

Implementing Peak Power Shift Function With bq24770

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ABSTRACT

The bq24770 is a narrow-voltage DC (NVDC) battery charge controller with power path management that regulates adapter power to charge the battery and supply system loading. There has been wide usage to force battery discharge even with the adapter connected to the device because of reducing electrical demand during peak periods and shifting power consumption to off-peak periods. The various methods to implement the peak power shift (PPS) function are discussed in this application note.

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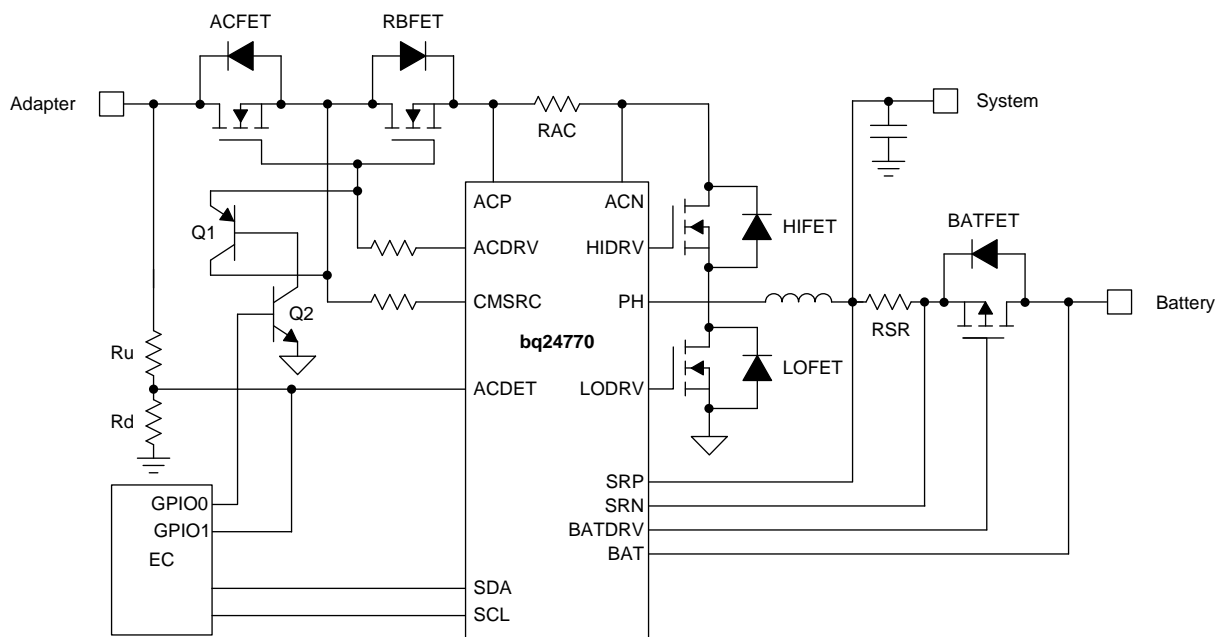
1 Introduction

The focus of this application note is to present the design solutions for implementing the peak power shift (PPS) function with the bq24770. The PPS has been a widely used method for reducing the cost of power and increased ecological responsibility. By reducing electricity demand during peak periods and shifting power consumption to off-peak periods, total power demand and rates can be reduced. The bq24770 charger can contribute to this by preventing power drawn from the wall adapter during peak power periods and forcing battery discharge to the system.

The article discusses various approaches to implement PPS using TI battery charger solutions like the bq24770, bq24773, bq24715, bq24725, bq24725A, bq24735, bq24780, and bq24780S. The following document is intended for any application which requires forcing battery discharge with an adapter connected to device. The consideration and benefits of each approach to implement the PPS function are also discussed.

2 Implementation

Figure 1 illustrates the bq24770 circuit for implementing the PPS function.



