Calculating and Measuring the No Load Input Current of the Boost Converter

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ABSTRACT

This application report introduces how to calculate the no load input current of a low quiescent current boost converter. It also provides a simple method to measure the no load input current without using a current meter.

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1 Introduction

The no load or very light load input current of a boost converter is critical for some applications that require primary battery and a boost converter to power the whole system. In these applications, the system loads operate at idle mode for most of the time, which consume little energy. The efficiency of a boost converter at this special condition may be not found in the datasheet. So we need to calculate or measure the total input current of the boost converter (also the output current of the battery) at the idle mode to estimate the battery lifetime.

Taking TPS610981 as an example, this application report introduces the methods to calculate and measure the input current of a boost converter at no load or very light load condition.

2 Input Current Calculation

As shown in Figure 1, the input current is determined by the current consumed by the boost IC, the feedback divider and the system load. For fixed output voltage version IC, the resistor divider current is zero.

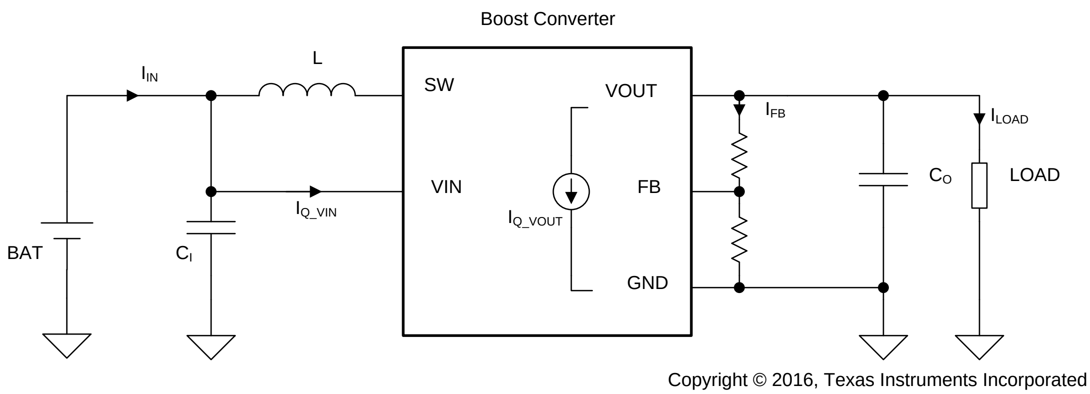

Figure 1. Current Consumption of the System

The current consumed by the internal circuit of the IC has two parts, the quiescent current IQ into the VIN pin and into the VOUT pin, which is shown in Table 1. Details about the definition of IQ can be found in *I_Q: What it is, what it isn't, and how to use it*, SLYT412.

Table 1. IQ Specification from TPS610981 Datasheet

Parameter		Test Condition	MIN	TYP	MAX	UNIT
I_{Q_VIN}	Quiescent current into VIN pin in Low Power Mode	MODE = Low, Boost or Pass-through		5	90	nA
I_{Q_VOUT}	Quiescent current into VOUT pin in Low Power Mode	MODE = Low, Boost or Pass-through, No Load, No Switching, TJ = 25°C		300	400	nA

The current into the VOUT pin, the current flowing through the resistor divider and the load current I_{LOAD} are tranfered from the battery when the device is switching. So the total input current of the boost covnerter can be calculated by Equation 1. The unknown parameter of the formula is the efficiency η_1.

$$I_{IN} = I_{Q\_IN} + \frac{V_{OUT}}{V_{IN} \times \eta_1} \times \left(I_{Q\_OUT} + I_{FB} + I_{LOAD}\right)$$

where

- I_{Q_VIN} is the I_Q into the VIN pin
- V_{OUT} is the output voltage of the boost converter
- V_{IN} is the input voltage of the boost converter, or the battery voltage
- η_1 is the efficiency when the boost converter is switching
- I_{Q_VOUT} is the I_Q into the VOUT pin
- I_{FB} is the current of the feedback resistor divider. It is zero in TPS610981
- I_{LOAD} is the load current. (1)

