Design Guide: TIDA-00556
Ship Mode for Wearables

Description

Ship Mode is a low power state that prolongs battery life during the shipment stage of a product. This design showcases a space saving *Ship Mode* that features a simple, low cost load switch solution. This solution is targeted specifically for wearables and other small portable electronics.

Resources

TIDA-00556	Design Folder
TPS22916B	Product Folder

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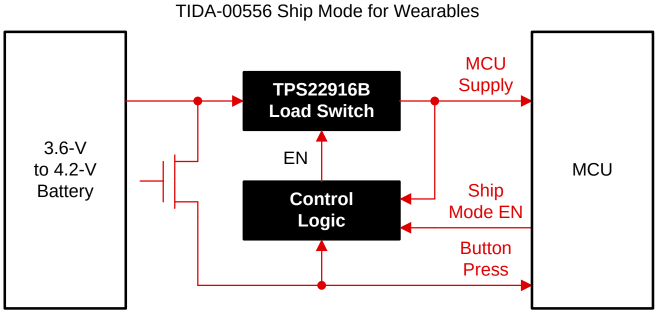
Features

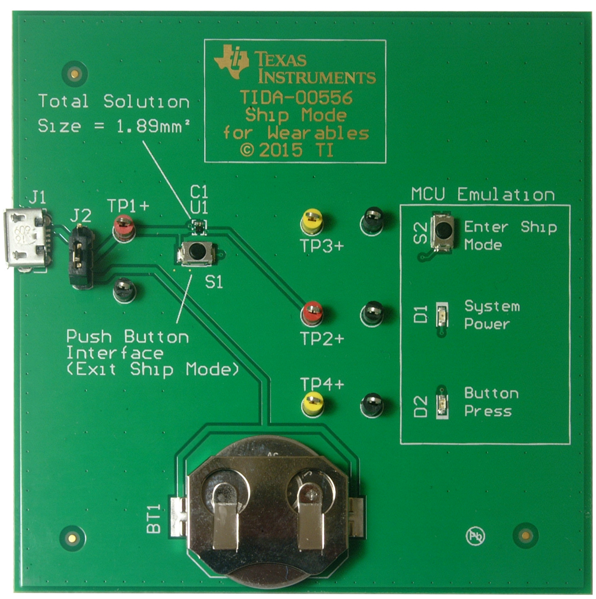
- Small solution size of 1.89 mm^2 fits easily into any design
- 10-nA shutdown current during low-power state extends shelf life for a seamless out-of-box experience
- Component count of 4 keeps BOM costs low and enables scalability across multiple platforms

Applications

- Wearables (non-medical)
- Portable electronics

TIDA-00556 Ship Mode for Wearables





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1 System Description

As the presence of global manufacturing and distribution increases, many original equipment manufacturers are looking for creative ways to extend battery life during shipping and while on-the-shelf at big-box warehouses. Keeping the battery sufficiently charged during shipment enables a consistent *out-of-box* experience for the end user. A solution that has gained popularity is the use of a *ship mode* feature that helps keep devices in a low-power state during shipment and while on-the-shelf.

The purpose of this design is to prolong battery life during shipment of wearable electronics and to provide customers with a consistent *out-of-box* experience. Load switches offer many advantages compared to a discrete solution using field-effect transistors (FETs). Load switches offer controlled turnon, limiting the damaging effects of inrush current. Load switches also have low leakage current when disabled and draw minimal power when enabled, improving battery life in portable applications. Load switches are cost-and size-optimized to replace discrete solutions where channel density and space is critical. Many load switches offer a Quick Output Discharge (QOD) feature that dissipates any residual energy on the output after the switch is disabled. Other load switches offer reverse current protection to protect upstream circuitry in the case that the supply potential dips. Learn more about load switches on TI.com.

1.1 *TPS22916B*

The TPS22916 device is a 5.5-V, 2-A load switch in a 4-pin CSP package. To reduce voltage drop for low-voltage and high-current rails, the device implements a 60-mΩ resistance P-channel MOSFET, reducing the dropout voltage through the device. The device has a fixed slew rate that may reduce or eliminate power supply droop due to large inrush currents. During shutdown, the TPS22916 has low leakage currents, that reduce unnecessary leakages for downstream modules during standby. Integrated control logic, driver, reverse current blocking, and output discharge FET eliminate the requirement for any external components, reducing solution size and bill of materials (BOM) count. Figure 1 shows the TPS22916B block diagram.

