Implementation of PID controller for DC-DC converter using microcontroller

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마이크로컨트롤러를 이용한 DC-DC 변환의 PID 제어기 설계

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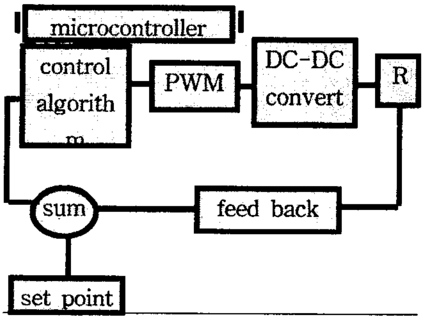
Abstract

This paper presents an implementation of PID controller for DC-DC converter using the microcontroller. The features of the microcontroller such as the on chip ADC and Pulse width Modulator (PWM) eliminate the external components needed to perform these functions. The duty rate cycle for the DC-DC converter can be updated every time when the (ADC) conversation and the calculation time are finished. The stable response can be obtained for any kind of DC-DC converters. The SMPS controller looks at the converter output, compares the output to a set point, performs a control algorithm (PID algorithm) and finally applies the algorithm output to the PWM. PWM output is then used to drive the DC-DC converter. Figure (1) shows a simplified block diagram of a complete DC-DC converter system.



Block diagram Of DC-DC converter

1-Introduction

In many applications a DC-DC converter is used to produce a regulated voltage or current, derived from an unregulated power supply. Reliable, efficient well regulated DC-DC converter power conversation equipment is critical for mission on most space platforms. As plat forms especially manned spacecraft, it become more sophisticated, reliable operation of complete power management and distribution (PMAD) systems. As a result there is much interest in determining how and what areas a more intelligent and robust control structure might be of value. Replacing the present analog control solution with digital computer based control is one approach toward satisfying this need. Either microcontroller or DSP approaches have been realize sophisticated control algorithms such as PID or FUZZY LOGIC. Applying PID on the microcontroller is the focus of the work to be reported in this paper.

Most DSP systems are not optimized for non linear arithmetic, despite being able to compute very quickly and with high precision. also it do not contain the full complement of functions needed to implement a feedback system, i.e functions like analog to digital (A/D) converter or pulse width modulation (PWM) out put may be added externally. On the other hand, microcontrollers often include a wealth of control and communication functions in hardware. An alternative approach is to generate a low cost SMPS function in a smart microcontroller. This paper shows a method of using microcontroller to perform simple SMPS control functions.

2-PID controller

A feedback controller is designed to generate an output that causes some corrective effort to be applied to a process so as to drive a measurable process variable towards a desired value known as the set point. Virtually all feedback controllers determine their output by observing the error between the set point and a measurement of the process variable. Errors occur when an operator changes the set point intentionally or when a disturbance or a load on the process changes the process variable accidentally. The controllers mission is to eliminate the error automatically

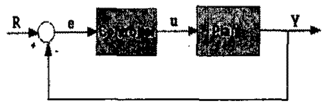
PID is acronym for PROPORTIONAL, INTEGRAL and DERIVATIVE. This control action allows a measurement (process value) to be controlled at a desired set point by continuously adjusting a control parameters act on the error. PID looks at the current value of the error, the integral of the error over a recent time interval and the current Derivative of the error to determine not only how much of a correction to apply but for how long. The important part is setting the tuning constants so as to produce a controller out put that steadily derives the process variable in the direction required to eliminate the error. Standard methods for tuning loops have been used for many years, but should be reevaluated for use on modern digital control systems. While the basic algorithm has been unchanged for many years, the actual digital implementation of the algorithm has changed and differs from one system to another .the discussion will be the digital PID control algorithm implementation method for the buck converter.

The algorithm is normally available in several combinations of these elements:

	rise time	O-shoot	S-time	ST-error
KP	decrease	increase	small-ch	decrease
KC	decrease	increase	increase	eliminate
KD	small-ch	decrease	decrease	small-ch

1-Proportional only. 2-Proportional and Integral (most common). 3-Proportional, Integral, and Derivative. 4-Proportional and Derivative. The effect of each controller is as shown in the next table.

3- PID CONTROLLER DESIGN FOR A BUCK CONVERTER



PID controller system

PID controller design designed for the buck converter is began with the very familiar small-signal model

$$\frac{\hat{v}_O}{\hat{d}}(s) = V_I \times \frac{R}{R+R_L} \times \frac{1+R_C \times C}{1+s\times\left[C\times\left(R_C+\frac{R\times R_L}{R+R_L}\right)+\frac{L}{R+R_L}\right]+s^2\times L\times C\times\frac{R+R_C}{R+R_L}}$$

The variable D is the duty cycle. The circuit parameters for this converter are Vin= 12 V, V0= 5 V, L = 400 μH, C = 1000 μF, and R = 10. The parasitic elements RC and RL were estimated to be 30 m and 10 m, respectively. The switching frequency is 20 kHz. This system has a very small phase margin. A compensator must be designed to ensure that the gain at low frequencies is high enough to minimize the steady-state error. The compensator in this investigation was a PID controller which is described by the following transfer function:

G(s) = Kp+Ki/s+Kd*s

The PID controller was designed in the continuous time domain and then converted to the discrete time domain using the backward integration method (Euler rule) . The following difference equation can be produced from the discrete time transfer function.

u(k) = Kp*e(k)+Ki*T*sum (e(k)) + Kd/T*(e(k)-e(k-1)

In this equation, u(k) is the new duty cycle calculated from the kth sample, and e(k) is the error of the kth sample. The error e(k) is calculated as e(k) = Ref-ADC(k), where ADC(k) is the converted digital value of the kth sample, and Ref is the digital value corresponding to the desired output voltage. The second term in the equation is the sum of the errors and e(k)-e(k-1) is the difference between the error of the kth sample and the error of the (k-1)th sample.

