Designing Boost Converter TPS61372 in Low Power Application

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ABSTRACT

The application report introduces how to design a small power, small solution size boost converter using the TPS61372 device. The external components of the converter are calculated and selected based on the designed target. The stable and transient performances are measured at different conditions to show the behavior of the converter.

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1 Introduction

TPS61372 is a 16-V, 3.6-A peak current synchronous boost converter. The integrated synchronous MOSFET improves the solution efficiency and also provides capability for forced PWM operation if fixed switching frequency is required. The isolation MOSFET in series with the synchronous MOSFET disconnects the input from output when TPS61372 shuts down. This feature reduces the shutdown current consumption below 1 µA. The isolation MOSFET also protects the TPS61372 and the power source when short circuit happens at the output.

The typical output power of the TPS61372 is 5 Watts. However, the device can also be used in low power applications. This application report provides a small solution targeting following application condition:

- Input voltage V_{IN}: 3.6 V
- Output voltage V_{OUT}: 12 V
- Output current I_{OUT}: 50 mA

2 External Component Design

The TPS61372 has a MODE pin to set the operation mode. When the mode is logic high, the device operates at forced pulse width modulation (PWM) mode. At forced PWM mode, the device switches with 1.5 MHz (typical) disregarding the loading. This results in very low efficiency at light load condition. To improve efficiency, the MODE pin is set to low in this application report. The TPS61372 can operate at three types of mode depending on the loading, as shown in Figure 1

- At light load, the device operates at pulse frequency modulation (PFM). At PFM, the inductor peak current is clamped at I_{CLAMP} , which is typical 900 mA at 12-V output voltage. The I_{CLAMP} decrease to 500 mA at 5-V output and increases to 1200 mA at 16-V output. The frequency f_{PFM} changes with loading to regulate the output voltage.
- At medium load, the device operates discontinued conduction mode (DCM). At this mode, the device has fixed operating frequency f_{DCM}, which is approximately 1.5 MHz. The inductor peak current is higher than I_{CLAMP} and increase with the loading. The inductor current decline to zero before next cycle. Both the high side and low side power MOSFET turn off during zero inductor current period.
- At high load, the device operates at continued conduction mode (CCM). The switching frequency f_{CCM} is the same as f_{DCM}, and peak inductor current increases with the loading. The minimum inductor current is higher than zero, so the there will be one power MOSFET turning on at any time. both the DCM and CCM belong to PWM.

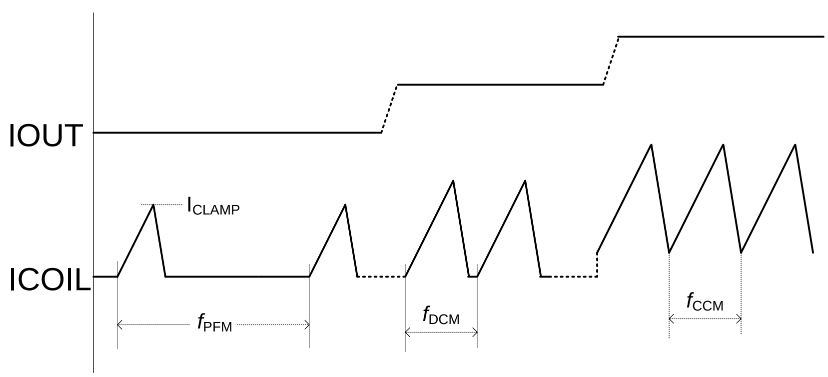

Figure 1. Operating Mode at Different Load Conditions

The boundary loading current between PFM and DCM is defined by Equation 1.

$$I_{OUT\_B} = \frac{1}{2}\frac{\eta \cdot L \cdot I_{CLAMP} \cdot f_{DCM}}{V_{OUT} - V_{IN}} \quad (1)$$

where

- I_{OUT_B} is the boundary output current between PFM and DCM.
- η is efficiency of the boost converter. It can be set to 0.8.
- L is the inductor value.
- I_{CLAMP} is approximately 900 mA.
- f_{DCM} is 1.5 MHz,
- V_{OUT} and V_{IN} is the output voltage and input voltage, respectively.

According the TI application note *How to Select a Proper Inductor for Low Power Boost Converter*, a 1-µH inductor can be selected to reduce the solution size. At 3.6-V input voltage and 12-V output voltage condition, the I_{OUT_B} is approximately 64 mA. As the I_{OUT_B} is higher than designed maximum output current, the device always operates at PFM. Based on the inductance and peak current, DFE201208S-1R0M = P2 or other similar components can be selected.

