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Designand Simulation of Open-Loop Buck Converter with Losses

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Abstract

A DC to DC converter is a lossless dc transformer that must supply regulated output voltage under varying load and input voltage condition as well as the converter parameter values changes with time and physical quantity like temperature etc.This paper presents the design and simulation of an open loop buck converter in MATLAB/Simulink and also the calculation of various losses of components used in buck converter. When efficiency estimation is required in the design, losses in Buck circuit should be considered. The efficiency can be improved by reducing the losses and the reliable and low-cost power system can be designed. The selection of component affect the efficiency, so to improve the efficiency proper selection of component is required to be considered. The ideal dc-dc converter exhibits 100% efficiency; in practice, efficiencies of 70% to 95% are typically obtained due to the losses of selected components. The selection of switching frequency is also determined by the efficiency requirement. If high efficiency is the most important parameter to achieve, then a low switching frequency may be the best choice.

Keywords: *Buck converter, Open loop, Losses, Efficiency,Simulink(MATLAB)*

I. INTRODUCTION

A buck converter is the most basic SMPS topology. It is widely used throughout the industry to convert a higher input voltage into a lower output voltage and those applications require fast load and line transient responses and high efficiency over a wide load current range. They can convert a voltage source into a low regulated voltage. The analysis, design, control and stabilization of switching converters are the main factors that need to be considered [1]. The topology of DC-DC convertors consists of two parts linear (resistor, inductor and capacitor) and nonlinear (diode and active switch). Because of the switching properties of the power elements, the operation of these convertors varies with time [7].

II. Buck Topology

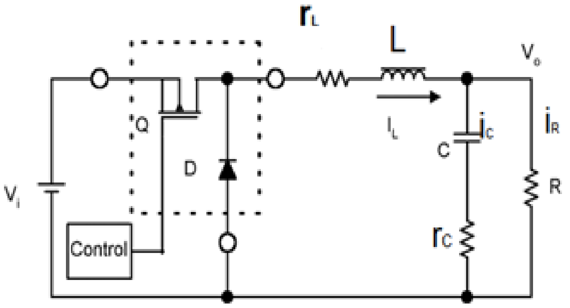


Fig 1: Basic Buck converter circuit

Fig1 is the basic circuit of buck converter [6]. When switch Q is ON, current flows from V_i through the coil L and charge the output capacitor C and passes through the resistor R and develop output voltage V_o. The current when passes through the coil L, stores the energy. When switch Q is OFF, free-wheeling diode D turns ON and energy stored in L is then released to the output side [5].

There are two types of Conduction Modes

(1) Continuous Conduction Mode (CCM):In CCM inductor current remains positive and continuous throughout the switching period and never falls to zero as shown in Fig 2 [8].

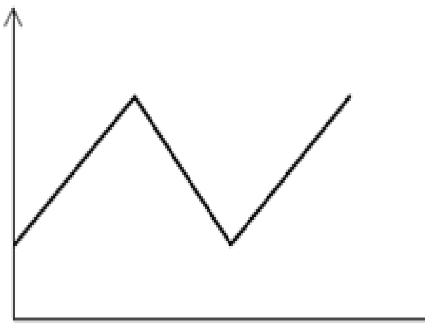
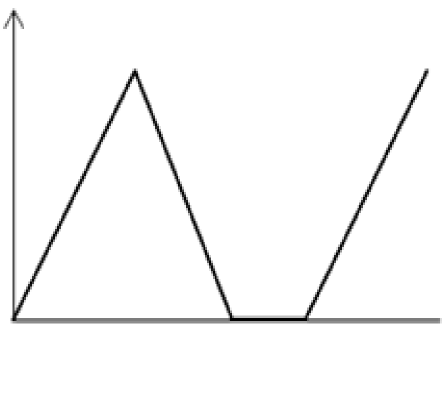


Fig 2: CCM of Buck Converter

(2) Discontinuous Conduction Mode (DCM):In DCM inductor current does not flow continuously and remains zero for some time in the switching period as shown in Fig 3.

Fig 3: DCM of Buck Converter



If the buck converter operates in Continuous Conduction Mode (CCM), the relation between the input voltage (Vi), output voltage (Vo):

$$Vo = Vi \times D$$

Where,

$$D = \frac{Ton}{Ton + Toff}$$

While designing the buck converter shown in section III, several losses occurs due the elements used in design of buck converter, which affect the efficiency of buck converter. The way to improve the efficiency is as follows:

(1) MOSFET
- Low $R_{ds(on)}$ for High Duty Cycle
- Low Gate Charge for L`ow Duty Cycle
- Paralleling for High Current

(2) Schottky Diode
- Low forward drop
- Short recovery time

(3) Inductor
- Multiple parallel winding such as Bifiliar (two windings), Trifiliar (three windings)

(4) Capacitor
- Low ESR
- Paralleling caps (increasing capacitance while reducing ESRs)

III. Design Equation

A simulation run for a Buck Converter is carried out whose design parameters are specified in Table 1.

