AN-861
APPLICATION NOTE

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ADP1653 Evaluation and Test Methods

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GENERAL DESCRIPTION

This application note presents some methods used in evaluating the ADP1653 white LED driver. The ADP1653 evaluation board, sold by Analog Devices, Inc., is used during the evaluation, but users may choose to design their own evaluation boards. For simplicity, however, all the testing procedures in this application note are based on the Analog Devices ADP1653 evaluation board.

The ADP1653 evaluation board is designed specifically for the purpose of evaluation. There are numerous jumpers and test points on the board for users to measure currents, voltages, or probe important nodes.

There are also switches on the board that allow users to easily change voltages at certain pins. Note, however, that even though this application note is based on the ADP1653 evaluation board, it is not a user manual that shows how to use the board and the included software. For more details, see the document *ADP1653 Flash LED Driver Evaluation Board Manual.*

FUNCTIONAL BLOCK DIAGRAM

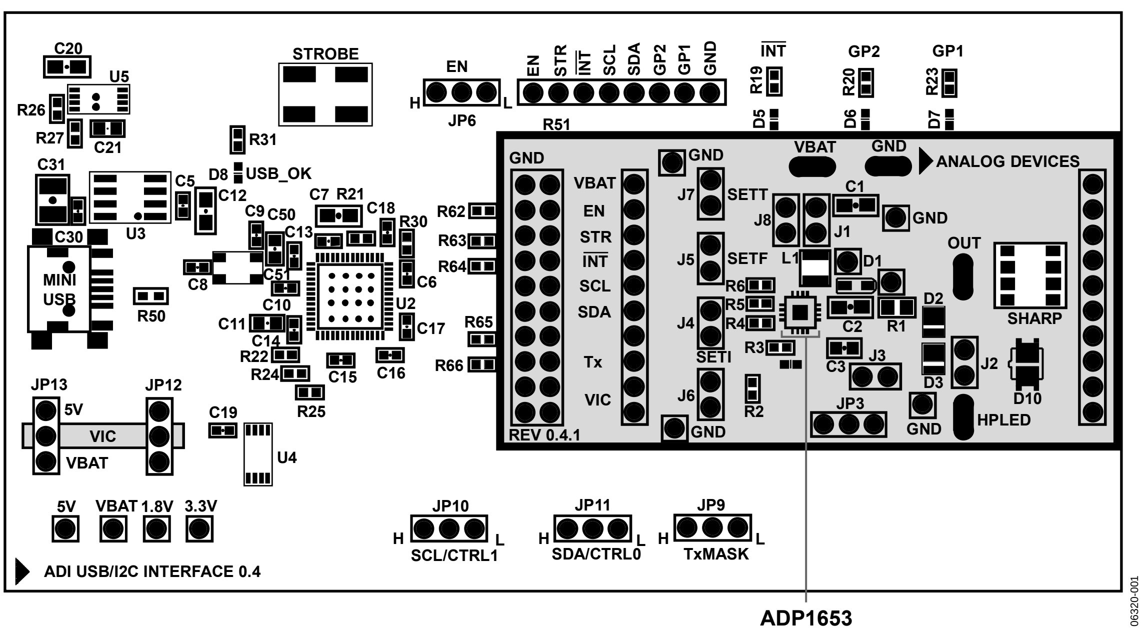

Figure 1.

