta I}$ C= $\frac{VinD(1-\delta)}{8Lf\,^\wedge 2\Delta Vc}$

Designed open loop Buck converter as per parameters shown in Table1 and got output voltage waveform as shown in Fig.2

**TABLE I: Buck Converter Design Parameters**

| Parameters | Values |
|---|---|
| Output Power ($P_0$) | 10 W |
| Input Voltage ($V_{in}$) | 12 V |
| Reference Voltage ($V_{ref}$) | 5 V |
| Switching Frequency ($f_r$) | 100 KHz |
| Input ripple current ($\Delta$I) | 0.4 A |
| Output ripple voltage ($\Delta V_C$) | 50 mV |
| Inductor (L) | 72 µH |
| Capacitor (C) | 10 µF |
| Duty Cycle ($\delta$) | 41.66% |

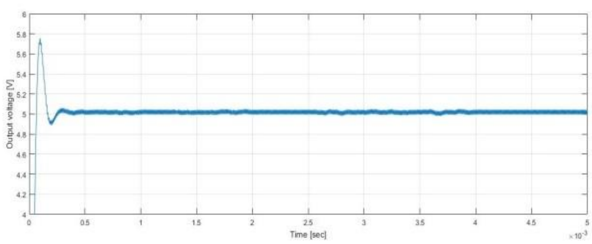

**Fig.2. Output voltage waveform in open loop Buck converter**

## 4. CLOSE LOOP BUCK CONVERTER

In closed loop, the buck converter operates in Discontinuous Conduction Mode (DCM). It is controlled with the help of voltage-mode-controlled PWM [2] and PI controller.

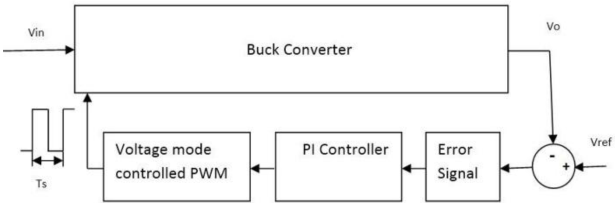


**Fig.3. Block diagram of close loop of Buck converter**

The results are obtained using simulation in MATLAB. In simulation to generate PWM, we have summed the PID error correction and duty cycle calculation which is further compared with saw tooth waveform as shown in figure3.

## 5. PI CONTROLLER

PI controller is mostly used in industrial controller because of its simplicity. It is able to tune few parameters automatically. It shows robust performance with wide range of operating conditions. Figure.4 explains operation of PI controller. The basic parameters of PI controller are Proportional (P) and Integral (I). The proportional (P) follows the desired set point and Integral (I) accumulates the past errors and rate of change of errors in complete process [9].

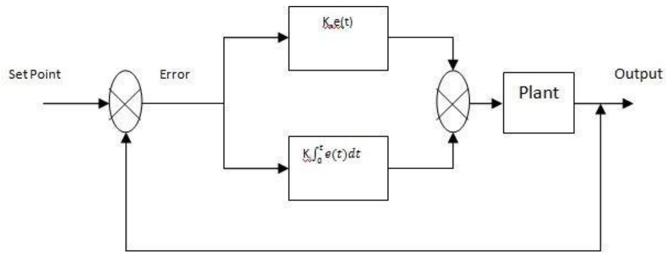


**Fig.4. Schematic diagram of PI controller**

## 6. SIMULATION & RESULTS

Simulation of close loop Buck converter using PI controller

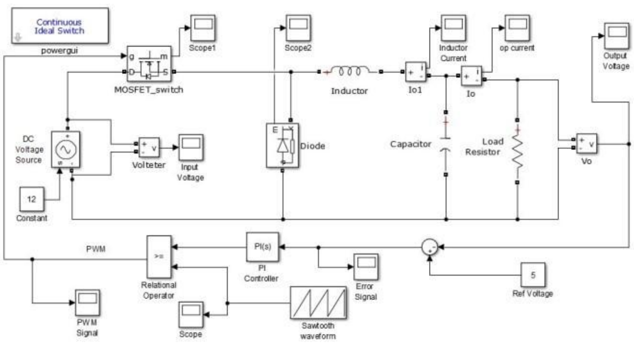


**Fig5. Close loop Buck converter using PI controller.**

### 6.1 Static Performance of Buck Converter

1. By taking 5 readings for output voltage when input voltage was 12V. The reference voltage was 5V and load resistance was varied from 2.5Ω to 12.5Ω.
   0.07V was maximum error in output voltage. Therefore 1.86% deviation occurred from reference voltage. Here, rate of change of output voltage with respect to load resistance was 0.0228V/Ω.

