

# DESIGN OF A CLOSED LOOP CONTROL OF THE BOOST CONVERTER (AVERAGE MODEL)

AHMED MAJEED GHADHBAN

Diyala University, Electrical Power and Machines Engineering Department,

Collage of Engineering.

Diyala. Iraq.

Asm725@yahoo.com

**Abstract**— This paper addresses the design of closed loop control of the boost converter based on specific criteria given. The closed loop boost converter is used to convert a low level DC input voltage from a DC power supply and use to control the average model. The average model is useful when investigating the dynamic behavior of the converter when it is subject to changes in operating parameters. The design methodology will comprise of hand calculation that involves theory and simulation. The simulation carried out in Pspice software. The Performance analysis, which covers the closed loop control of the average model on related waveforms of output voltage, current and power are discussed and achieved.

**Keywords**— DC-DC Converter, boost converter, closed loop control, PSpice simulation, DC chopper.

## INTRODUCTION

A Boost converter or step-up switch mode power supply that can also be called a switch mode regulator. It steps up the input voltage to produce a higher output voltage. The popularity of a switch mode regulator is due to its high efficiency, compact size and low cost. Generally, any basic switch power supply consists of the same basic power components: two switches, usually a MOSFET, and a diode  $D$ , an inductor and an output capacitor, all components are same as the buck and buck-boost converter but placed in different circuit locations. The boost converter was configuration is shown in Figure (1).

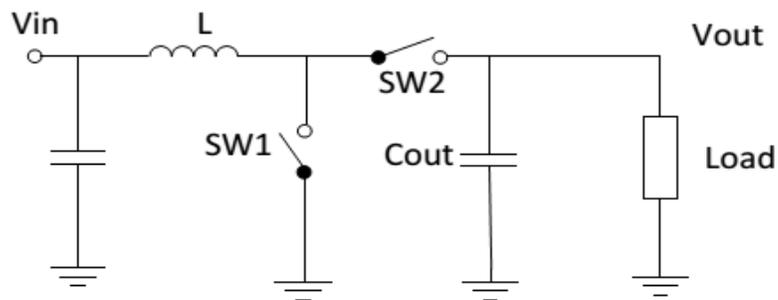


Figure (1). Basic boost converter topology

Deriving the output voltage conversion ratio will be done by evaluating the inductor Volt Second balance as described in [2]. In steady state, the inductor average voltage must equal zero, which means that the energy flows into the inductor is equal to the energy flows out of the inductor over one complete switch cycle

The DC-DC converters have two fundamentally different modes of operation: Continuous Conduction Mode (CCM) and Discontinuous-Conduction Mode (DCM)[3]. The boost converter and its control are designed based on both modes of operation. In the Continuous Conduction mode, the inductor current flows continuously that is the inductor current is always above zero throughout the switching period [4].

A boost converter is designed to step up a fluctuating or variable input voltage to a constant output voltage of 24 volts with input range of 6-23volts in [5]. To produce a constant output voltage feedback loop is used. The output voltage is compared with a reference voltage and a PWM wave is generated, here PIC16F877 microcontroller is used to generate a PWM signal to control switching action.

A DC to DC converter is used to step up from 12V to 24V in [6]. The 12V input voltage is from the battery storage equipment and the 24V output voltage serves as the input of the inverter in solar electric system. In designing process, the switching frequency,  $f$  is set at 20 kHz and the duty cycle,  $D$  is 50%. The tool that has been used for circuit simulation and validation are National Instrument Multisim and OrCAD software.

Here author introduced an approach to design a boost converter for photovoltaic (PV) system using microcontroller in [7]. The converter is designed to step up the solar panel voltage to a stable 24V output without storage elements such as a battery. It is controlled by a microcontroller unit using voltage-feedback technique.

Finally, This paper concerns with design and simulation of closed loop control to the boost converter (average model) with specific criteria. The system has a nonlinear dynamic behavior, as it works in switch-mode. Moreover, it is exposed to significant variations which may take this system away from nominal conditions, due to changes in load is changing subjected to half load to full load and to half load again. The input is obtained from a DC power supply. In this paper the boost converter is analyzed and a design component and simulation of DC/DC boost converter is proposed. The simulation is done in PSpice software

## DESIGN AND CALCULATION

To calculate the parameters of the components which are used for control. The error amplifier as showed in Figure (2) compensated compares the converter output voltage with a reference voltage to generate an error signal which adjusts the duty ratio of the switch. The amplifier should have a high gain at low frequency and low gain at high frequency. Usually the controller crossover frequency of the total open-loop transfer function. This is usually around an order of magnitude less than the converter switching frequency. It is about 1/10 of switching frequency. The switching frequency is 100 kHz.