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BOARD SCHEMATICS

MOTHERBOARD

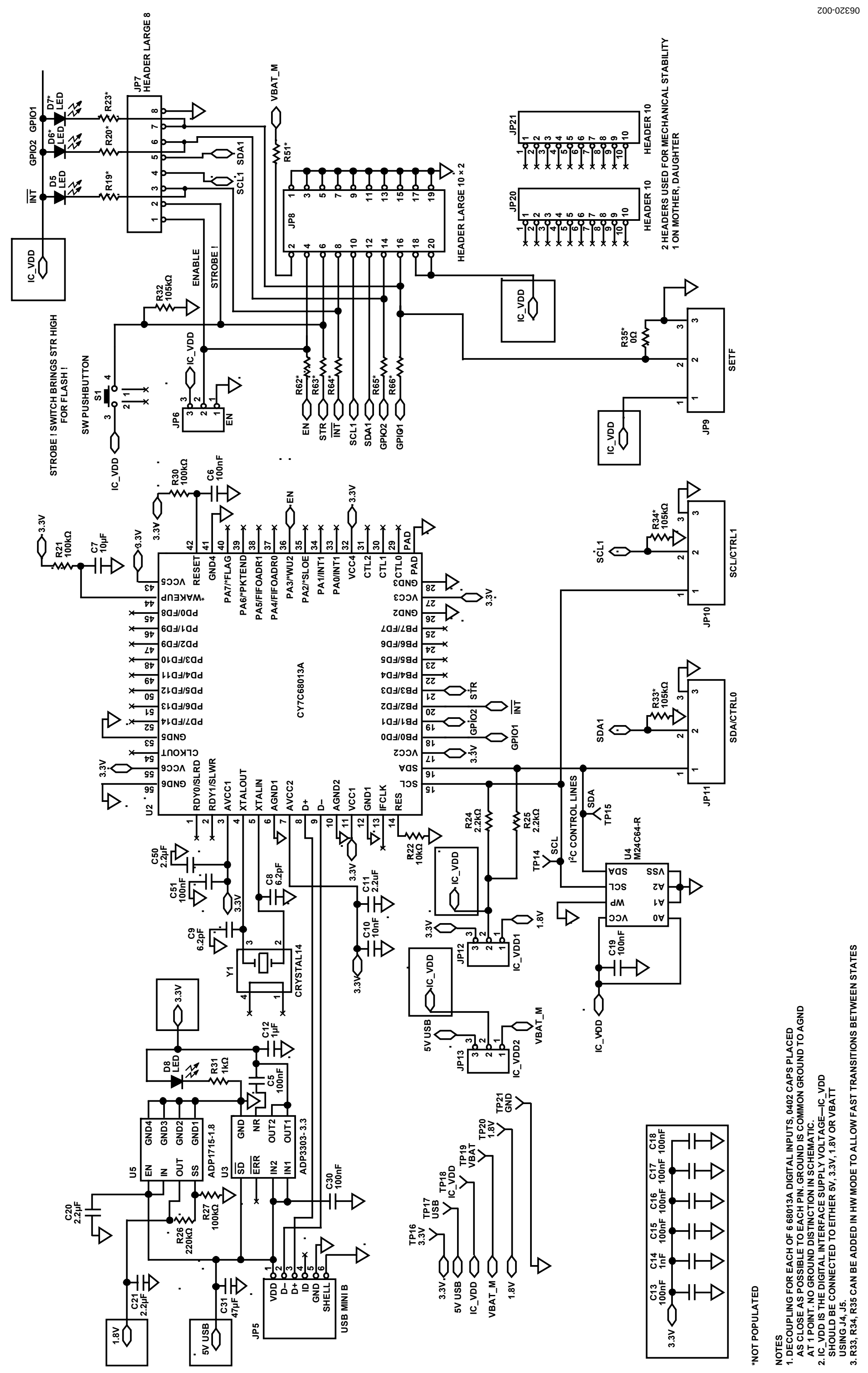

Figure 2. Motherboard Schematics

DAUGHTER BOARD

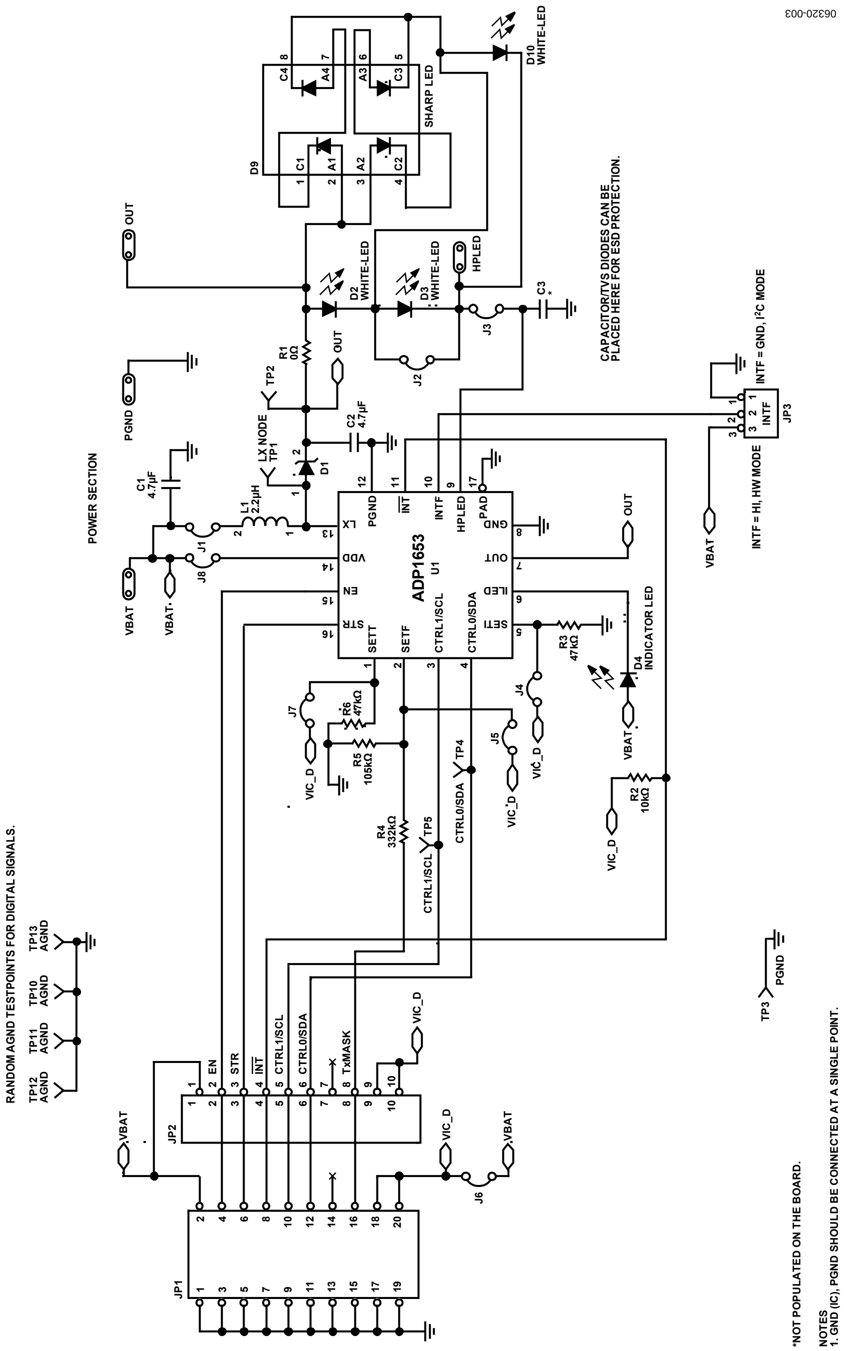

Figure 3. Daughter Board Schematics

GENERAL CONSIDERATIONS

CABLES

Because the ADP1653 is a high current, high power device, the cables used to connect the power supply to the chip must be as thick and short as possible to minimize the series resistance. However, no matter how short and thick a cable is, it still has a finite resistance, and the voltage at the VBAT pin is lower than the power supply voltage. For example, if the cable resistance is 0.1 Ω and the input current is 1 A, there is a 0.1 V drop between the power supply and the VBAT pin. That means if the supply is set to 2.8 V, the chip gets only 2.7 V, and, in some cases, this can trigger the UVLO.

Users are, therefore, advised to take into account the IR drop across cables. It is recommended that the voltage be measured at VBAT with a voltmeter and the supply adjusted until the desired VBAT voltage is obtained.

AMMETER

Even though an ammeter is convenient to use, because of the large current levels in power devices its internal resistance could cause incorrect measurements. As a result, care must be taken when using an ammeter.

Users should ensure that the scale is set to the order of magnitude of the current being used to minimize the series resistance of the ammeter. For example, when measuring a current that is expected to be on the order of hundreds of microamperes, the scale should be set to hundreds of microamperes or a few milliamperes.

If the current measured is going to be high (hundreds of milliamperes or even amperes), then using an ammeter could cause a significant error. In such cases, a small, high precision power resistor should be used. A good choice is a 1%, 0.1 Ω power strip that has a rating of several amps. Then, measuring the voltage across the resistor and dividing it by the resistance gives the current reading.

TEMPERATURE MEASUREMENT

Because the Cypress CY7C68013A chip on the motherboard is not rated at −40°C, it is not recommended to subject the motherboard to temperature testing. As a result, a ribbon cable is provided so users can separate the motherboard and daughter board for temperature measurement. Connect both ends of the ribbon cable to the headers on the motherboard and daughter board and place only the daughter board under temperature stress.

EVALUATION METHODS

SHUTDOWN CURRENT

To measure the shutdown current, connect an ammeter in series with the power supply and the VBAT pin. The ammeter should have enough resolution to measure down to tens of nanoamperes. Otherwise, it is difficult to distinguish the actual current from noise.

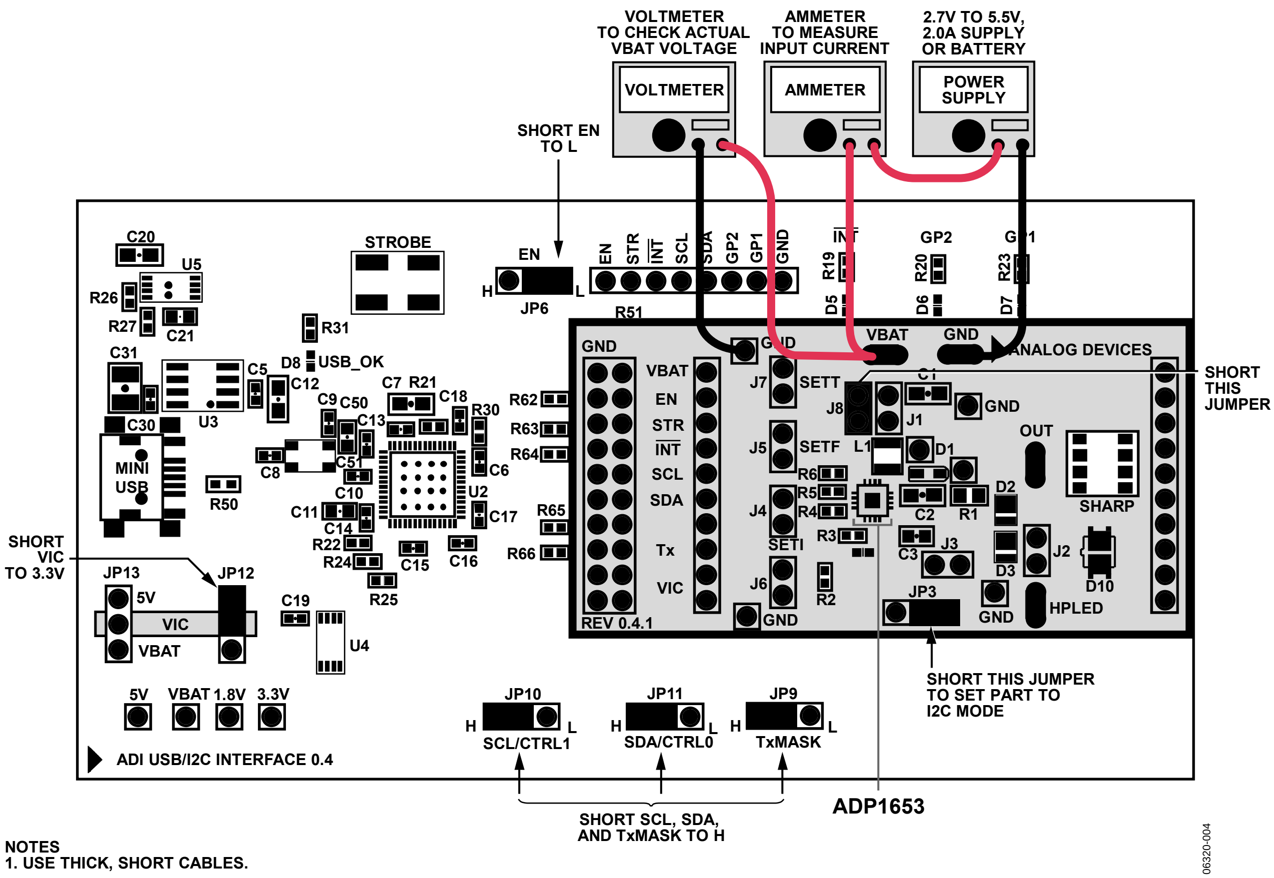

Figure 4. Measuring Shut-Down Current

V_{DD} SOFT POWER-DOWN CURRENT

The V_{DD} soft power-down current is the current that the part draws when it is enabled but not boosting. It is measured in the same way as the shutdown current.

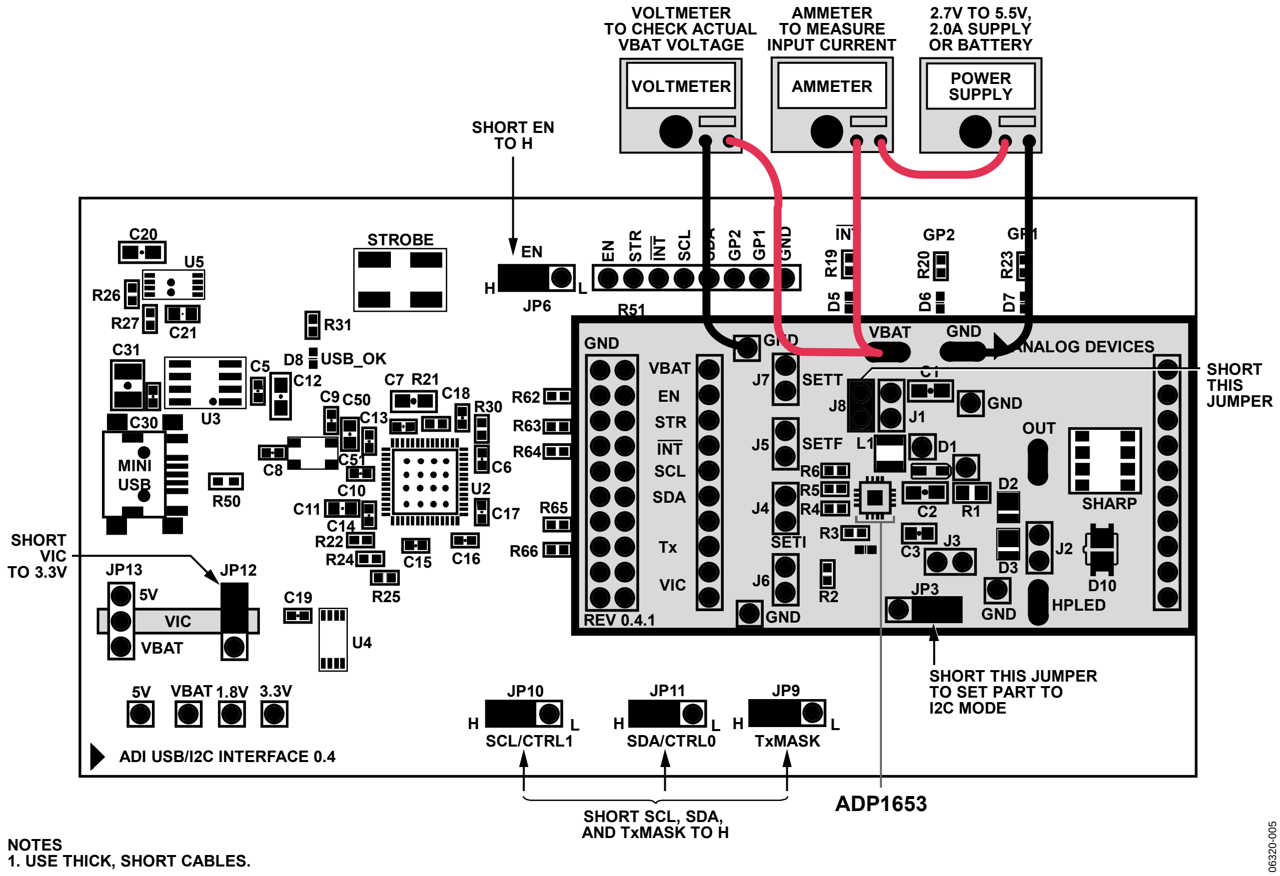

Figure 5. Measuring Soft Power-Down Current

V_{DD} OPERATING CURRENT ILED REGISTER = 001

The test setup for this is the same as that of the soft power-down current. With the device powered up, use the software to program 001 to the ILED register and read the supply current from the ammeter. To get an accurate reading, make sure the scale of the ammeter is set to larger than hundreds of microamperes.

