Application Report
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Various Applications for Voltage-Tracking LDO

Jason Liu MSA-AVL

ABSTRACT

Voltage-tracking low dropout regulator (LDO) is widely used in automotive off-board sensors and small current off-board modules for its off-board protection and high voltage-tracking accuracy advantages. This application note describes in detail the various applications for voltage-tracking LDOs in different electronics systems.

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1 Typical Application for Voltage-Tacking LDO

For automotive off-board sensors and small current off-board modules, systems must take special consideration for their power supplies on both protection and output accuracy.

In these systems, the power supply always runs through a long cable from the main board. Sometimes, the long cable can be damaged due to the harsh automotive environment, which may result in short-to-GND or short-to-battery situations on the power supply output. In these cases, the system needs to implement a protection mechanism in order to protect on-board components from being damaged.

Meanwhile, it is necessary to keep the voltage-tracking tolerance between the off-board sensors power supply and the MCU/ADC power supply to the lowest level. An ultra-low tolerance tracking voltage as power supply for off-board sensors is critical for achieving high-quality data acquisition.

A voltage-tracking LDO is a perfect solution for driving above the previously-mentioned off-board loads. Voltage-tracking LDO offers full protection features (short-to-GND, short-to-battery, overload protection, thermal protection and others) and ultra-accurate output tracking voltage.

Figure 1 illustrates a typical voltage tracking LDO application for an automotive off-board sensor system.

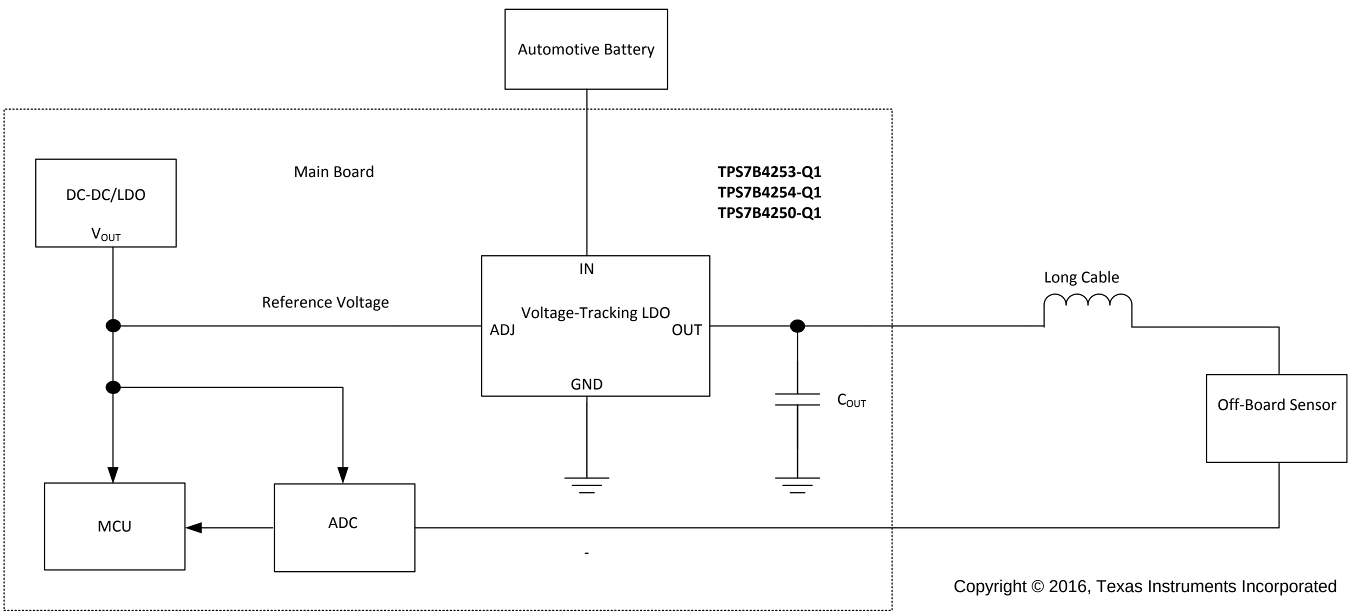

Figure 1. Voltage-Tracking LDO Used for Off-Board Sensor Power Supply

2 Adjacent Applications for Voltage-Tracking LDO

Based on its unique characters, voltage-tracking LDO can support many different topologies. The following sections describe several topologies with voltage-tracking LDO, to explain the benefits and characteristics of each configuration.