Table 1: Design Specifications

Input voltage (V_i)	12V
Output voltage (V_o)	5V
Maximum power (P_{max})	10W
Switching frequency (F_s)	400KHZ
Output voltage ripple (ΔV)	0.05V (1% of output voltage)
Output ripple current (I_{ripple})	0.6A(30% of load current)
Duty Cycle(D)	0.416
Load current (I_o)	2A

Output voltage ripple of the DC-DC converter is minimized by proper selection of inductor and capacitor [4].

Filter Inductor and Output Capacitor:

The filter inductor value and its peak current are determined on the basis of specified maximum inductor current ripple.
The function of the output capacitor is to filter the inductor current ripple and produce a stable output voltage.
For the specifications given in Table 1 the calculated value of inductor and capacitor is shown in Table 2:

Table 2: Component Value

Component	Value
Inductor	12.13µH
Inductor peak current	2.3A
Capacitor	3.75 µF

3.1 Efficiency

With the selected components, we will calculate the system efficiency. When efficiency estimation is required in the design, losses in Buck circuit should be considered.

Several major losses are shown in Table 3:

Table 3: Calculation of Losses

Conduction loss of MOSFET	0.033W
Switching loss of MOSFET	0.297 W
Diode loss	0.468W
Inductor's copper loss	0.148W
Capacitor's ESR loss	0.01332W
Total Losses	0.93W

So, the Efficiency:

$$\eta = \frac{Po}{Po+Ptotal} = \frac{10}{10+0.93} = 91.49\,\%$$

IV. Modelling in Simulink and Results

A. Open-Loop Buck Converter

Open loop buck converter is analyzed in MATLAB for the model discussed in section II [3]. Open loop Simulink model of buck converter is shown in Fig.2 and the results of buckconverter are shown in Fig.3 [6].

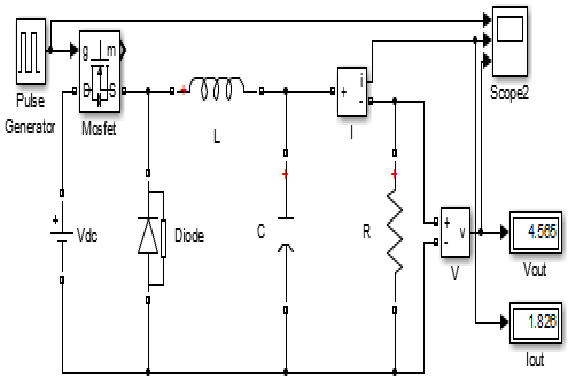


Fig 4: System Model of Buck Converter

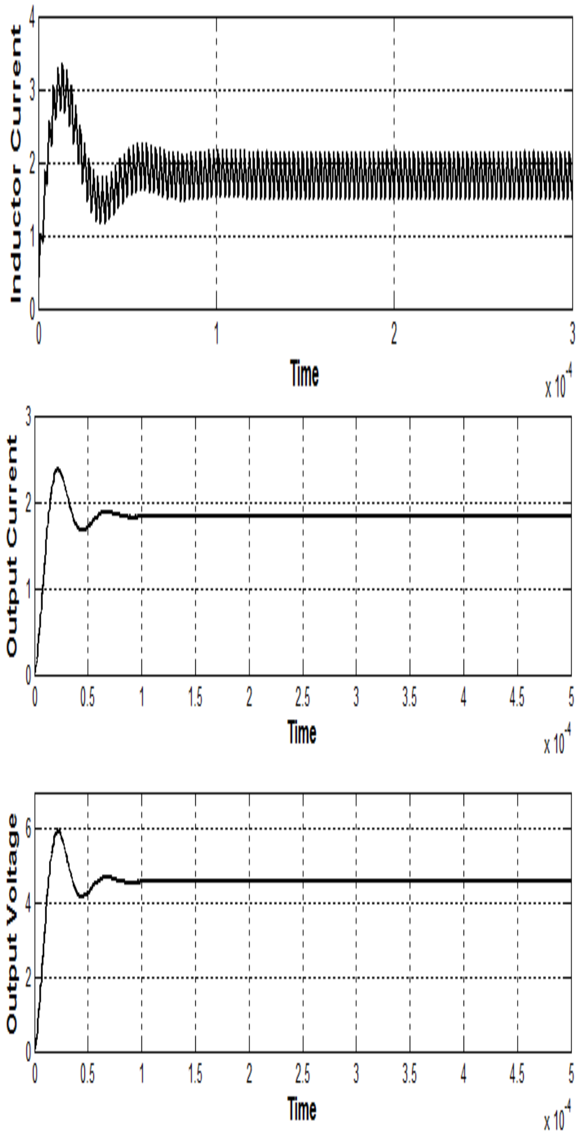


Fig 5: Response of Open-Loop Buck converter
Waveform 1: Inductor Current
Waveform 2: Output Current
Waveform 3: Out voltage Waveform

V. Conclusion:

In any power system, selection of parameter is key to optimum performance. System design requirements will determine the amount and type of parameter for any design. By following the parameter specification in the data sheet and selecting parameter based on our actual operating conditions and improve the efficiency by reducing the losses, a reliable, low-cost power system can be designed.

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