

A Novel V-I Converter Used in the Slope Compensation of a Boost Converter

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Abstract: A novel voltage to current circuit used in the slope compensation of a boost DC-DC converter is proposed. Compared with the normal V-I converter, it has a better linear relation and a larger input voltage range. It can implement slope compensation of the power converter, eliminate the sub-harmonic oscillation and decrease the noise infection effectively.

Index Terms: Boost converter, Voltage-current converter, Slope compensation.

I. INTRODUCTION

Slope compensation is essential part in current control mode converter circuit, which is mainly used to dispel or improve the system's unsteadiness phenomena in large duty cycle. This paper based on the design theory of boost converter and some new relative fruits. According to V-I converter's function and action, we design a novel linear voltage-current converter circuit to achieve the converter's slope compensation.

II. THE THEORY OF CONVERTER'S SLOPE COMPENSATION

A. The current control mode converter

Current control mode converter is based on voltage control mode. It adds a inner loop-current feed back loop to make it changed into a double controlled system. Then the current of inductance is not a independence variable. Two order model of converter is take of inductance current and change into one order model^[1,2]. Current signal V_s is compared with output voltage of error amplifier V_e , then output pulse drive power MOSFET open. The pulse current of the current loop increases gradually. When signal of sampling current swing is achieve the voltage of V_e , pulse width modulation (PWM) comparator is turn on and power MOSFET is closed^[3]. System is just in this wag to check and adjust current pulse one by one to achieve the control of the output voltage. If the current pulse reach the scheduled swing, the current loop will work to change the pulse width to ensure the output voltage is stable, and control the current .Loop could periodic adjust the

output voltage and obtain the high precision output voltage and diminish the ripple voltage.

B. The importance of slope compensation

Boost converter of this paper is use the way of peak value current control. As Fig. 1 show, under the peak current control mode difference duty cycle that one is less than 0.5 and the other is lager than 0.5 has different inductance current wave. V_e is the voltage of amplifier's output of current enactment value. ΔI_0 is wave current. m_1, m_2 is the edge's slope of inductance current raise and fall . We can see from the figure. When duty cycle is lager than 0.5, after one period the signal of wave current will be large and it couldn't work steady^[4,5]. By now PWM comparator's import need to add a slope compensation for the circuit stability, As Fig.2 show.

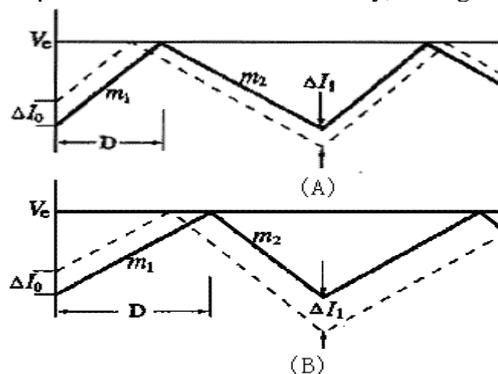


Fig 1 (A) duty cycle is less than 50%; (B) duty cycle is larger than 50%

C. Method of slope compensation

Current control mode includes peak-current value control mode and average current control mode. In this paper, the current peak value control mode is used. Compared with actual inductance current and current of out voltage loop enactment in PWM comparator's two imports, Ways of peak-current value control mode of Slope compensation could divides into two kinds. One kind is copy the power MOSFET current sense and add same phase voltage slope. The other way is add opposite phase voltage slope in error amplifier's output port^[1]. This paper use fist way. V_g means import voltage, V means output voltage, m_1 means slope of increased inductance current. $-m_2$ means slope of decreased inductance

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current^[6] $m_1 = \frac{V_g}{L}$, $-m_2 = \frac{V - V_g}{L}$. As show in Fig.2.

The slope of new add control quantity is $-m_c$.

When $|\alpha| < 1$, $\alpha = -\frac{m_2 - m_c}{m_1 + m_c}$, system could achieve steady^[6]. So if we could produce the slope of circuit $-m_c$, then we could achieve slope compensation.