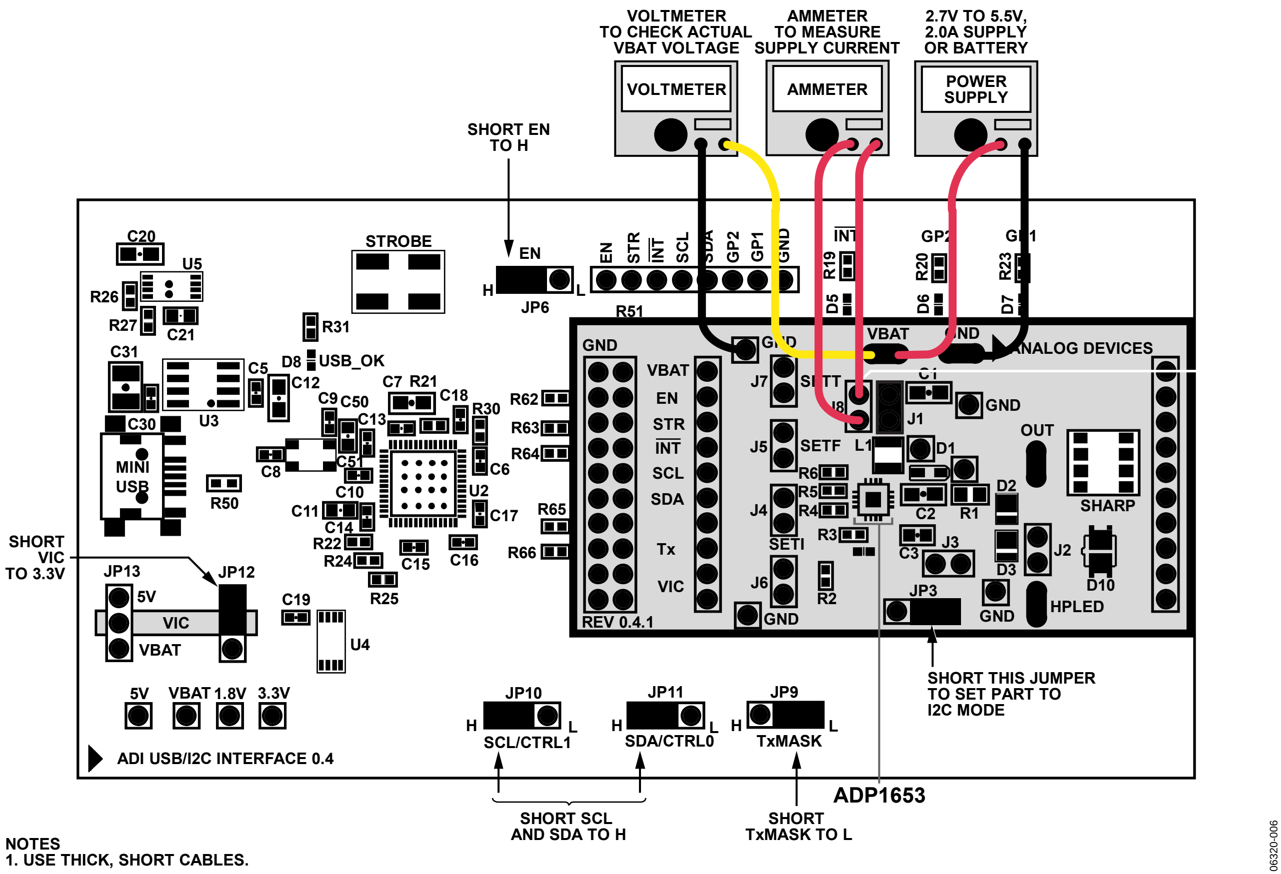

Figure 6. Measuring Supply Current (ILED)

V_{DD} OPERATING CURRENT HPLED REGISTER = 001 (BOOST NOT RUNNING, ONE LED)

This test measures the supply current when the HPLED register is set to 001, the ILED register is set to 0, and the part is not boosting. This means only one LED is on, and VBAT is greater than V_{OUT}. To measure the supply current with boost disabled, place a jumper on J2 to short out one of the LEDs, and make sure the supply voltage is greater than the forward voltage of the diode.

The Tx mask voltage can be set to either HI, LO, or left floating. The current is different in each case. See the ADP1653 data sheet for more information on Tx mask.

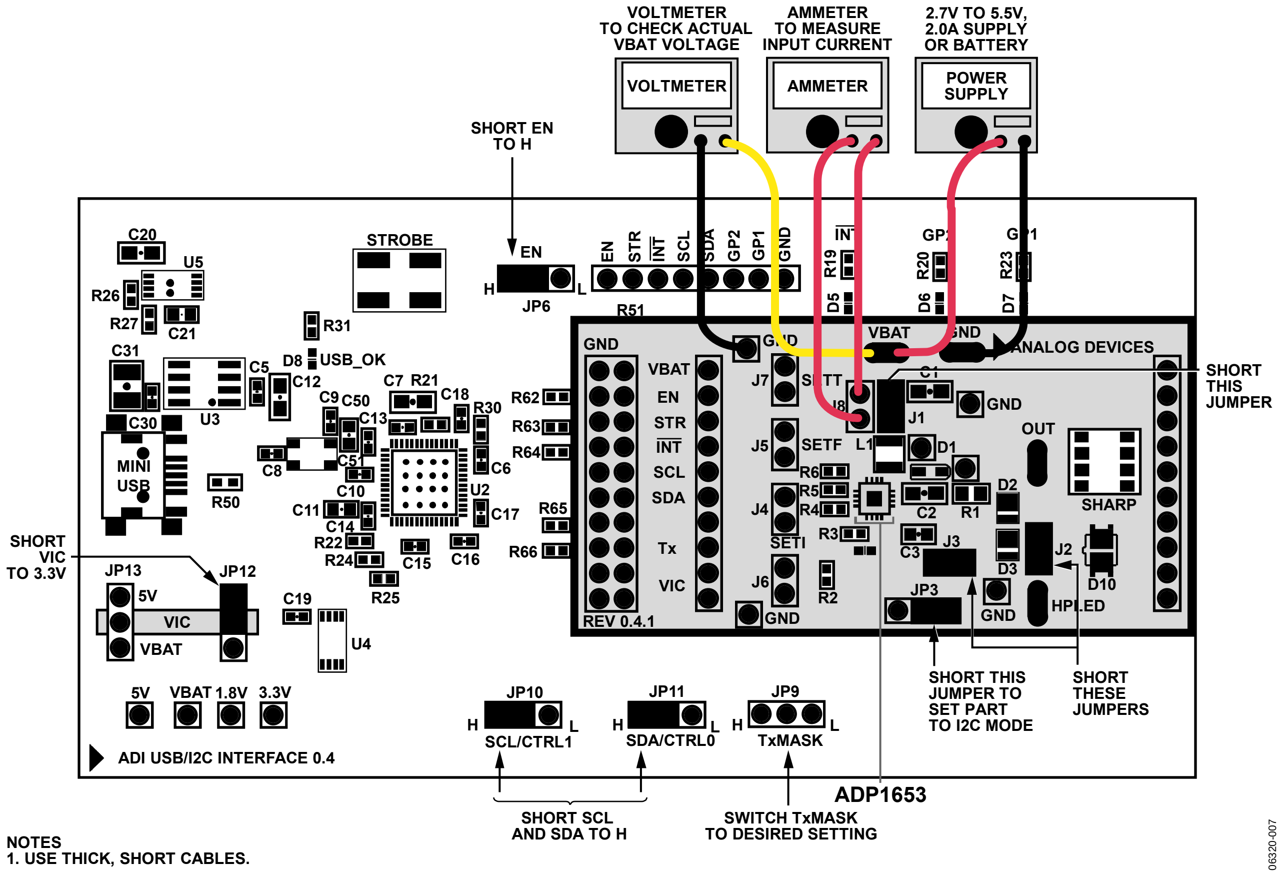

Figure 7. Measuring Supply Current (HPLED—Boost Disabled)

V$_{DD}$ OPERATING CURRENT HPLED REGISTER = 001 (BOOST RUNNING, TWO LEDs)

This test measures the supply current when the HPLED register is set to 001, the ILED register is set to 0, and the part is boosting. Therefore, both LEDs should be on and Jumper J2 should not be shorted.