The output capacitor is selected through the ripple requirement. In PFM operation, the maximum output ripple happens at no load condition, thus the maximum output ripple can be calculated by Equation 2.

$$V_{RIP} = \frac{L \cdot {I_{CLAMP}}^2}{2(V_{OUT} - V_{IN}) \cdot C_{OUT}} \quad (2)$$

Setting output voltage ripple to 30mV, the output capacitance will be approximately 1.7 µF. Note that this is the effective capacitance. For a ceramic capacitor, the effective capacitance could be much lower than the rating capacitance after applying DC bias voltage. For example, a 10-µF, 25-V, 0603 package capacitor GRM188R61E106MA73 has only 1.6 µF effective capacitance at 12-V bias voltage. So the GRM188R61E106MA73 is selected for this application condition.

In PFM mode, compensation resistor and capacitor connected to COMP pin don't impact the respond of the converter. The converter is controlled by internal parameter. However, the compensation resistor and capacitor can be still designed based on PWM operation to ensure the stability of the converter at any load condition. With V_{IN} = 3.6 V, V_{OUT} = 12 V, 1-µH inductor, 1.6-µF output capacitance and 50-mA loading, the compensation resistor and capacitor can be set to 40 K and 680 pF to stabilize the device even at PWM mode operation.

3 Bench Test Result

The ripple waveforms of the TPS61372 at 0-mA and 50-mA loading condition are shown in Figure 2 and Figure 3. In the waveforms, the blue line is output voltage ripple, and the green line is the inductor. The device operates at PFM and its switching frequency changes with the loading. the output voltage ripple is approximately 30 mV as the calculation.

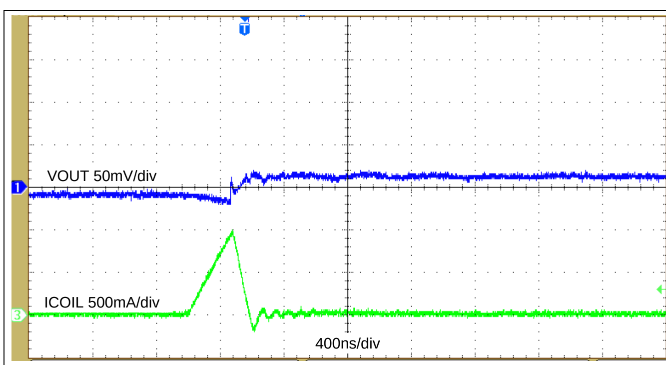

Figure 2. Output Voltage Ripple at No Load Condition

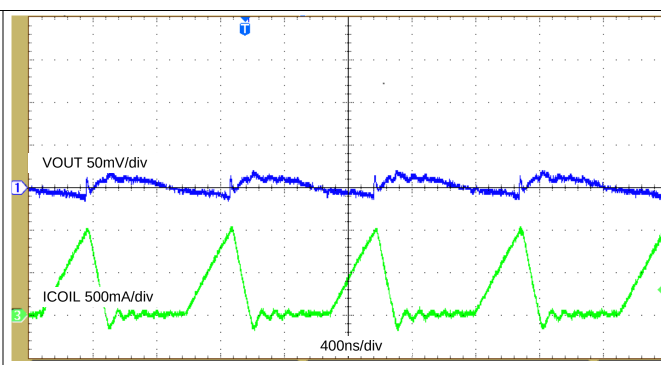

Figure 3. Output Voltage Ripple at 50-mA Load condition

Figure 4 and Figure 5 shows the output ripple at different output voltage and no load condition. The peak current is approximately 500 mA at 5-V output voltage condition and 1200 mA at 16-V output voltage condition. The output capacitance can be increased if want to have smaller ripple.

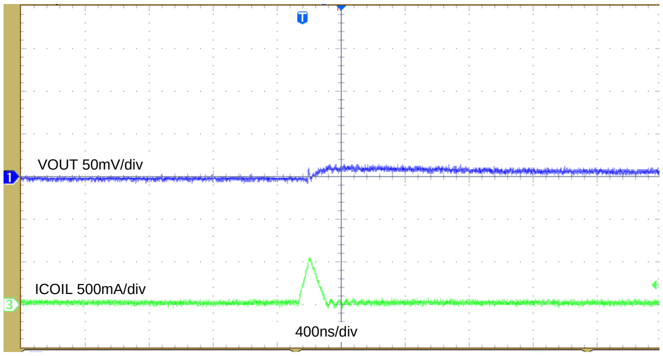

Figure 4. Output Ripple at 5-V Output and no load condition

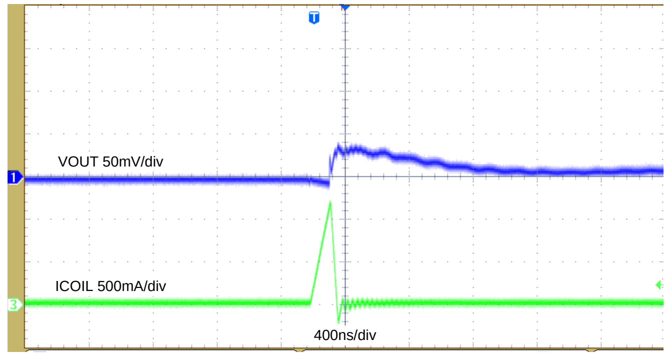

Figure 5. Output Ripple at 16-V Output and No Load Condition

The start-up waveforms by EN pin are shown in Figure 6 and Figure 7. The output voltage starts from zero and increases to 12 V smoothly.

