*Application Note*

# *How to Implement Ship Mode for Battery Powered End Equipment*

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**ABSTRACT**

This application note presents a ship mode implementation that can fully connect or disconnect the battery from any TI battery charger and its system load. The operating principles of the circuit, discussion of key MOSFET selection criteria, and demonstration of how the design can be implemented with either internal, external or no battery FET architectures are discussed.

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## Trademarks

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# 1 Introduction

Ship mode, sometimes referred to as transportation mode, is a setting that is used in many electronic devices, specifically during transportation, storage and for extended periods of inactivity. The objective of ship mode is to minimize battery drain and prevent damage to the battery while in the idle state. To achieve this, the battery must be electrically disconnected from the battery charger and system load. This process minimizes quiescent current into the battery charger and to downstream circuitry, thereby, preserving battery capacity until the device is ready for use.

# 2 Detailed Description

## 2.1 Circuit Operation

The block diagram shown in Figure 2-1 demonstrates the ship mode implementation.

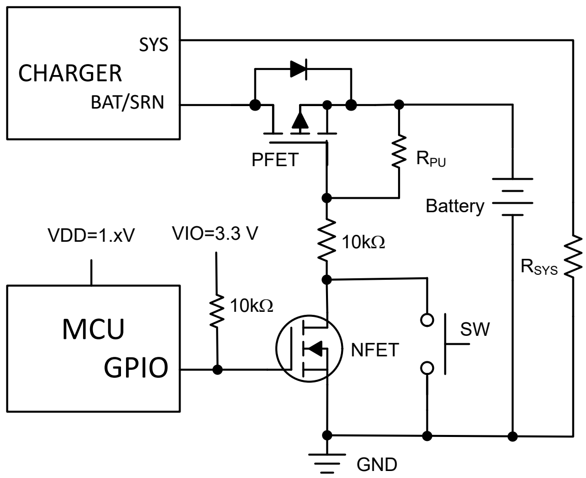


**Figure 2-1. Block Diagram of Discrete Ship Mode Circuit**

This circuit uses a low $R_{DS(ON)}$ P-channel MOSFET (PFET) as well as a low-cost N-channel MOSFET (NFET) connected to a micro-controller's or processor's (MCU) General-Purpose Input/Output (GPIO), to control the gate voltage of the PFET. The MCU in the diagram is assumed to have an open drain GPIO that needs a 3.3V pull up voltage. Power for the MCU's VDD and GPIO pins is provided by low-quiescent linear regulators (e.g.TPS7A02) that are directly connected to the battery.

The PFET serves as the main battery disconnect switch. When the PFET is on, current flows from the battery to the charger's BAT or SRN pin and system load, allowing the device to operate normally. At this point, the device is not in ship mode. When PFET is off, the battery is electrically isolated from the battery charger and system, enabling the device to enter ship mode. The GPIO pin cannot connect directly to the PFET gate pin to prevent the GPIO from seeing the full battery voltage. So, a low cost NFET (e.g. 2N7002) is needed to provide a level (and logic) shift. The GPIO controls the NFET's gate-to-source voltage ($V_{GS}$). When the NFET's gate pin voltage is pulled to GND by the GPIO pin, the PFET's gate pin is pulled to ground, turning the PFET on. By pulling the PFET gate low, current flows from the battery to the charger and system. The NFET turns off when the gate voltage is pulled up to the 3.3V rail. The PFET's gate pin voltage is pulled up to the battery voltage, the same voltage at the PFET source pin, which disconnects the battery from the charger and system, thereby, placing the end equipment into ship mode. The purpose of the 10k resistor between the NFET drain pin and PFET gate pin is to slow down the PFET turn on, which reduces voltage ringing at the charger's BAT or SRN pin. An optional mechanical switch can be used instead of or in addition to a GPIO controlled NFET system.

Because the ship mode circuit is placed between the battery and the battery charger IC, the device can be used with battery chargers that employ either an internal or external BATFET (i.e. NVDC chargers) or have no BATFET.

## 2.2 MOSFET Selection Considerations

Selecting the proper MOSFET is critical for reliable ship mode operation, minimal battery leakage and protection. The MOSFET must be chosen based on the system voltage, load current, gate-drive voltage, on-resistance, leakage current and thermal requirements. The key considerations for the PFET are listed below:

1. drain-to-source voltage, $V_{DS}$, rating higher than the maximum battery voltage.
2. continuous drain current $I_{DS}$ rating greater than the maximum charge current plus maximum system load current
3. low resistance, $R_{DS(ON)}$, less than the that of charger's BATFET, if present, for minimal effect on charging efficiency (typically less than 20mohm)
4. low $I_{GSS}$ (gate leakage current) so that the voltage drop across the high value pullup resistor ($R_{PU}$) created by the $I_{GSS} \times R_{PU}$ is less than the PFET's turn on voltage, $V_{GS-TH}$

If the PFET has low $I_{GSS}$, $R_{PU}$ can then be sized in the mega-Ω range to minimize battery discharge current. With the NFET's 10kΩ drain resistor to minimize voltage ringing at PFET turn on, $R_{PU}$ must also be sized high enough so that the voltage divider created by the 10kΩ and $R_{PU}$ sets the PFET gate voltage well below the battery voltage less the PFET's $V_{GS-TH}$.

## 2.3 Test Results

The waveform in Figure 2Figure 2-2 shows the system entering and exiting ship mode.