2.1 LDO Parallel Connection

In automotive systems, thermal performance is always a critical concern for battery direct connection LDOs.

Automotive battery voltage varies from 9 V to 16 V. The LDO connected to the car battery needs to convert this down to 5 V, 3.3 V, or even lower voltage for powering MCU, CAN bus, and other logic devices. In these situations, the voltage drop on the LDO might be 10 V or even higher. Power dissipation on the LDO is larger than 1 W for a 100-mA loading current. If the system demands several hundred milliamps of current, a single LDO is not able to handle this large power dissipation.

Voltage tracking LDO's parallel configuration can help address the challenge.

Figure 2 shows an example of parallel topology with the TPS7B6750-Q1 and TPS7B4253-Q1. TPS7B6750-Q1 is 450-mA low quiescent current (IQ) LDO, and TPS7B4253-Q1 is a 300-mA voltage-tracking LDO. This topology has the ability to support load current up to 600 mA.

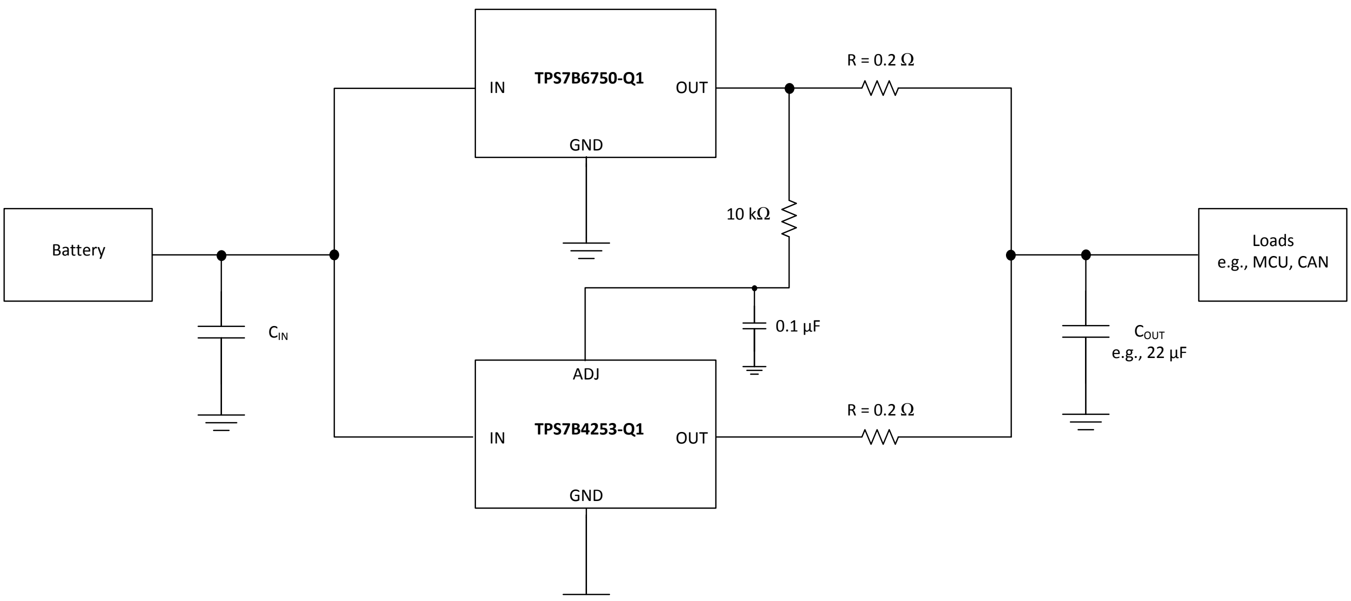

Figure 2. LDO Parallel Topology With TPS7B6750-Q1 and TPS7B4253-Q1

The tracking tolerance of TPS7B4253-Q1 is within ±4 mV across all conditions. With two 0.2-Ω current ballasting resistors, the maximum current difference between TPS7B6750-Q1 and TPS7B4253-Q1 can be calculated with Equation 1:

$$\Delta I = \frac{\Delta V}{R} = \frac{\pm 4 \text{ mV}}{0.2\ \Omega} = \pm 20 \text{ mA}$$

where

- ΔI is the current different between each channel
- ΔV is the tracking tolerance of TPS7B4253-Q1
- R is the series resistor (1)

The current difference is reduced when the series resistor value is increased. For example, the maximum current difference will be ±10 mA for a 0.4-Ω resistor. However, higher resistance results in higher voltage drop.

More voltage-tracking LDOs could be paralleled to get higher output current and the power consumption distributed into multiple devices. Figure 3 shows the parallel topology of one TPS7B6750-Q1 and two TPS7B4253-Q1 devices. This configuration supports maximum loading current up to 900 mA.

