Improving the Efficiency of a HV9930/AT9933 Controlled Boost-Buck Converter

Introduction

The HV9930 based Boost-Buck converter offers many advantages - tight regulation of the output current, ability to boost or buck the input voltage and continuous input and output currents. It also features input current limiting during overload or input under voltage conditions by direct sensing of the input current. While being a minor factor in lower power applications, power dissipation in the input current sense resistor can degrade the overall efficiency as the input current increases. This Application Note offers a simple modification of the HV9930 circuit that minimizes this power loss.

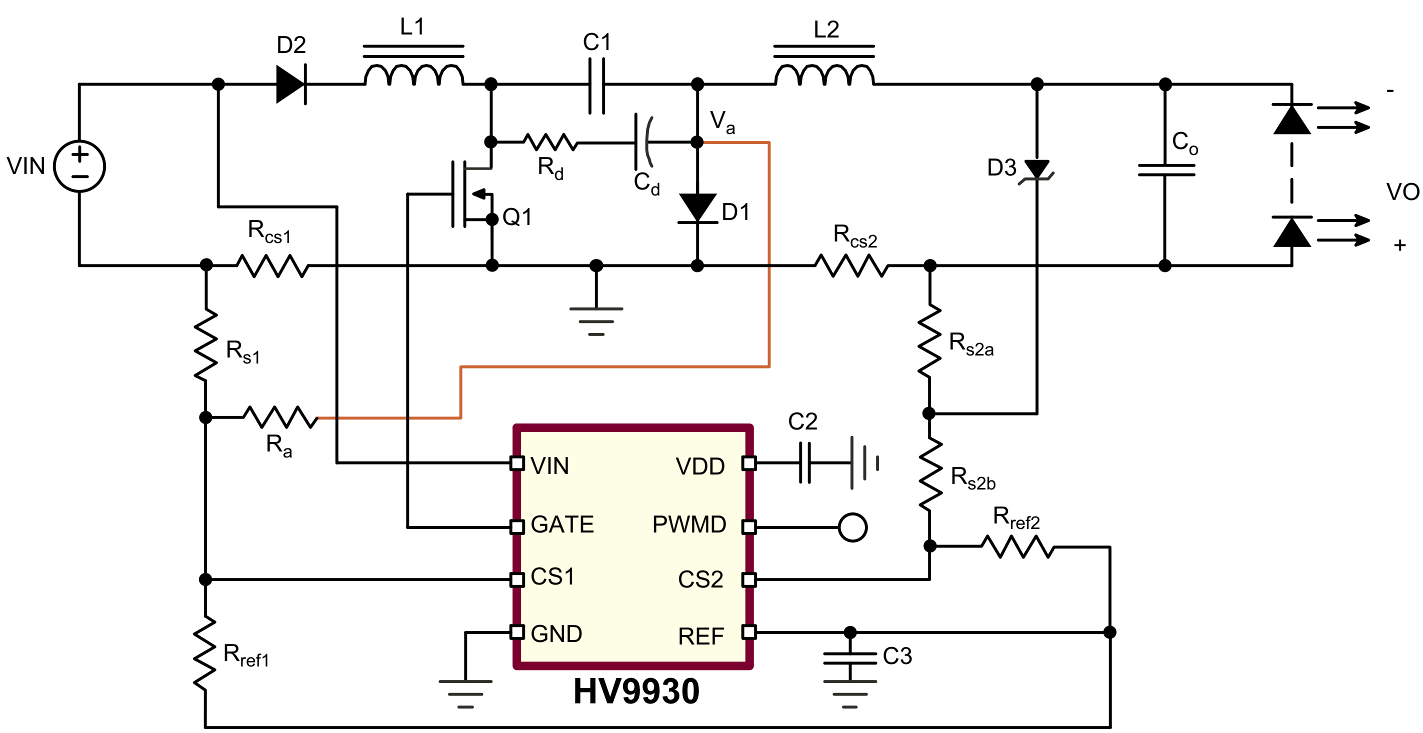
The following design procedure can reduce the value of the input current sense resistor needed and hence minimize the power dissipation in it.

