

# Implementing Peak Power Shift Function With bq24770

Andrew Hung

Taiwan Field Application Engineer

## 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.

## Contents

1	Introduction .....	2
2	Implementation .....	2
3	Summary .....	9

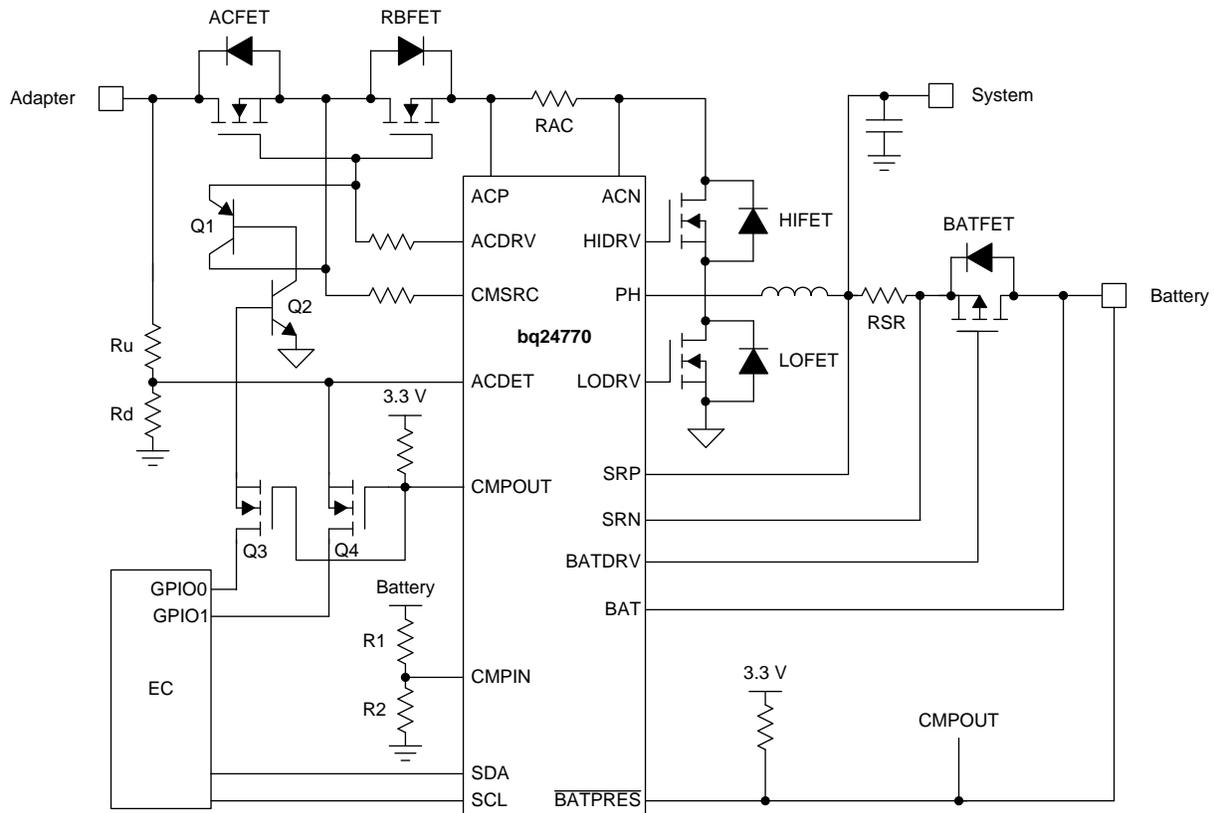
## List of Figures

1	bq24770 Circuit for Implementing PPS Function .....	2
2	bq24770 Circuit for Implementing PPS Function With Battery Removal .....	3
3	bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Short to GND and ACOK Falls.....	4
4	bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Short to GND and Charger Stops Switching	4
5	bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Released and ACOK Rises .....	5
6	bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Released and Charger Resumes Switching	5
7	bq24770 Circuit Using EC GPIO0 to Control ACDRV, ACDRV is Disabled and ACOK Remains High.....	6
8	bq24770 Circuit Using EC GPIO0 to Control ACDRV, ACDRV is Disabled and Charger Stops Switching .....	6
9	bq24770 Circuit Implementing PPS With ACDRV Control, ACDRV is Released and ACOK Remains High....	6
10	bq24770 Circuit Using EC GPIO0 to Control ACDRV, ACDRV is Released and Charger Remains Switching.	7
11	bq24770 Circuit Using LEARN Command, When LEARN is Enabled the ACOK and ACDRV Stays High While Charger Stops Switching .....	7
12	bq24770 Circuit Using LEARN Command, When LEARN is enabled and Battery Discharges .....	8
13	bq24770 Circuit Using LEARN Command, When LEARN is Disabled and Charger Resumes Switching.....	8
14	bq24770 Circuit Using LEARN Command, When LEARN is Disabled and Battery Starts Charging .....	8
15	bq24770 Circuit Using LEARN Command, When LEARN Mode is Exit With Removing Battery and Releasing BATPRES HIGH .....	9