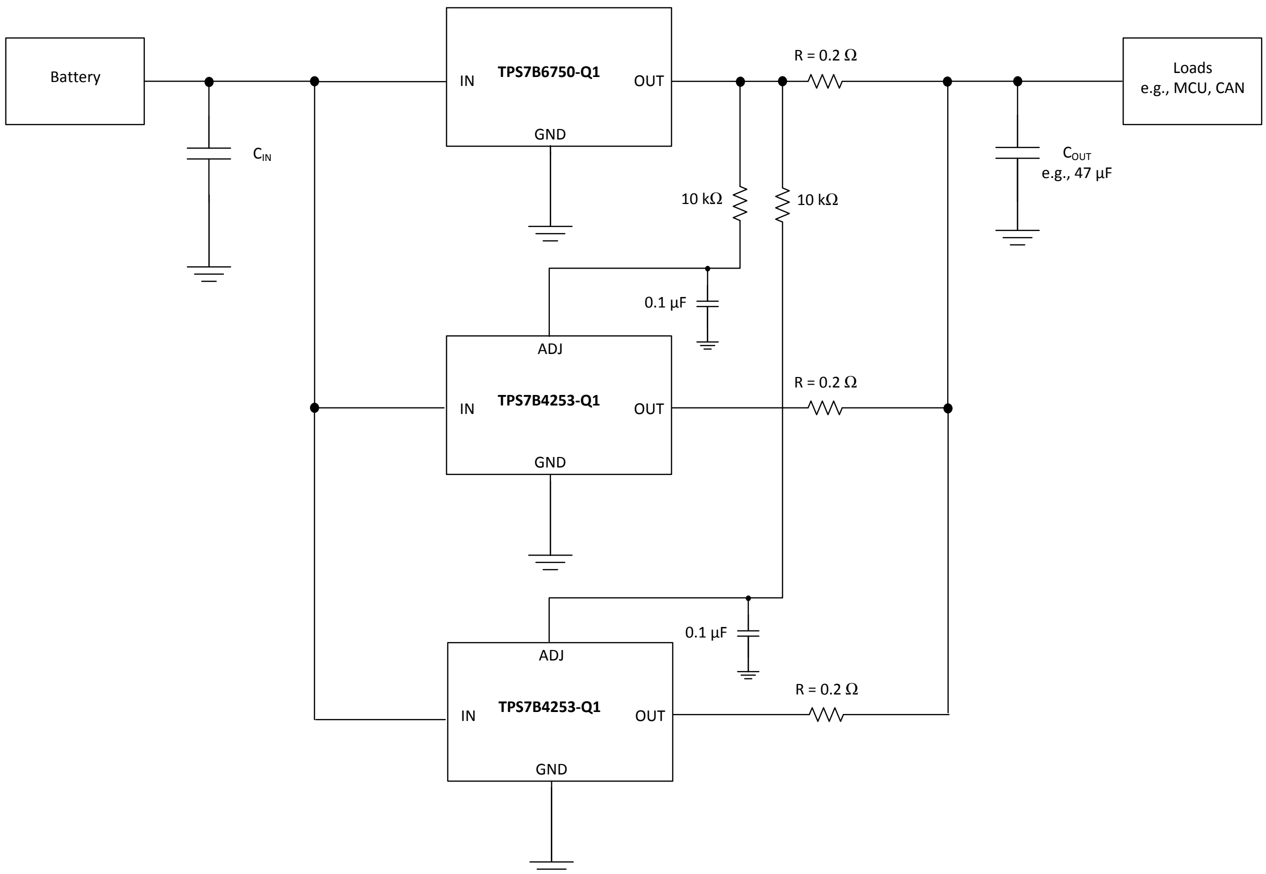

Figure 3. LDO Parallel Topology With TPS7B6750-Q1 and Two TPS7B4253-Q1 Devices

In order to keep the stability of this parallel topology, the output capacitor must be adjusted. With two devices in parallel, C_{OUT} should be higher than 2 times the minimum requested output capacitor of both devices. The effective capacitance value for each device is C_{OUT} / 2. When three devices are parallel configured, the effective capacitance value for each device is C_{OUT} / 3.

The TI reference design TIDA-00863 discusses this LDO parallel application.

2.2 High Accuracy LDO

In some applications, accurate output voltage is preferred. But high-accuracy LDO is not common in the market, due to process and topology limitations. With a simple shunt element, voltage-tracking LDO can meet this market requirement.

Figure 4 describes a combination of voltage-tracking LDO (TPS7B4253-Q1) and common precise voltage reference (REF5050A-Q1). This configuration achieves 300-mA high-output accuracy LDO.

