How to Sample the Small APD Current Precisely With the TPS61390 Boost Converter

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ABSTRACT

In the optical receivers and modules application, even a 5-µA APD current needs to be detected precisely. The TPS61390 and TPS61391 devices are high voltage boost converters for biasing the APD. They can accurately mirror the APD current. This application report presents guidance on how to select the resistors from the MON1, MON2 to GND so that the APD current can be precisely detected.

Contents

List of Figures

List of Tables

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1 Introduction

The TPS61390 device is a fully-integrated boost converter with an 85-V FET to convert a low-input voltage to a higher voltage for biasing the APD. The device can accurately mirror the APD current ranging from 0.5 µA to 2 mA. There are two ratio options for the current proportional to APD current: the MON1 (4:5) and MON2 (1:5). By connecting a resistor from the mirror output (MON1 or MON2) to GND, the current flowing through the APD is converted into the voltage crossing the resistor from MON1, MON2 to GND.

This application note provides the MON1 and MON2 voltage calculation formula, then shows how to select the resistors from the MON1, MON2 to GND based on a continuous optical current application.

2 Device Calculation

Figure 1 shows the TPS61390 typical application circuit. There are two current mirror options for TPS61390: the gain of 4:5 (MON1) and 1:5 (MON2). The maximum voltage of MON1 and MON2 is 2.5 V.

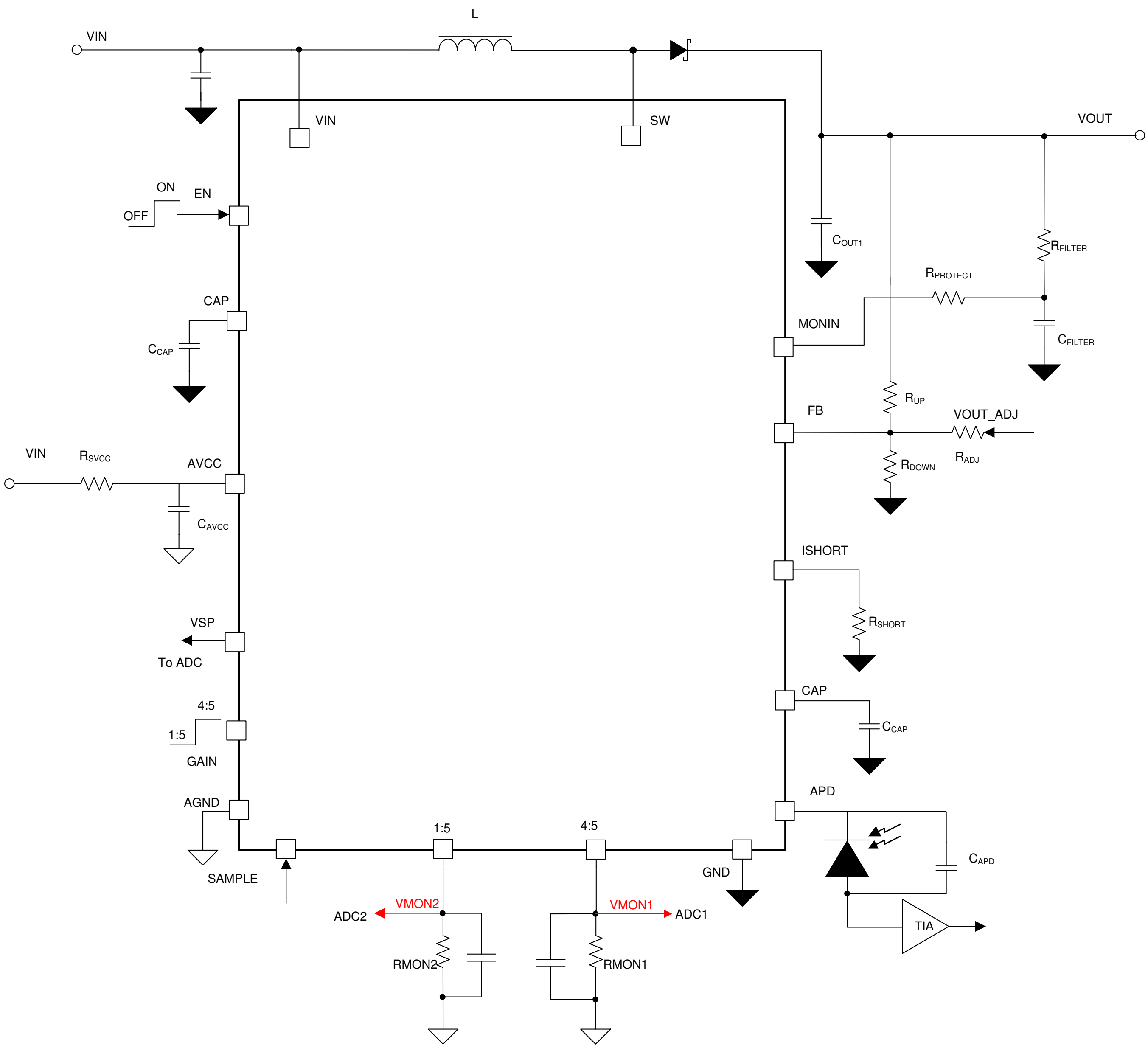

Figure 1. TPS61390 Typical Application

The voltage measured on the MON1 pin can be calculated with Equation 1.