**TABLE II: Value of output voltage with variation in load resistance**

| Load Resistance ($R_L$) | 2.5 | 5 | 7.5 | 10 | 12.5 |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Output Voltage (V0) | 4.964 | 4.907 | 5.02 | 4.974 | 4.85 |

2. By taking 5 readings for output voltage when input voltage varied from 8V to 16V. The reference voltage was 5V and load resistance was unchanged.
   Maximum error in output voltage was 0.197V. Therefore 3.94% deviation occurred from reference voltage. Here, rate of change of input voltage with respect to output voltage is 15mV/V.

**TABLE III: Value output voltage with variation in input voltage**

| Input Voltage (Vin) | 8 | 10 | 12 | 14 | 6 |
|---|---|---|---|---|---|
| Output Voltage (V0) | 4.803 | 4.843 | 4.964 | 4.916 | 4.954 |

**6.2 Dynamic Performance of Buck Converter**

1. Maintaining the input voltage regular and converting the load resistance from 2.5Ω to 12.5Ω we got output voltage waveform as shown in figure.6
   Here fluctuation occurred was about 300mV and settled within less than 0.5ms time using MATLAB simulation

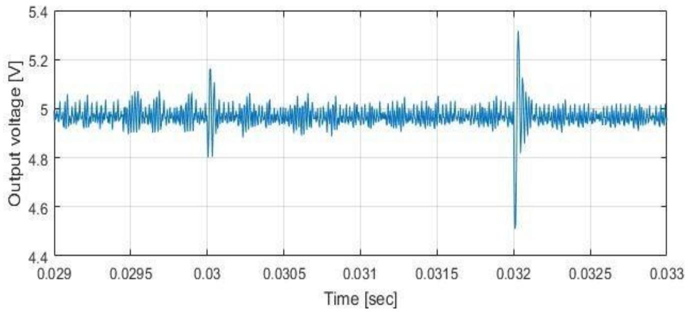


**Fig.6. Output voltage and variation in load resistance**

2. Maintaining the load resistance constant and varying the input voltage from 8V to 16V we got output voltage waveform as shown in figure.7
   Here fluctuation occurred about 70mV within less than 0.8ms time using MATLAB simulation

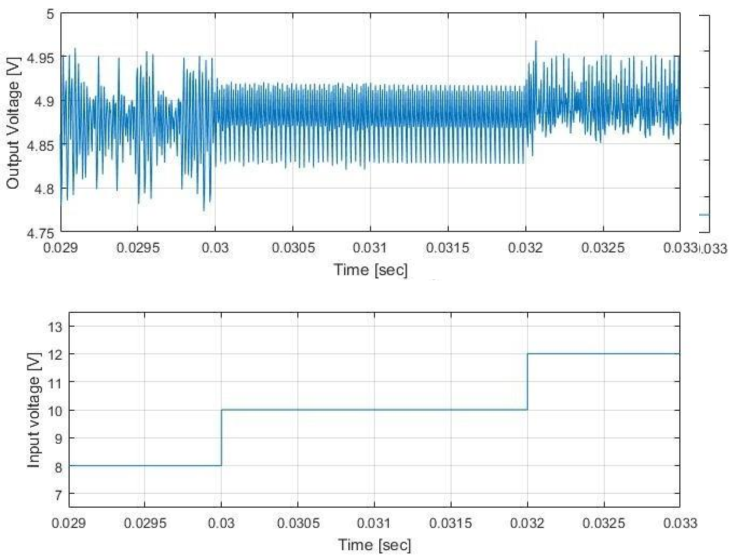


**Fig.7 Output voltage and variation in input voltage**

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## 7. CONCLUSION

The designed system works nicely for all feasible values of duty cycle, change in load resistance and input voltage, keeping inductance and capacitance constant.

This paper uses PID controlled method and PWM method to design buck converter and display simulation consequences. PID operation for output and self-adapted duty cycle has been realized in this paper.

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