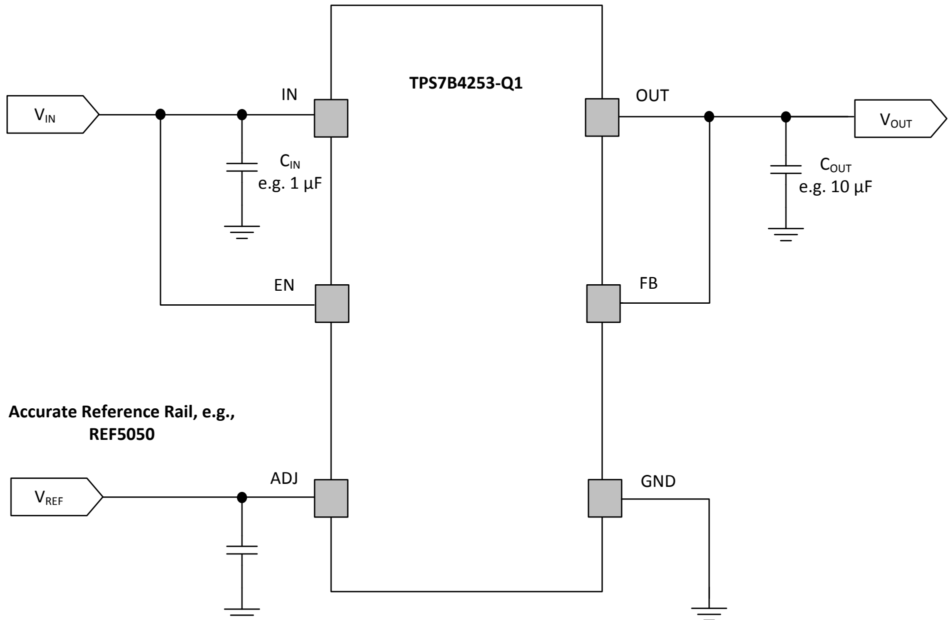

Figure 4. High-Accuracy LDO Application

Assume the reference voltage, generated by shunt element, is 5 V with 0.1% accuracy, the tracking tolerance between ADJ and OUT is max ±4 mV, ensured by tracking LDO. The output accuracy is calculated with Equation 2:

$$\text{Accuracy}_{VOUT} = \frac{V_{REF} \times 0.1\% + 4\text{ mV}}{V_{REF}} \times 100\% = \frac{5 \times 0.1\% + 0.004}{5} \times 100\% = 0.18\% \tag{2}$$

2.3 High-Side Switch Configuration

In some automotive applications, a high-side switch with reverse current protection is required.

By connecting the FB pin to the GND pin, the TPS7B4253-Q1 device is used as a high-side switch with current-limit, thermal shutdown, output short-to-battery, and