4- integral Windup

when the controlled process has a positive gain and a positive set-point change occur, the controller will then try to reduce the error between set-point and output, which is initially positive. The integral component will sum these positive errors to generate the necessary integral action. An overshoot occurs, whereupon the errors become negative. However, the direction of the control signal will not change to compensate if the sum of previously positive error dominates, in which case the overshoot becomes prolonged. The direction of control action will change only when the contribution of negative errors cancels the accumulated positive errors sufficiently.

There are several ways to deal with this problem. One is to use the velocity algorithm. In the integral term in the velocity algorithm, only the previous control output and the sample instant error e(n) are used to calculate the output. If the previous output is limited by a clipping procedure, then the maximum value of the integral term is the previous output plus the integral of e(n).Another method is the Stop Summation method. This states that if the system saturates, then the integral summation should stop.

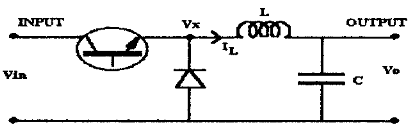
***5-Advantage* of the PID**

Quick action to a change in the error effective prevention of runaway. Decrease settling time for processes with slow dynamics and fast disturbances.

***6-Disadvantage* of the PID**

1-Three parameters to tune. 2- Amplifies measurement noise effect

7- DC-DC converter analysis



Buck converter circuit .

Generally any basic switched power supply consists of five components:

Control by pulse-width modulation, is necessary for regulating the output. In this paper a PWM controller is the PID algorithm applied in the microcontroller. **The transistor** switch is the heart of the switched supply and it controls the power supplied to the load. Transistors chosen for use in switching power supplies must have fast switching times and be able to withstand the voltage spikes produced by the inductor. **An inductor** is used in a filter to reduce the ripple in current. When the current through an inductor tends to fall, the inductor tends to maintain the current by acting as a source. **A capacitor** is used in a filter to reduce ripple in voltage. Since switched power regulators are usually used in high current, high-performance power supplies, the capacitor should be chosen for minimum loss. Loss in a capacitor occurs because of its internal series resistance and inductance. **The diode** used in a switched regulator is usually referred to as free-wheeling diode or sometimes as a catch diode. The purpose of this diode is to direct current flow in the circuit and to ensure that there is always a path for the current to flow into the inductor. It is also necessary that this diode should be able to turn off relatively fast. Diodes known as the fast recovery diodes are used in these applications. Most of the switched supplies need a minimum load to ensure that the inductor carries current always.

According to the continuous mode the buck converter analysis will be in the two situations of the switch as follow:-

First situation when the switch is closed. In this situation the diode will be OFF and thus the equations:-

VL = VS - VO (1)

In the second period when the switch is open the diode is ON. and thus:-

VL = -VS (2)

From equations (1) and (2) we find

dI_L=(VS-VO)*t/L=(VS-VO)*DTS/L eq.(3)

dIL=VO*t/L=VO*(1-D)TS/L eq.(4)

Recognizing the equality of eq.(3) and eq.(4) allows us to determine the output voltage:-

(VS-VO)*DTS/L = VO*(1-D) TS/L (5)

(VS-VO)*D=VO(1-D) (6)

From which

VO = D VS (7)

In a buck regulator, D is varied using feedback to regulate VO.

8- The Efficiency of SMPS

From the elements of switch mode converter point of view, the efficiency is defined as the ratio of the output to the input power. With switching regulators, the efficiency is primarily determined as:-

Efficiency = Pout/Pin

9- Conclusion

This paper demonstrates the using of DC-DC converter (buck converter) as a plant for the microcontroller to show the ability of PID controller algorithm to control and correct the error which produces from the difference between the desert output and the actual output. The following table is summary of the Constant Voltage DC/DC Converter performance.

PARAMETERS	STATUS
Vin=8.8 ;Vout=4.8v	Efficiency=72%; Io=520mA
Vin=8.8 ;Vout=4.8v	Efficiency=67%; Io=100mA
Vin=14.8 ;Vout=4.8v	Efficiency=45%;Io=100mA
Vin=14.8 ;Vout=4.8v	Efficiency=62%;Io=520mA

As a future works on this paper there are many additional issues can be added:-

1-genetic algorithm (GA) can be applied In the PID control problem. The required three-terms-parameters should be optimally determined. These parameters can be optimally obtained via GA.

2- Using full capability of the Atmel 163 to do more efficient control.

10-References

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