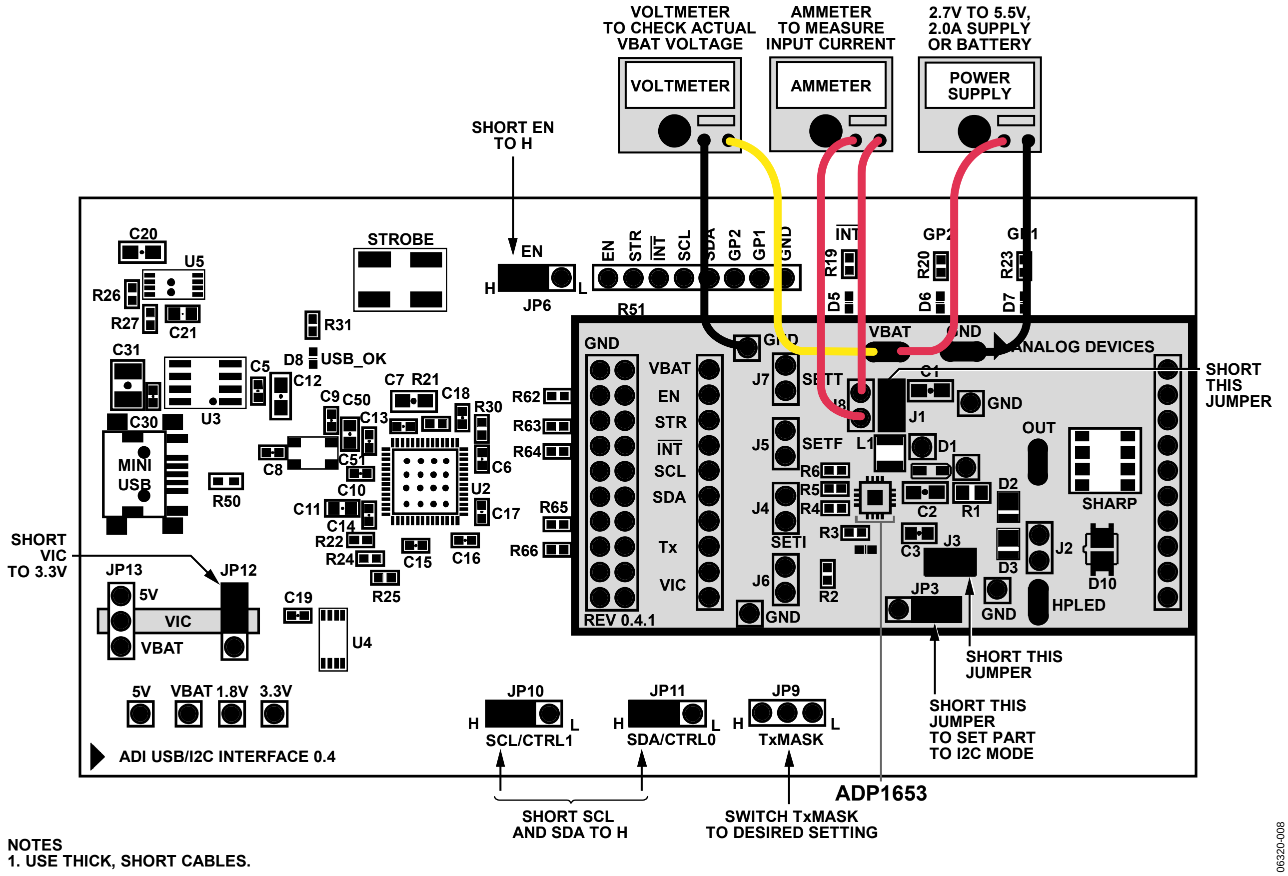

Figure 8. Measuring Supply Current (HPLED—Boost Enabled)

UNDERVOLTAGE LOCKOUT THRESHOLD (UVLO)

The UVLO is the VBAT voltage required to turn on or turn off the part. There are two UVLOs: UVLO (V_{DD} rising) is the voltage at which the part turns on, and UVLO (V_{DD} falling) is the voltage at which the part turns off. To measure UVLO (V_{DD} rising), apply a low voltage to the part and slowly increase it, 1 mV at a time. For each increase in the voltage steps, use the software to try to turn on the ILED.

The first voltage at which the ILED is able to turn on is the UVLO (V_{DD} rising). To measure UVLO (V_{DD} falling), power up the part and use the software to turn on the ILED. Then slowly decrease the supply voltage in 1 mV steps until the ILED turns off. The voltage at which turn-off occurs is the UVLO (V_{DD} falling).

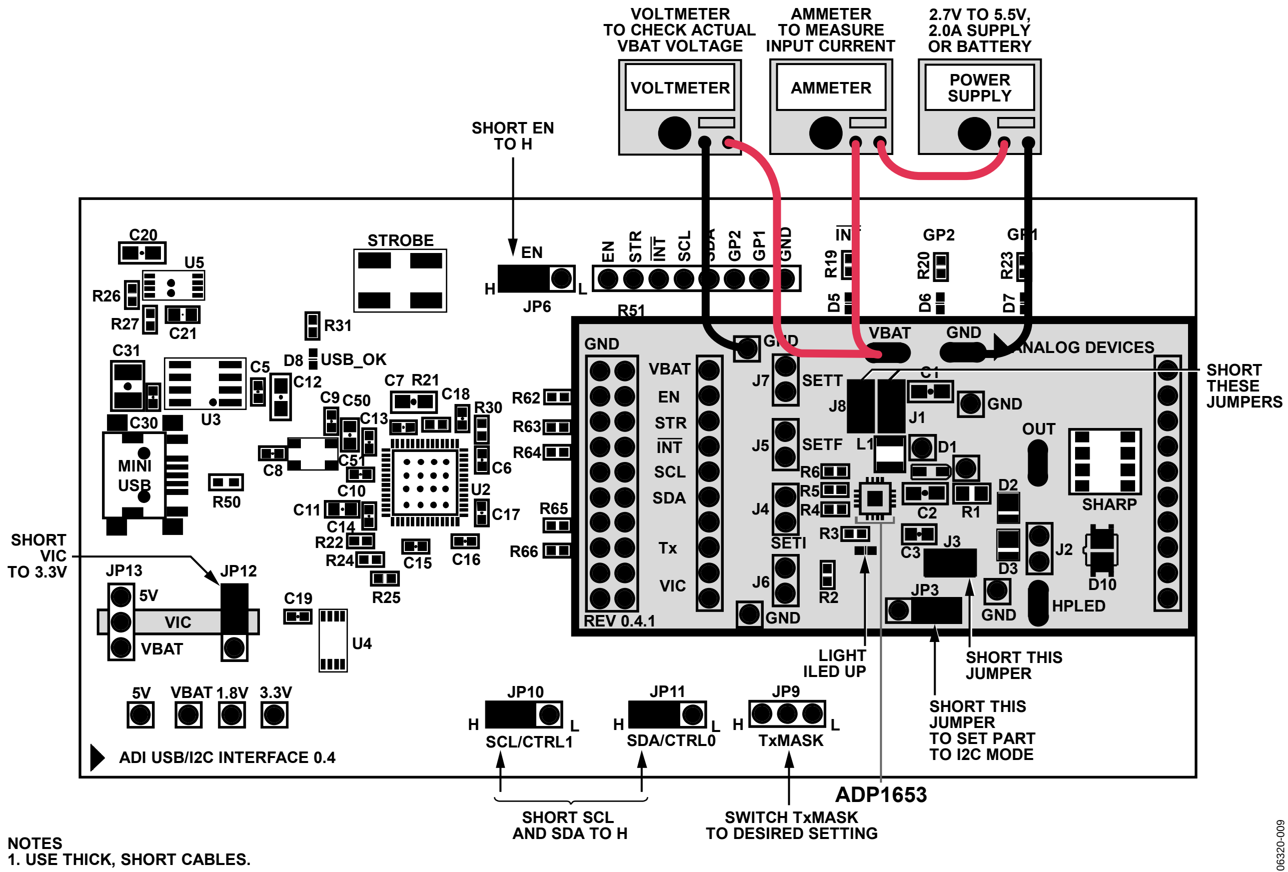

Figure 9. Measuring UVLO (Rising and Falling)

OUT OVERVOLTAGE THRESHOLD

The ADP1653 has a safety feature that turns itself off when the voltage at the OUT pin rises above 10.2 V (nominal).

To measure this voltage, first power up the part and use the software to turn on the ILED. Then apply an external voltage to the OUT pin and keep raising it until the ILED turns off. That voltage is the overvoltage threshold.