Figure 2 shows the operating waveform of the TPS610981 at burst mode with 1.2-V input voltage. In the Phase #1, the boost converter switches and transfers the energy from the battery to the output side. In the Phase #2, the boost converter stops switching and the energy in the output capacitors supports the I_{Q_VOUT} and I_{LOAD}. The efficiency η_1 of Phase #1 is approximately the same at different load conditions if the boost converter still operates in the burst mode. So we can set the η_1 to be the efficiency value at the load condition that is one hundred times of the larger one of the I_{Q_VOUT} and I_{Q_VIN}. The reason is that the I_{Q_VOUT} and I_{Q_VIN} have little impact on the efficiency at this load condition if the IC still works in burst mode.

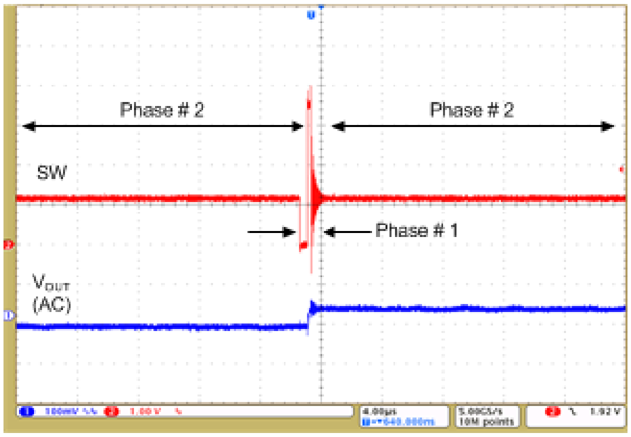

Figure 2. Operation Waveform at Burst Mode

In the TPS610981, we can choose the efficiency value at I_{LOAD} = 100 × I_{Q_VOUT} = 40 µA condition to be η_1. Figure 3 shows the TPS610981 efficiency curve from the TPS610981 datasheet (SLVS873D). The efficiency at I_{OUT} = 40 µA, VIN = 1.2 V condition is approximate 85%. And the efficiency increases to 90% when VIN = 2 V.

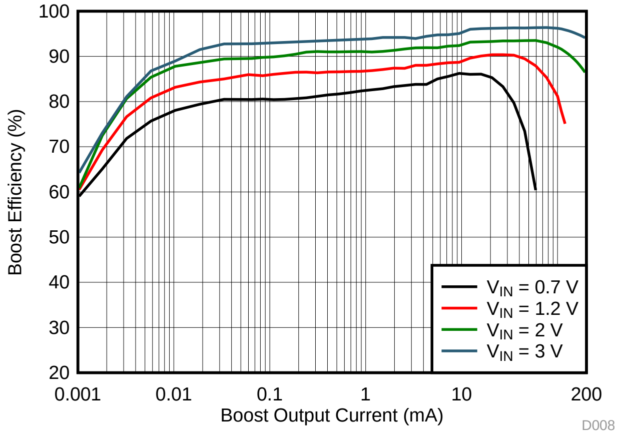

Figure 3. Efficiency of TPS610981 at Low Power Mode

Then the no load input current at VIN = 1.2 V can be calculated as shown in Equation 2. The output voltage is 3.4 8V when I_{LOAD} = 0 mA.

$$I_{IN} = I_{Q\_IN} + \frac{V_{OUT}}{V_{IN} \times \eta_1} \times \left(I_{Q\_OUT} + I_{FB} + I_{LOAD}\right) = 0.005 + \frac{3.48}{1.2 \times 0.85}\left(0.4 + 0 + 0\right) \approx 1.36\mu A \tag{2}$$

When the VIN is 2 V, the η_1 is 0.9 and the no load input current is approximately 0.778 µA.

3 Input Current Measurement

At no load or very light load condition, the switching frequency of the boost converter is very low, as shown in Figure 4. The input current is pulsating in the same frequency which makes the input current hard to be measured using a current meter.

