Texas Instruments

Application Report
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MODIFYING THE PFM OPERATION OF TPS61016 BY ADDING 1-MΩ RESISTOR AT COMP PIN

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ABSTRACT

This application report presents a way to modify the PFM mode of operation of the TPS61016 boost converter to meet low ripple voltage requirements at light load by changing the transconductance amplifier output compensation with detailed explanation and test results.

1 Description

The TPS61016 is a boost converter based on a fixed-frequency, current-mode PWM controller that goes automatically into power-save mode (i.e., PFM or pulsed frequency modulation) at light loads for higher efficiency during this load condition. The controller enters this power-save mode if the following two conditions are met:

1. Output voltage is 99% above nominal value.
2. Inductor current becomes discontinuous.

In power-save mode, the controller only switches on the internal switch if the output voltage trips below a set threshold voltage. It ramps up the output voltage with one or several pulses, and goes again into power-save mode once the output voltage exceeds a set threshold voltage. However, this mode of operation causes higher ripple voltage at the output during the PFM mode operation.

Figure 1 shows the schematic with internal block diagram of the TPS61016, and Figure 2 shows the output ripple voltage and inductor current of TPS6101x during PFM operation and PWM operation. Figure 3 and all subsequent illustrations show the effect of adding the 1-MΩ resistor across the COMP pin of TPS61016.