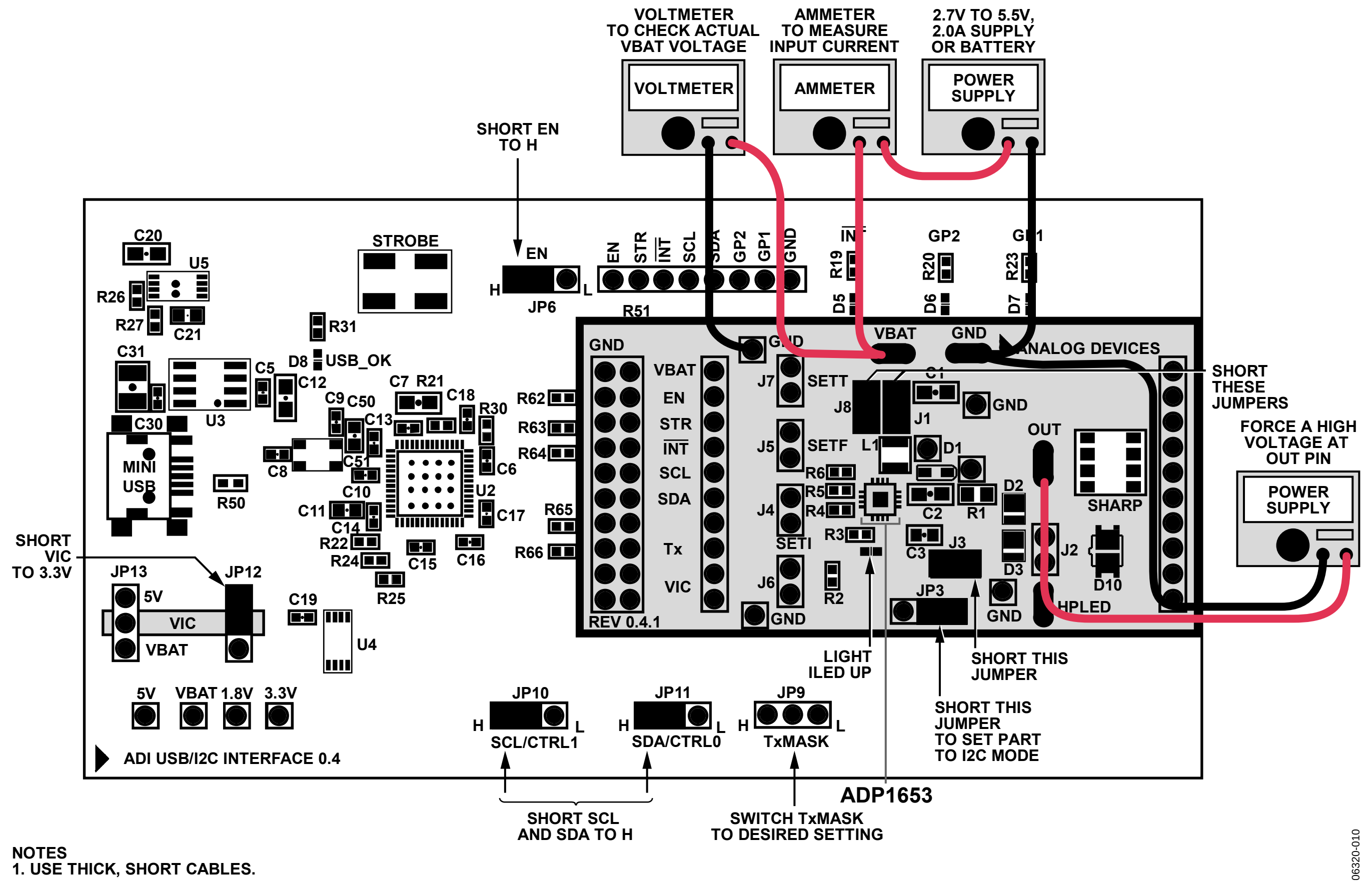

Figure 10. Measuring Overvoltage Protection

LX SWITCHING FREQUENCY

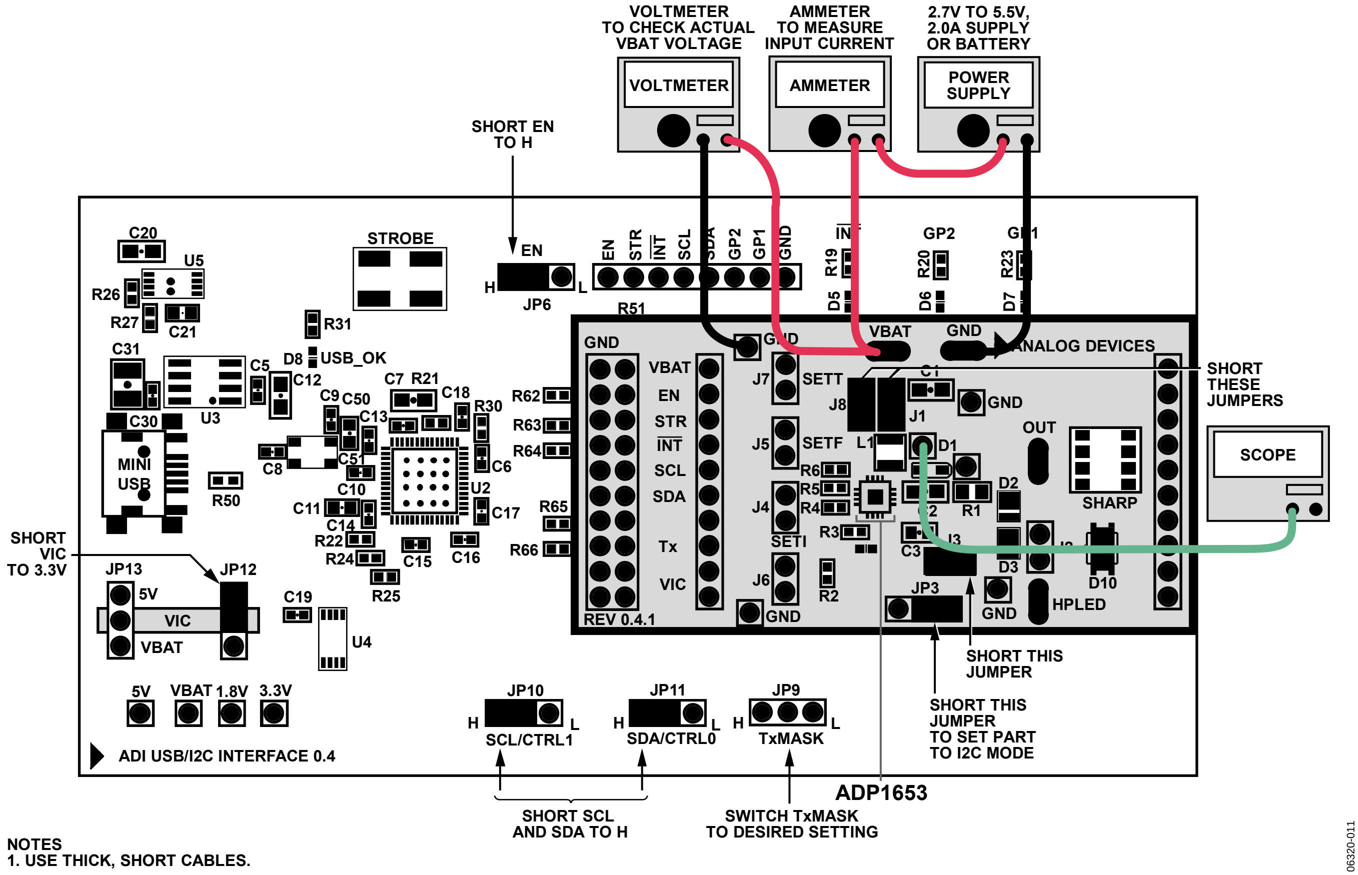

Figure 11. Measuring Switching Frequency

To see the LX switching waveform, power on the device and use the software to turn on the HPLEDs. Probe the test point right above Diode D1. Then, using the cursor function on the scope, measure the switching frequency.

Note that some switching waveforms contain ringing that should be included in the switching frequency measurement. The ringing is caused by the part going into the discontinuous mode of operation (the inductor current ripple dropping to 0) and is completely normal.

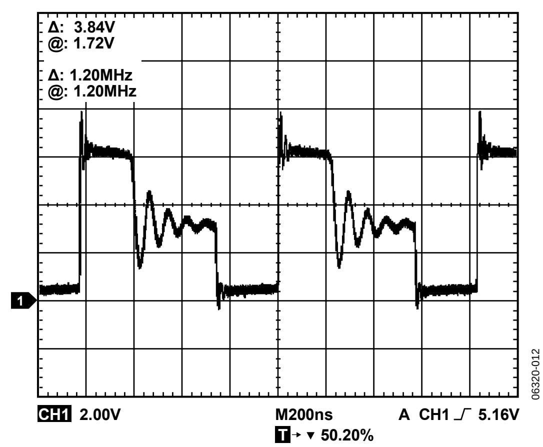

Figure 12. LX Pin, Discontinuous Conduction Mode

OUT SOFT START RAMP

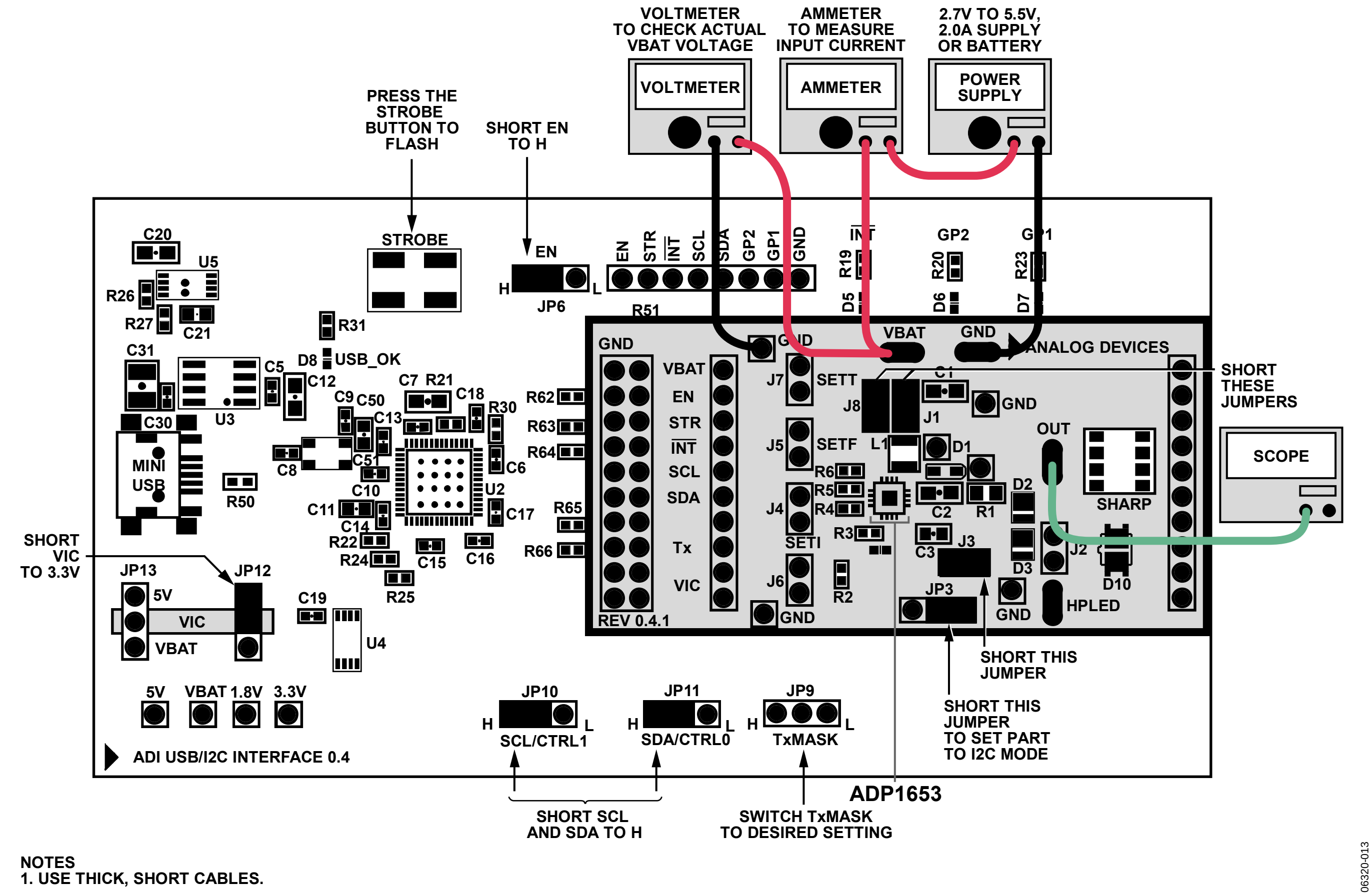

Figure 13. Measuring OUT Soft Start Ramp

The ADP1653 contains a soft start feature at the OUT pin to reduce the output voltage ramp rate. This prevents a large inrush current to the chip, as well as accidental tripping of the overvoltage threshold. To measure the OUT soft start ramp rate, hook up a scope to the OUT pin.

