Analyze Buck Converter with PWM Feedback Circuit Using Matlab Simulink tool

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***Abstract*–The buck converter is commonly analyzed based on Hspice tool in circuit design filed. However, it takes lots of time to design and analyze the buck converter circuit in transistor level. To shorten the analysis time, the system level analysis is applied in this paper using Matlab Simulink tool. In this paper, the stabilization time of buck converter circuit with PID feedback control and PWM generator for buck converter circuit is analyzed and verified using Matlab tool.**

I. INTRODUCTION

The conventional buck converter circuit is generally designed using the proportional-integral and derivative (PID control) feedback technique [1-3]. The traditional design method is adding a proportional-integral in the feedback part of the buck converter circuit (PI controller) [4]. If the proportional gain (K_p) cannot be precisely adjusted to the accurate value, the addition of derivative gain (K_d) will produce high frequency oscillation and the system is unstable. Therefore, the circuit designer will aim to calculate the accurate proportional gain (K_p) so that the stabilization time can be decreased and the stability of the circuit can be enhanced.

II. CIRCUIT DESCRIPTION

The block diagram of buck converter with PWM feedback circuit is shown in Fig. 1. In the figure, *r(t)* is the desired process value or setpoint, and *y(t)* is the measured process value. The overall control function can be expressed as follows:

$$u(t) = K_p e(t) + K_i \int_0^t e(t')\,dt' + K_d \frac{de(t)}{dt} \quad (1)$$

The system level structure is generated using Matlab Simulink tool as shown in Fig. 2. With this structure, function of the buck converter can be analyzed. The output of the converter is set as 9V. Hence, the voltage error of PID controller is equal to 9V minus the output voltage. The voltage error go through the PID controller and relational operator to generate PWM signal for MOSFET gate signal. It becomes a close loop control system and the PID controller will keep the output at 9V within 80ms. In Fig. 2, the upper part of this circuit is a buck converter and the lower part is a PID controller feedback system and PWM operator. The output of PWM operator is a switching mode signal which is the MOSFET Gate input signal. When the output voltage of the buck converter reach to reference voltage (9V), the PID controller will keep tracking the buck converter's output to keep at reference voltage (9V) automatically.

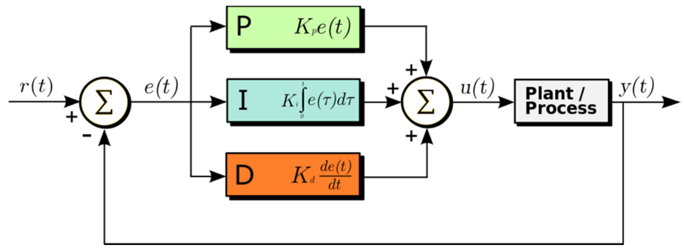

Figure 1. The block diagram of the buck converter with PWM feedback circuit.

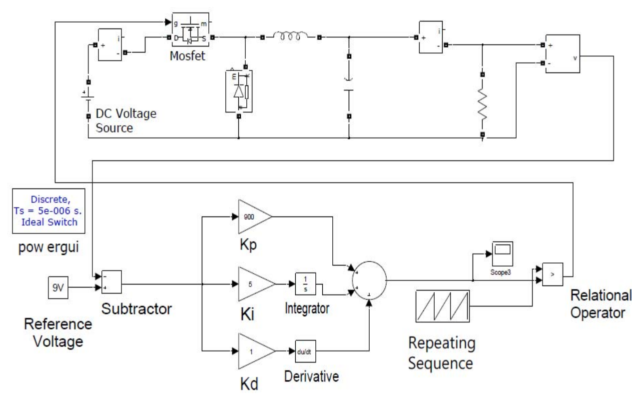

Figure 2. The system level structure of the buck converter circuit.

III. K_P CALCULATION OF PID CONTROLLER

Fig. 3 shows the waveform of the repeating sequence. The signal is sawtooth wave. The minimum output ΔV is 0.01V. If the set point of the buck converter is 9V, the gain K_p can be derived as follows:

$$K_p = \frac{Setpoint}{\Delta V} = \frac{9V}{0.01V} = 900 \quad (2)$$

The function of K_P is proportional to the value of voltage error *e(t)*. The voltage error is equal to the reference voltage subtract the output voltage of the buck converter.