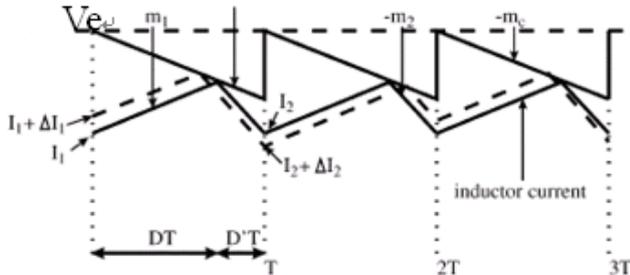


Fig.2 Theory of slope compensation

D. Design of Voltage-current circuit in converter slope compensation

The theory of Voltage-current circuit in converter slope compensation is use saw tooth wave which is produced by oscillator as input signal. Then we could get isochronous slope compensation signal of which the frequency is same as the whole circuit. We use a novel linear voltage-current converter that the output signal is current in the structure of the circuit. This signal adds to current sense signal to achieve slope compensation.

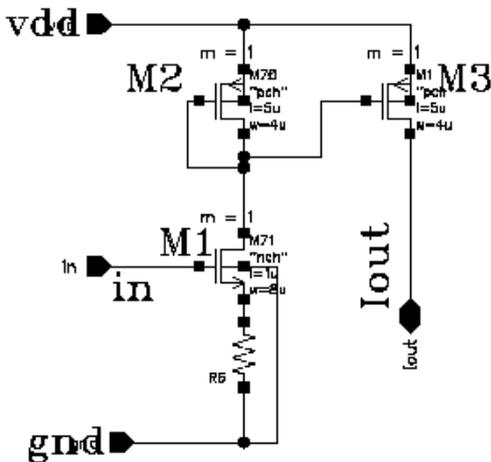


Fig 3 traditional V-I invert circuit

First we introduce traditional V-I invert circuit. As Fig. 3, we could get^[7]:

$$I_{out} = \frac{V_{IN} - V_{THN} - \sqrt{\frac{2 * I_{out}}{B_1}}}{R} \approx \frac{V_{IN} - V_{THN}}{R} \quad (1)$$

$$V_{IN-MINIMUM} = V_{THN} \quad (2)$$

$$V_{IN-MAXIMUM} = V_{PWR} + V_{THN} - V_{THP} - V_{DSAT} \quad (3)$$

So the range of input voltage was restricted in a small range (V_{THN} to $V_{PWR} + V_{THN} - V_{THP} - V_{DSAT}$). The novel voltage-current converter circuit is show as Fig. 4.

$$I_{M1} = I_1 - (V_{IN} - V_{TH}) / R \quad (4)$$

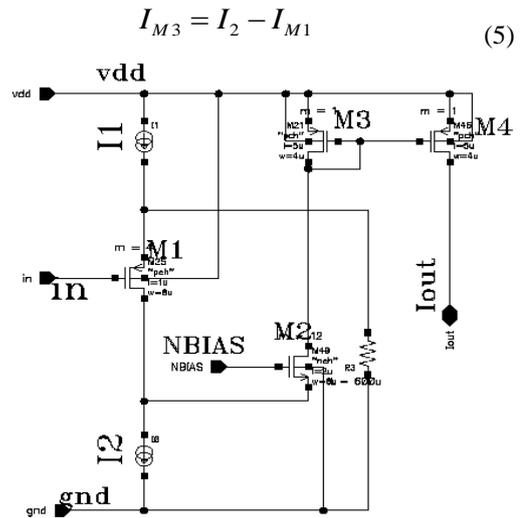


Fig 4 new V-I invert circuit

Suppose $I_1 = 4I, I_2 = 3I$, then

$$I_{M3} = I_2 - I_1 + (V_{IN} - V_{TH}) / R$$

$$= (V_{IN} - V_{TH}) / R - I \quad (6)$$

$$I_{out} = I_{M3} = (V_{IN} - V_{TH}) / R - I \quad (7)$$

We could see I_{out} and input voltage V_{IN} has linear relationship and the range of input voltage is larger than traditional. It's range is from 0 to $V_{PWR} - V_{TH}$. Fig. 5 is the entire circuit with the bias current circuit.

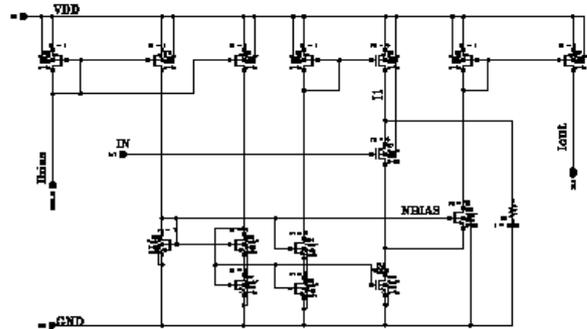


Fig 5 after add setting circuit of V-I

As the value of sense current is start from 0 and then join with the slope compensated current, we need subtract a benchmark current to make it start from 0. As show in Fig. 6, two V-I circuits combination could achieve:

$$I_{out} = k(V_{IN1} - V_{IN2}) = I_4 - I_3 \quad (8)$$

Where K is linearity modulus, V_{IN2} is benchmark voltage, the swing of sawtooth wave which is produced by oscillator is 0.5V to 1.1V, then after slope compensation the current starts from 0.

