

Using TPS63805 for Extreme Low Ripple in Optical Module



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ABSTRACT

This application note includes the requirements of a voltage stabilizer in optical module and uses TPS63805 as voltage stabilizer for the precise 3.3 V output. With proper designed LC filter, 5mV output voltage ripple is achieved.

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1 Introduction

Optical modules are normally supplied from 3.3 V. However, the voltage deviation of initial power supply could be quite high, up to +/-10%. Additional details can be found in [Buck-Boost Converters Solving Power Challenges in Optical Modules](#). Figure 1-1 shows the block diagram of optical module. The trans-impedance amplifier (TIA) on the receive side requires much higher voltage accuracy to guarantee its functionality and performance. To achieve this, a voltage stabilizer after initial 3.3 V power supply is necessary.

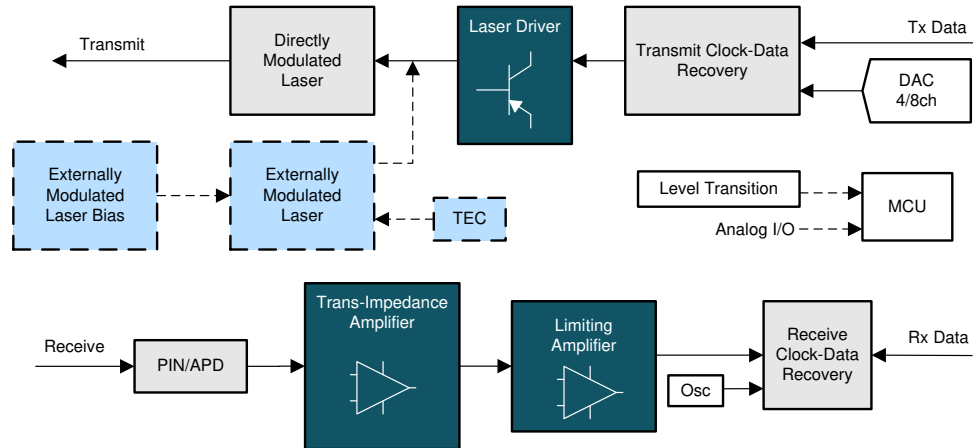


Figure 1-1. Block Diagram of Optical Module

Considering that optical modules are hot-plugged and small-sized, voltage stabilizer in optical module has several requirements:

1. A load capacity
2. Smaller than 2mm×2mm size
3. 90% efficiency. at least
4. Maximum 10mV output voltage ripple

2 TPS63805 Features

TPS63805 is a high-efficient non-inverting buck-boost converter. The input voltage can be higher or lower than output voltage. TPS63805 meets the requirements listed above, as shown in [Table 2-1](#). Therefore, TPS63805 is a good option for the voltage stabilizer application.

Table 2-1. Main Specifications for TPS63805

Part number	Input range	Output range	Package Group	I _q (Typ)	I _{out} (Max)
TPS63805	1.3 V-5.5 V	1.8 V-5.2 V	DSBGA 15 (2.3mm×1.4mm)	DSBGA 15 (2.3mm×1.4mm)	2 A

To regulate the output voltage V_{OUT} when input voltage V_{IN} is higher, lower or equal, the TPS63805 has three operation mode as shown in [Figure 2-1](#). The figure also shows a hysteresis (non-overlapping area) among mode transitions in TPS63805. For certain load, when the converter enters buck-boost mode no matter from buck mode or boost mode, it would exit until the converter gets over the hysteresis area. Taking the 1 A load current as an example, the converter will enter buck-boost mode from boost mode when input voltage increases to 3.02 V but exit buck-boost mode until input voltage reduces to 2.78 V. The hysteresis not only expands the buck-boost mode area but also avoid a frequent mode transitions on the boundaries, this feature greatly benefit the voltage accuracy and ripple performance for voltage stabilizer.

