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TPS23752 Maintain Power Signature Operation in Sleep Mode

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ABSTRACT

The TPS23752 is a 20-pin integrated circuit combining a Power-over-Ethernet (PoE) powered device (PD) interface and a current-mode DC/DC controller optimized specifically for applications requiring high efficiency over a wide load range. The TPS23752 integrates the additional Sleep Mode feature. Sleep Mode disables the converter, minimizing power consumption while still generating the Maintain Power Signature required by IEEE 802.3at. This application report supplies an explanation of the operation of the TPS23752 Sleep Mode and gives some relative experiment results.

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1 Introduction

The TPS23752 is a 20-pin integrated circuit that combines a Power-over-Ethernet (PoE) powered device (PD) interface and a current-mode DC/DC controller optimized specifically for applications requiring high efficiency over a wide load range. TPS23752 integrates the additional Sleep Mode feature. The Maintain Power Signature (MPS) is an electrical signature presented by the PD, assuring the PSE that it is still present after operating voltage is applied. A valid MPS consists of a minimum DC current of 10 mA (or a 10-mA pulsed current for at least 75 ms every 325 ms) and an AC impedance lower than 26.3 kΩ in parallel with 0.05 µF.

The Sleep Mode permits power savings at night (or some other system-driven criteria) by turning the active load circuits off while maintaining enough functionality for the PD to respond to a local power-up request. The Sleep Mode is initiated by command of a local device controller (microprocessor) when the SLPb input is driven low. Sleep Mode is latched by this event, the converter is disabled. The TPS23752 signals the PSE that it wants to remain powered during sleep by drawing enough current to satisfy the IEEE 802.3at MPS requirements. The input current consists of the TPS23752 bias current and the LED sink current, assuming no additional loading on V_C or V_B. The MPS current draw is inhibited when APD is active. A local pushbutton switch is monitored by the WAKE pin and the latched sleep state exits when the button is pressed.

2 Operation of Sleep Mode

Figure 1 shows the TPS23752 Sleep Mode functionality block diagram. Four pins related with Sleep Mode are described as below.

LED: The LED pin drives an external status LED. Connect the LED and its series current limiting resistor from V_C to the LED pin. While in Sleep Mode, the controller pulls the LED pin to ARTN. LED current can be set up as application requirement. If a status LED is not required, leave this pin open.

MODE: If this input is low when SLPb transitions low, the pulsed MPS function is enabled during Sleep Mode. Otherwise, a DC MPS current of 10.6 mA (typical) is drawn during Sleep Mode. Either MPS ensures that the PSE does not disconnect power from the PD while it is asleep. MODE is latched when SLPb falls, and is ignored during sleep. An MPS is not generated if the APD pin is held high (> 1.5 V). During normal operation, pulling MODE low causes the LED pin to pull low.

SLPb: The SLPb pin controls entry into Sleep Mode. The sleep state is latched active by a falling SLPb, which is then ignored during the Sleep Mode. This mode of operation disables converter switching, increases the current limit of the internal V_C regulator, and pulls the LED output low. Cycling V_{DD} or pulling the WAKE pin low terminates the Sleep Mode and restores normal operation.

WAKE: This pin performs several functions. During Sleep Mode, it outputs a current-limited 2.5 V. Pressing the external wakeup button during Sleep Mode connects the WAKE pin to the optocoupler and makes the TPS23752 exit Sleep Mode. The optocoupler alerts the system controller that the button has been pressed during sleep operation. Note that the WAKE pin is at V_B during normal operation.

The Sleep Mode supply current is shown in Table 1.

Table 1. Sleep Mode Supply Current

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Sleep supply current when APD is enabled	V_{APD} = 2 V, SLPb ↓ , measure I_{VDD}		0.5	1.0	mA
MPS supply current	Pulsed mode(1): V_{MODE} = 0 V, SLPb ↓ ,Measure I_{VDD}, 0 ≤ I_{LED} ≤ 10 mA	10.0	10.6	11.5	mApk
	DC mode: V_{MODE} = V_B, SLPb ↓ ,Measure I_{VDD}, 0 ≤ I_{LED} ≤ 10 mA	10.0	10.6	11.5	mA
MPS pulsed mode duty cycle	MPS pulsed current duty cycle(1)	28.80%	28.88%	28.95%	
	MPS pulsed current ON time	75	87.5		ms
	MPS pulsed current OFF time(1)		215	250	ms

Note 1: Parameters provided for reference only and do not constitute part of TI published specifications for purposes of TI product warranty.