Use the software to program the first flash setting to the part. Program the HPLED register to 0x09 or any other setting, as desired, and press the strobe button to flash the LEDs. Capture the output voltage waveform on the scope, and measure the amount of rise in the output voltage and the time it takes. Dividing the output voltage rise by the time yields the soft start ramp rate.

In the example shown in Figure 14, the soft start ramp rate is

$$\frac{3.52\ \text{V}}{183\ \mu s} = 19.23\ \text{V}/\mu s$$

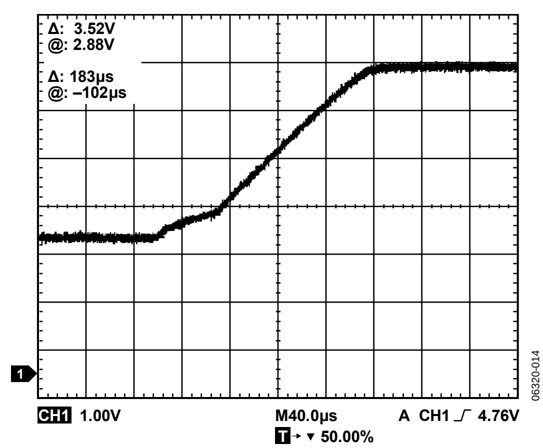

Figure 14. Typical Soft Start Ramp

START-UP INRUSH CURRENT

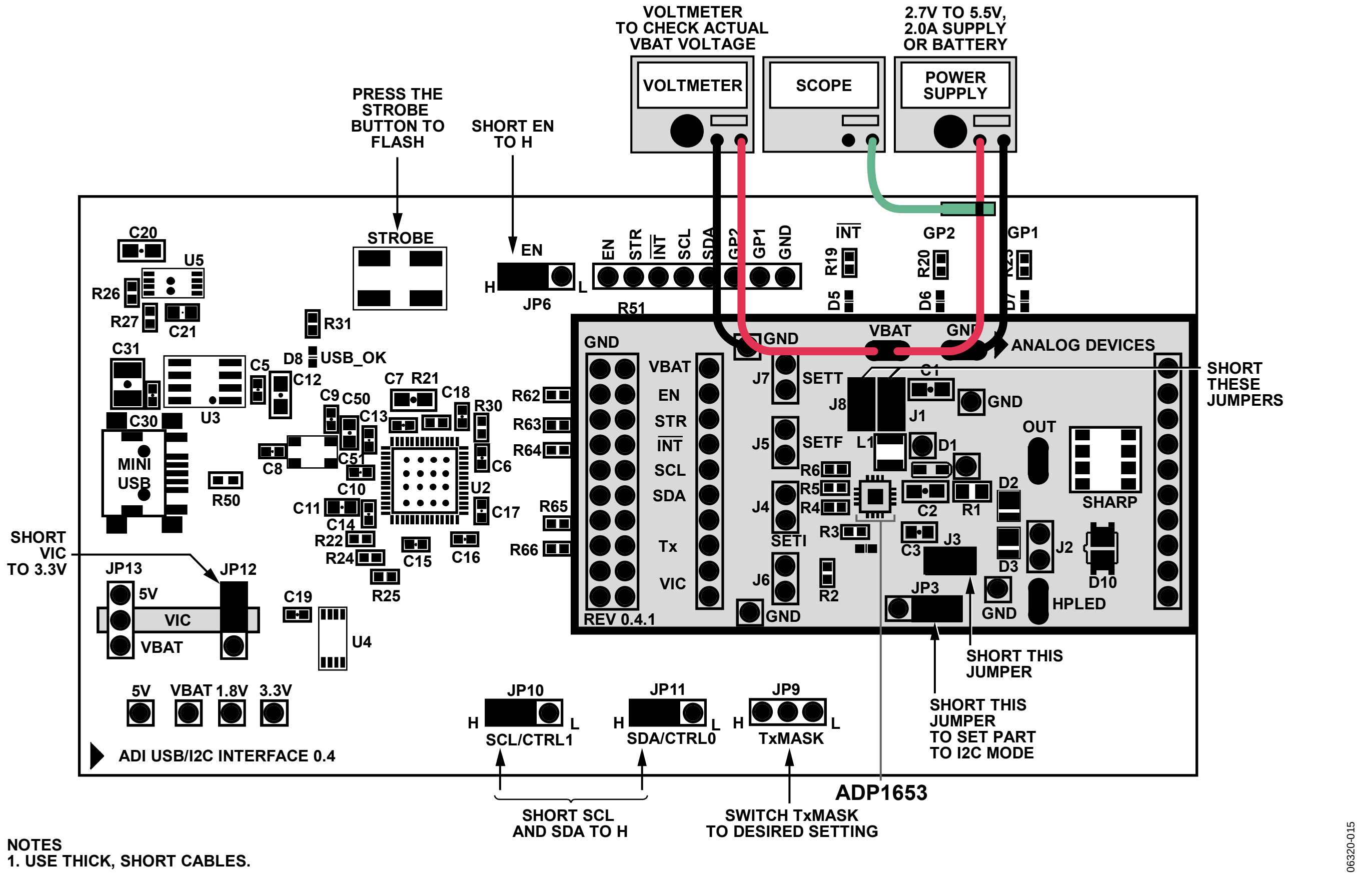

Figure 15. Measuring Inrush Current at Startup

When the ADP1653 first starts boosting, it may initially draw slightly more current than required, which is known as the start-up inrush current. To measure the inrush current, place a current probe on the positive power supply cable, use the software to program the HPLED register to the desired setting (press the strobe button if in the flash mode), and capture the input current waveform on the scope.

Figure 16 shows an example of the start-up inrush current, and the overshoot is the inrush current. How much overshoot there is depends on the external components, such as the input/output capacitors.

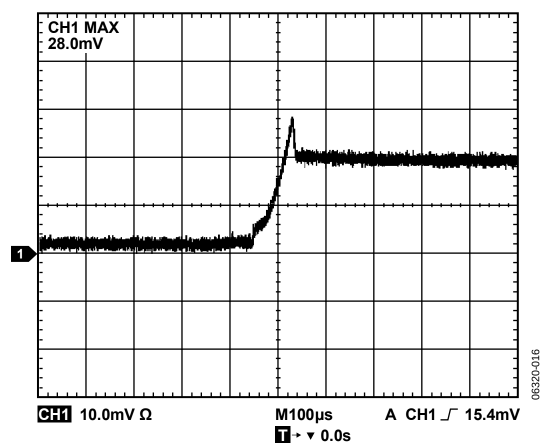

Figure 16. Typical Supply Inrush Current Waveform

EFFICIENCY

Torch Mode

LED efficiency is computed using the following equation:

$$\frac{V_{LED} \times I_{OUT}}{V_{BAT} \times I_{IN}}$$

The user must first measure V_{LED}, I_{OUT}, VBAT, and I_{IN} separately. VBAT and I_{IN} are easily measured with a voltmeter and an ammeter. For I_{OUT}, it is recommended that a high power current-sensing resistor of a small value be used, such as 0.1 Ω. Solder the leads of the resistor directly onto Jumper J3 without using any wires, because the wire resistance could be on the same order of magnitude as that of the resistor. Measure the voltage drop across the resistor and divide it by the resistance to compute the output current. Note that there is some loss in efficiency due to the current-sensing resistor. The amount of loss depends on the size of the resistor. For example, if R = 0.1 Ω and I_{OUT} = 500 mA, then V_{LOSS} = 0.05 V and P_{LOSS} = 25 mW.

Under normal boost conditions, V_{LED} ≈ 6.5 V; therefore, P_{OUT} = 3.25 W, and the efficiency loss due to the sense resistor is 0.77%. The user can add that loss back to the calculated efficiency to get the real efficiency.

When measuring V_{LED}, the two terminals of the voltmeter must be connected to the OUT pin and the HPLED pin, respectively. This measures the voltage across the LEDs, and the efficiency computed from it is the LED efficiency. If the negative terminal of the voltmeter is connected to ground, then the voltage measured is the pure boosted output voltage, and the efficiency calculated is the boost efficiency. The LED efficiency is always lower than the boost efficiency, because there is approximately a 350 mV loss at the HPLED pin when the part is boosting.

In addition, when measuring the efficiency at different output currents and a fixed VBAT voltage, increasing the output current inevitably decreases the supply voltage that the part receives due to the internal resistance of the cables. As a result, the user must adjust the power supply so the voltage at the VBAT pin stays constant.