The transfer function and frequency response can be obtained by using PSpice as follows:

- For the filter with load  $R$  and  $R$  ESR shows the gain at 10kHz = -20.84 dB, Phase angle =  $-97^\circ$
- The error amplifier output voltage  $V_c$  is compare to a saw tooth waveform with amplitude  $V_p$ , for this design  $V_p$  is 3 V. Hence the PWM converter gain is:  $\text{Gain} = 1/V_p = 1/3 = -9.54\text{dB}$ , Phase angle =  $0^\circ$
- The combination of gain filter and converter is :

The compensated error amplifier must have gained +30.38 to make loop gain=0dB.

$$30.38\text{dB} = 20\log \frac{v_{o\sim}}{v_{o\sim}} \quad (1)$$

Phase error Amplifier, From K-factor table  $K=3$  is chose hence  $\theta_{co} = -217^\circ$ .

Table 1. K-factor

K	2	2.5	3	4	5	6
$\theta_{co}(^\circ)$	-233	-224	-217	-208	-203	-199

Combined gain (filter + PWM)

$$\text{Gain} = -20.84 + (-9.54\text{dB}) = -30.38\text{dB}, \text{ Phase angle, } \theta_{filter} = -97^\circ$$

To calculate  $C_1$  and  $C_2$ ;

$$K = \frac{\omega_{co}}{\omega_z} = \frac{\omega_p}{\omega_{co}} \quad (2)$$

$$\omega_p = K\omega_{co} = \frac{1}{R_2 C_2} \quad (3)$$

Where

The resonance frequency  $\omega_{co}$

$\omega_p$  Is the dominant-pole

$\omega_z$  Is the capacitor ESR Zero

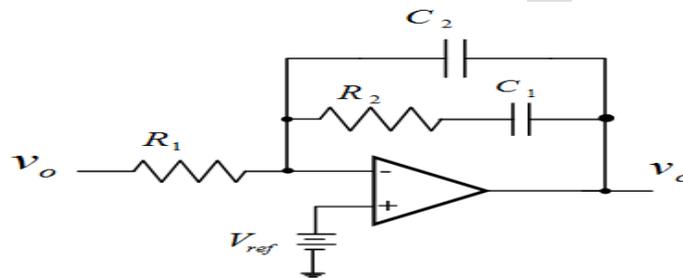


Figure (2). Compensate Amplifier

## SIMULATION RESULTS AND DISCUSSION

The Figure (3) shows the full circuit design of the controller of the boost converter (average model). The average model is useful when studying the dynamic behavior of the converter when it is subject to changes in operating parameters. Such an analysis is essential when the output is regulated and controlled through a feedback loop, which is intended to keep the output at a set level by adjusting the duty ratio of the switch to accommodate variations in the load.