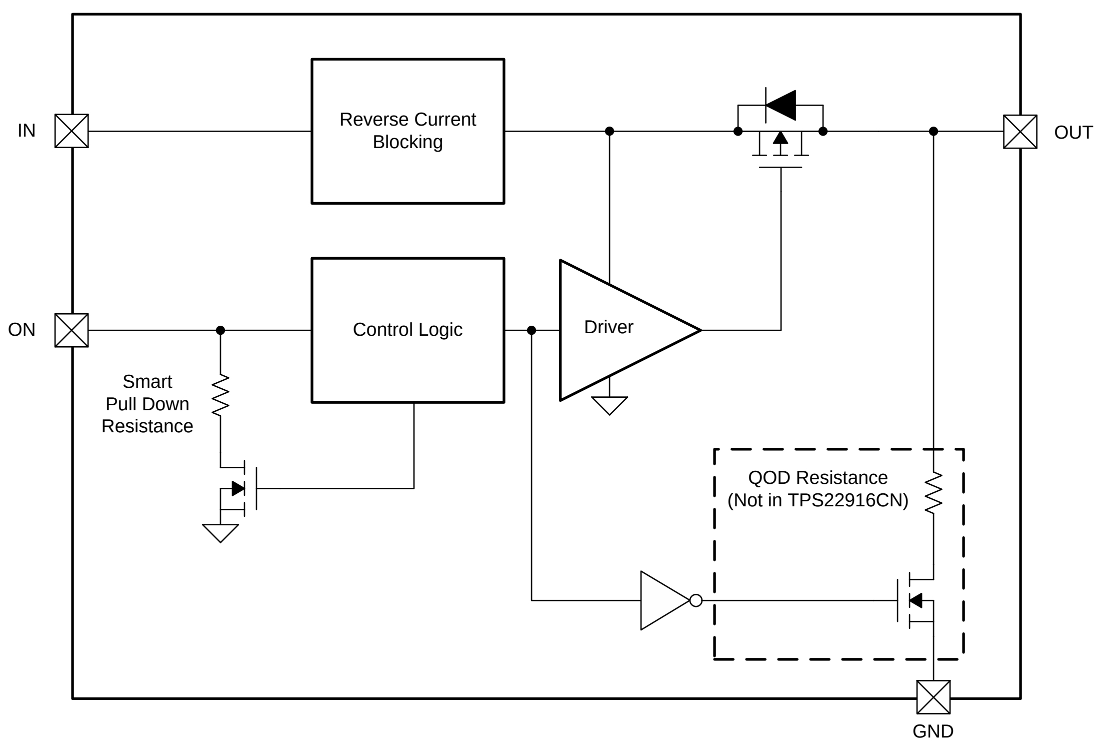

Figure 1. TPS22916B Block Diagram

2 Key System Specifications

Table 1 lists the system electrical specifications.

Table 1. System Electrical Specifications

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNIT
V_{IN}	Input voltage		1		5.5	V
I_{OUT}	Output current				2	A
T_A	Free air temperature range		–40		85	°C
I_{SD}	System leakage current	V_{ON} = 0 V		10	100	nA
I_Q	System quiescent current	V_{IN} = 1 - 5.5 V		.5	1	µA
$t_{ON(90\%)}$	System turnon time (90% of V_{OUT})	V_{IN} = 5.0 V		115		µs
		V_{IN} = 3.6 V		140		µs

3 Block Diagram

The ship mode TI Design emulates the connection between the battery and system in a typical wearable application. The voltage from the battery passes through the TPS22916B load switch when the push-button is pressed. The load switch is latched on even after the button is released. Further button presses are registered by the rest of the system. The microcontroller block uses hardware to emulate GPIO signals, which come from a microcontroller. The microcontroller puts the TPS22916B into ship mode by emulating a GPIO signal to disable the control logic of the ship mode circuit. Figure 2 shows the block diagram of the TPS22916B.

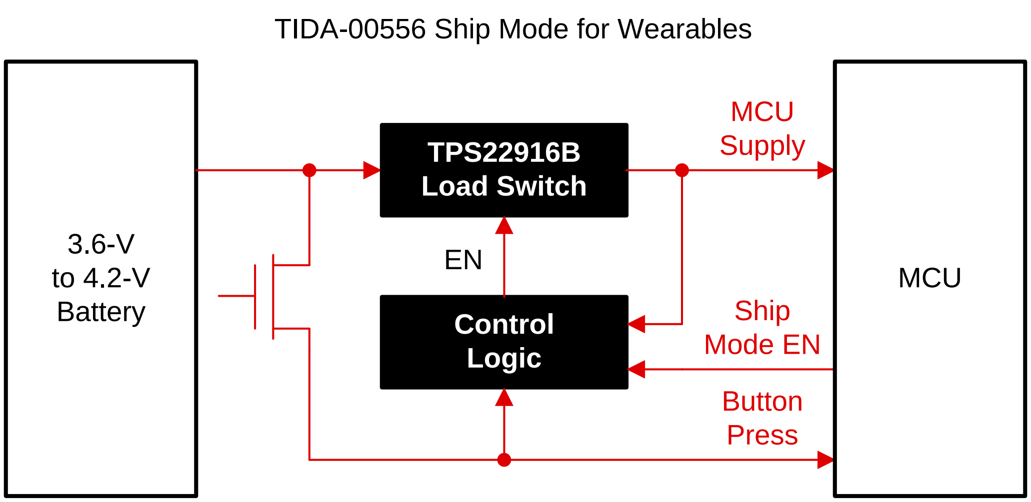

Figure 2. Block Diagram of the TPS22916B

4 System Design Theory

This TI Design focuses on the ship mode application used primarily by wearables customers. When considering their system, observe the following:

- Wearables are getting smaller and a minimal solution size is key. CSP devices are typically used for these space constrained products.
- To extend battery life, devices with low leakage current and active power consumption.
- A low BOM count keeps the wearable product at a low price.
- The system must withstand a battery voltage of at least 4.35 V and stay on even when the voltage discharges to a lower value.

Figure 3 shows the ship mode diagram.

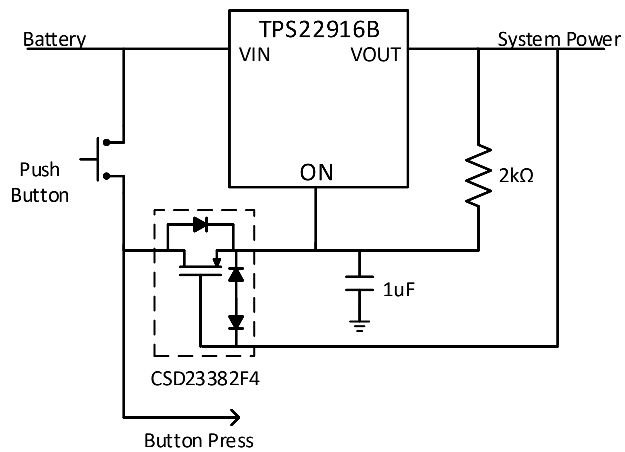

Figure 3. Ship Mode Diagram

TI chose the TPS22916B because it requires three additional discrete components, which keeps the BOM count low while still maintaining a small solution size. This load switch has a low shutdown current (10 nA typical) to prolong battery life during shipment. The TPS22916B can operate from battery voltages from 1 V and 5.5 V. The 0.74-mm × 0.74-mm CSP package requires a small footprint to implement. The CSD23382F4 transistor features a footprint of 0.6 mm × 1.00 mm, and helps to minimize the total solution size. The resistors and capacitors chosen are 0201 components, making the total solution size 1.89 mm^2.