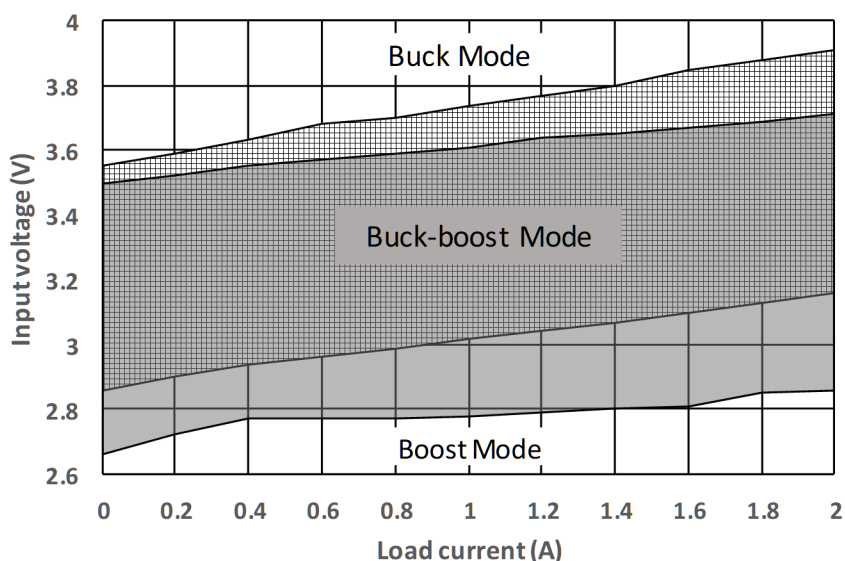


Figure 2-1. Mode Transition Thresholds of TPS63805 at V_{out}=3.3V

There are also two operating modes for TPS63805, which can be selected by MODE pin.

1. Auto power save mode and PWM mode. The efficiency at light loading condition is high in this mode but the output voltage ripple will be large;
2. Forced PWM mode. The efficiency is low at light loading condition in this mode but the output voltage ripple will be small.

Due to low output voltage ripple required in optical modules, forced PWM mode must be chosen when using TPS63805 as a voltage stabilizer. [Figure 2-2](#) shows measured output voltage ripple on TPS63805EVM-026 with default setting. Though the ripple is smaller in forced PWM mode, it is still up to 20mV. The 10mV ripple requirement is not achieved.

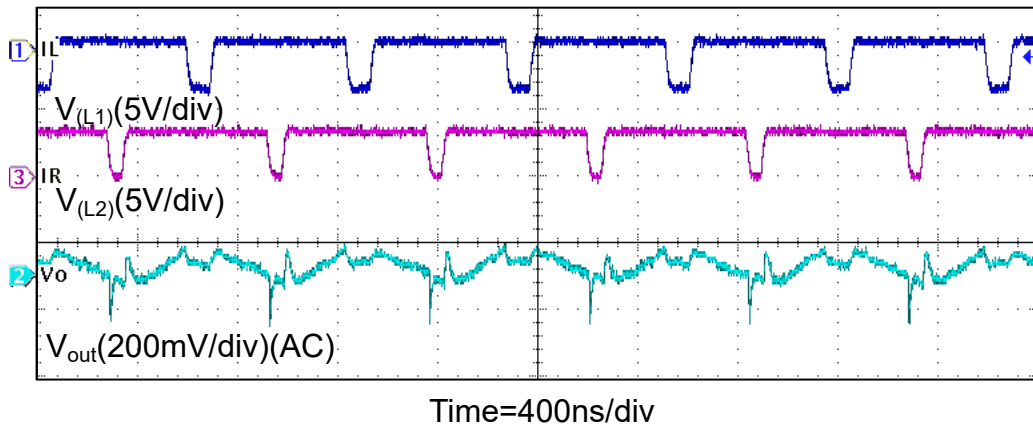


Figure 2-2. Output Ripple Waveforms of TPS63805 at $V_{in}=3.6V$, $V_{out}=3.3V$, $I_{Load}=0.5A$

To minimize output ripple, simply increase output capacitance is useful but it will bring much larger total solution size. Adding a low-pass inductor-capacitor (LC) filter on the output side can attenuate ripple effectively.

