

# Designing a Robust Backup Power System for Automotive Applications



## Introduction

Backup power systems exist in vehicles to provide critical functions for drivers, and the urgency of these systems to work requires engineers to ensure that backup power is always available. Two vehicle subsystems that use supercapacitors to provide brief, last-gasp backup power are ADAS domain controllers and Emergency Latches (E-latches). ADAS domain controllers process information from the numerous sensors around the vehicle and respond in case of emergency. ADAS domain controllers have started to adopt supercapacitors to provide backup power to critical processors, so the processor can shut down properly to save data in case the main car power is suddenly removed. E-latches leverage supercapacitor backup power to automatically unlock electrically driven door locks in case the main power is disconnected. There are several design challenges to ensure ADAS domain controller and e-latch backup power systems provide their critical functions. First, supercapacitors can be fully discharged from their total charge voltage down to 0V, and engineers must design the system to charge and discharge the supercapacitors over their full voltage range. Failure to account for the entire supercapacitor voltage range can result in less backup power time which puts the backup operation in jeopardy. In addition, some of these designs rely on a microcontroller unit (MCU) to update components with I<sup>2</sup>C commands for the design function properly. It is critical to account for when the MCU is unexpectedly disconnected and cannot configure components which could result in unexpected behavior of the backup power system. Finally, the processor in ADAS domain controllers constantly provides critical functionality of interpreting data from sensors and cameras and cannot get damaged. How can a backup power system be designed to address each of these design challenges?

## Maximizing Backup Time

A design commonality between E-latches and ADAS Domain Controllers is addressing how to charge and discharge the supercapacitors across their entire voltage range to maximize backup power time. When charging the supercapacitors, the input voltage and supercapacitor stack voltage affect the required charger topology. Supercapacitor stack voltage ( $V_{CAP}$ ) could range from 5.1V up to 12.5V in e-latches while ADAS domain controllers typically have a 60V  $V_{CAP}$ . Assuming a 12V input voltage from the car battery, a buck topology is required to charge the supercapacitors if  $V_{CAP} < 12V$  while a boost topology is required if  $V_{CAP} > 12V$ . In the discharge case, it is assumed the 12V  $V_{in}$  is no longer present and the system voltage ( $V_{SYS}$ ) is critical for determining the topology needed to discharge the supercapacitor stack. E-latches normally operate at a 12V  $V_{SYS}$  to unlock the doors while ADAS domain controllers operate at a 7V  $V_{SYS}$  to power the processor.  $V_{CAP}$  will be above and below  $V_{SYS}$  during discharge down to 0V in both applications which requires a buck-boost device to buck  $V_{CAP}$  when  $V_{CAP} \geq V_{SYS}$  and boost  $V_{CAP}$  when  $V_{CAP} < V_{SYS}$ . As shown in the diagram below, a two-chip solution can be reduced to a one-chip solution with a bidirectional, buck-boost supercapacitor charger integrated circuit (IC) that can change power flow direction. The bidirectional buck-boost charges the supercapacitors from the car battery input and then discharges the supercapacitors in the opposite direction to power the system. This type of charger IC helps engineers reduce component count on their design while utilizing all the energy in the supercapacitors to maximize backup power time.

## Functioning Without an MCU

Many backup power designs rely on the MCU to configure the components shown in Figure 2, but what happens to the backup power system if the MCU loses power or disconnects? The system settings like charging current and  $V_{CAP}$  could reset to their default values in an MCU-reliant design if the MCU is disconnected which could

result in incorrect settings jeopardizing the backup power functionality. Selecting ICs with resistor-settable pins can help mitigate the risk of system settings resetting to default values in case of MCU disconnection. The value of resistor-settable pins is often calculated by the resistor value being proportional to a constant value,  $K$ , specified in the IC's datasheet. If the I<sup>2</sup>C connection is severed on an IC with resistor-settable pins or if no I<sup>2</sup>C command is ever sent, the IC will use the product of  $K * \text{the resistance}$  as the pin's setting. This functionality enables engineers to design a system that will still provide backup power even if the MCU is disconnected or if there is no MCU in the system entirely.

## Protecting the System

Processors in applications like ADAS domain controllers are essential for collecting and interpreting data from car sensors and alerting drivers appropriately. A non-functioning processor is a risk to driver safety, so protecting this component is essential. One case that could cause processor damage is exceeding the processor's absolute maximum input voltage ( $V_{IN\_ABS\_MAX}$ ) which is typically 40V. As mentioned earlier, ADAS domain controllers use a 60V capacitor to provide enough backup power time for the processor to shut down properly when the 12V car battery is disconnected. However, a high side FET short on the bidirectional buck-boost in Figure 1 can result in a 60V  $V_{IN}$  which exceeds the 40V  $V_{IN\_ABS\_MAX}$ , so engineers must design their systems to protect the processor from the high voltage of the backup capacitor in case of a high side FET short.