4.1 Exit Ship Mode

Pressing the *Exit Ship Mode* button exits ship mode. The voltage from the battery is passed through the PMOS to the ON pin of the TPS22916B. The voltage enables the TPS22916B, brings V_{OUT} high, turns off the PMOS, and activates the *System Power* LED. The ON pin is pulled up to V_{OUT}, which keeps the load switch enabled even after the button is released. Further button presses may be registered by the rest of the system and cause the *Button Press* LED to illuminate. Figure 4 shows the exit ship mode schematic.

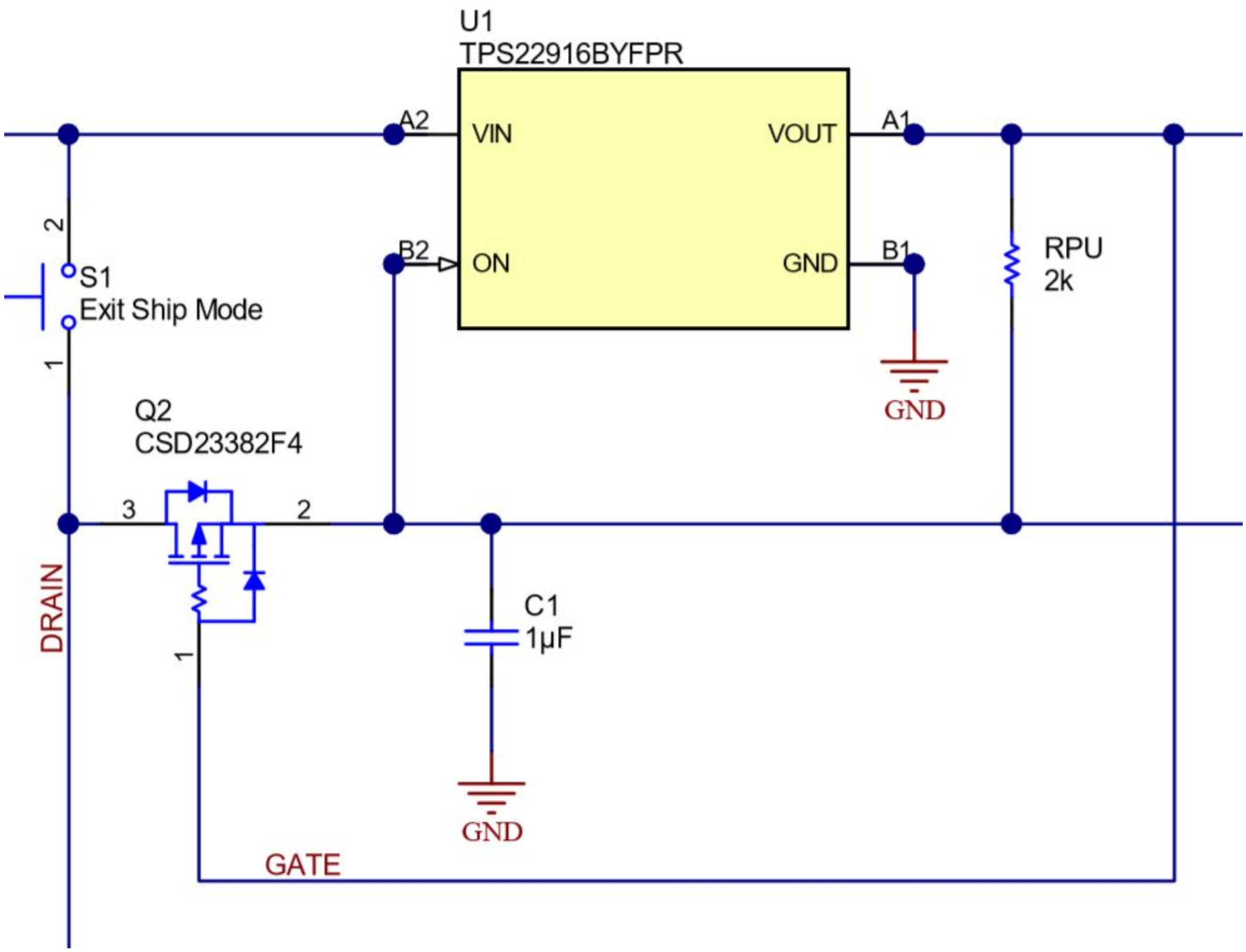

Figure 4. Exit Ship Mode Schematic

4.2 Enter Ship Mode

Pressing the *Enter Ship Mode* button enters ship mode and emulates a GPIO from the microcontroller, pulling the ON pin low. With the ON pin low, the TPS22916B shuts down and disables power to the rest of the system. Figure 5 shows the enter ship mode schematic.