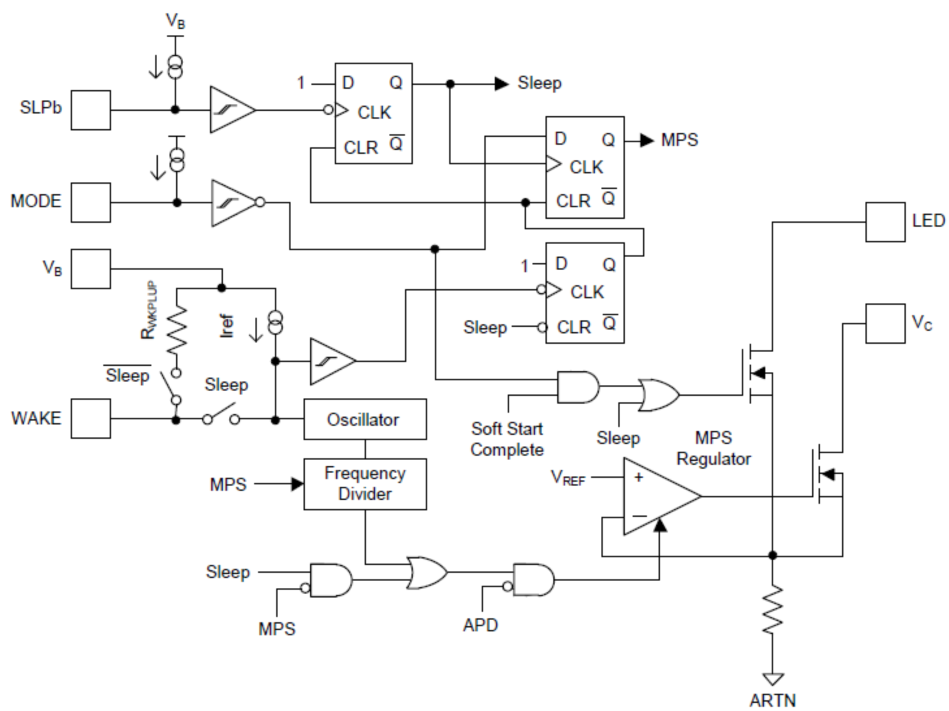

Figure 1. TPS23752 Sleep Mode Functionality Block Diagram

Entering Sleep Mode is triggered by a falling edge signal on the SLPb pin. When in Sleep Mode, the DC/DC converter is disabled, V_{DD} regulates V_C to 12.8 V, and the 2.5-V regulator provides voltage at some low current to WAKE pin. The MPS regulator provides a control signal to the internal MOSFET connected with the V_C pin, thus an MPS is generated at the input side. The LED pin also draws current from V_C and shares the same current-sensing resistor with the V_C internal MOSFET.

TPS23752 senses the LED current and draws the extra current to satisfy the IEEE 802.3at MPS requirement. Figure 2 shows the MPS current in pulsed MPS mode. LED current can be set as application requirement. Some applications require more LED current to be drawn from Vc to LED in Sleep Mode for higher LED brightness. This means that except for sleep supply current (I_{VDD}), no more current should be consumed inside the controller. In pulsed MPS mode, LED current should be traded off with input power consumption in order to have higher LED brightness while being able to meet energy saving standard (for example, 0.5-W Energy Star standard). Equation 1 shows the calculation of the average input current. LED current is adjustable with the series resistor and I_{VDD} consumption in Sleep Mode during the (1 – D_{MPS}) period is typically 0.5 mA.

$$I_{IN\_avg} = (D_{MPS} \times 10.6\ mA) + [(1 - D_{MPS}) \times (I_{VDD} + I_{LED})] \quad (1)$$

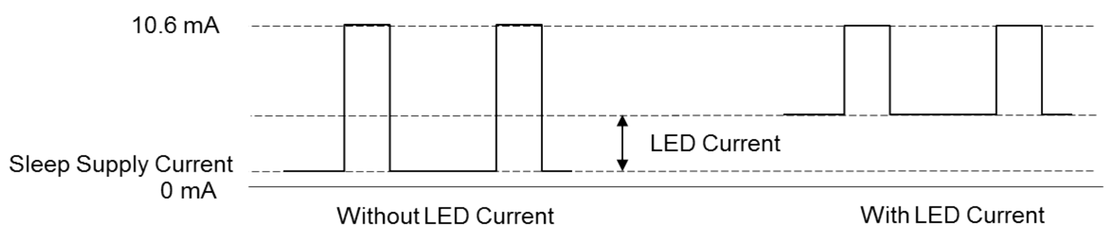

Figure 2. TPS23752 Pulsed MPS Current in Sleep Mode

When the PD is powered by an adapter, LED current is still generated in Sleep Mode, but no MPS current is driven from adapter.