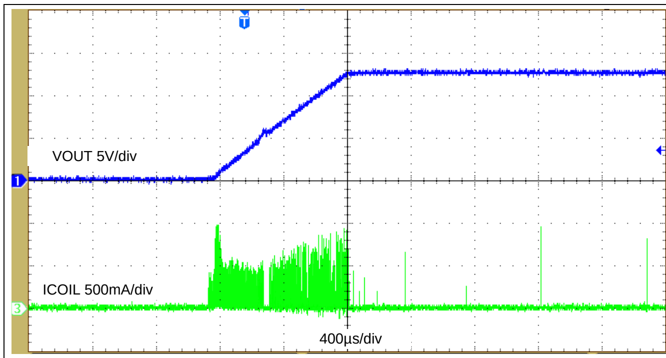

Figure 6. Start-up at No Load Condition

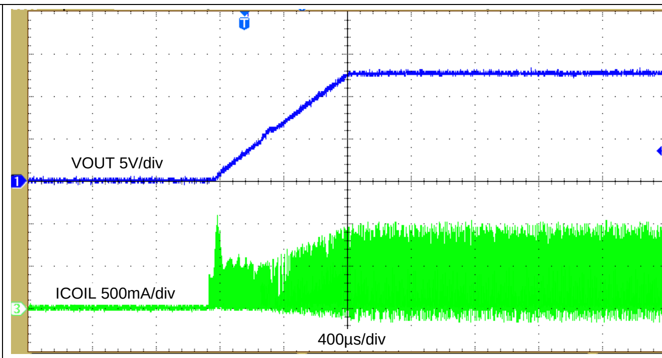

Figure 7. Start-up at 50-mA load

To estimate the stability of the converter, load transient performance can be measured. The load transient performance from 5 mA to 45 mA is shown in Figure 8. The output voltage recovers to the setting output voltage smoothly during the load transient, which means the stability of the device is good.

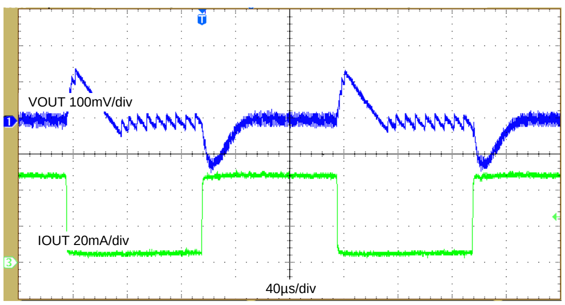

Figure 8. Load Transient From 5 mA to 45 mA

Figure 9 shows the efficiency of the solution at different input from 0.1 mA to 50 mA. The efficiency is approximately 83% at 3.6-V input voltage and 50-mA output current.

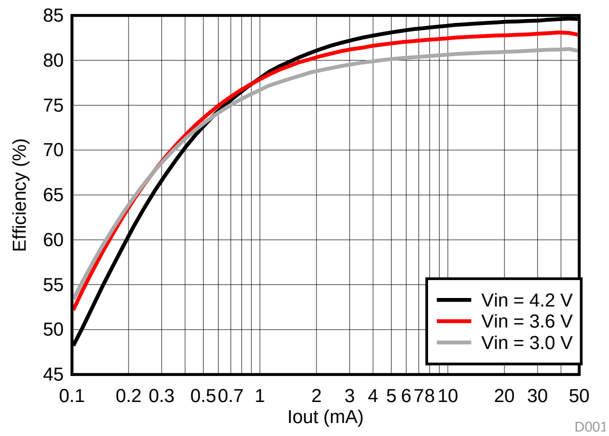

Figure 9. Efficiency at Different Input Voltages

4 Summary

This application report introduces the behavior of TPS61372 at different load conditions. With this device, a small power boost converter solution is designed. Output ripple, start-up waveform, stability performance and efficiency are tested to verify the solution.

5 References

- TI data sheet *TPS61372 16 V/3.6 A Sync Boost With Load Disconnect*
- TI application note *How to Select a Proper Inductor for Low Power Boost Converter*

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