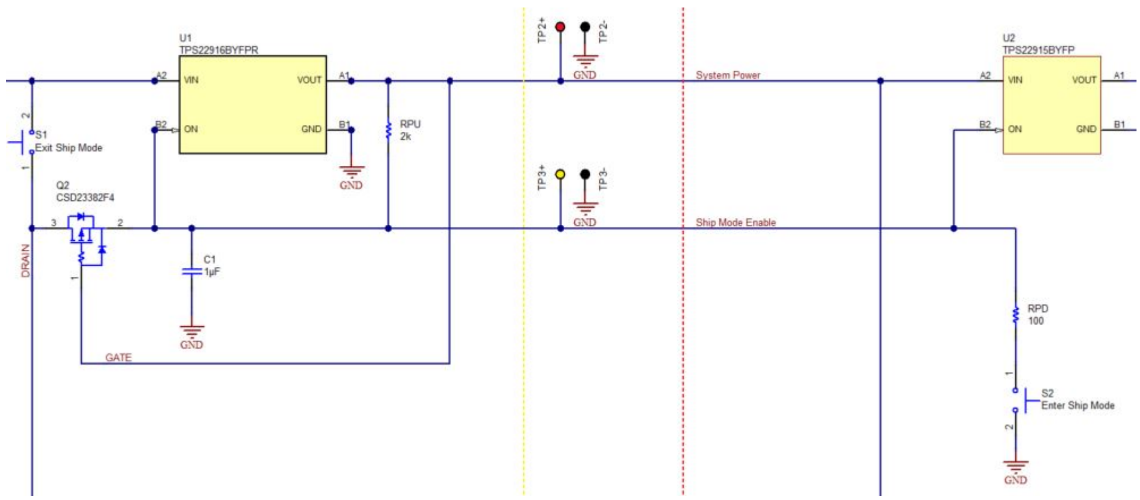

Figure 5. Enter Ship Mode Schematic

4.3 Button Press

The *Exit Ship Mode* button may be used as an input to the system after exiting ship mode. Pressing the button causes the *Button Press* light to activate, indicating that the system detects the button press.

For use as a microcontroller GPIO, the button press signal may be regulated to a lower voltage. This is the case if the battery voltage is higher than the GPIO voltage tolerance. Figure 6 shows two potential solutions.

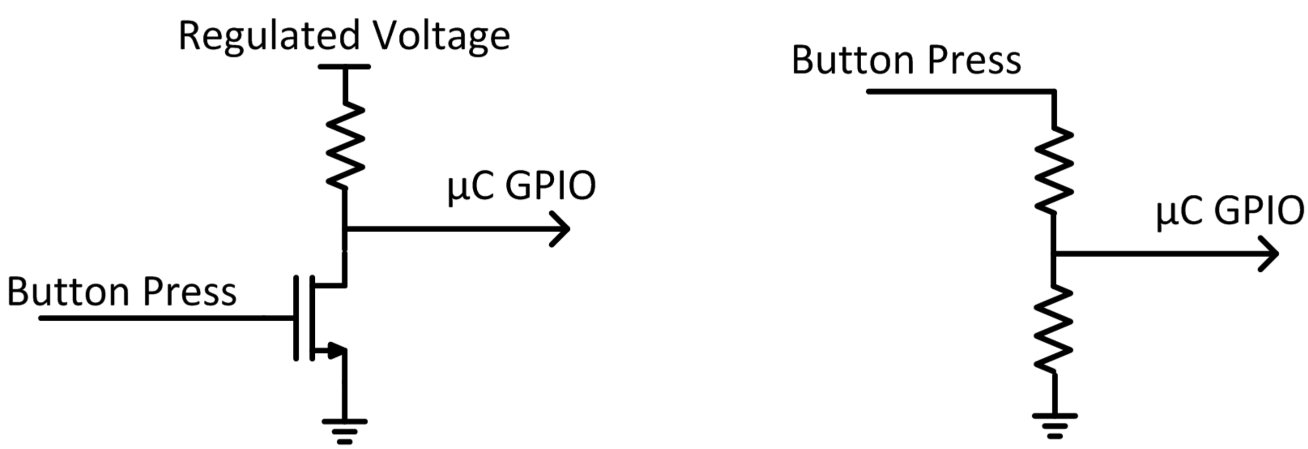

Figure 6. Regulating the Button Press Signal for a GPIO Input

The first solution pulls the GPIO to a regulated voltage in the system, whereas the second solution uses a resistor divider to lower the button press voltage. TI recommends including a series resistance to limit current into the GPIO pin before the microcontroller is powered.

4.4 Using a Rechargeable Battery

If using a rechargeable battery and battery charging IC, place the ship mode circuit between the battery and IC, as shown in Figure 7.

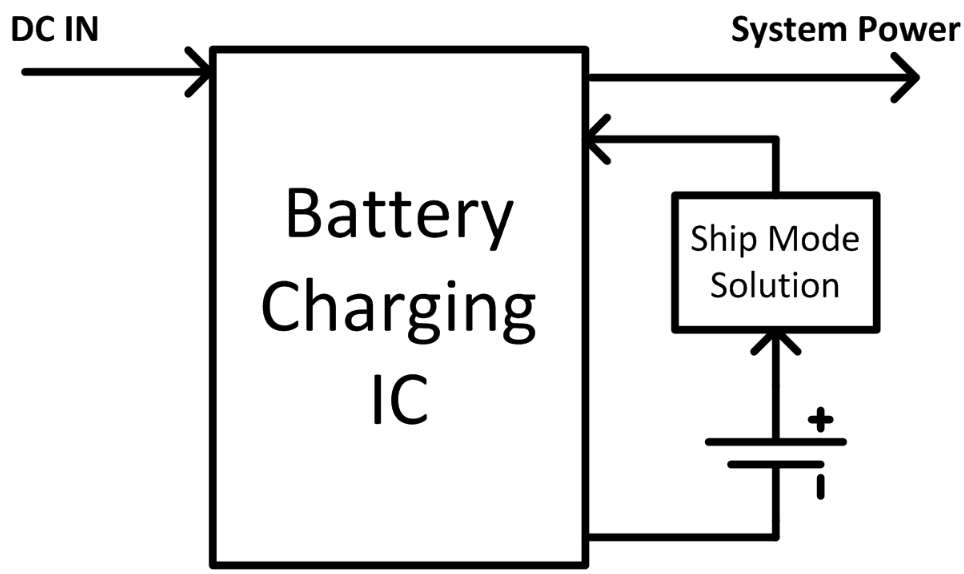

Figure 7. Ship Mode Implementation With a Rechargeable Battery IC

5 Getting Started Hardware

The following sections detail how to set up the system and the results of basic functional testing.