3 LC Filter Design for Extreme Low Output Voltage Ripple

After adding a LC filter on the output side of buck-boost, the schematic is shown as Figure 3-1. To get lower than 10mV ripple, the LC filter will be designed to make an attenuation of 20dB at switching frequency. To effectively attenuate the output ripple, the resonant frequency must be lower than switching frequency.

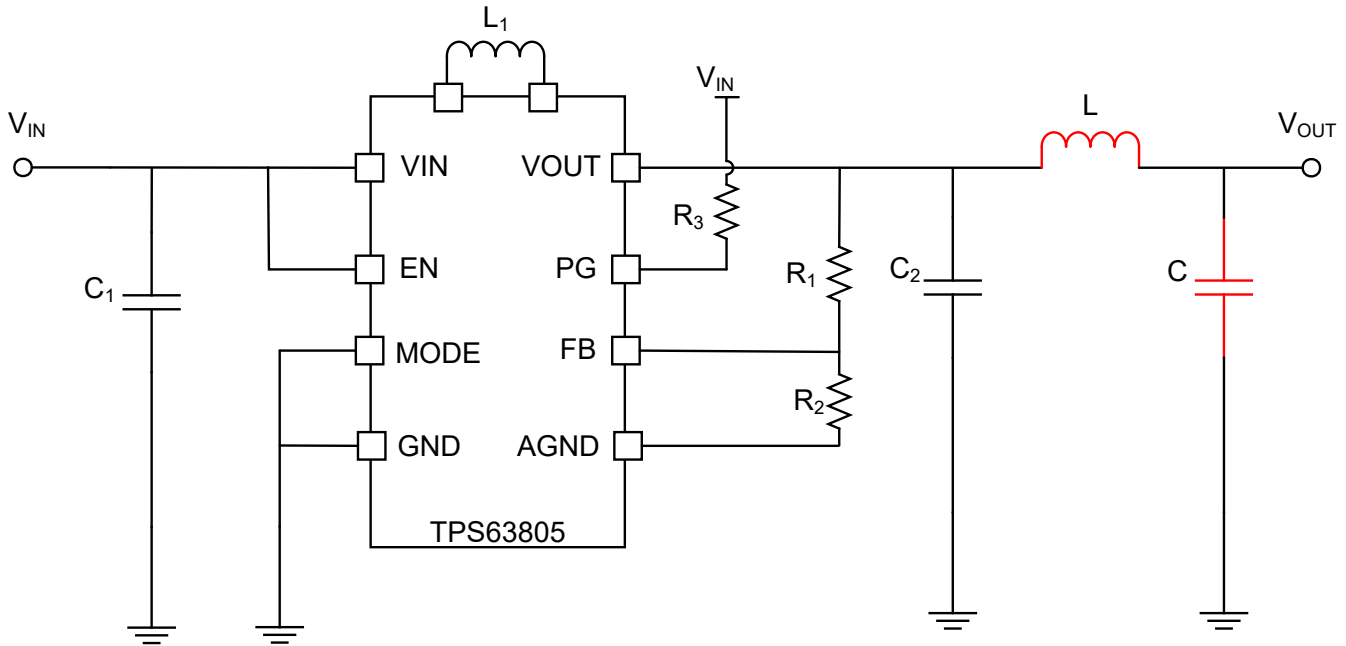


Figure 3-1. TPS63805 Circuit with LC Filter

To avoid affecting loop stability, LC filter need to be configured cautiously. LC filter will bring double poles to the loop and might cause lower phase margin, so the resonant frequency must be far away from the gain crossover frequency f_c at which the open loop gain of the buck-boost is zero. LC filter with high Q might lead to a low gain margin at resonant frequency due to peaking, so the resonant frequency should also be kept away from the phase crossover frequency f_x where open loop phase is zero. Besides, a damping resistor could be used to damp the Q. Details are given in [Design a second-stage filter for sensitive applications](#).