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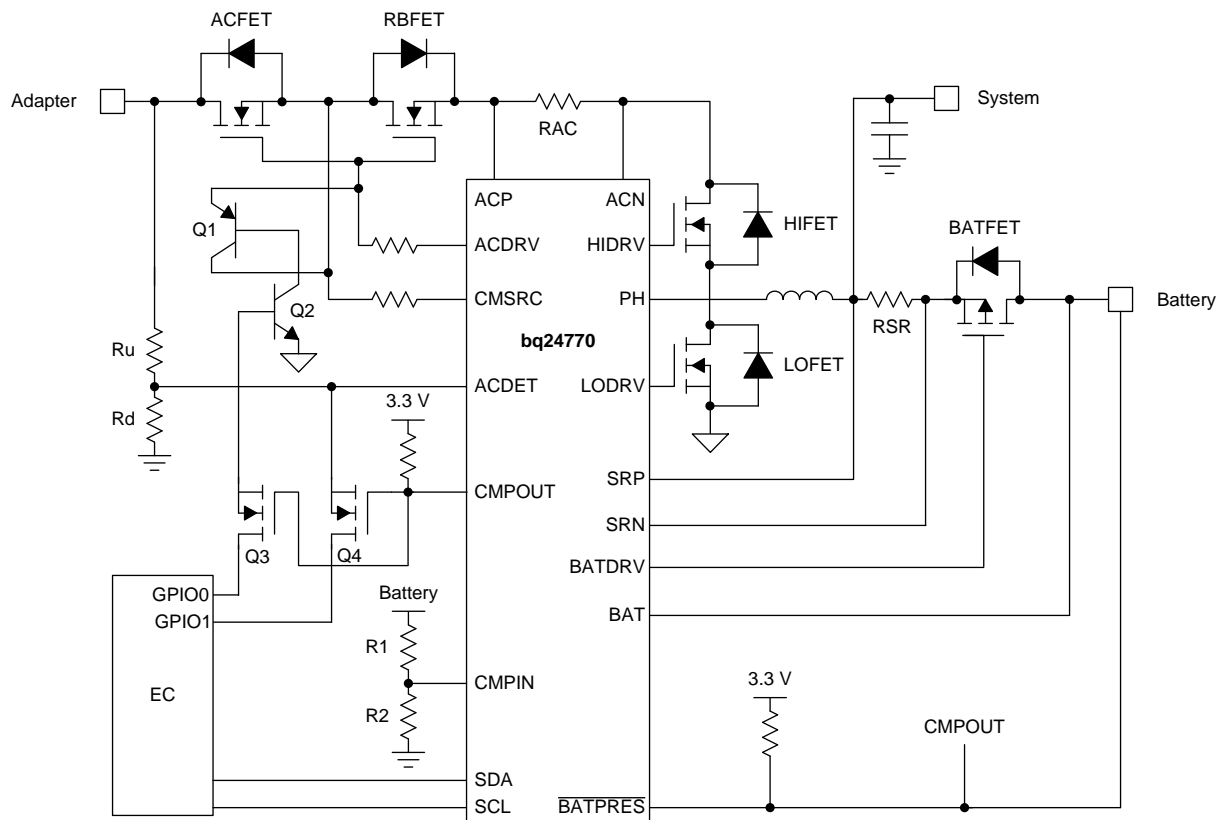
Figure 1. bq24770 Circuit for Implementing PPS Function

Apart from the typical application circuit of the bq24770, the various implementations for PPS function are shown together in Figure 1. The methods are:

1. With ACDET short to GND: EC GPIO1 is used
2. With ACDRV disabled: Q1/Q2 and EC GPIO0 are used
3. With LEARN mode: SDA/SCL lines are used for SMBUS command

Any one of the previous methods can be selected for implementation. The EC general purpose input outputs (GPIO) are open drain outputs.

For the conditions when the battery is removed or when the battery voltage falls too low, the charger must exit the PPS function and switch to draw adapter power. In order for the charger to automatically exit PPS during these conditions, additional circuitry must be added as shown in Figure 2.