5.1 Operation from USB

Step 1. Connect one end of the USB cable to a computer (or powered USB port).
Step 2. Connect the other end of the USB cable to the micro USB connector on the board (J1).
Step 3. Press the *Exit Ship Mode* button.
Step 4. Verify the system power and button GPIO LEDs activate.
Step 5. Press and release the *Exit Ship Mode* button.
Step 6. Verify the Button GPIO LED activates and deactivates with each press.
Step 7. Press the *Enter Ship Mode* button.
Step 8. Verify the system power and button GPIO LEDs deactivate.

Figure 8 shows the ship mode circuit powered using a USB cable.

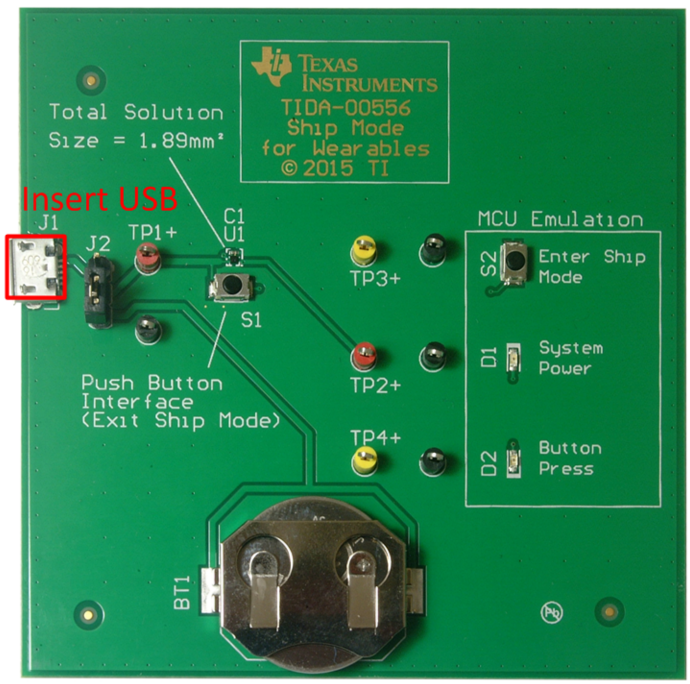

Figure 8. Ship Mode Circuit Powered Using a USB Cable

5.2 Operation from Battery

The system can be powered from a standard CR2025 or CR2032 lithium coin cell battery. Use the following as an alternative to Step 1, then follow Steps 2 through 4 from Section 5.1.

Figure 9 shows the ship mode circuit powered using a battery.

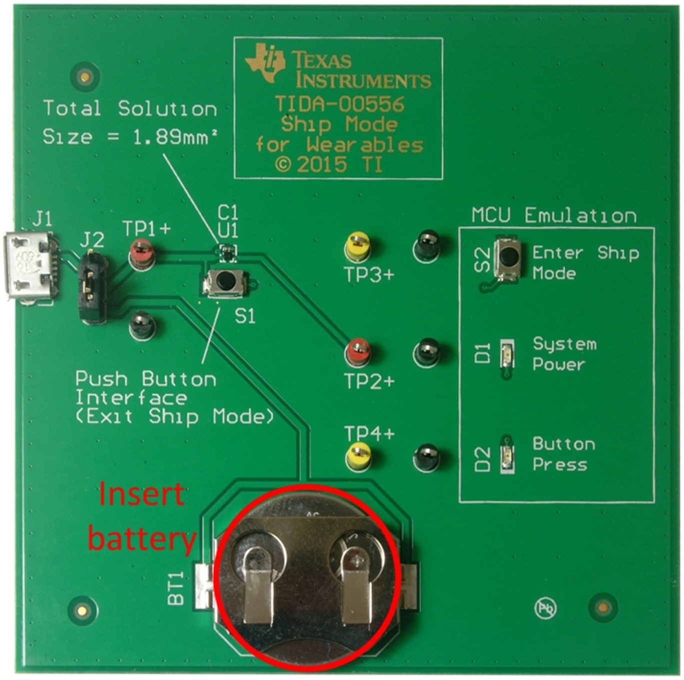

Figure 9. Ship Mode Circuit Powered Using a Battery

Make sure to place the coin cell in the battery holder BT1 with the positive (+) terminal facing away from the board.

6 Test Setup

6.1 Shutdown Current

To measure shutdown current, the system is connected as shown in Figure 9.

The system is put into ship mode, the input voltage from the sourcemeter (SMU) is varied, and the shutdown current is logged at each voltage.

Figure 10 shows the configuration for shutdown current measurements.

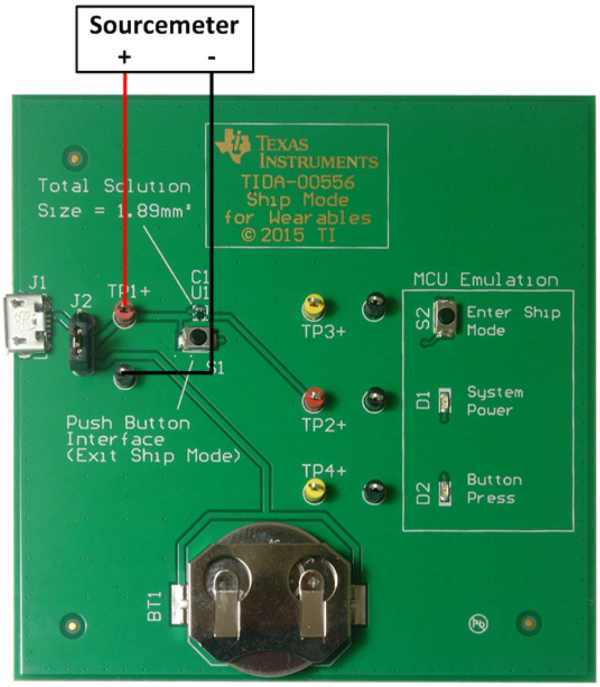

Figure 10. Configuration for Shutdown Current Measurements

6.2 Enter Ship Mode

Figure 15 shows the system power and control signals while entering ship mode. The device is operating normally, and the *Enter Ship Mode* button is pressed. Figure 11 shows the configuration for entering ship mode.