## List of Tables

1	PPS Function .....	9
---	--------------------	---





Copyright © 2016, Texas Instruments Incorporated

**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  $\mu$ 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.

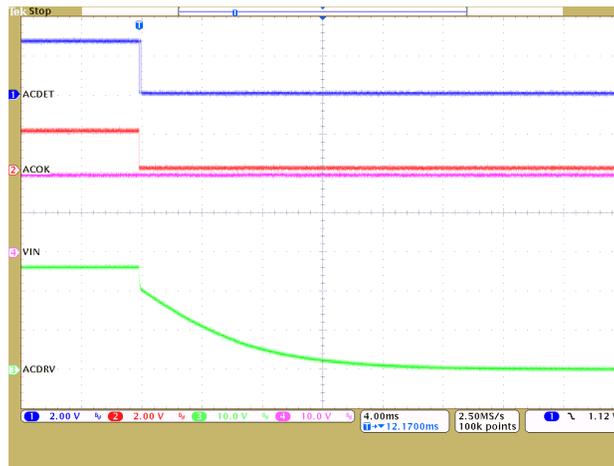


Figure 3. bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Short to GND and ACOK Falls



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

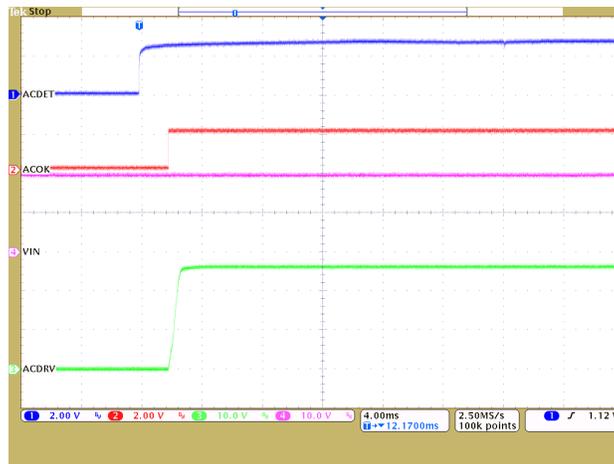


Figure 5. bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Released and ACOK Rises

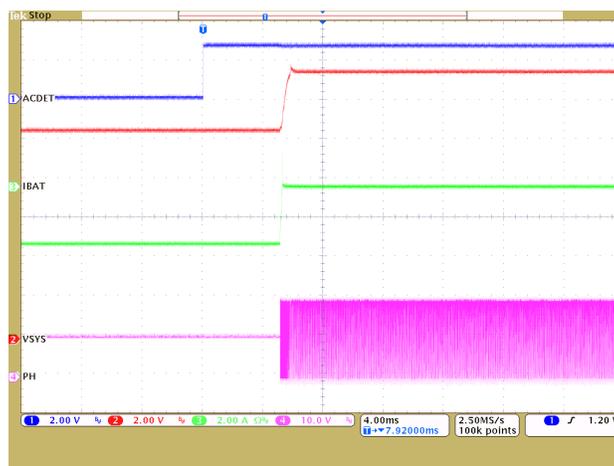


Figure 6. bq24770 Circuit Using EC GPIO1 to Control ACDET, ACDET is Released and Charger Resumes Switching

## 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.

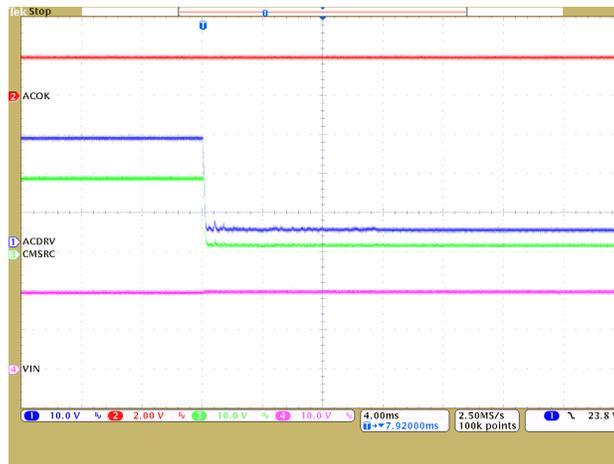


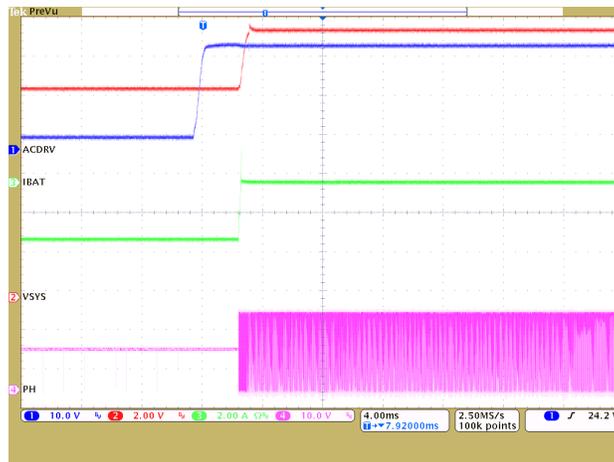
Figure 7. bq24770 Circuit Using EC GPIO0 to Control ACDRV, ACDRV is Disabled and ACOK Remains High