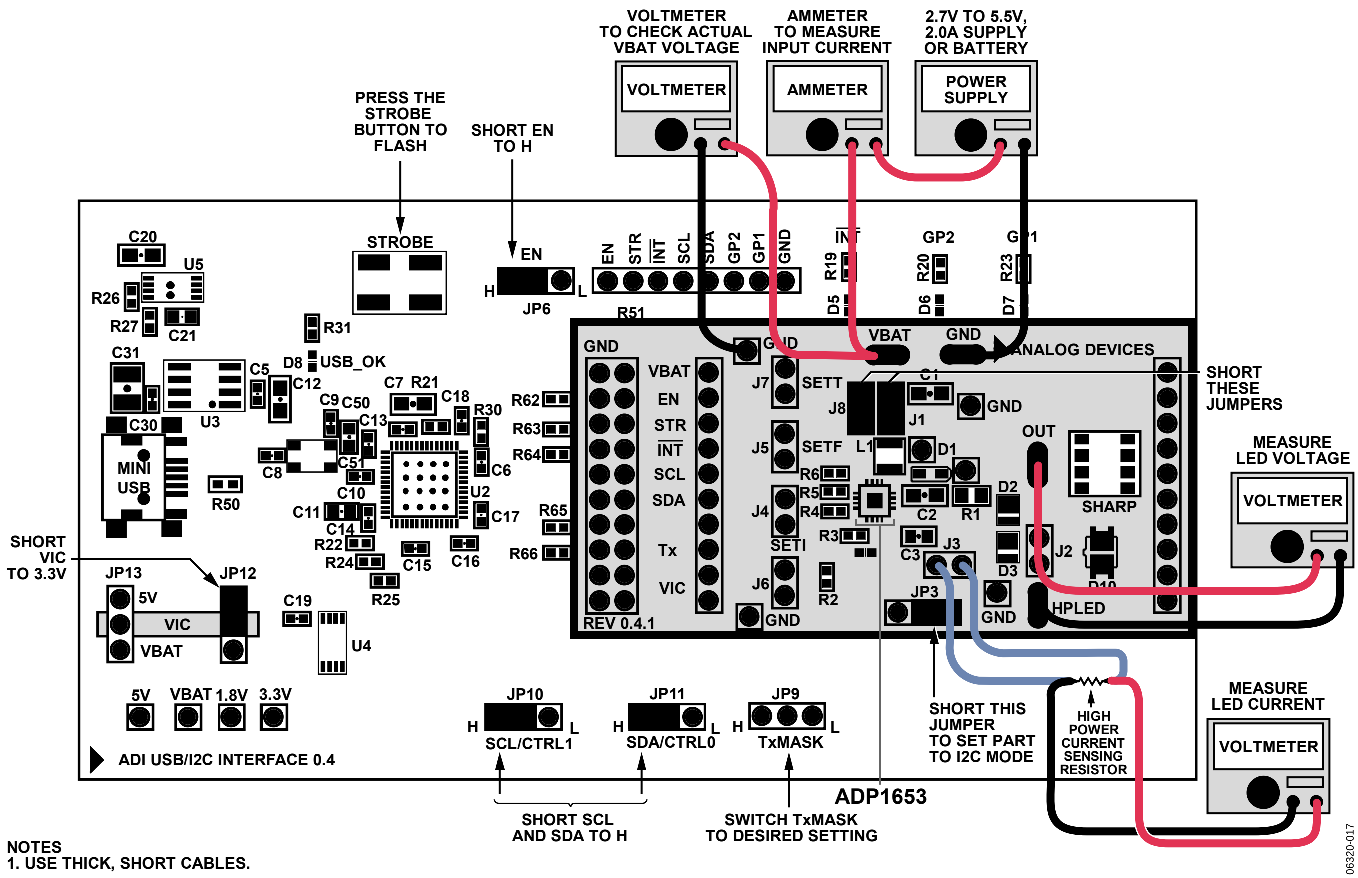

Figure 17. Measuring Efficiency in Torch Mode

Flash Mode

Efficiency measurement in the flash mode is not as straightforward as in the torch mode because the boost only lasts less than a second. As a result, scopes must be used to capture the waveforms. Use a 4-channel scope to capture VBAT, I_{IN}, V_{OUT}, and I_{OUT}, and use a separate scope to probe V_{HPLED}. Subtracting V_{HPLED} from V_{OUT} gives V_{LED}.

To measure I_{IN}, use a current probe on the power supply cable. To measure I_{OUT}, place a thick wire loop on Jumper J3 and use another current probe to measure the current.

Keep in mind that scopes do not have as much resolution as a voltmeter or ammeter, so the flash efficiency computed may have some error. It is advisable to use a calibrated electronic load to do regular probe calibration of the wire used in the measurement.