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Figure 2. bq24770 Circuit for Implementing PPS Function With Battery Removal

This method requires the use of the independent comparator (CMPIN/CMPOUT) to monitor the battery voltage. When the battery is removed or the battery voltage falls too low that it can no longer support system operation, the comparator identifies this and uses CMPOUT to send a signal and control other circuitry. The circuitry used are:

1. With ACDET short to GND: Q4 controlled by CMPOUT
2. With ACDRV disabled: Q3 controlled by CMPOUT
3. With LEARN mode: $\overline{\text{BATPRES}}$ pin controlled by CMPOUT and battery ID pin

The independent comparator uses the power on reset settings. Internal reference is set at 2.3 V (0x3B[7] = 0) and when CMPIN is above the internal threshold, CMPOUT is LOW (0x3B[6] = 0). The comparator is enabled to the shortest deglitch time: 2 μ s (0x3B[5:4] = 01). CMPIN senses the resistor divided battery voltage, for example, when battery voltage falls below 8 V for 3S battery or 5 V for 2S battery, it changes CMPOUT from LOW to HIGH, and disables the GPIO control over ACFET/ACDRV. The $\overline{\text{BATPRES}}$ pin is connected to the battery ID pin and is normally LOW, the signal is pulled to high when the battery is removed.

All the tests were performed on the bq24770 EVM with the following conditions: Vchg = 13.5 V, Vadp = 20 V, Vbat = 11.5 V, Ichg = 3 A, Isys = 3 A, 3-cell setting.

2.1 ACDET to GND

The ACDET pin is the bq24770 adapter detection input, users can program adapter valid input threshold by connecting a resistor divider (R_p/R_d) from adapter input to ACDET pin to GND. When ACDET pin is above 2.4 V, and VCC is above BAT, but below ACOV, ACOK goes HIGH and ACFET/RBFET turns on. When ACDET pin is below 0.6 V, ACOK goes LOW and ACFET/RBFET turns off.

By driving a LOW output with the EC GPIO1, the ACDET pin is pulled to GND. The ACOK is LOW and ACDRV is turned off (Figure 2) causing the charger to stop switching and force battery discharge (Figure 3). By releasing the EC GPIO1, the ACOK is HIGH and ACDRV is turned on (Figure 4) causing the charger to resume switching and charge battery after an approximate 5 ms delay (Figure 5).

The benefit of this method is the low cost implementation without the need to add external components, only the EC GPIO connection to ACDET pin is required. As the ACOK is also LOW, to the system design it would be simpler design as the adapter can be treated as unplugged.



Figure 3. bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Short to GND and ACOK Falls



Figure 4. bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Short to GND and Charger Stops Switching

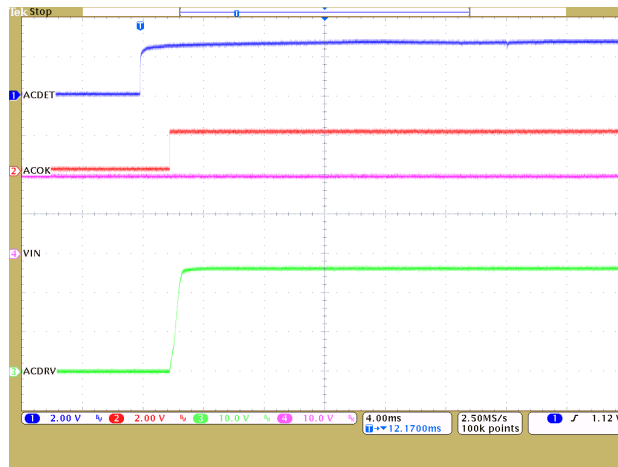


Figure 5. bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Released and ACOK Rises