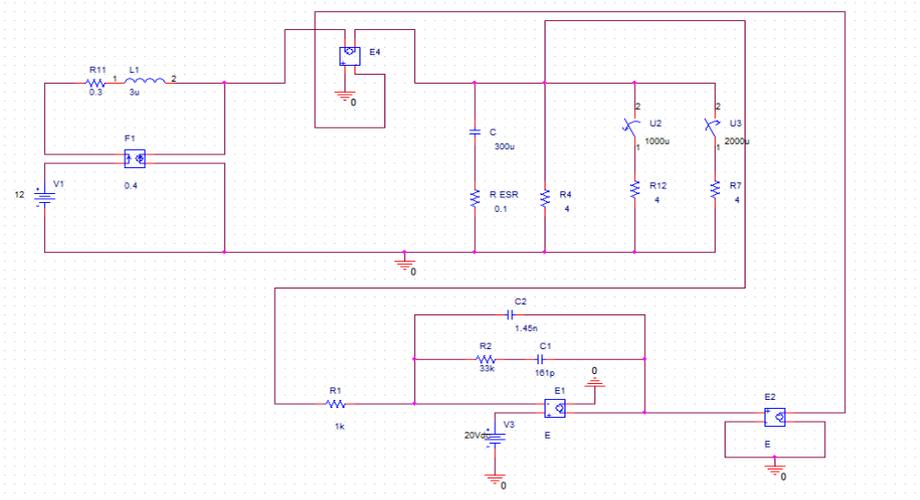


Figure (3). Circuit of the controller of the boost converter

Figure (4) shows the output voltages and shows the changing in the output voltage due to the load changing from half load to full load and then to half load again and that switches used. The (S1) is closed, according to that there are two resistances in parallel so the load will be half loaded. Then the (S1) opens, that's mean

one resistance and it is the full load. The (S2) is closed and we get two resistances in parallel so the load will be half again.

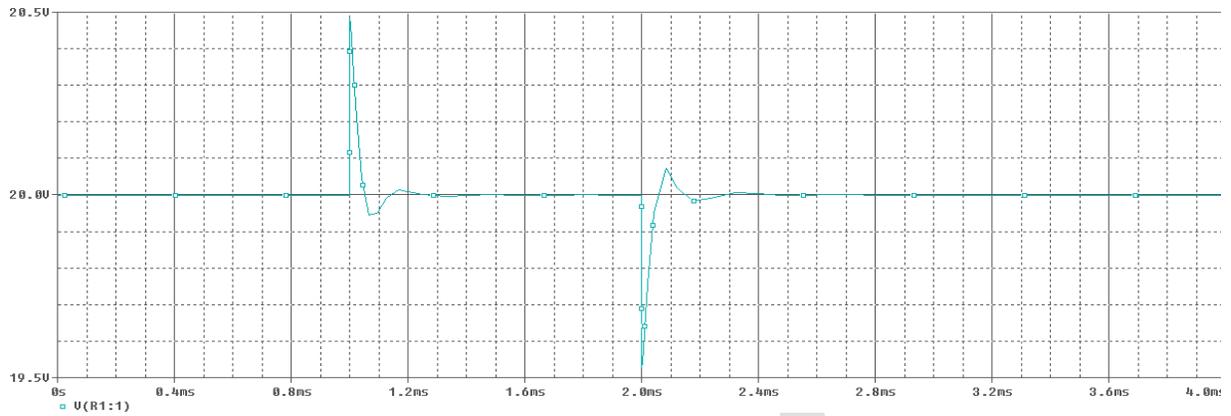


Figure (4). Output voltage waveform

Figure (5). Shows the output current waveform and changing the current value according to the load changing.