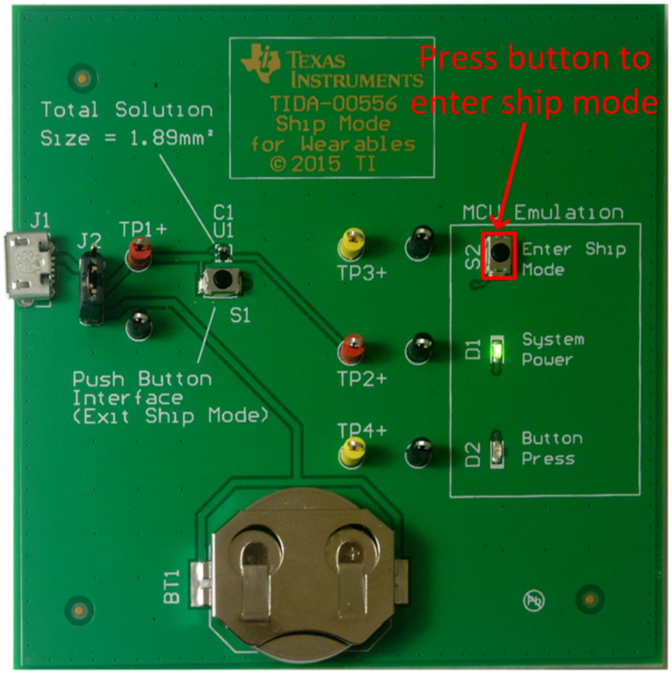

Figure 11. Configuration for Entering Ship Mode

6.3 Exit Ship Mode

Figure 12 shows the system connected in exit ship mode to observe the system power and control signals while exiting ship mode. The device is in ship mode, and the *Exit Ship Mode* button is pressed.

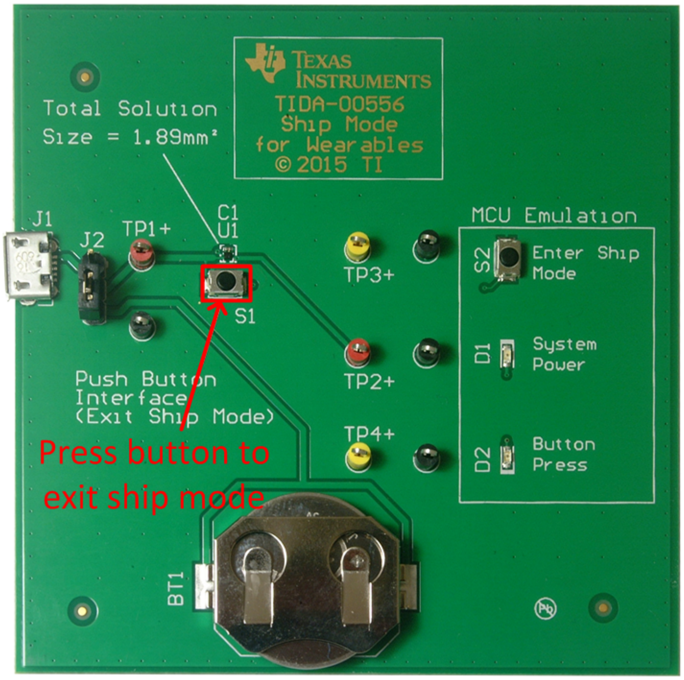

Figure 12. Configuration for Exiting Ship Mode

6.4 Quiescent Current Testing

To measure the quiescent current draw, a source meter was used to power the circuit and the system was kept in the exit ship mode state. Disconnect the load from the solution to get accurate measurements of the device itself. The source meter voltage was swept, and the current supplied was recorded for each voltage.

Figure 13 shows the configuration for quiescent current measurements.

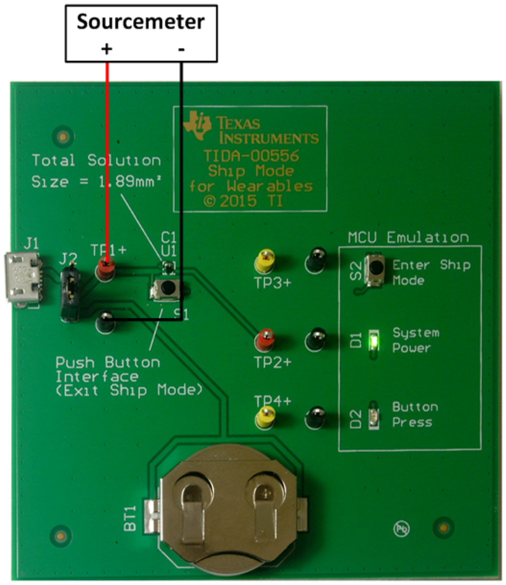

Figure 13. Configuration for Quiescent Current Measurements

7 Test Data

7.1 Shutdown Current

Table 2 lists the ship mode shutdown current data acquired through testing. For typical and max shutdown current values refer to the data sheet.

Table 2. Ship Mode Shutdown Current Data

INPUT VOLTAGE (V)	SHUTDOWN CURRENT (nA)
5.5	5.1
5	3.3
4.35	2.45
4.2	2.2
3.3	1.85
2.5	1.45
1.8	1.35
1.2	1.2
1	1.2

Figure 14 shows the shutdown current plot.