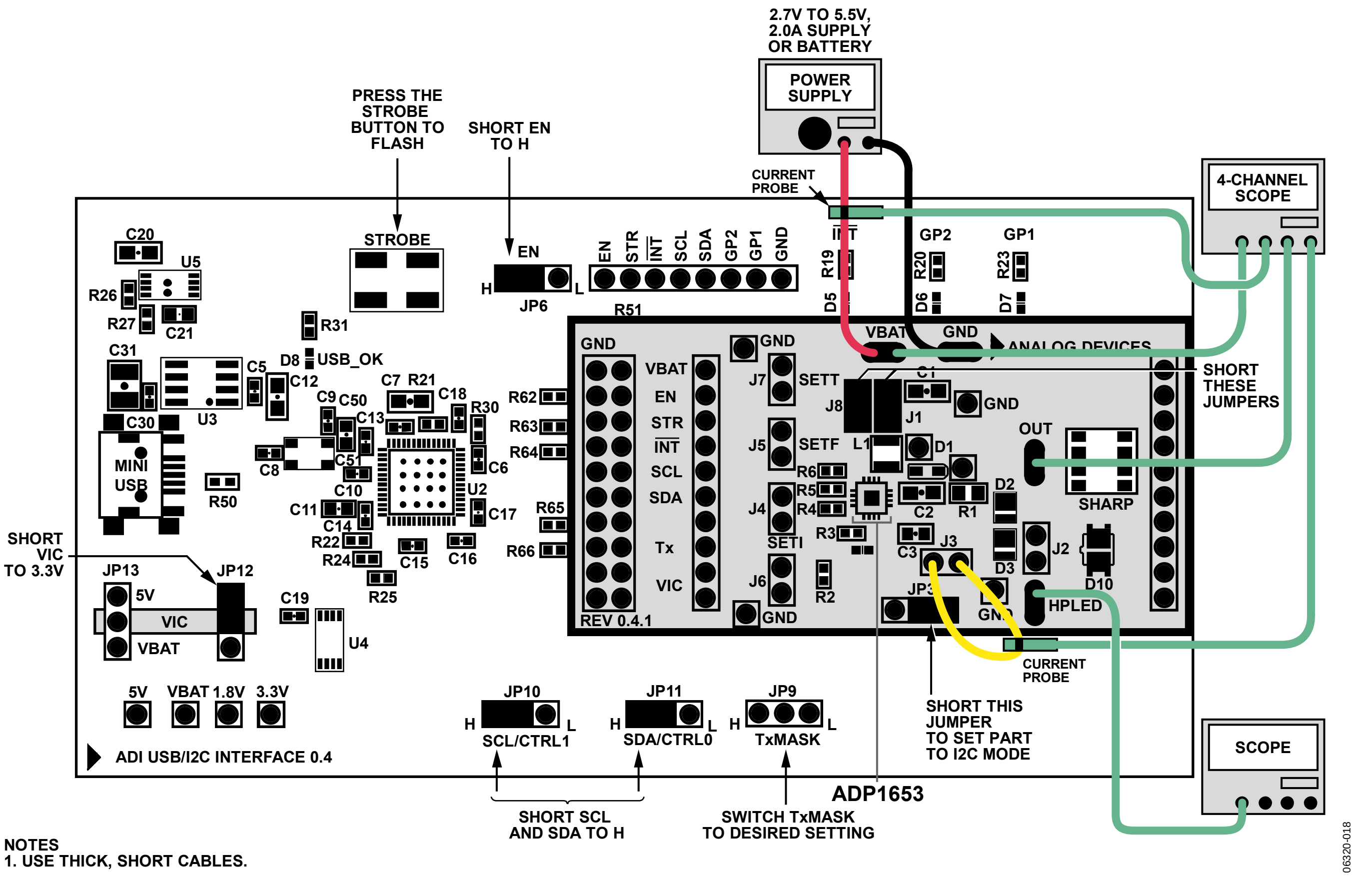

Figure 18. Measuring Efficiency in Flash Mode

CURRENT LIMIT

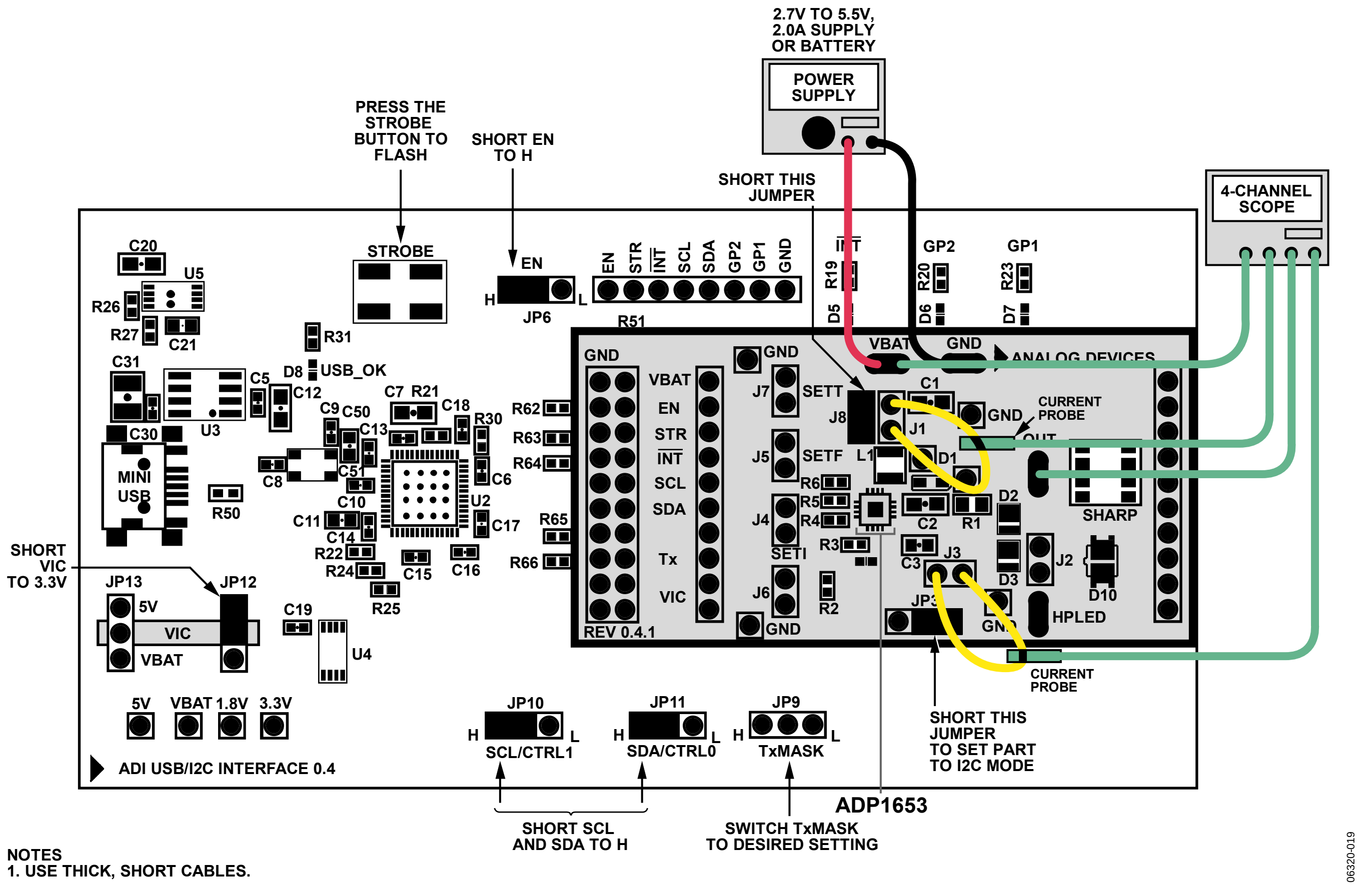

Figure 19. Measuring Current Limit

The purpose of the current limit is to restrict the amount of input current so the battery does not get overloaded. When the current limit is reached, both the input and LED currents stop increasing, even if the user tries to program a higher LED current setting.

To measure the current limit, place a thick wire loop on Jumper J1 and use a current probe to capture the inductor current waveform on the scope. Then, use the software to increase the LED current setting, until a point when the inductor current stops increasing. The peak of the inductor current is the current limit.

It may be useful, as well, to measure the LED current to know the maximum LED current that can be achieved with the particular external components.

Figure 20 shows the inductor current ripple when the current has NOT been reached, and Figure 21 shows when the current limit has been reached. In the figures, Channel 1 is input voltage, Channel 2 is inductor current ripple, and Channel 4 is output current.

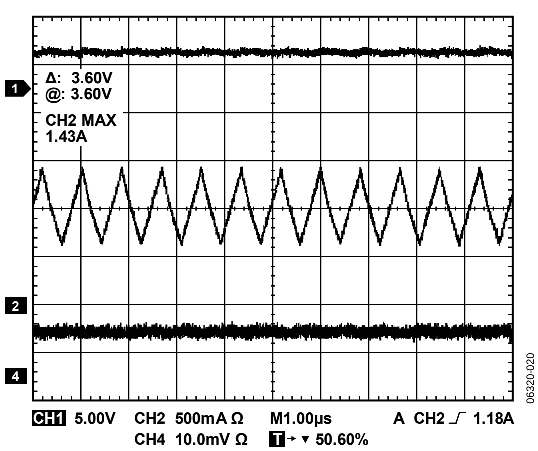

Figure 20. Inductor Current Waveform

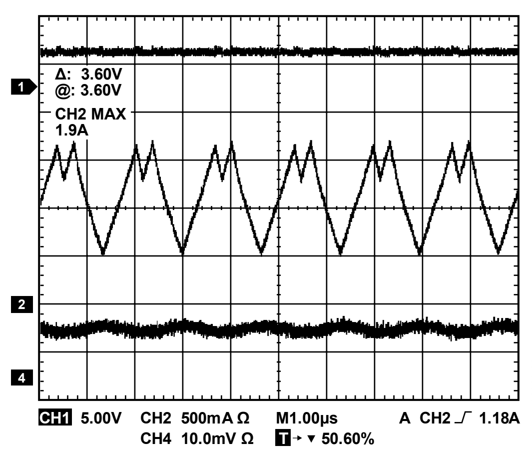

Figure 21. Inductor Current Waveform at Current Limit

LINE REGULATION

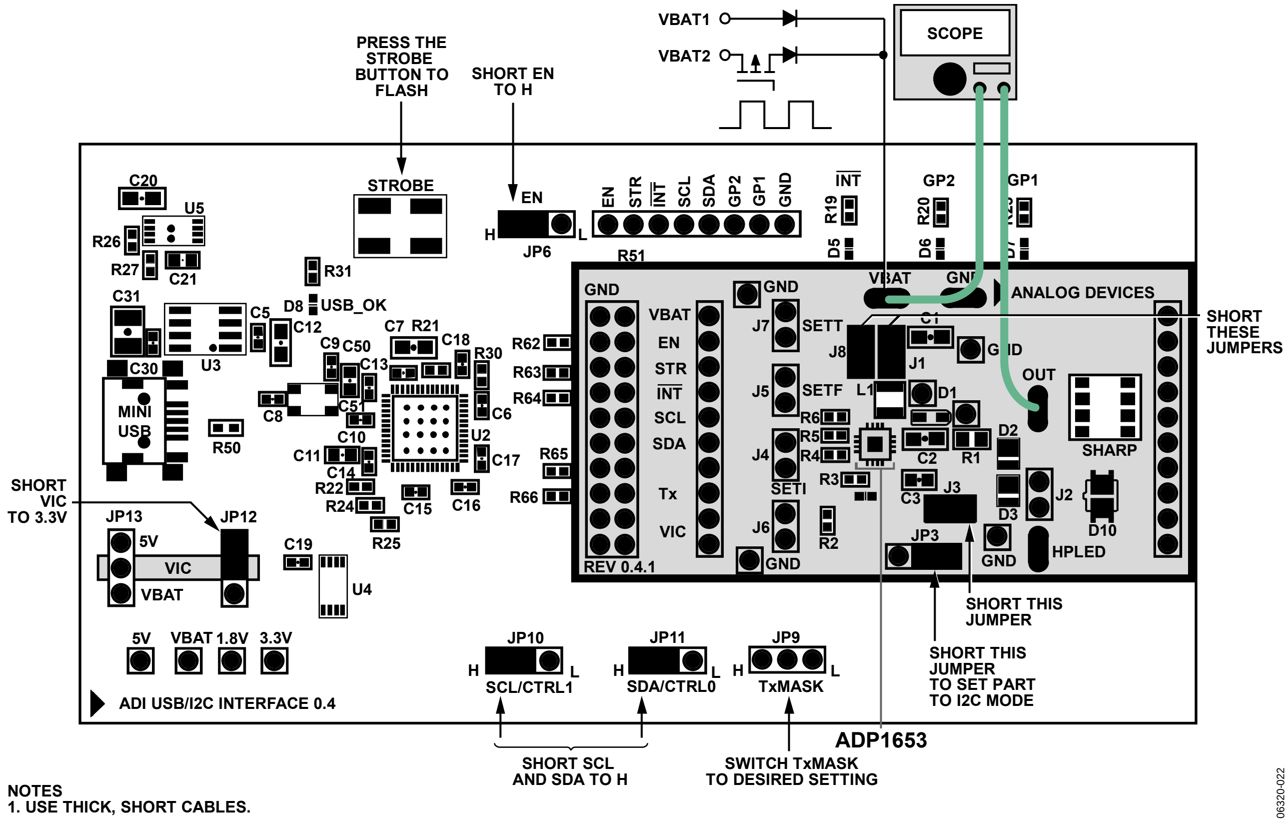

Figure 22. Measuring Line Regulation

Line regulation measures how much the output voltage changes in response to a change in the input voltage. To test this, the setup shown in Figure 22 can be used with two high power Schottky diodes and a P-channel power MOSFET. Use a function generator to generate a square wave for the gate of the MOSFET. If VBAT1 < VBAT2, when the gate of the MOSFET is low, the top diode is reverse-biased, and VBAT = VBAT2. When the gate is high, the bottom diode is reverse-biased, and VBAT = VBAT1.

Figure 23 shows the line regulation when VBAT1 = 3.3 V and VBAT2 = 4.0 V. Because ADP1653 is a current-mode controller, it is insensitive to changes in the supply voltage, and the line regulation is very good.

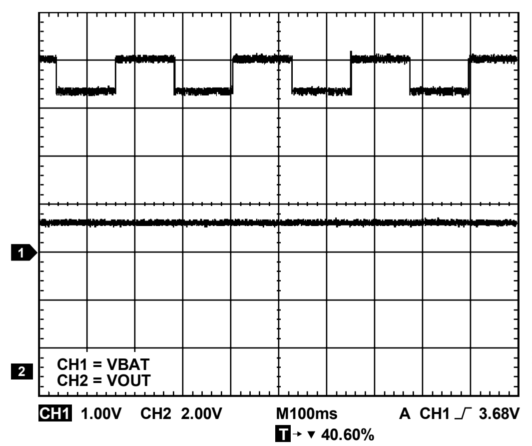

Figure 23. Typical Line Regulation Plot

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