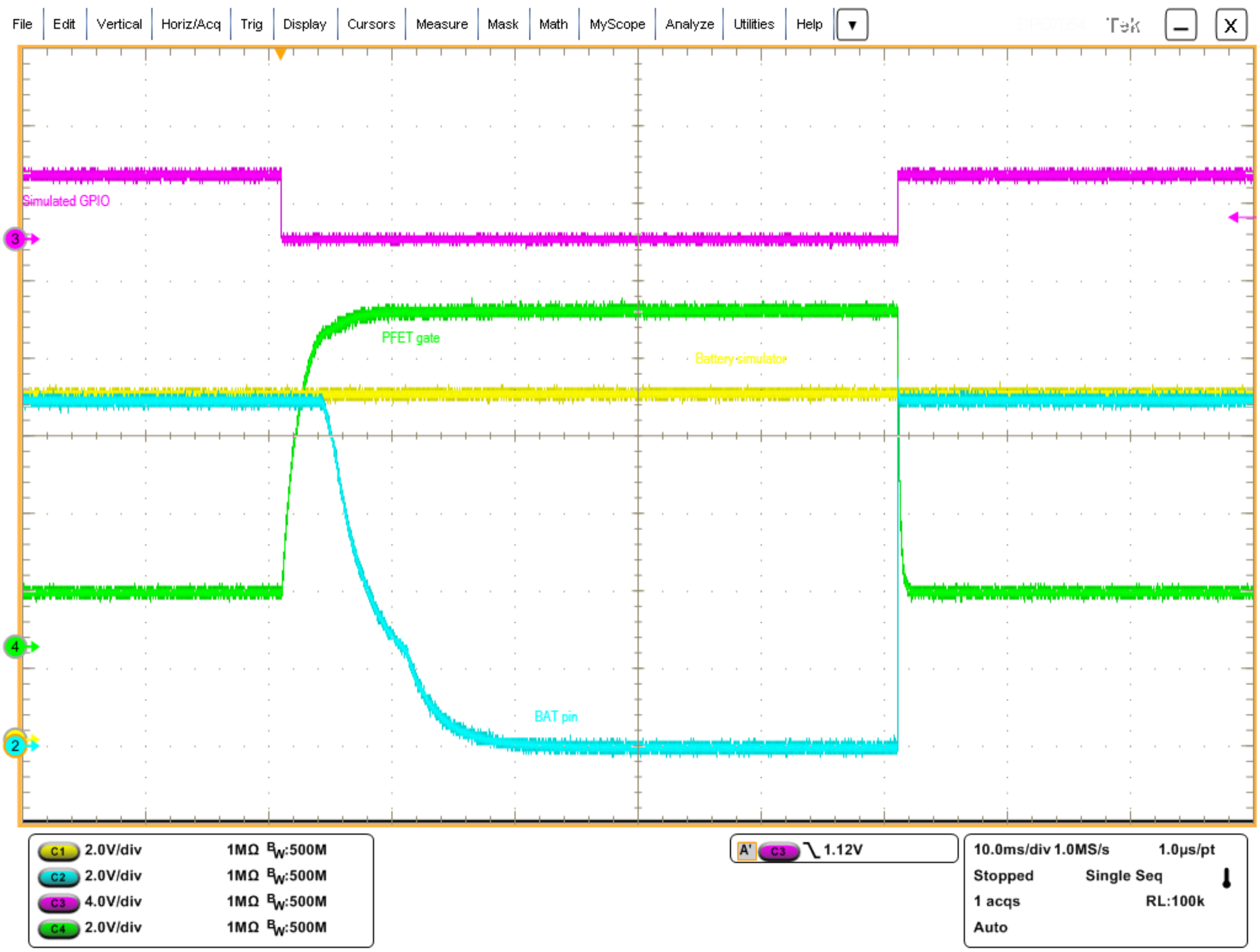


**Figure 2-2. PFET Entering and Exiting Ship Mode**

The PFET was TI's CSD25404Q3. $R_{PU}$ was 5MΩ and $R_{SYS}$ was 500Ω. Channel 1 (Yellow) shows simulated battery output voltage. Channel 2 (Blue) shows the voltage that BQ25790EVM BAT pin. Channel 3 (Pink) shows the simulated MCU's GPIO from a function generator. Channel 4 (Green) shows the PFET gate voltage. From the image we can observe that as the simulated GPIO output drops to 0V, the PFET gate voltage is pulled up, activating ship mode. We can confirm this by looking at channel 2, observing how the BQ25790 BAT pin voltage drops as the PFET gate rises. Lastly, as the GPIO rises back up to the original state, we observe that the PFET turns back on, reconnecting the simulated battery to the charger BAT pin.

## 3 Summary

This application note provides a ship mode design that electrically isolates the battery from the battery charger and system load to preserve battery capacity during storage and transportation. This design is preferred for a system with an internal, external, or even no BATFET. Lastly, careful selection to the specific P-channel MOSFET is critical because it directly impacts performance, efficiency, and reliability of an electronic circuit.

## 4 References

1. BQ25790 I2C Controlled, 1-4 Cell, 5-A Buck-Boost Battery Charger with Dual-Input datasheet
2. BQ25690 Standalone/I2C Controlled, 1-7 cell Li-Ion, 3A Buck-Boost Bidirectional Battery Charger with Bypass datasheet (Rev. A)
3. CSD25404Q3 –20 V P-Channel NexFET™ Power MOSFET datasheet