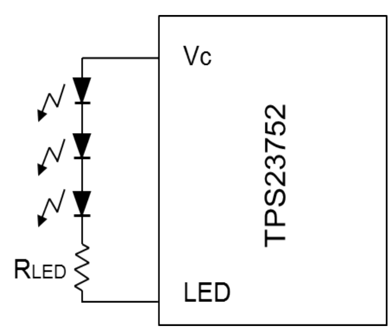

Figure 3. LEDs Connection For Higher Brightness

Usually Vc (12.8 V) is used to power LEDs. To achieve the highest brightness LED, it is possible to connect 3 or more LEDs in series, as shown in Figure 3, without drawing more power from the 48-V bus. So the power consumed by R_{LED} is lower without more waste.

When the wakeup button is pressed, an internal current comparator detects the WAKE current and when I_{WAKE} > 150 µA, the TPS23752 exits Sleep Mode and changes to the normal operation state. The WAKE pin now connects back to the internal 5.33 kΩ pull-up resistor R_{WKPLUP}.

With the TPS23752, the Sleep Mode signals are referenced to AGND after the hot swap, meaning that no costly optocoupler and diodes are required for any of the three sleep and wakeup signals, if in a non-isolated application.

When an optocoupler with low CTR is used for the WAKE signal, more wakeup current is required. Use the application circuit shown in Figure 4 to ensure the processor wakeup signal when the wakeup button is pressed.

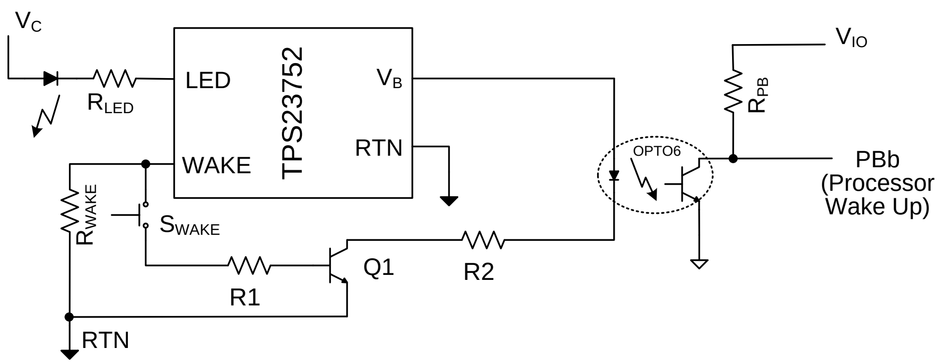

Figure 4. WAKE Pin Connection with Low CTR Optocoupler

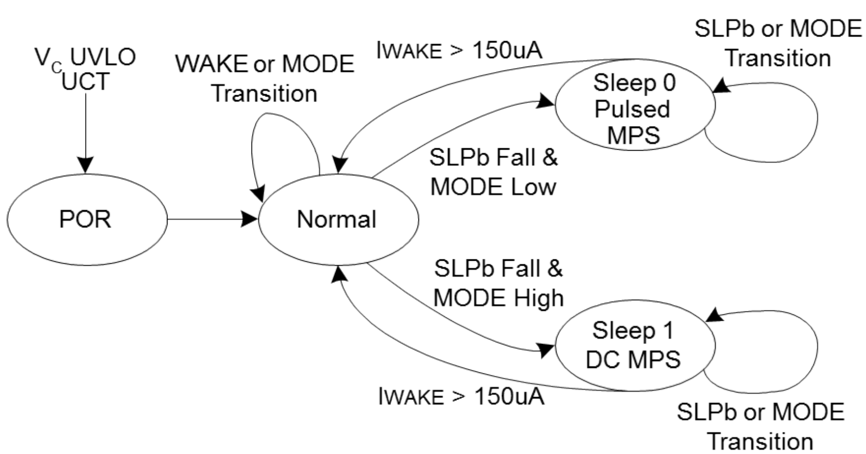

Figure 5. TPS23752 Sleep Mode Operation

For Sleep Mode operation, Figure 5 shows the status switching operation. “Sleep 0” stands for the pulsed-MPS Sleep Mode status that SLPb transitions low with the MODE pin low, “Sleep 1” stands for the DC MPS Sleep Mode status that SLPb transitions low with the MODE pin high.

3 Test Result of Sleep Mode

For the Sleep Mode test, use the TPS23752EVM-145 board with the Sleep Mode functionality. The opto-isolated circuits and associated circuits support the sleep or low-power mode of the TPS23752. The typical input and output voltage is 48 V and 5 V. In order to clearly observe the MPS (input current) when entering and exiting Sleep Mode, we connect a resistive load of 10.2 Ω to the 5 V output (input current is about 60 mA). For Sleep Mode control, install a shunt on J8 while J6 is shorted to enable pulsed MPS. Install a shunt on J8 while J6 is open to enable DC MPS. Table 2 lists the detailed Sleep Mode related connector functionality.