Description

The reduction of the current sense resistor is achieved by feeding the voltage V_a at the anode of the Synchronous Diode to the CS1 pin of the HV9930 through a resistor (Fig. 1). The equations in this section will enable us to reduce the hysteresis required by the input comparator.

Consider the operation of the converter when it is in the input current limit mode at nominal input voltage. When the switch is ON (Fig. 2), the input inductor current increases and voltage $V_a = -V_c$. During this time, the internal reference to the comparator is at 0mV. In this case, the current being sourced out of the REF pin is divided between the two other branches connected at the CS1 pin. Thus, the current through R_{s1} will be less than in the case when R_a was not present and thus the voltage drop across R_{s1} also decreases. Using Kirchoff's Current Law (KCL) at the CS1 node,

Fig.1. Modification of the HV9930 Boost-Buck Converter



$$\frac{V_{ref}}{R_{ref}} = \frac{V_{c,nom}}{R_a} + \frac{\left(I_{in,lim} + \frac{\Delta I_{in}}{2}\right) \cdot R_{cs}}{R_{s1}} \qquad (1)$$

Fig. 2. Switch is ON

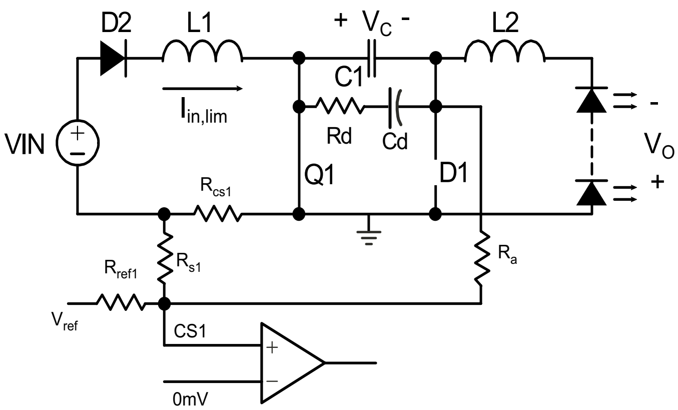
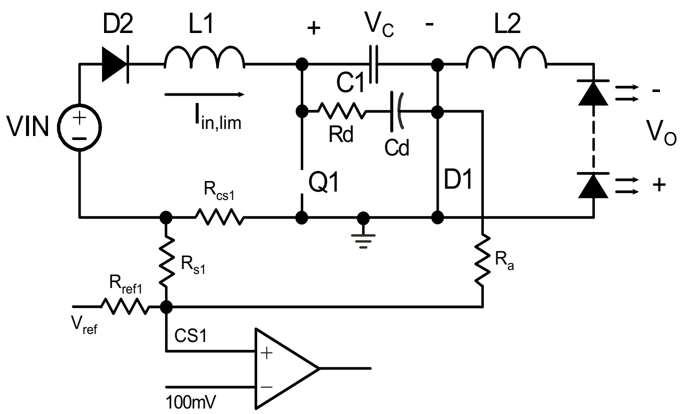


Fig. 3. Switch is OFF



where $V_{c,nom} = V_{in,nom} + V_o$

When the switch is OFF (Fig. 3), the input inductor current decreases and the freewheeling diode is conducting. So the voltage V_a will be zero. During this time, the internal reference to the comparator is at 100mV. Since the resistor R_a is very large (since it sees $-V_c$ in the other time period), the effect of R_a in this time period can be ignored.

$$\frac{V_{ref} - 0.1V}{R_{ref}} = \frac{0.1V}{R_a} + \frac{0.1V + \left(I_{in,lim} - \frac{\Delta I_{in}}{2}\right) \cdot R_{cs1}}{R_{s1}} \approx \frac{0.1V + \left(I_{in,lim} - \frac{\Delta I_{in}}{2}\right) \cdot R_{cs1}}{R_{s1}} \qquad (2)$$