reverse polarity protection. The switching on and off of the device is then controlled through the EN and ADJ pins.

Figure 5 shows the high-side switch configuration with voltage-tracking LDO.

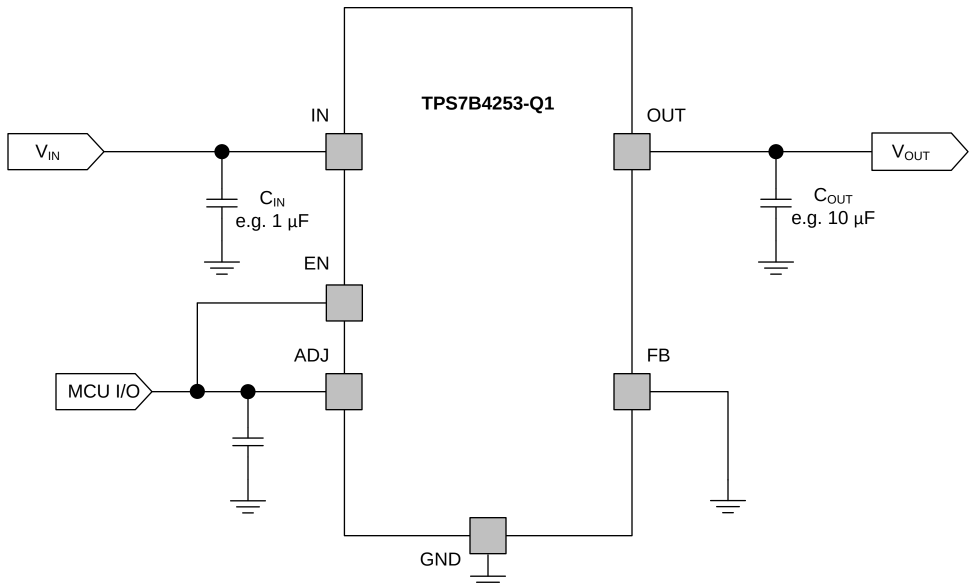

Figure 5. High-Side Switch Application With TPS7B4253-Q1

Figure 6 shows the waveform of the high-side switch configuration, with conditions of V_{IN} = 14 V, EN/ADJ 5-V high voltage level and 100-mA load at the output.

Figure 6. Waveform of High-Side Switch Application

2.4 General LDO Applications

Tracking LDO could be used as a general LDO to provide wide range and stable output voltage. For example, with different topologies, TPS7B4253-Q1 can support output voltage ranges from 1.5 V to 40 V.