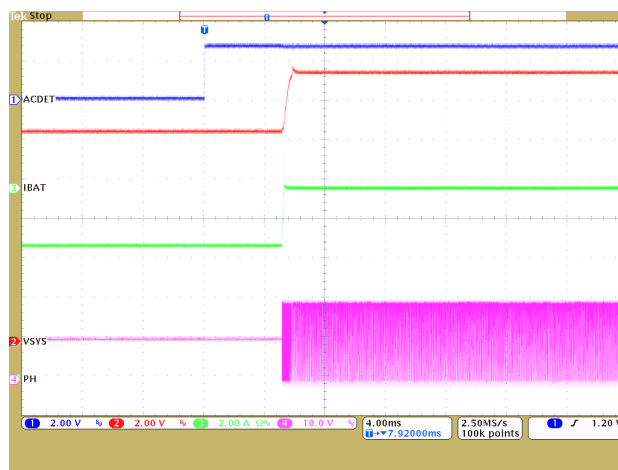


Figure 6. bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Released and Charger Resumes Switching

2.2 ACDRV Disable

The ACDRV is the charge pump output to drive both adapter input n-channel MOSFET (ACFET) and reverse blocking n-channel MOSFET (RBET). ACDRV voltage is 6 V above CMSRC to turn on ACFET/RBFET when ACOK goes HIGH. The CMSRC is the ACDRV charge pump source input.

Turning on Q1/Q2 by driving the EC GPIO0 output LOW will short the ACDRV and CMSRC pins together. The ACDRV turns off while maintaining ACOK HIGH (Figure 6) and the charger stops switching to let the battery discharge (Figure 7). By releasing the EC GPIO0 output, the ACDRV turns back on while ACOK is still HIGH (Figure 8) and switching resumes in approximately 2 ms (Figure 9).

The benefit of this method is shorter delay timing for resume switching. The ACOK signal is also always HIGH giving indication to the system that the adapter is present.

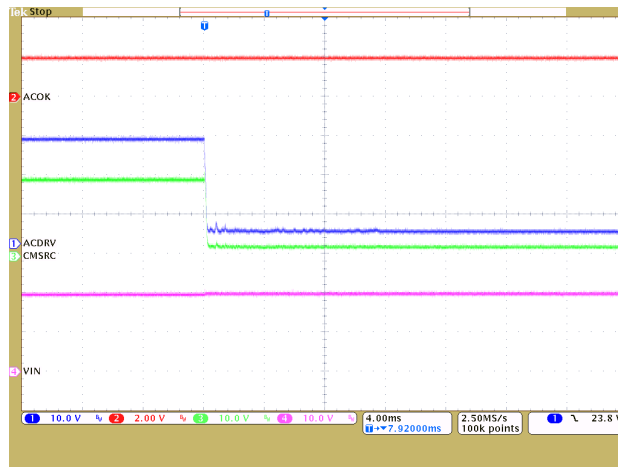


Figure 7. bq24770 Circuit Using EC GPIO0 to Control ACDRV, ACDRV is Disabled and ACOK Remains High

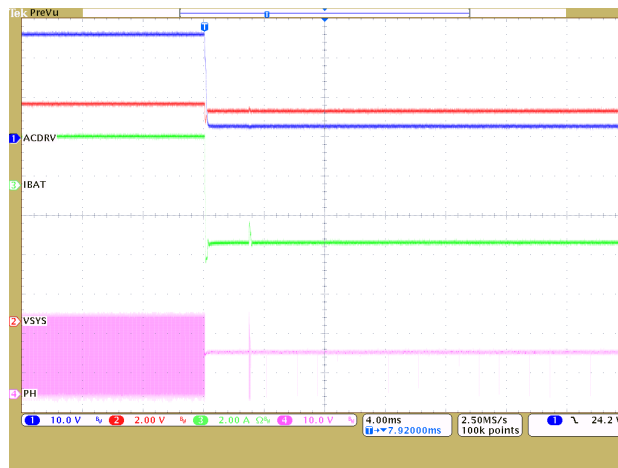


Figure 8. bq24770 Circuit Using EC GPIO0 to Control ACDRV, ACDRV is Disabled and Charger Stops Switching



Figure 9. bq24770 Circuit Implementing PPS With ACDRV Control, ACDRV is Released and ACOK Remains High