The frequency response tested on the TPS63805EVM-026 with default configuration is shown in Figure 3-2, the gain crossover frequency is 49.75kHz and the phase crossover frequency is 205.22kHz.

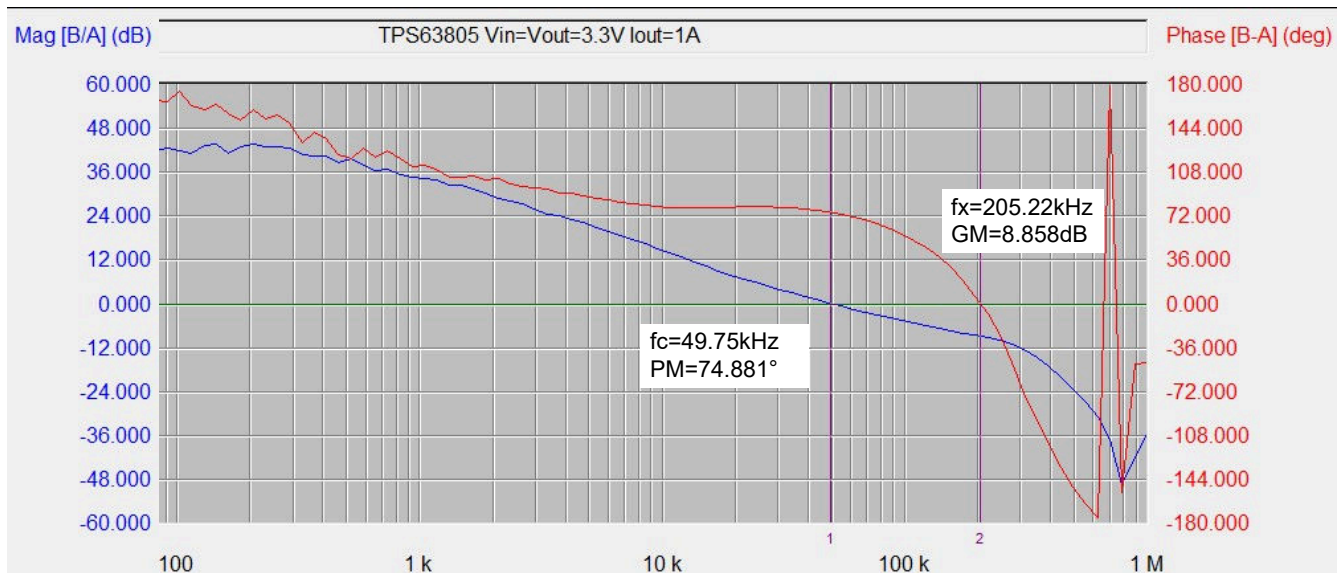


Figure 3-2. Bode Plot of TPS63805 with Default Configuration

According to the TPS63805 data sheet, the switching frequency of buck-boost mode is 1.4MHz. Since the gain of LC filter will drop with a slope of -40dB/dec, the desired resonant frequency is calculated by Equation 1.

$$f = \frac{f_{sw}}{10^{\frac{A}{40}}} = 442.7kHz \quad (1)$$

where

- f_{sw} is switching frequency.
- A is desired attenuation at switching frequency.

The inductor and capacitor can be calculated by Equation 2.

$$f = \frac{1}{2\pi\sqrt{LC}} \quad (2)$$

Table 3-1 and Table 3-2 shows the LC filter configuration. This LC filter is added on the output side of TPS63805EVM-026 to filter the output ripple.

Table 3-1. Inductor of LC Filter Configuration

Inductor Value[μ H]	Saturation Current[A]	DCR [m Ω]	Part Number	Manufacture	Size(LxWxH mm)
0.33	6.3	21	DFE201612E-R33M	MURATA	2.0×1.6×1.2

Table 3-2. Capacitor of LC Filter Configuration

Capacitor Value[μ F]	Voltage Rating[V]	ESR [m Ω]	Part Number	Manufacture	Size(LxWxH mm)
0.33	25	15	885012206074	Würth	1.6×0.8×0.8

Figure 3-3 shows the TPS63805 reference circuit used as voltage stabilizer.