Table 2. Sleep Mode Related Connector Functionality

Connector	Label	Description
J6	SLP	Shorting pin 1 to pin 2 causes the TPS23752 to enter Sleep Mode. Sleep Mode is entered when the SLPb pin is pulled low during normal operation.
J8	MODE	Install a shunt on J8 while J6 is shorted to enable pulsed MPS. Remove the shunt from J8 while J6 is shorted, enabling DC MPS.
S1	WAKE	Depressing S1 when the TPS23752 is in Sleep Mode restarts the DC/DC converter.

3.1 Entering Sleep Mode

Enter the Sleep Mode test by shorting pin 1 to pin 2 of J6, pulling the SLPb pin low, thus causing the TPS23752 to enter Sleep Mode. Test with both MODE pin in low and high voltage when shorting J6.

Figure 6 and 7, respectively; illustrate entering Sleep Mode with the MODE pin low and high. With the MODE pin low, pulsed MPS is enabled as shown in Figure 6. The input current drops from DC 60 mA to 10.6 mA pulsed current for about 84 ms every 292 ms. The WAKE pin voltage drops from 5 V to 2.5 V. Because power pin 2 of J6 and J8 is connected with the output of the DC/DC converter, when TPS23752 enters Sleep Mode, the DC/DC converter turns down and the output voltage falls to zero, so the voltage of the SLPb pin and the MODE pin rise to high voltage, after entering Sleep Mode. With the MODE pin high, a valid MPS consisting of a DC current of 10.6 mA is enabled as shown in Figure 7. After the TPS23752 enters Sleep Mode, the voltage of the MODE pin remains high and the SLPb pin voltage rises to high.