2.4.1 Topology I: Output Voltage is Lower Than Reference Voltage

With an external resistor divider applied at the ADJ pin and FB pin ties to the OUT pin, as illustrated by Figure 7, TPS7B4253-Q1 generates output voltage lower than V_{REF}.

$$V_{OUT} = \frac{V_{REF} \times R2}{R1 + R2} \quad (3)$$

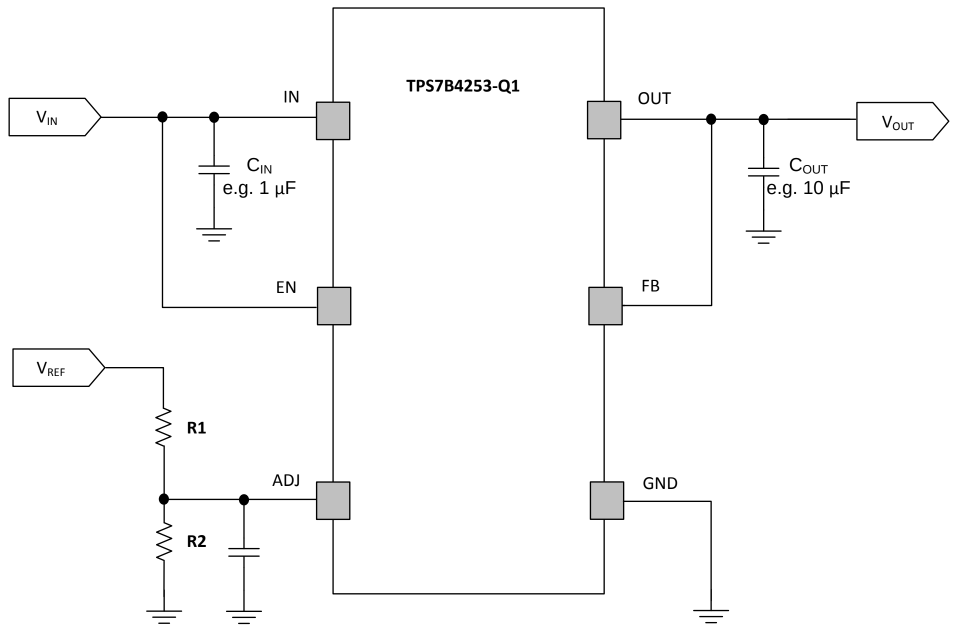

Figure 7. OUT Voltage Lower Than Reference Voltage

2.4.2 Topology II: Output Voltage Equals to Reference Voltage

With the reference voltage applied directly to the ADJ pin and the FB pin tied to the OUT pin, the output voltage equals to reference voltage.