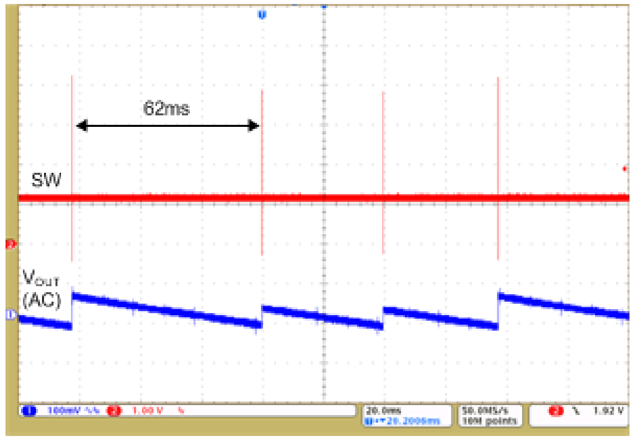

Figure 4. Switching Frequency at No Load Condition

A simple RC filter circuit shown in Figure 5 helps to solve this problem. The cut-off frequency of the RC filters must be much lower than the switching frequency of the boost converter.

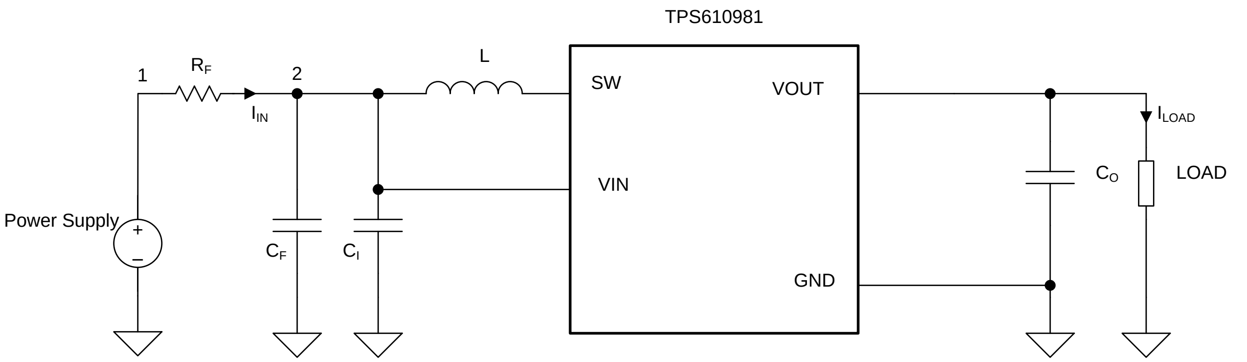

Figure 5. Method to Measure the No Load Input Current

From Figure 4, the switching period is 62 ms, so the time constant of the RC filter can be set to 6 seconds. Based on the input current calculated by Equation 2, we can select 10 kΩ for R_F and 600 µF for C_F. Large R_F results in large voltage difference between the power supply voltage and the real input voltage, which cause trouble in setting the right input voltage. Small R_F results in large ceramic C_F, which increase the cost.

Firstly, connect the power supply to node 2 shown in Figure 5 to charge the C_F and start up the boost converter. Then move power supply quickly to node 1. The input current can be calculated by measuring the voltage drop across the R_F with a multi-meter. It is suggested to wait at least ten minutes until the input current becomes stable. Table 2 shows the calculation and measurement results of the no load input current at different input voltages conditions. The calculated values are closed to the measurement results.

Table 2. Calculation and Measurement Results of No Load Input Current

Calculation and Measurement Results of No Load Input Current			
VIN (V)	1.2	2.4	3
Calculation (µA)	1.36	0.65	0.51
Measurement (µA)	1.24	0.62	0.50

4 Conclusion

The application note introduces methods to calculate and measure the input current at no load or very light load condition. If the load current is known, a formula can be used to estimate the input current; if load condition is unknown or accuracy data is required, the input current can be measured by adding a simple RC filter.

5 References

I_Q: What it is, what it isn't, and how to use it

TPS61098x Ultra-Low Quiescent Current Synchronous Boost with Integrated LDO/Load

Products		**Applications**	
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