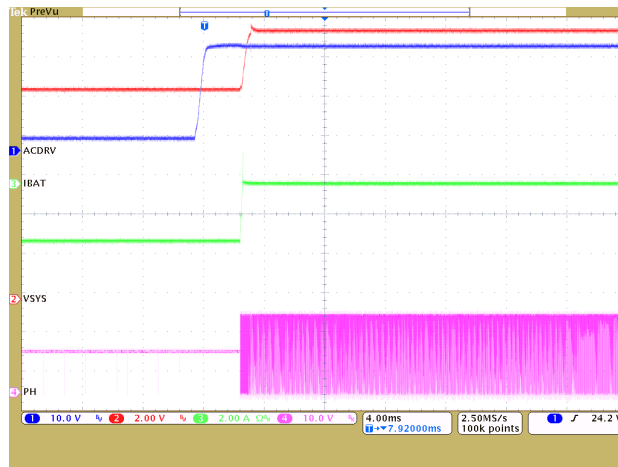


Figure 10. bq24770 Circuit Using EC GPIO0 to Control ACDRV, ACDRV is Released and Charger Remains Switching

2.3 LEARN Command

While the LEARN command was originally intended for battery learn cycle, it can also be used to achieve the PPS function. By writing a LEARN Enable command (0x12[5] = 1) via SMBUS, the system is powered from the battery by keeping the ACFET/RBFET on while turning off the buck controller. When the LEARN command is issued by the EC over SMBUS, the ACDRV and ACOK remain high while the controller stops switching (Figure 10) and the battery discharges (Figure 11). When the EC issues a LEARN disable (0x12[5] = 0), the controller resumes switching (Figure 12) while the battery resumes charging immediately within 100 μ s (Figure 13).

The bq24770 also supports the hardware pin $\overline{\text{BATPRES}}$ to immediately exit LEARN mode. If the user removes the battery during LEARN mode, the system must be powered momentarily from the system capacitance before the controller resumes switching to draw adapter power. By driving the $\overline{\text{BATPRES}}$ pin HIGH, the controller resumes operation within 100 μ s. A 1.72-V voltage drop is observed with 3-A loading condition before the charger resumed operation in 78 μ s (Figure 14). The $\overline{\text{BATPRES}}$ pin is pulled high to a 3.3-V reference voltage, but will be pulled to GND when the battery is connected. This could be achieved by a BAT ID pin or thermal pin inside the battery pack.

The benefit of using the LEARN command is the low-cost implementation and fast recovery to resume controller switching whenever the LEARN command is disabled or the battery pack removed. The ACOK is also kept HIGH to indicate an adapter is present to the system.

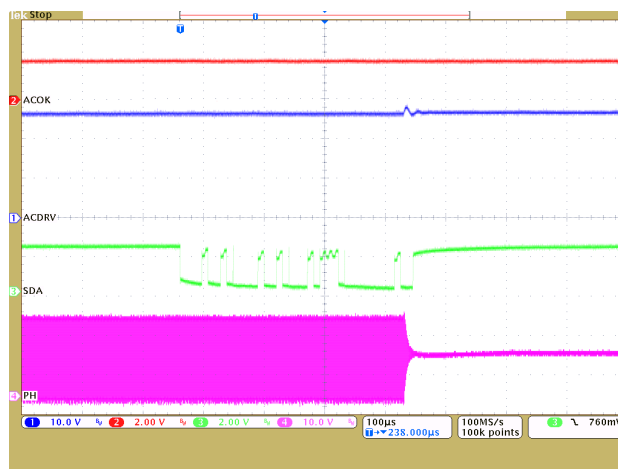


Figure 11. bq24770 Circuit Using LEARN Command, When LEARN is Enabled the ACOK and ACDRV Stays High While Charger Stops Switching