$$VMON1 = 0.8 \times I_{APD} \times RMON1 + I_{BIAS} \times RMON1 \quad (1)$$

The voltage measured on the MON2 pin can be calculated by Equation 2.

$$VMON2 = 0.2 \times I_{APD} \times RMON2 + I_{BIAS} \times RMON2$$

where:

- VMON1 is the voltage sampled on the MON1 pin
- VMON2 is the voltage sampled on the MON2 pin
- I_{APD} is the current flowing through the APD pin
- RMON1 is the resistor connecting with MON1 pin

- RMON2 is the resistor connecting with MON2 pin
- I_{BIAS} is the bias current of current mirror (2)

The bias current is around 20 μA (typical) when there is no APD current flowing through. The bias voltage of MON1 or MON2 is 60 mV given a 3-kΩ MON resistor connected with MON1 or MON2, or 100 mV given a 4.99-kΩ MON resistor connected with MON1 or MON2.

3 Typical Application

3.1 Design Requirement

Table 1 shows the design requirement of this application report.

Table 1. Design Requirement

Parameter	Value
Input voltage range	2.7 V–5.5 V
Output voltage	48 V
Operating frequency	700 kHz
APD current	0 to 2 mA

3.2 Design Procedure

The MCU will sample the MON1 pin voltage (VMON1) and the MON2 pin voltage (VMON2). When the APD current is low, VMON1 will be sampled, when the APD current gets higher and VMON1 reaches the full detection scale, VMON2 will be sampled.

The maximum voltage of MON1 and MON2 is clamped at 2.5 V. The lowest level of this clamping voltage is 2.3 V, considering lot-to-lot difference. So to leave some margin, the full scale voltage is set at 2.1 V in this application report.

The value of RMON1 and RMON2 can be deduced from Equation 1 and Equation 2.

$$\mathrm{RMON1} = \frac{\mathrm{VMON1}}{0.8 \times I_{APD} + I_{BIAS}} = \frac{V_{FULL}}{0.8 \times I_{APD} + I_{BIAS}} \tag{3}$$

$$\mathrm{RMON2} = \frac{\mathrm{VMON2}}{0.2 \times I_{APD} + I_{BIAS}} = \frac{V_{FULL}}{0.2 \times I_{APD} + I_{BIAS}} \tag{4}$$

If setting the target full scale maximum sampling current through the MON1 pin at 500 μA, set the target full scale maximum sampling current through the MON2 pin at 2 mA, then the resistance of RMON1 and RMON2 can be calculated out with Equation 5:

$$\mathrm{RMON1} = \frac{2.1\ \mathrm{V}}{0.8 \times 500\ \mu\mathrm{A} + 20\ \mu\mathrm{A}} = 5\ \ \mathrm{k\Omega} \tag{5}$$

So RMON1 = RMON2 = 4.99 kΩ can be chosen in this application report.

$$\mathrm{RMON2} = \frac{2.1\ \mathrm{V}}{0.2 \times 2\ \mathrm{mA} + 20\ \mu\mathrm{A}} = 5\ \ \mathrm{k\Omega} \tag{6}$$

From the previous equations, it is known that when the resistance of RMON1 and RMON2 is the same, then the full scale detection voltage is the same. Then as a result, the maximum sampling current through the MON2 pin is 4 times that of through the MON1 pin.

The resistance of RMON1 and RMON2 can also be set at different values based on the real application. For example, if the resistance of RMON2 is one fourth of RMON1, then under the same energy, the voltage across RMON1 is 16 times of the voltage across RMON2, which is a 12 dB difference.

If the target maximum detection current is very small, much less than 1 mA, then RMON1 and RMON2 can choose a 10-kΩ resistance to achieve higher detection precision.

4 Summary

This application report describes how to sample the APD current precisely by choosing a right resistor at the MON1 pin and the MON2 pin. When the resistance of RMON1 and RMON2 is equal, the maximum sampling current through the MON2 pin is 4 times that of through the MON1 pin. The resistance of RMON1 and RMON2 can also be set at different values based on the real application.

5 References

1. Texas Instruments, *TPS61390 85-V_{OUT} Boost Converter With Current Mirror and Sample / Hold Data Sheet*
2. Texas Instruments, *TPS61391 85-V_{OUT} Boost Converter with Current Mirror Integrated Data Sheet*