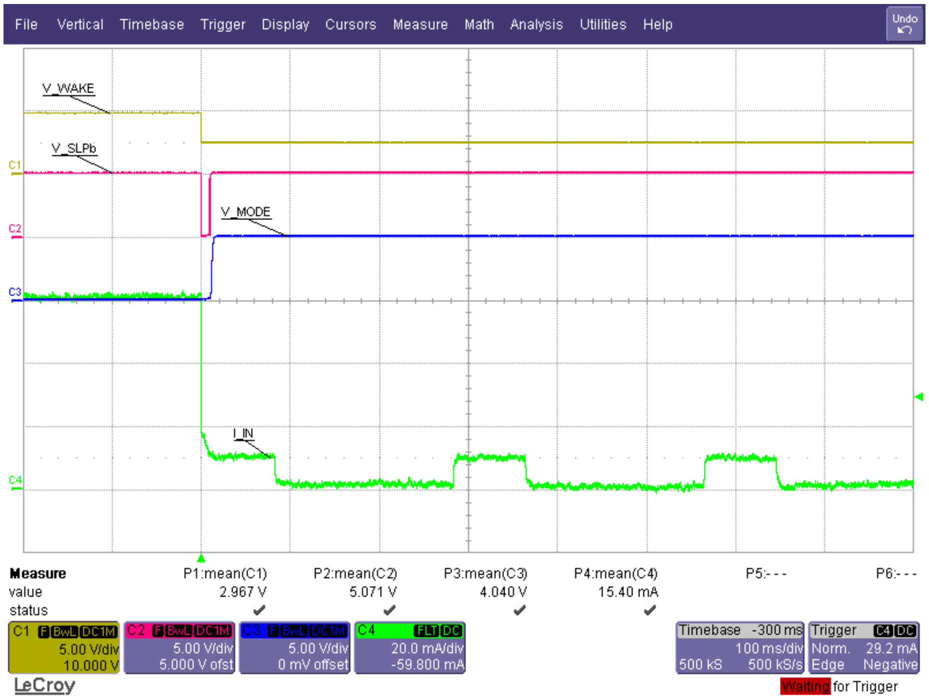

Figure 6. Entering Sleep Mode with MODE Low

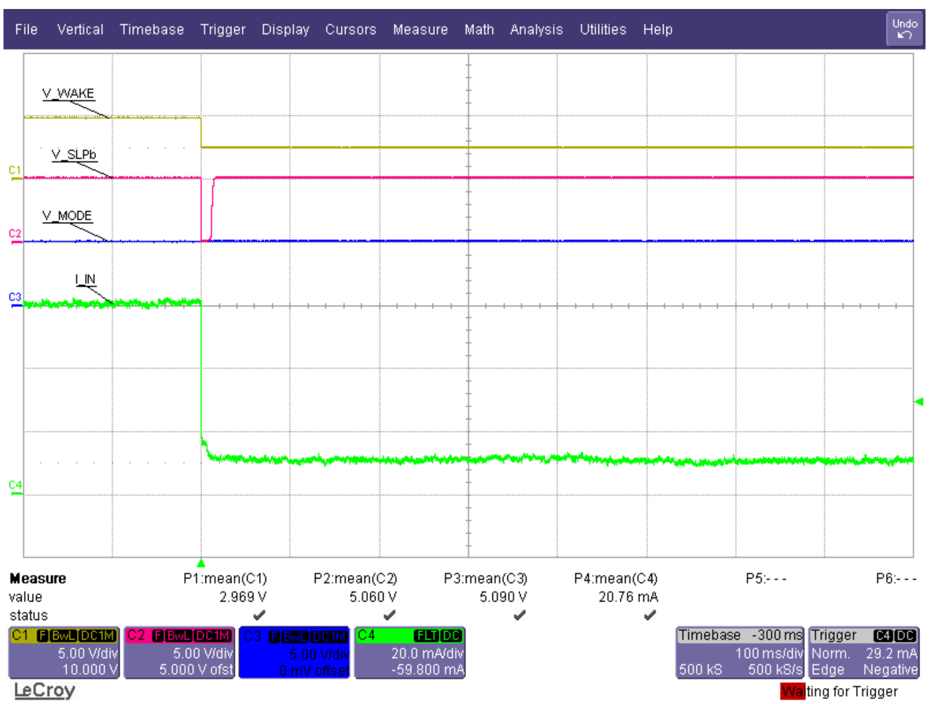

Figure 7. Entering Sleep Mode with MODE High

3.2 Input Current in Sleep Mode

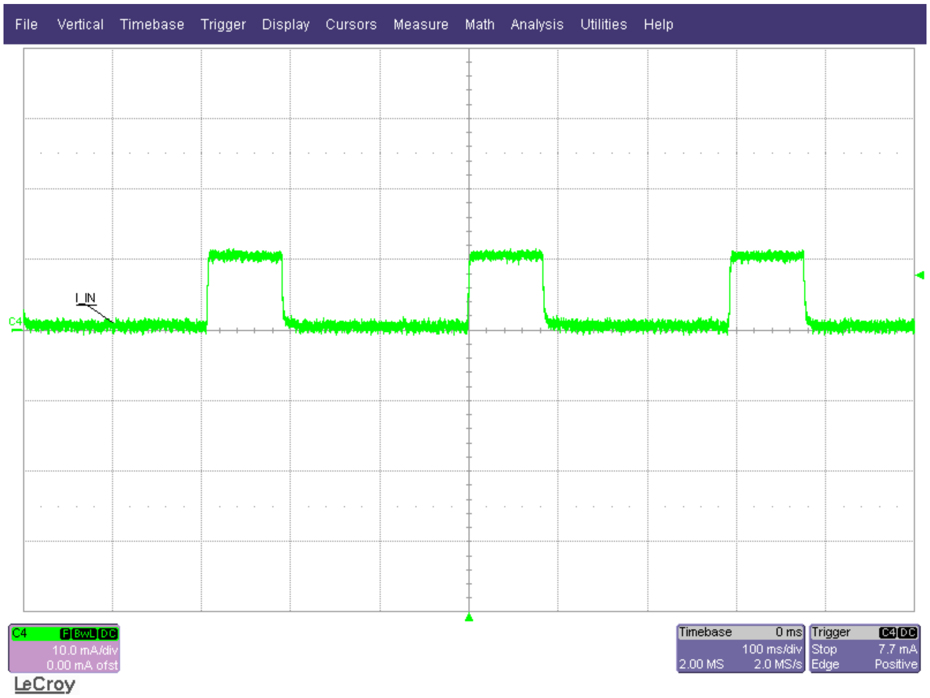

Figure 8. Input Current in Sleep Mode with MODE Low (I_{LED} = 0 mA)