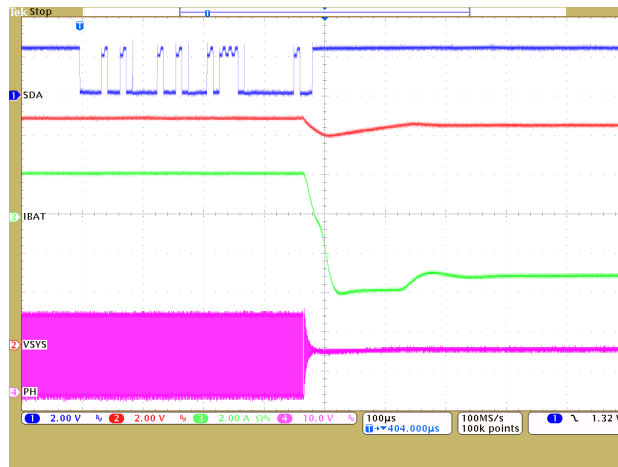


Figure 12. bq24770 Circuit Using LEARN Command, When LEARN is enabled and Battery Discharges

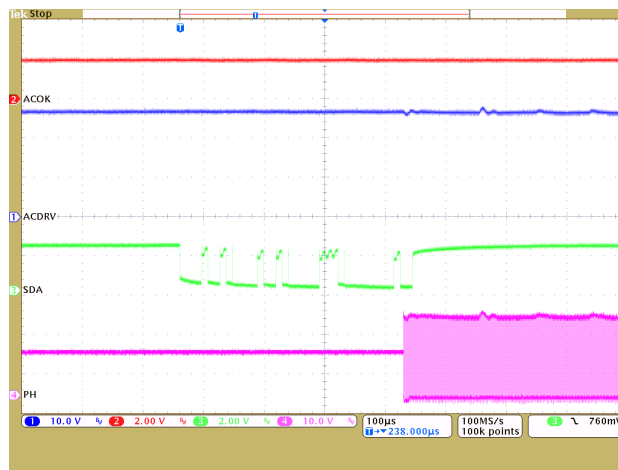


Figure 13. bq24770 Circuit Using LEARN Command, When LEARN is Disabled and Charger Resumes Switching



Figure 14. bq24770 Circuit Using LEARN Command, When LEARN is Disabled and Battery Starts Charging

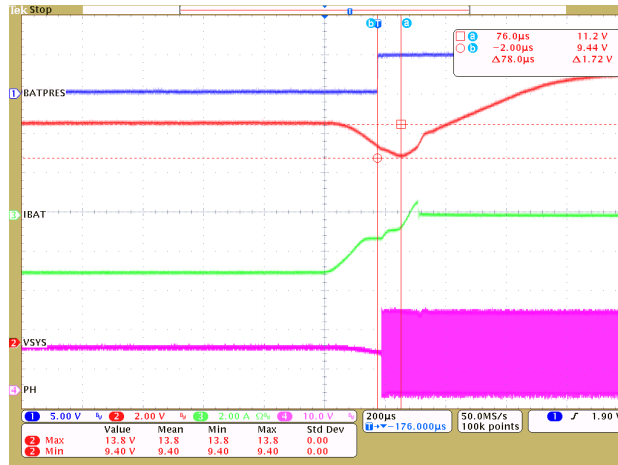


Figure 15. bq24770 Circuit Using LEARN Command, When LEARN Mode is Exit With Removing Battery and Releasing BATTRES HIGH

3 Summary

The consideration and benefits of each approach to implement the PPS function are summarized in Table 1:

Table 1. PPS Function

Method	Control	Resume Switching Time Delay	ACOK Indication	Benefits
ACDET to GND	EC GPIO1	5 ms	LOW	No additional BOM cost
ACFET disable	EC GPIO0 Q1/Q2	2 ms	HIGH	Simple GPIO control
LEARN command	SMBUS 0x12[5] = 1	76 µs	HIGH	Prevent system shutdown for battery removal during LEARN

The choice of the methods depends on whether the system designer prefers a hardware control method (ACDET to GND, ACFET disable) or software control method (LEARN command). The hardware implementation presents a simple control without requiring changes to the software algorithm and control schemes, whereas the software control method provides superior performance without additional costs.

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