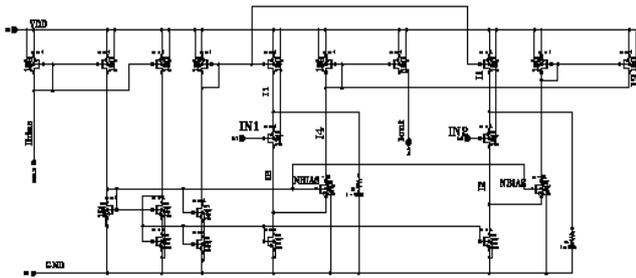


Fig 6 general V-I slope compensation circuit

E. Design of sigma circuit

Sigma circuit converge the Sense current and slope compensation current, then change it into the voltage signal form by resistor and put it into PWM comparator's one port, the voltage signal compared with the output of the error amplifier. As Fig. 7 shows, the power MOSFET open and close are controlled by PWM comparator's overturn.

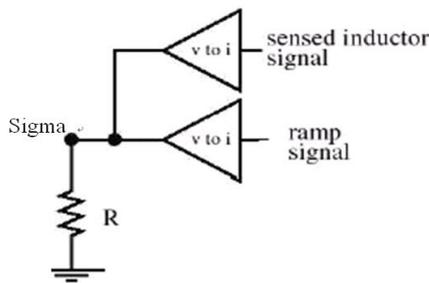


Fig 7 theory of Sigma circuit

III. SIMULATION RESULT OF CIRCUIT

A. Simulation result of V-I circuit

We can see from Fig 8, in different supply voltage condition, this circuit could still keep linear relationship of output current and input voltage, and the input voltage is start from zero. Compared with traditional V-I circuit, this circuit enlarger the range of input voltage and hold a good linear relationship which is not affected by the supply voltage.

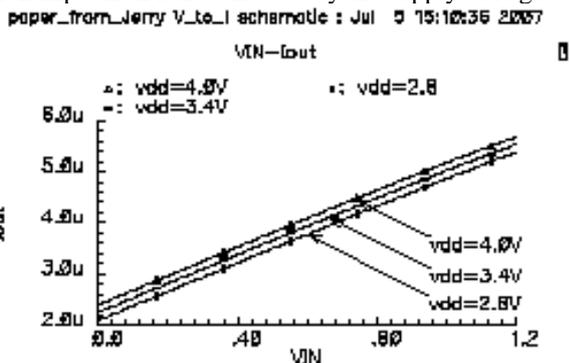


Fig 8 relationship of output current and input voltage

B. Simulation result of Boost converter slope compensation V-I

As Fig. 9 show, it is slope compensation wave, slope compensation circuit change the sawtooth wave which is produced by oscillator into current wave which has been slope compensated. It achieved slope compensation of boost converter.

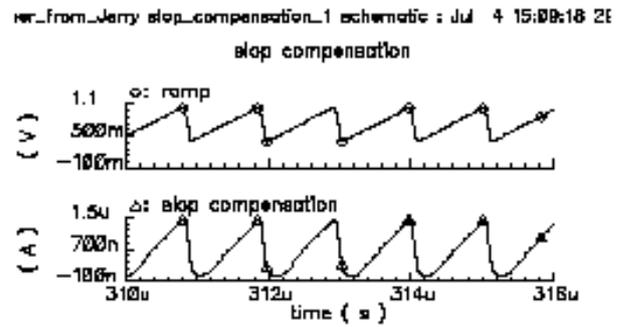


Fig 9 wave of slope compensation

IV. CONCLUSION

Under current peak value control mode, current loop will present sub-harmonic oscillation, after slope compensation, we could disappear sub-harmonic oscillation^[8]. Using a novel V-I converter circuit, we achieved slope compensation of boost converter, disappeared sub-harmonic oscillation and effectively eliminate the noise. The simulation result indicate that this V-I converter circuit compared with traditional circuit has larger range of input voltage. Input and output has a very well linear relationship, which is not effected by supply voltage.

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