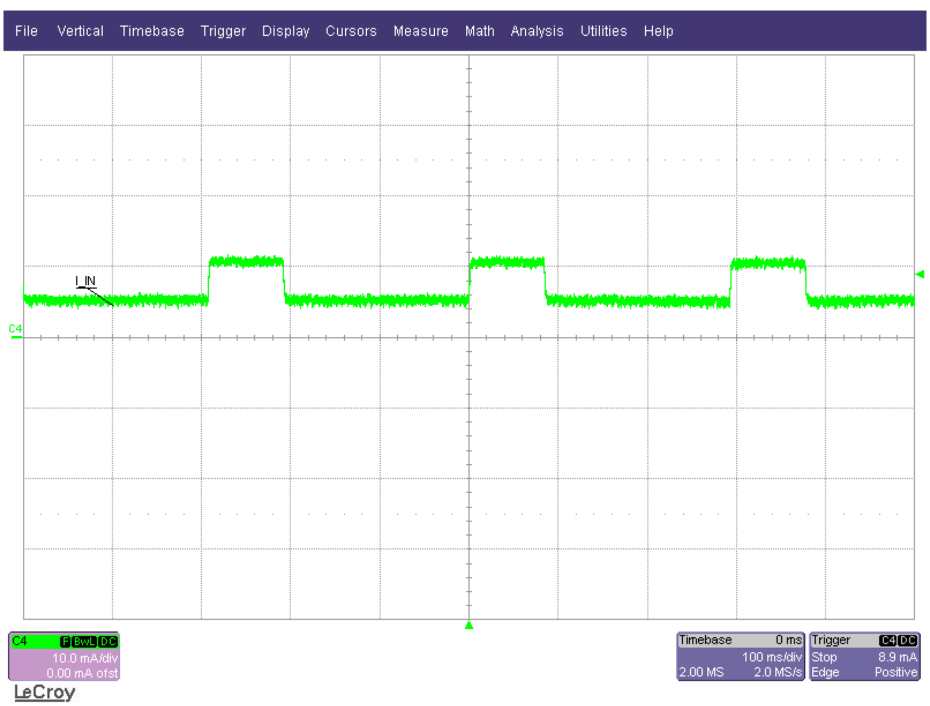

Figure 9. Input Current in Sleep Mode with MODE Low (I_{LED} = 4 mA)

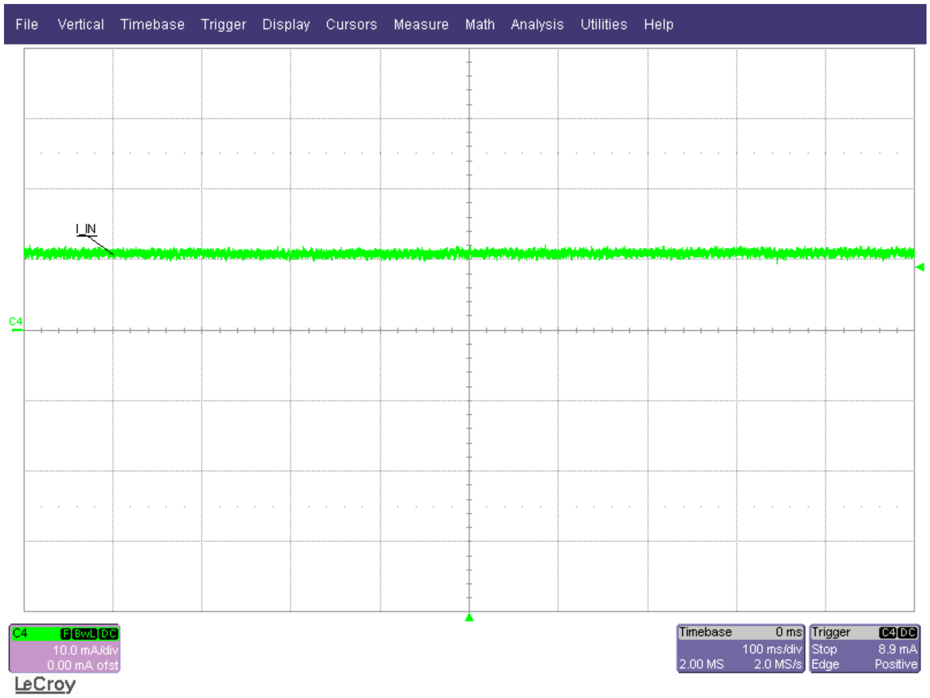

Figure 10. Input Current in Sleep Mode with MODE High

Figure 8, 9, and 10 show the MPS current of the PD when in Sleep Mode with the MODE pin low and high when entering Sleep Mode. When entering Sleep Mode with the MODE pin low, a valid MPS of 10.6 mA pulsed current for about 84 ms every 292 ms is enabled, as shown in Figure 8 and 9, with different LED currents set to 0 mA and 4 mA. With the MODE pin high when entering Sleep Mode, an MPS consisting of a 10.6 mA DC current is enabled, as shown in Figure 10.

3.3 Exiting Sleep Mode

Exit the Sleep Mode test by depressing S1 when the TPS23752 is in Sleep Mode thus restarting the DC/DC converter.