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



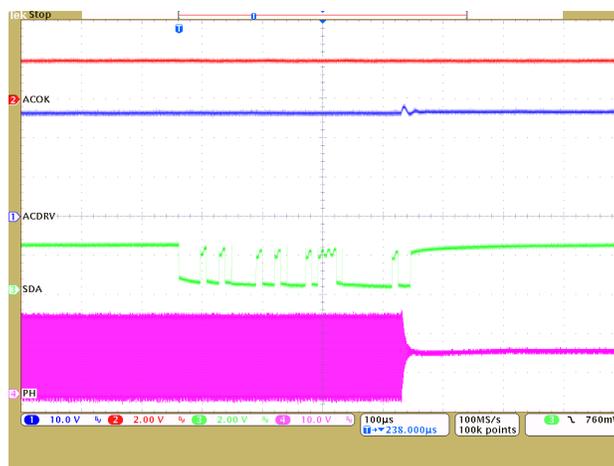
**Figure 10. bq24770 Circuit Using EC GPIO0 to Control ACDRV, ACDRV is Released and Charger Remains Switching**

### 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  $\mu$ 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  $\mu$ s. A 1.72-V voltage drop is observed with 3-A loading condition before the charger resumed operation in 78  $\mu$ 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**

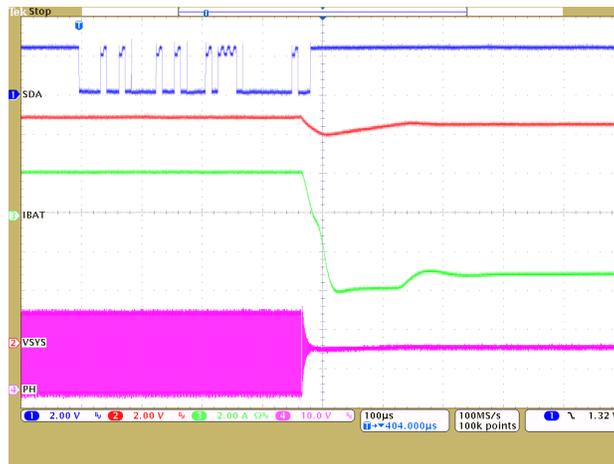


Figure 12. bq24770 Circuit Using LEARN Command, When LEARN is enabled and Battery Discharges

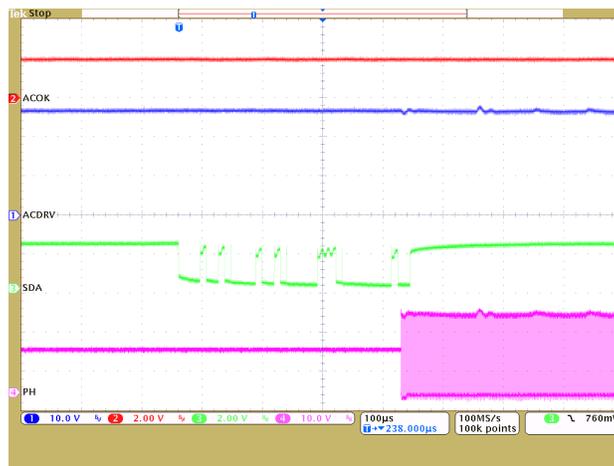


Figure 13. bq24770 Circuit Using LEARN Command, When LEARN is Disabled and Charger Resumes Switching

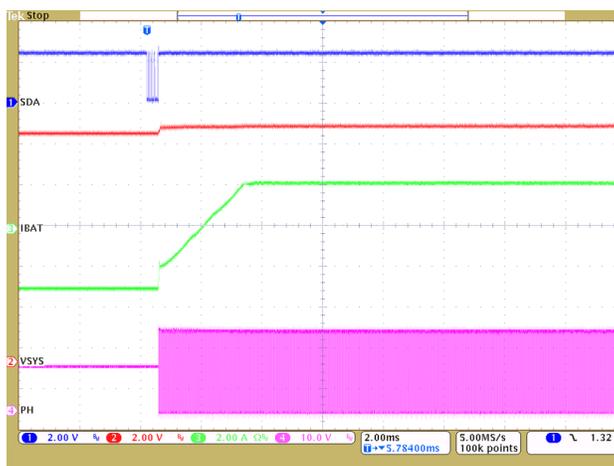


Figure 14. bq24770 Circuit Using LEARN Command, When LEARN is Disabled and Battery Starts Charging



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

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as "components") are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI's terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers' products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers' products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI's goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or "enhanced plastic" are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Applications Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

### TI E2E Community

[e2e.ti.com](http://e2e.ti.com)