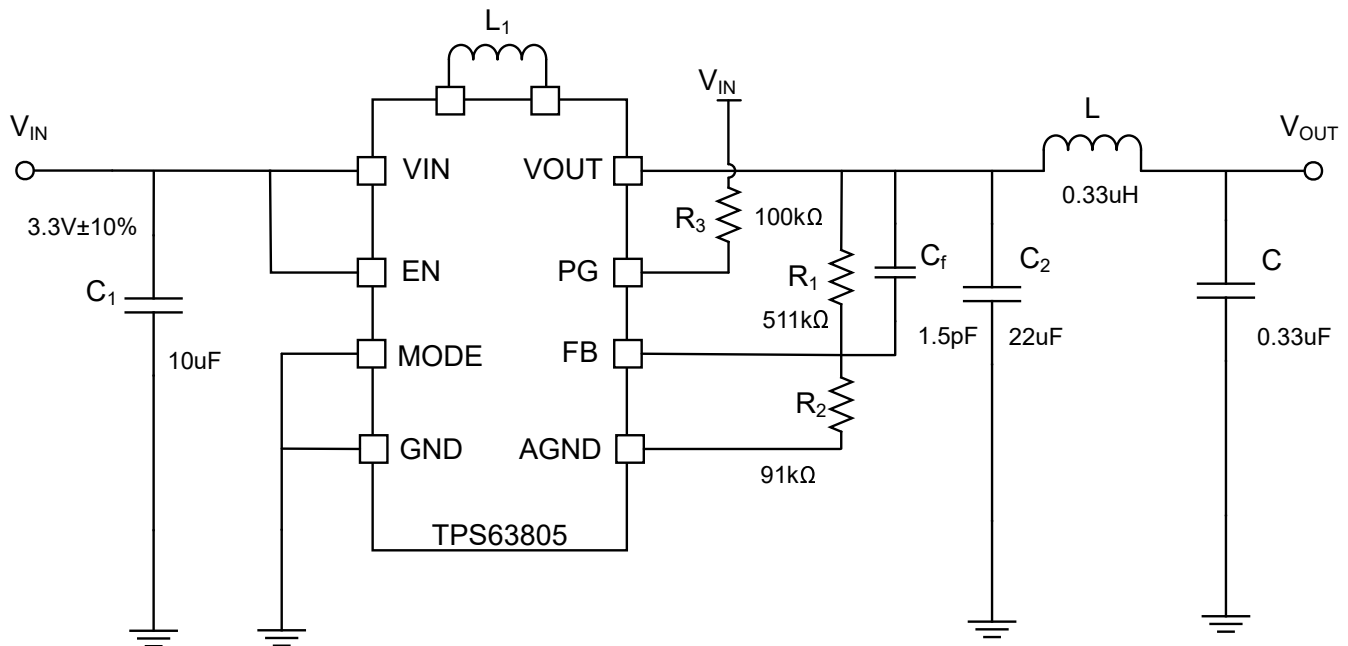


Figure 3-3. Reference Circuit of Voltage Stabilizer

As shown in Figure 3-4, the frequency response is not much affected after adding the LC filter. Figure 3-5 shows the output voltage ripple filtered by LC, which is kept below 5mV when loading 1 A.