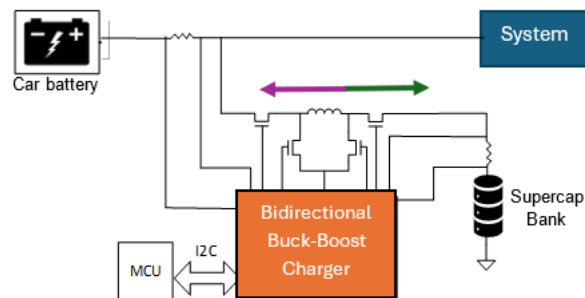


Figure 1. Bidirectional Block Diagram

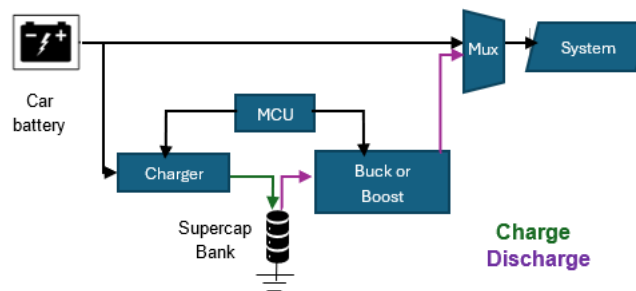
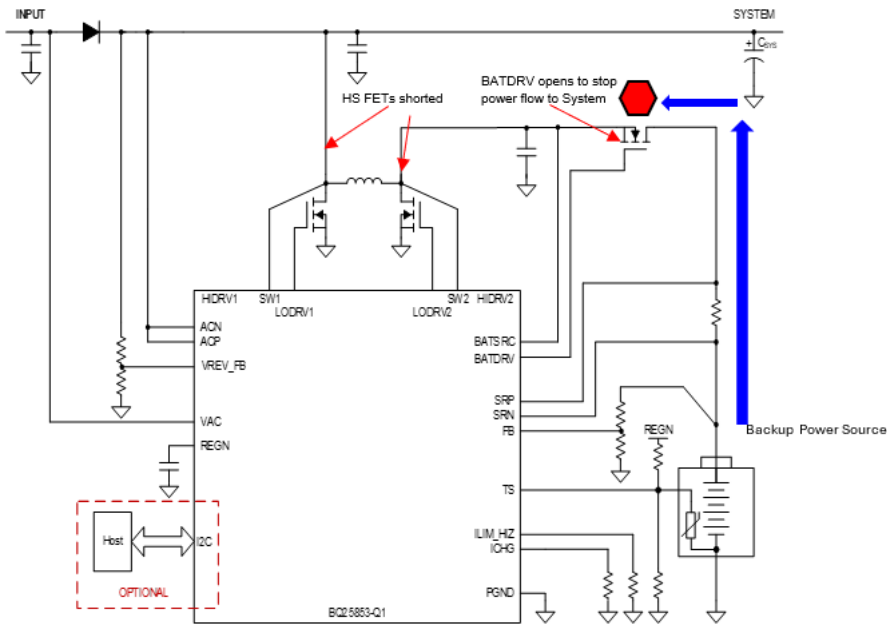


Figure 2. Discrete Block Diagram

## BQ25853-Q1 for Supercapacitor Backup

BQ25853-Q1 is a capacitor charger IC that can help mitigate the challenges mentioned above for backup power systems. BQ25853-Q1 utilizes a bidirectional buck-boost controller topology enabling the device to charge the capacitors if  $V_{IN} \geq V_{CAP}$  or  $V_{IN} < V_{CAP}$  and discharge the capacitors if  $V_{SYS} \geq V_{CAP}$  or  $V_{SYS} < V_{CAP}$ . BQ25853-Q1 can also charge and discharge capacitors with or without an MCU. The MCU can communicate with I<sup>2</sup>C to the charger or engineers can configure several parameters with hardware resistors such as charge voltage, charge current and output voltage during discharge. This flexibility helps ensure backup functionality is present regardless of the MCU status. Finally, BQ25853-Q1 protects system components in the high side FET short scenario using the BATDRV pin as shown in Figure 3. When the IC detects an over current or over voltage scenario, the BATDRV pin opens the BATFET preventing the voltage on the capacitor from reaching the system. This feature can help protect a critical component, like a processor, from damage due to shorts in other parts of the system.



**Figure 3. System Protection on BQ25853-Q1**

## Conclusion

Implementing life-saving electrical systems, like E-latches and ADAS domain controllers, demands designs that guarantee backup power and account for the worst-case scenarios. It is critical to utilize all the capacitor energy to maximize backup power time, ensure an MCU disconnection does not reset important system settings and protect important system components in case of shorts. A standalone and bidirectional buck-boost charger addresses these design challenges while reducing the PCB component count. The buck-boost topology ensures the capacitors are charged and discharged even if their voltage is above or below the car battery or system voltage, and the bidirectionality combines a charger IC and buck/boost converter IC into one chip which reduces the component count. The standalone settings then help keep the system settings constant in case the MCU is disconnected and no I<sup>2</sup>C updates can be communicated. BQ25853-Q1 incorporates all the features above while adding the backup power disconnect during a high side FET short making it an effective option for supercapacitor backup power designs.

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