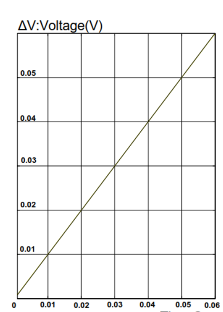

Figure 3. The waveform of repeating sequence.

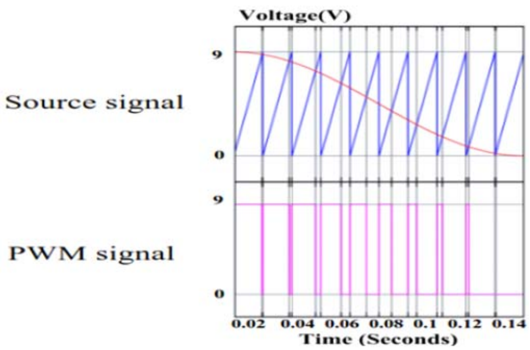

Figure 4. The output signal of PWM generator.

TABLE I
THE VALUE OF CIRCUIT PARAMETERS OF THE BUCK CONVERTER WITH PI/PID CONTROL CIRCUIT

Circuit Parameter	Value
DC Voltage Source	12V
Inductor	5mH
Capacitor	100uF
Resistor	10Ω
Setpoint	9V
Proportional Gain (K_P)	900
Integral Gain (K_I)	5.5
Derivative Gain (K_D)	1.3

IV. PWM SIGNAL GENERATOR

The PWM signal is generated by the relational operator as shown in Fig. 2. The simulation results of the output signal of PWM generator is shown in Fig. 4. The red line is the reference signal coming from PID controller. The blue line is output signal of repeating sequence. When the value of reference signal is larger than the value of output signal of repeating sequence, the PWM signal is set to the high state (logic 1). Otherwise, it is set to the low state (logic 0).

V. COMPARISON BETWEEN PI AND PID CONTROLLER

To analyze the stabilization time of buck converter with PI and PID control, the circuit parameter is set as shown in Table 1. Fig. 5 shows the simulation results of stabilization time of PI and PID control system. The stabilization time of buck converter with PI controller and PID controller is 120ms and 68.9ms, respectively. It is noted that the stabilization time of buck converter is decreased by applying PID controller.

To find the optimal PID value with 9V output, the proportional gain is calculated as 900 from (2). The integral gain K_I is first set to 3.5 and derivative gain K_D is set to 0.1. The fine tuning PID value is shown in Table II. By increasing K_I with 0.5 and K_D with 0.3, the optimal value to PID can be obtained as K_P=900, K_I=5.5, K_D=1.3.

VI. CONCLUSION

In this paper, a buck converter circuit with PID feedback control and PWM generator is analyzed using Matlab tool. The system level structure of the buck converter circuit is generated

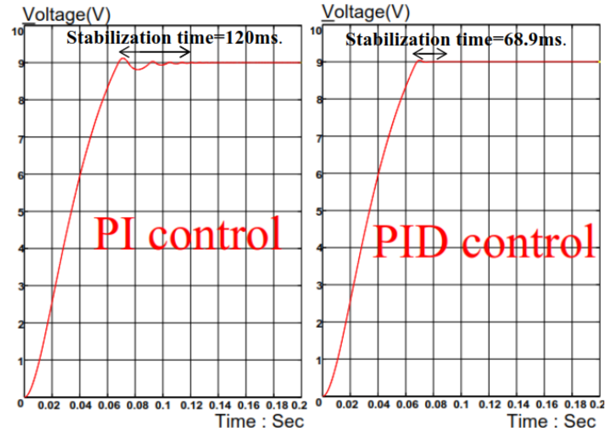

Figure 5. Simulation results of stabilization time of PI control and PID control system.

TABLE II
FINE TUNING PID VALUES

	Fine Tuning PID Values						
K_P	900	900	900	900	900	900	900
K_I	3.5	4	4.5	5	5.5	6	6.5
K_D	0.1	0.4	0.7	1	1.3	1.6	1.9
Stabilization time (ms)	110	89	83	78	68.9	68.6	75
Output Voltage (V)	9.001	9.001	9.001	9.001	9.001	9.002	9.002
Remark					**Best Value**	**Output over spec.**	

using Matlab Simulink tool. The stabilization time of buck converter with PI and PID control is analyzed using Matlab tool. From the simulation results, stabilization time of buck converter with PI controller and PID controller is 120ms and 68.9ms, respectively.

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