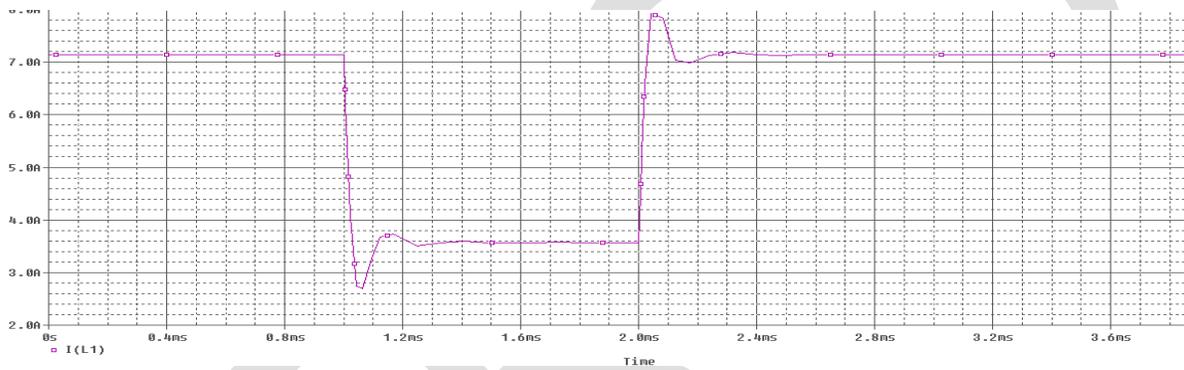
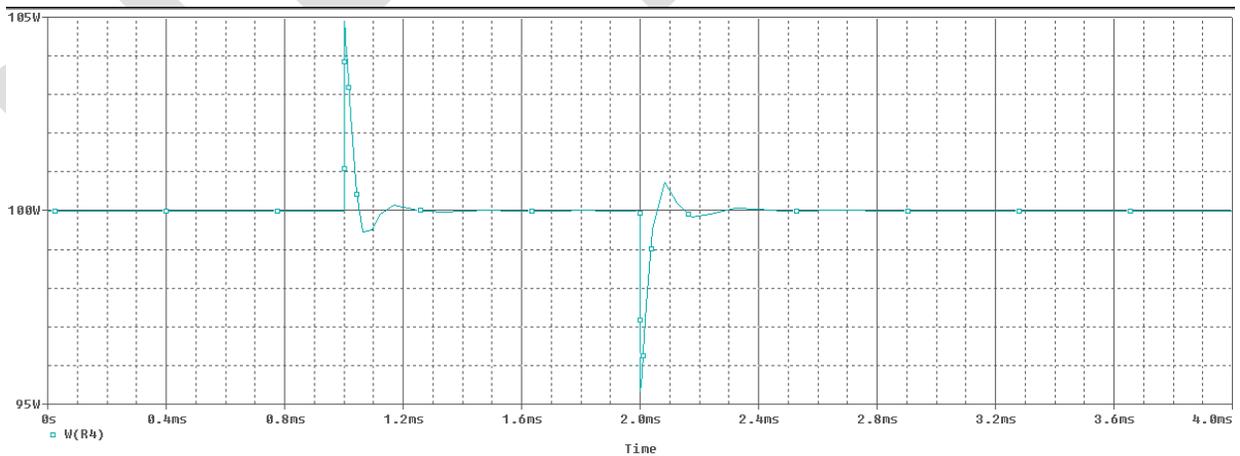


Figure (5). Output current waveform

Figure (6). Shows the output power waveform and changing the power value according to the load changing



Figure(6). Output power waveform.

## CONCLUSION

In this paper, a closed loop control to boost converter (average model) has been designed. The complete system has been simulated in PSpice which resulted in efficiency at full power as gave in specific data. By using compensate the amplifier makes the

compensation of the boost converter much easier as the power stage has a response of the system at low frequency and using a compensator, is adequate, which greatly simplifies the design process. And the controller can stabilize the output voltage when the load is changing.

#### REFRENECES:

- [1] T.NageswaraRao., V.C. Veera Reddy, (2012)“A NOVEL EFFICIENT SOFT SWITCHED TWO PORTS DC-DC BOOST CONVERTER WITH OPEN LOOP AND CLOSED LOOP CONTROL”. Indian Journal of Computer Science and Engineering, **Volume: 3 Issue: 3 PP: 394-400**
- [2] Zengshi Chen , Wenzhong Gao, Jiangang Hu --- Xiao Ye, (2011).“Closed-Loop Analysis and Cascade Control of a Nonminimum Phase Boost Converter”. IEEE Transactions on Power Electronics, **Volume: 26 Issue: 4 PP: 1237-1252.**
- [3] Wei-Chung Wu, R.M. Bass, J.R. Yeargan, “ Elimination the effects of the Right-half Plane Zero in Fixed Frequency Boost Converters”, IEEE Annual Power Electronics Specialists Conference 06/1998, 362 - 366 Vol.1.
- [4] R. Ridley, “Current Mode Control Modeling”, Switching Power Magazine, 2006,
- [5] S. Masri and P. W. Chang, “Design and development of a DC-DC Boost converter with constant output voltage”, IEEE, International conference on Intelligent and Advanced systems (ICIAS), June 2010.
- [6] Asmarashid Ponniran and Abdul Fatah Mat Said.,“DC-DC Boost Converter Design for Solar Electric System”, International Conference on Instrumentation, Control and Automation, October 20-22 (ICA 2009) Bandung.
- [7] Syafrudin Masri and Pui-Weng Chan, “Development of a Microcontroller-Based Boost Converter for Photovoltaic System”, European Journal of Scientific Research. ISSN 1450-216X Vol.41 No.1, pp. 38-47. <http://www.eurojournals.com/ejsr.htm>