Equation (1) shows us that the upper limit of the current sense signal:

$$V_{sense,max} = \left[I_{in,min} + \frac{\Delta I_{in}}{2}\right] \cdot R_{cs1} \qquad (3)$$

is a function of the voltage across the capacitor V_c. As V_c decreases, $V_{sense,max}$ has to increase according to (1). The increase in $V_{sense,max}$ means that the upper threshold of the input current ripple increases. Thus, this method fixes the lower end of the current ripple and changes the higher end depending on the input and output conditions. The lowest V_c and thereby the highest $V_{sense,max}$ occurs at startup (V_d = 0) with the lowest input voltage ($V_c = V_{in,min}$). At this point, the maximum input current should not exceed the saturation current rating (I_{sat}) of the input inductor.

Using this condition:

$$\frac{V_{ref}}{R_{ref1}} = \frac{V_{in,min}}{R_a} + \frac{I_{sat} \cdot R_{cs1}}{R_{s1}} \qquad (4)$$

The above equations can be solved to compute the unknown resistor values. The next section details the modification of the circuit in the AN-H51 using this method.

Note:
This method of making the ripple depend on the capacitor voltage will work only if the saturation current of the inductor is greater than the input current peak.

$$I_{sat} > I_{in,lim} + \frac{\Delta I_{in}}{2} \qquad (5)$$

If this is not the case, an inductor with higher saturation current rating needs to be chosen to use the above equations.

Procedure

Input Parameters (obtained from AN-H51):

Input current limit (average value)	$I_{in,lim}$ = 2.1A
Input current ripple (current limit mode)	ΔI_{in} = 0.63A
Peak Input current allowable	I_{sat} = 2.4A
Minimum input voltage	$V_{in,min}$ = 9.0V
Nominal capacitor voltage	$V_{c,nom}$ = 42V
Resistor	R_{ref1} = 10kΩ
Reference voltage	V_{ref} = 1.25V

Note that in this case, equation (5) is not satisfied. So we need to choose an inductor with a higher saturation current rating. Choose DR127-820 from Coiltronics with a saturation current of 4.06A (we will use I_{sat} = 3.0A in the following equations). This inductor has the same footprint and same inductance value, but is taller by 2mm.

From (1):

$$125\mu = \frac{42}{R_a} + 2.415 \cdot \frac{R_{cs1}}{R_{s1}} \tag{6}$$

From (2):

$$115\mu = \frac{0.1}{R_{s1}} + 1.785 \cdot \frac{R_{cs1}}{R_{s1}} \tag{7}$$

From (4):

$$125\mu = \frac{9}{R_a} + 3.0 \cdot \frac{R_{cs1}}{R_{s1}} \tag{8}$$

Solving for R_a using (6) and (8) gives:

$$125\mu \cdot \left(1 - \frac{2.415}{3.0}\right) = \frac{1}{R_a} \cdot \left(42 - 9 \cdot \frac{2.415}{3.0}\right)$$
$$\Rightarrow R_a = 1.43M\Omega \tag{9}$$

Substituting the value of R_a back in (6) (or (8)) gives:

$$\frac{R_{cs1}}{R_{s1}} = 39.55\mu \tag{10}$$

Using (10) in (7):

$$R_{s1} = \frac{0.1}{115\mu - 1.785 \cdot 39.55\mu} \tag{11}$$
$$= 2.25k\Omega$$

The current sense resistor value can be determined by substituting (11) in (10):

$$R_{CS1} = 0.089\Omega$$

Thus, the value of the current sense resistor has dropped from 0.228Ω to 0.089Ω, a drop in the value by about 60%! The power rating is now approximately 0.35W maximum (again a 70% drop from the 1W computed in AN-H51).

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