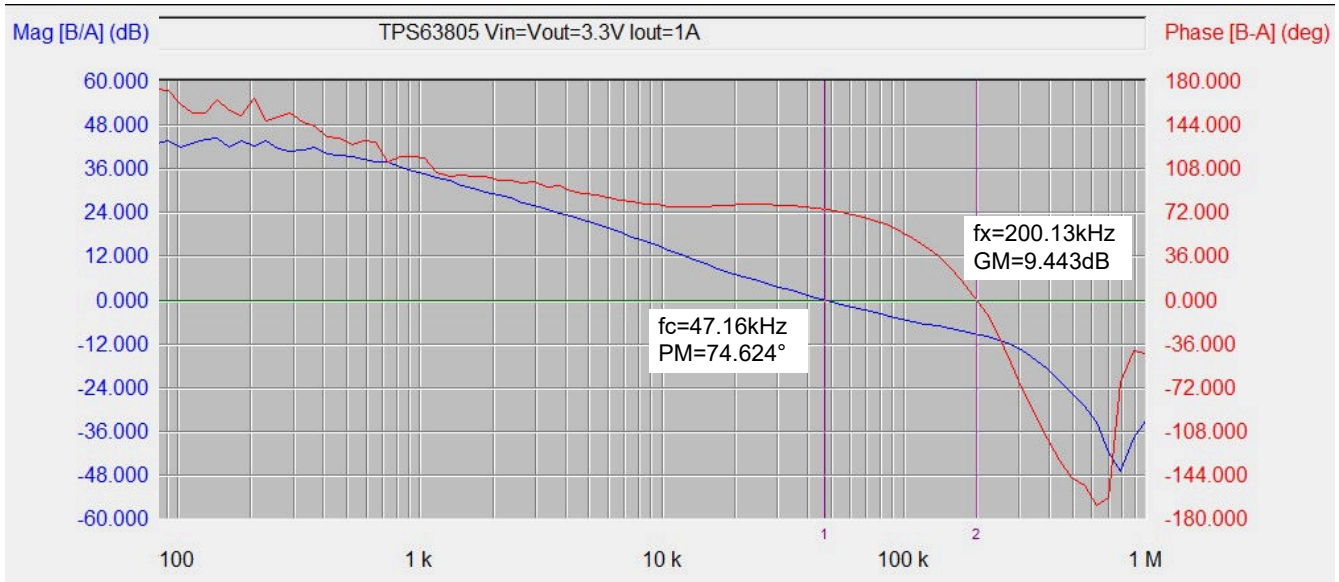


Figure 3-4. Bode Plot of TPS63805 with LC Filter

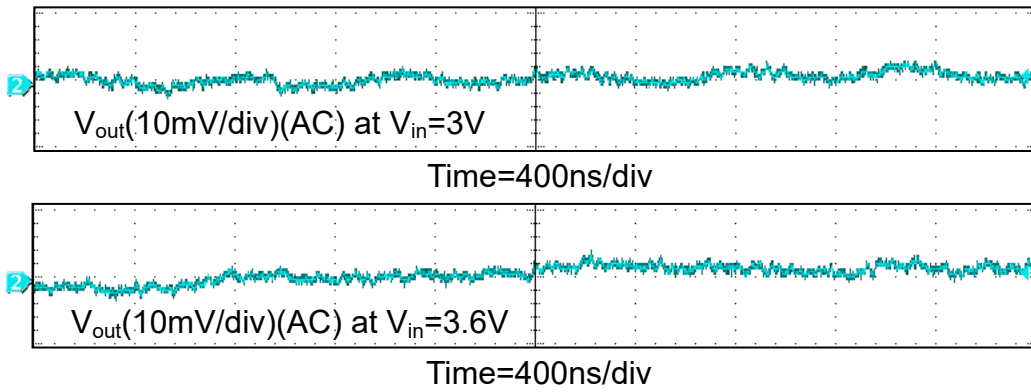


Figure 3-5. Output Voltage Ripple with LC Filter

4 Summary

TPS63805 is a good solution for voltage stabilizer in optical module due to its good performance on efficiency and load capacity as well as its tiny size. To obtain extreme low output voltage ripple, forced PWM mode and LC filter on the output side are recommended in optical module application. With proper configuration, the output ripple can be attenuated to 5mV level.

5 References

- Texas Instruments, [Under the Hood of a Noninverting Buck-boost Converter](#).
- Texas Instruments, [Buck-Boost Converters Solving Power Challenges in Optical Modules](#) application brief.
- Texas Instruments, [Using Non-Inverting Buck-Boost Converter for Voltage Stabilization](#) application note.
- Texas Instruments, [Output Noise Filtering for DC/DC Power Modules](#) application note.

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