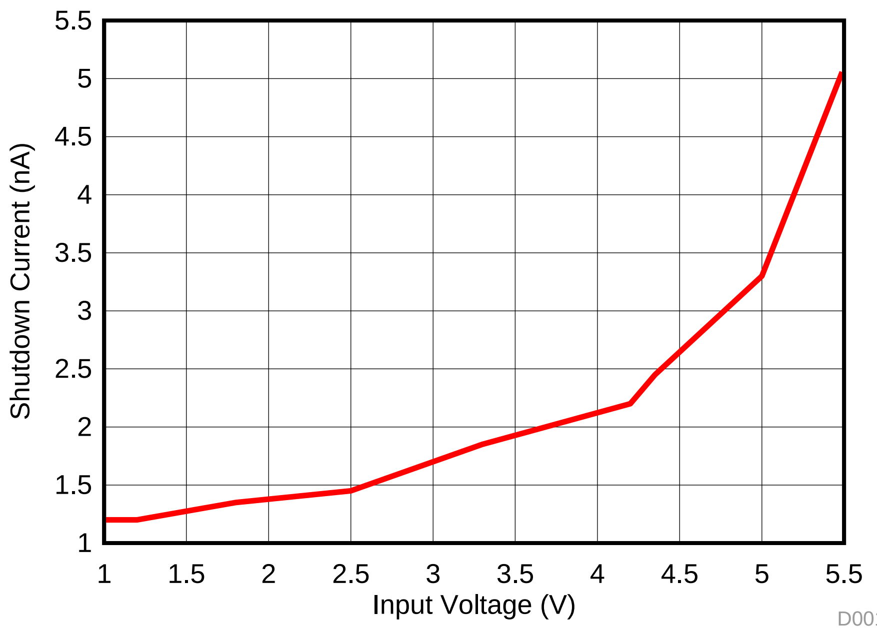

Figure 14. Shutdown Current Across Input Voltage

7.2 Enter Ship Mode

System Power, measured at test point 2, is the output signal of the load switch.

On, measured at test point 3, is the voltage at the ON pin of the load switch.

Button Press, measured at test point 4, toggles when the *Exit Ship Mode Button* is pressed.

Figure 15 shows the scope capture of the system entering ship mode as described in Section 4.2.

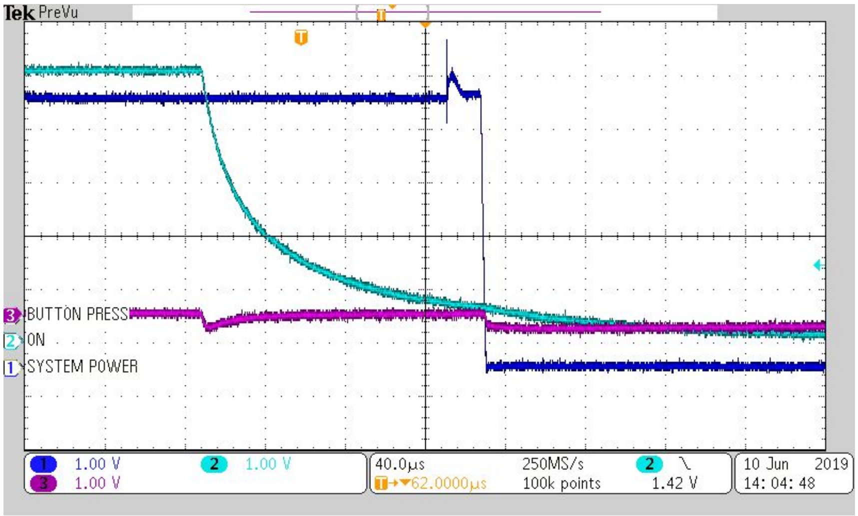

Figure 15. Scope Capture of the System Entering Ship Mode

7.3 Exit Ship Mode

To replicate the load switch functionality in a circuit the LED load was replaced with a resistive load.

Figure 16 shows the scope capture of the system exiting ship mode as described in Section 4.1.

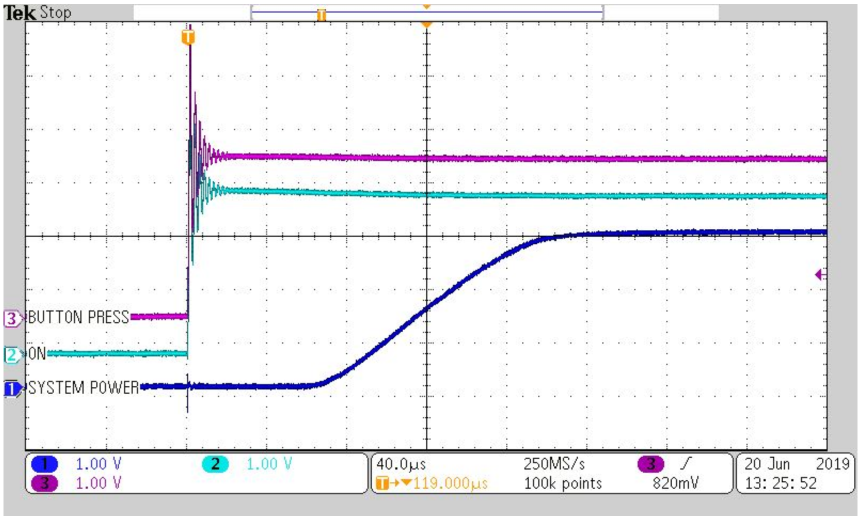

Figure 16. Scope Capture of the System Exiting Ship Mode

7.4 Quiescent Current Testing

Table 3 lists the ship mode quiescent current data, and Figure 17 shows the plot of quiescent current across input voltage which will not exceed 1µA.