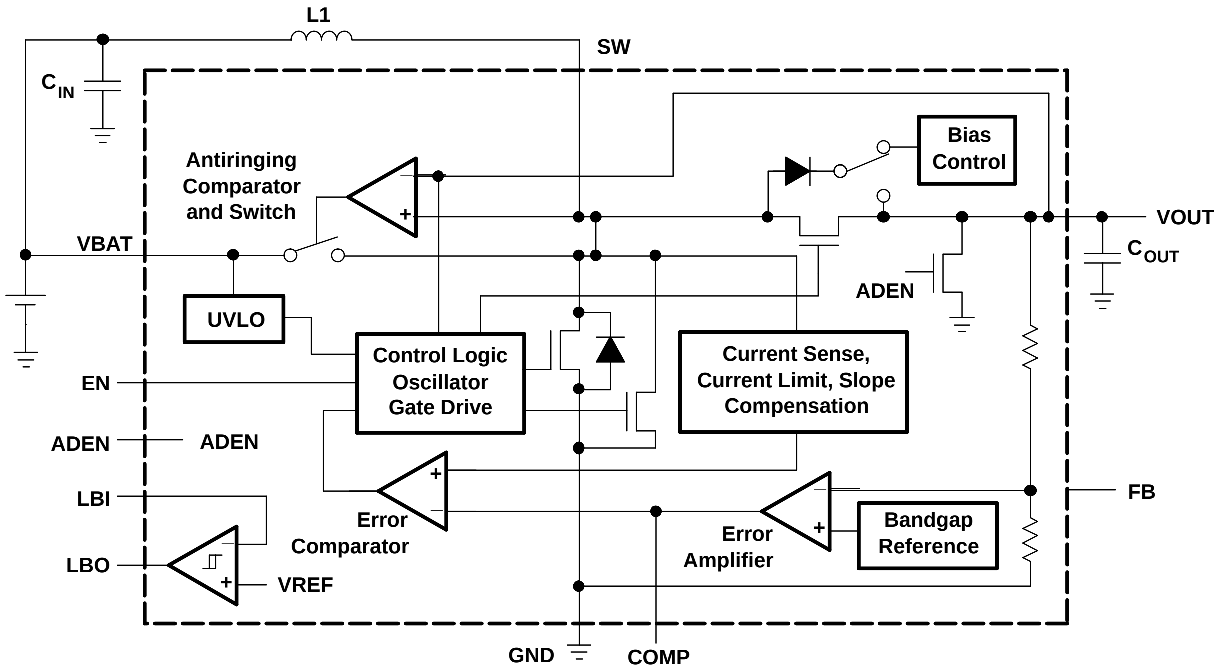

Figure 1. TPS61016 Internal Block Diagram

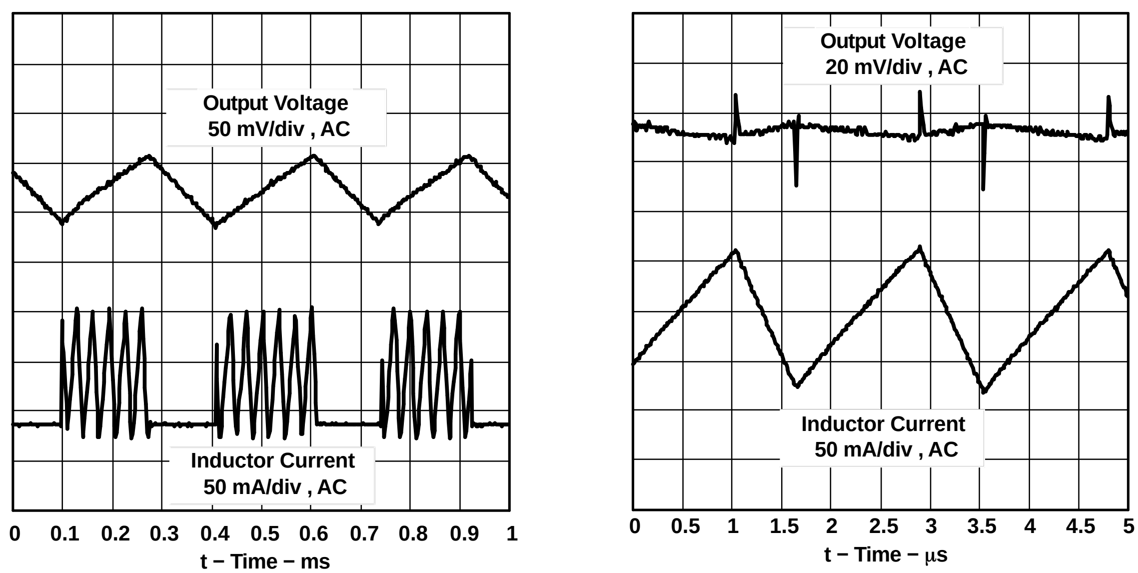

Figure 2. PFM Mode Operation (Left Waveform) and PWM Mode Operation (Right Waveform)

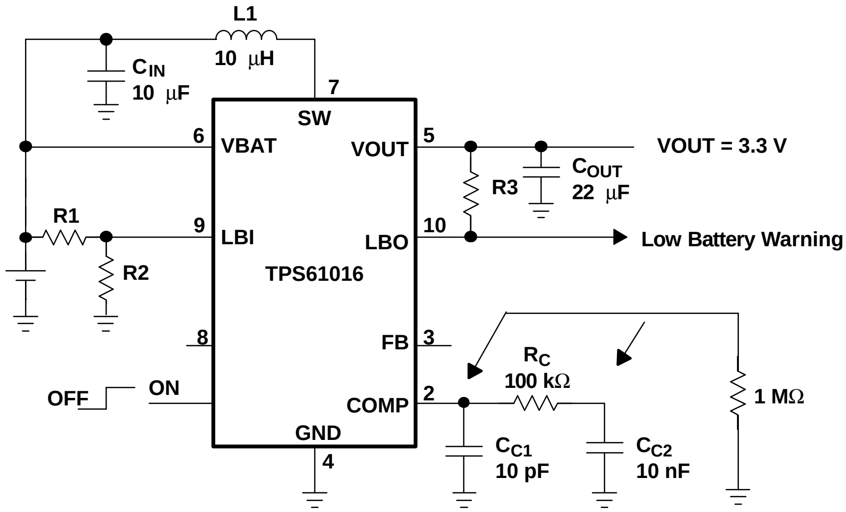

Figure 3. Adding an 1-MΩ Resistor Across COMP Pin

The COMP pin is the output of a transconductance amplifier (current output). When a resistor is connected at the COMP pin to ground, an offset at the error amplifier is generated, and the output voltage of the converter drops (in this example, the output voltage dropped from 3.289 V to 3.284 V).

With a 1-MΩ resistor connected at the COMP pin and with a COMP voltage of about 320 mV (see actual waveform in Figure 4), about 320 nA is drawn from the error amplifier output. This causes an input offset at the amplifier of 11.8 mV (gm = 27 µA/V for the amplifier). This means that the converter now regulates the output voltage to a voltage that is about 2% below the target value.

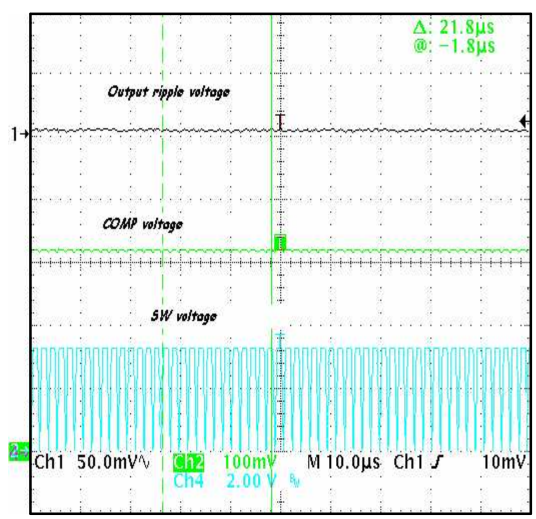

Figure 4. Output Ripple Voltage, COMP Pin Voltage, and SW Pin Voltage in Normal Operation

In the converter, a comparator detects if the output voltage is below or above -1% of the target output voltage. For output voltages below –1% of the target output voltage, the converter is not allowed to be in or go into the power-save mode. With an output voltage above this level, the converter enters the power-save mode when the inductor current is discontinuous.