Figure 11 and 12, respectively, show exiting Sleep Mode with the MODE pin low and high when entering Sleep Mode. Pressing wakeup button S1 causes the TPS23752 to exit Sleep Mode. The input current rises back to 60 mA. The MODE pin voltage turns to low in Figure 11 because of output voltage established, but remains high in Figure 12. The reason the WAKE pin voltage drops a little from 2.5 V and then rises to 5 V is because when S1 is still pressed, the WAKE pin connects back to the internal 5.33-kΩ pull-up resistor, R_{WKPLUP}, the voltage on WAKE pin is determined by all the connections to the pin. After S1 is disconnected, the WAKE pin voltage rises to about 5 V near to V_B.

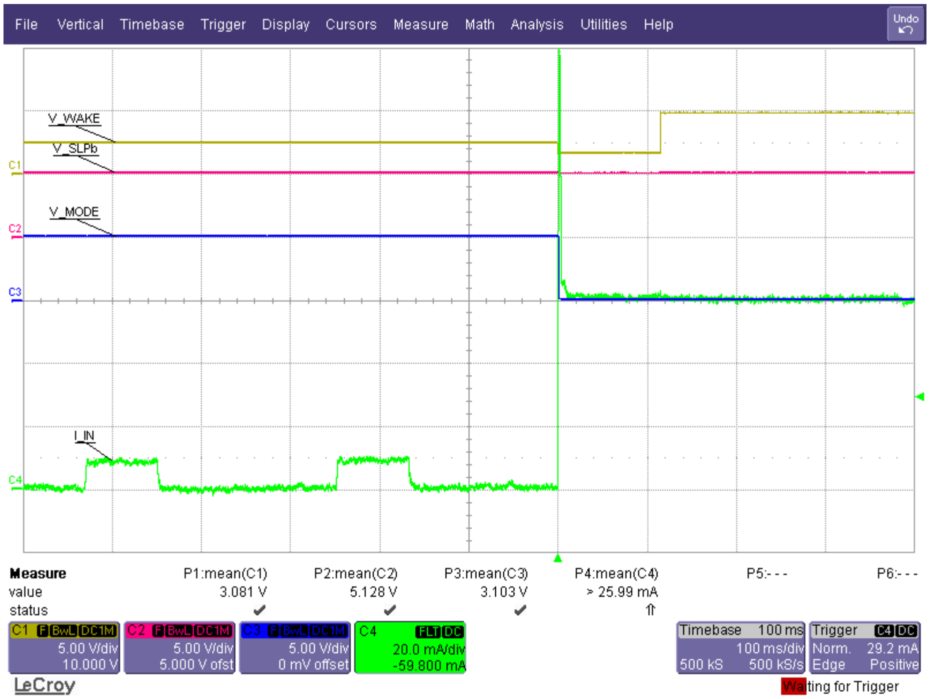

Figure 11. Exiting Sleep Mode with MODE Low and SLPb High

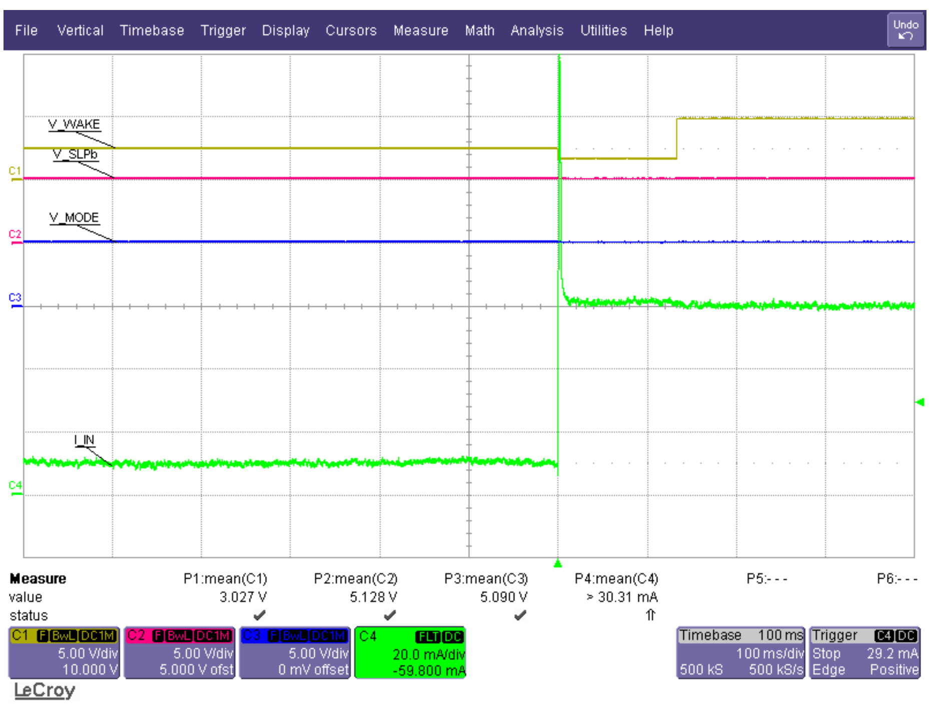

Figure 12. Exiting Sleep Mode with MODE High and SLPb High

3.4 Maximum LED Current Measurement

For some applications, more LED current is drawn from Vc in order to have the highest LED brightness possible, while meeting the 0.5-W Energy Star standard when in Sleep Mode. Connect 3 LEDs in series to the V_C pin as shown in Figure 3. Table 3 shows the test result for the average input current and input power consumption with different R_{LED}. Figure 13 shows the pulsed MPS current of the PD when in Sleep Mode with 9.081 mA LED current (R_{LED} = 365 Ω).