$$V_{OUT} = V_{REF} \quad (4)$$

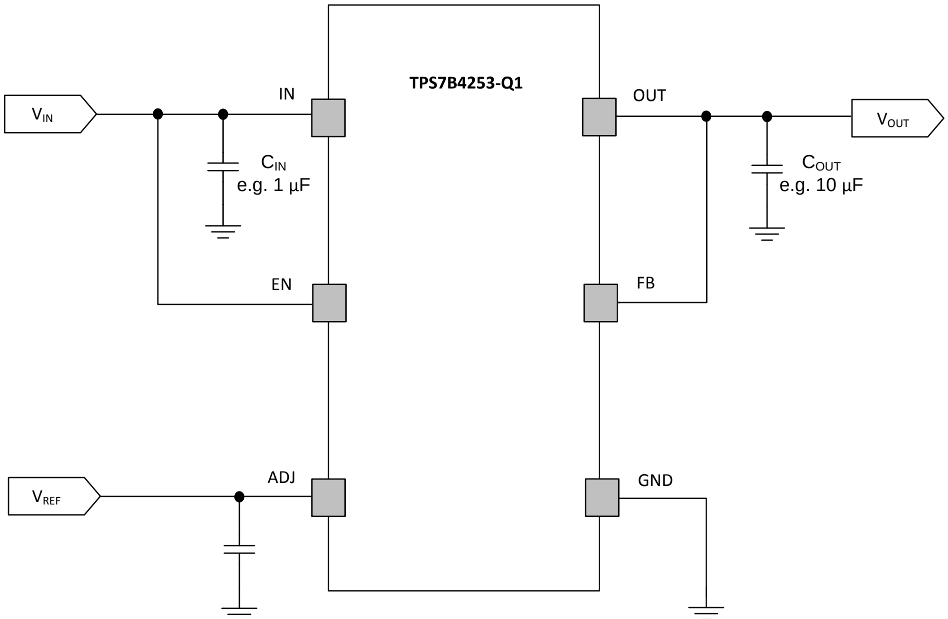

Figure 8. OUT Voltage Equals to Reference Voltage

2.4.3 Topology III: OUT Voltage is Higher Than Reference Voltage

By applying external resistor divider between OUT pin and FB pin, the output voltage can be higher than the reference voltage, as in Figure 9:

$$V_{OUT} = \frac{V_{REF} \times (R1 + R2)}{R2} \quad (5)$$

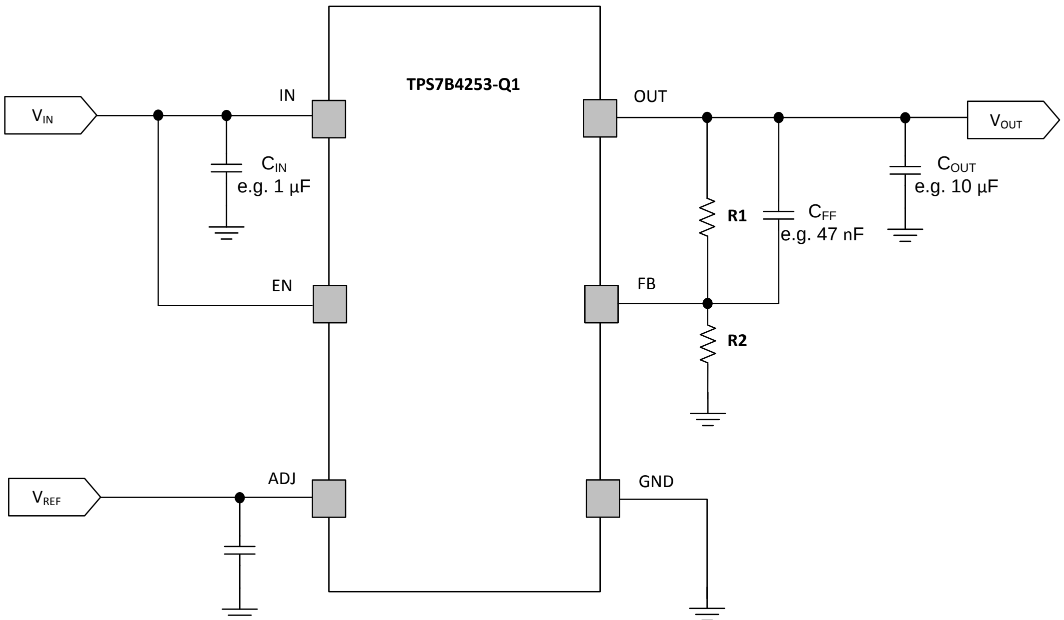

Figure 9. OUT Voltage is Higher Than Reference Voltage

3 References

For additional reference, see the following documents from TI:

- *TPS7B4253-Q1, 300-mA 40-V Low-Dropout Voltage-Tracking LDO With 4-mV Tracking Tolerance*, (SLVSCP3)
- *TPS7B4254-Q1, 150-mA 40-V Voltage-Tracking LDO With 4-mV Tracking Tolerance* (SLVSDI1)
- *TPS7B4250-Q1, Low-Dropout Voltage-Tracking LDO* (SLVSCA0)
- *LDO Parallel Solution Reference Design with TPS7B4253-Q1* (TIDUB16)

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