Therefore, with a 1-MΩ resistor connected at the COMP pin, the converter regulates the output voltage to –2% of the target value; the converter does not go into power-save mode and operates in discontinuous inductor current mode. This results in a much-reduced output ripple voltage at a lower efficiency due to constant switching losses in fixed frequency PWM mode operation.

When there is no load or a light load, the output voltage of the converter rises because of minimum on-time caused by the delays in the comparators, power stage, etc. When the output voltage rises above –1% of the target value, the converter enters power-save mode, and when the output voltage drops below the –1% point, the converter turns on again. (It is not exactly –1% because some hysteresis is also built in.)

Figure 5 shows that when the output load is low, the converter goes into power-save mode operation. This is with a 1-MΩ resistor added across the COMP pin.

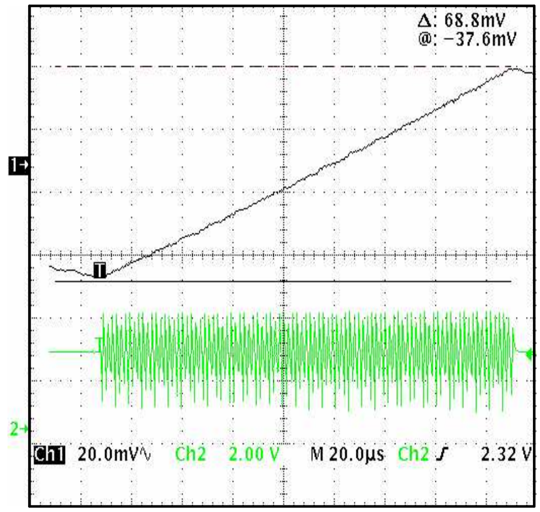

Figure 5. Output Ripple Voltage (Upper Trace) and SW Voltage (Lower Trace) Waveform, Vin = 2.5 V, Iout = 3.5 mA, PFM Mode Operation

Figure 6 shows that with the 1-MΩ resistor in place, the converter operates in PWM mode and is not allowed to enter power-save mode operation as previously discussed. The output ripple is significantly reduced.

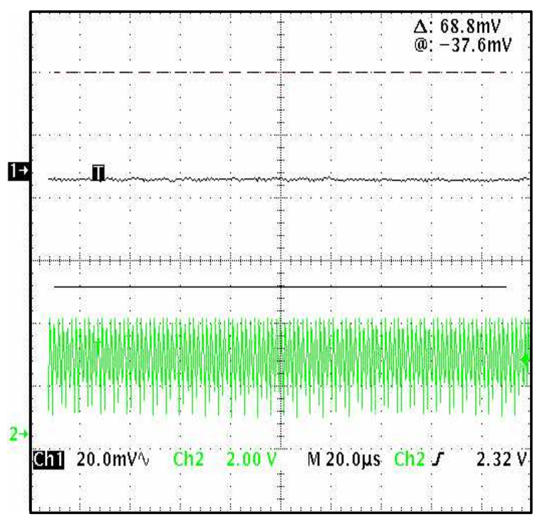

Figure 6. Output Ripple Voltage (Upper Trace) and SW Voltage (Lower Trace) Waveform, Vin = 2.5 V, Iout = 13 mA, PWM Mode Operation

Figure 7 shows that the ripple voltage reappears at the output (~10 mV) . However, this is not PFM mode operation; rather, the inductor current is switching between discontinuous inductor current and continuous inductor current operation. The discontinuous/continuous inductor current mode of operation is related to the output power vs input voltage and inductor value. This is a correct and expected behavior.