Table 3. Maximum LED Current Measurement Result

V_{IN} (V)	I_{IN_avg} (mA)	P_{IN} (W)	V_{LED} (V) [1]	R_{LED} (Ω)	I_{LED} (mA)
57	8.654	0.493	8.649	511	7.061
48	8.607	0.413	8.633	511	7.053
48	9.802	0.471	8.727	383	8.768
48	10.103	0.485	8.752	365	9.081
48	10.420	0.500	8.765	332	9.681

Note 1: LED part number: Everlight 23-21C/T1D-CP2Q2TY/2A. V_{LED} is the forward voltage of 3 LEDs in series.

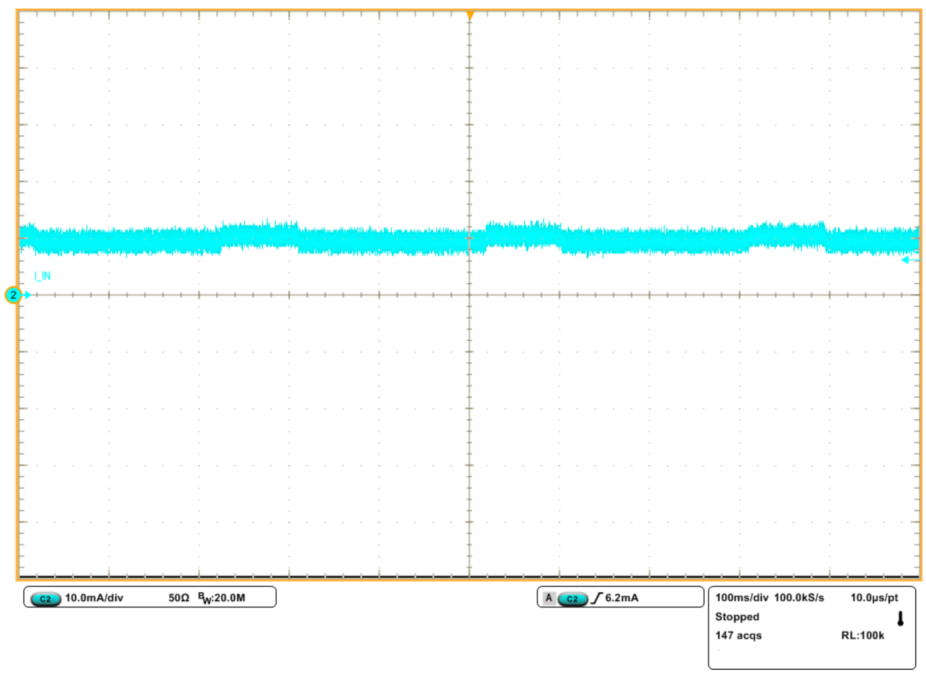

Figure 13. Input Current in Sleep Mode with MODE Low (I_{LED} = 9.081 mA)

4 Conclusion

The Maintain Power Signature when the TPS23752 enters Sleep Mode is valid and consists of a DC current of 10.6 mA or a 10.6-mA pulsed current according to the MODE pin select. The PD assures the PSE that it is still present after entering Sleep Mode according to IEEE 802.3at standard.

5 References

1. TPS23751/2: *IEEE 802.3at PoE Interface with Wide Range High Efficiency DC-DC Controller* (Rev. A). Texas Instruments Datasheet, SLVSB97A, July 2012, Revised August 2012.
2. *TPS23752EVM-145: Evaluation Module for TPS23752*. Texas Instruments User's Guide, SLVU753, July 2012.

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