Table 3. Ship Mode Quiescent Current Data

INPUT VOLTAGE (V)	QUIESCENT CURRENT (µA)
5.5	.876
5	.593
4.35	.535
4.2	.525
3.3	.476
2.5	.439
1.8	.581
1.2	.467
1	.433

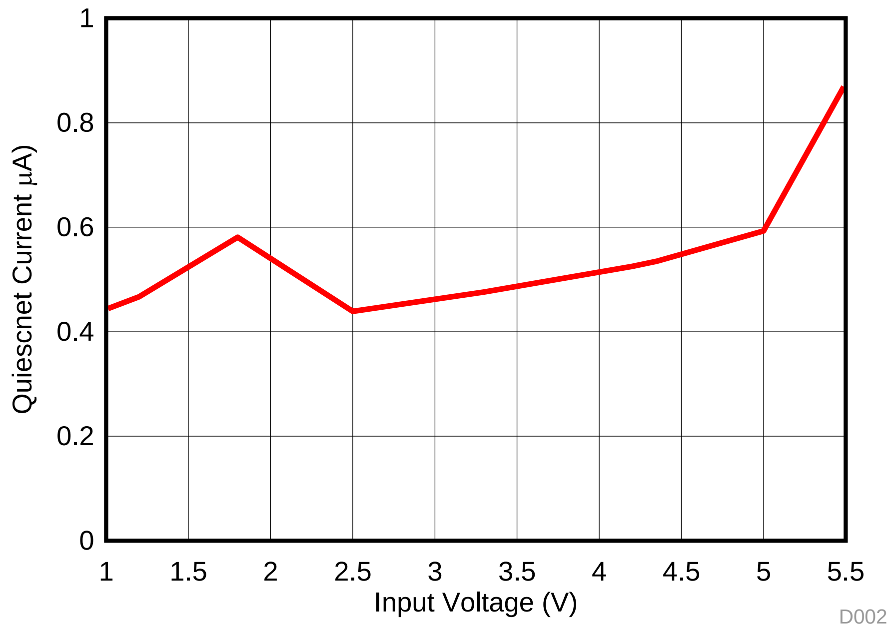

Figure 17. Quiescent Current Across Input Voltage

8 Design Files

8.1 Schematics

To download the schematic, see the design files at TIDA-00556. Figure 18 shows the ship mode schematic.

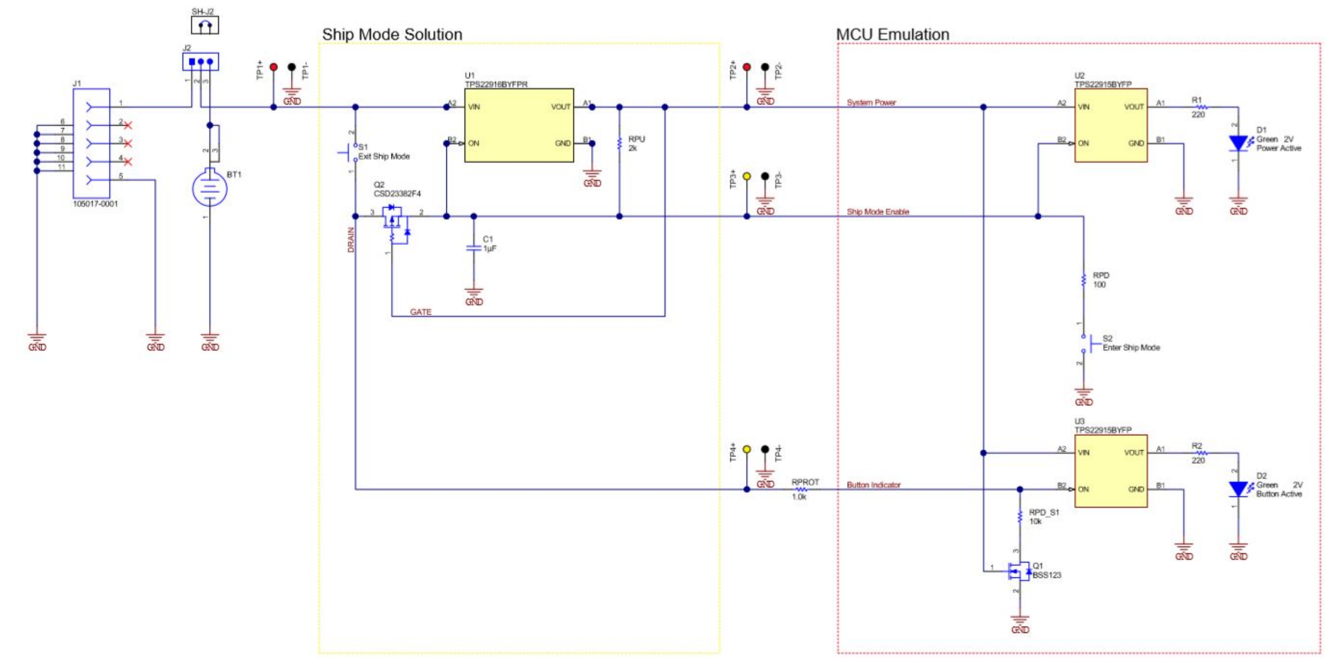

Figure 18. Ship Mode Schematic

8.2 Bill of Materials

To download the BOM, see the design files at TIDA-00556.

8.3 PCB Layout Recommendations

- Ensure input and output voltage traces load switches are as wide as possible to minimize series resistance and inductance for high-current applications.
- Place bypass capacitors as close to the device pins as possible.

9 References

- Texas Instruments, *Basics of Load Switches*
- Texas Instruments, *TPS22916xx, 1-V - 5.5-V, 2-A, 60-mΩ Ultra-Low Leakage Load Switch*

9.1 Trademarks

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10 Terminology

Ship Mode— A low-power state to prolong battery life during shipment.

11 About the Authors

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Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (November 2015) to A Revision	Page
• The TPS22916B device replaces the TPS22915B device in this version of the TIDA-00556 reference design.	1
• Replaced the TPS22915B device with the TPS22916B device in *Section 1.1*, *TPS22916B*.	2
• Updated entire *Test Data* section.	14