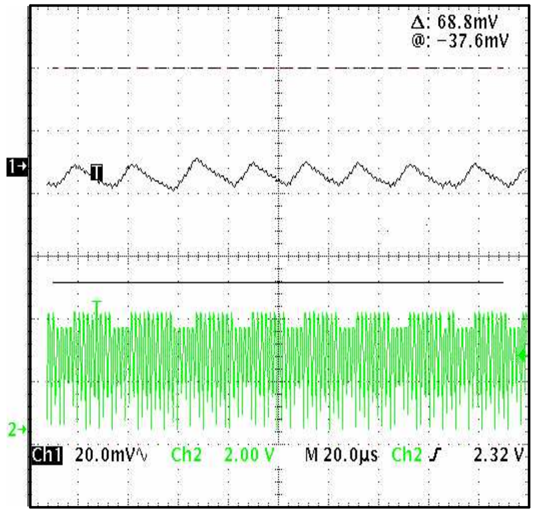

Figure 7. Output Ripple Voltage (Upper Trace) and SW Voltage (Lower Trace) Waveform, Vin = 2.5 V, Iout = 40 mA

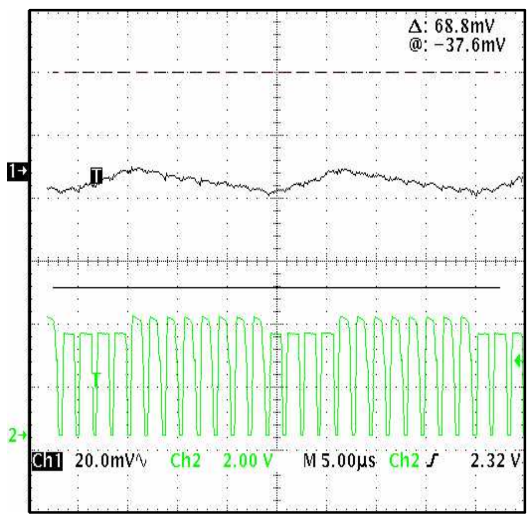

Figure 8. Expanded View of Figure 7

Figure 9 shows that with further increase of output load, the converter operates at continuous inductor current mode, and hence the output ripple is reduced again.

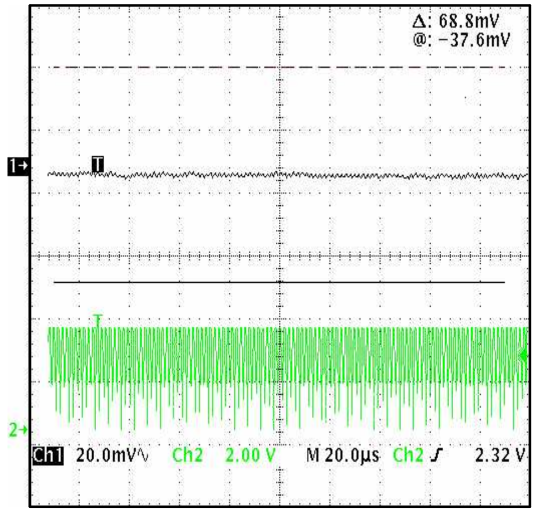

Figure 9. Output Ripple Voltage (Upper Trace) and SW Voltage (Lower Trace) Waveform, Vin = 2.5 V, Iout = 65 mA

Figure 10 shows the region of operation between continuous and discontinuous inductor current operation and region of operation between entering/exiting power-save mode operation when the 1-MΩ resistor is connected across the COMP pin.

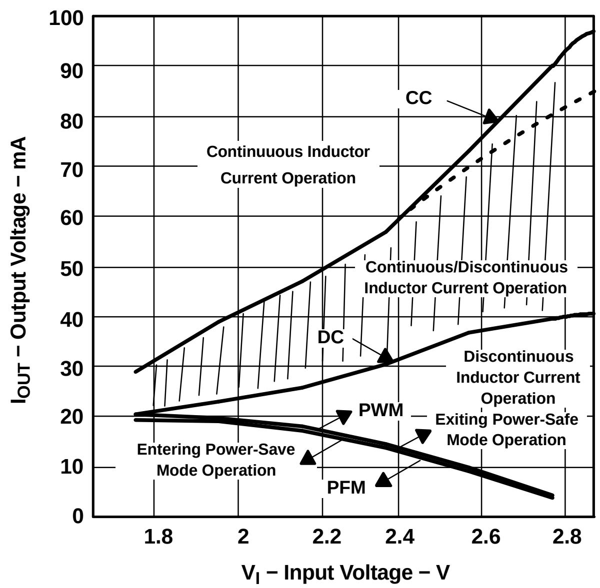

Figure 10. Regions of Operation Between Continuous/Discontinuous Inductor Current and Between Entering/Exiting Power-Save Modes

2 Summary

The TPS6101x automatically goes into PFM mode when the output voltage is 1% above the nominal voltage and when the inductor current is discontinuous. This might not be acceptable in noise-sensitive applications as the output ripple is much higher during PFM mode operation and might cause interference to their system performance. This application report presents a way to modify the PFM mode of operation to meet low ripple voltage requirements at light load by changing the transconductance amplifier output compensation with detailed explanation and test results.

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