High-Side Cutoff Switches for High-Power Automotive Applications

Mamadou Diallo, Carissa Washam Parish, High Power Drivers

In high power automotive applications, relays are commonly used as cutoff switches, such as battery load balancing and power distribution. Relays are used because they can control a high voltage system from a low power signal. However, they present many design constraints due to their mechanical nature, cost, and size causing long term reliability issues, slow switching speeds, and board space. Semiconductors, like MOSFETs and gate drivers, have been widely used to solve these issues increasing lifetime reliability and providing fast switching speeds. This tech note will describe methods to use gate drivers and MOSFETs as a solid state cutoff switch to replace mechanical relays in order to extend lifetime and reliability.

Mechanical Relays Design Constraints

A relay is an electromechanical switch which uses the magnetic field of an energized coil to make or break electrical contact in a circuit. This coil is typically controlled by a signal from a low powered circuit such as a microcontroller, and provides a way to isolate the two. In automotive applications, the most common type of relay used is the single-pole double-throw (SPDT). When the coil is not energized, points Y and Z are shorted therefore connecting the system to the battery. When there is a fault condition, the MCU sends a signal allowing current to pass through the coil and disconnecting the battery from the rest of the system as shown in Figure 2.

Mechanical contacts wear out due to friction and oxidation. Over time this can lead to slow switching speeds. Cycling the contact at high voltage or current can form arcs, liquefying or vaporizing contact metal and forming pits which reduce the current capability and contact reliability.

Gate Driver and MOSFETs as Solid State Cutoff Switch

Designers can avoid these issues by using a gate driver with a MOSFET device to form a solid state relay. There are many integrated solutions on the market for this kind of application, however for higher power applications, where the MOSFET gate charge \( \left( Q_g \right) \) is higher, and faster switching rates are desired, a higher current drive is needed. MOSFETs have higher switching cycles over lifetime because there are no physical moving parts therefore no metal fatigue and...
wear. In automotive applications, for example, solid state drive solutions exhibits infinite effective lifetime as opposed to mechanical parts. Figure 3 shows the switching cycle performance of MOSFETs over mechanical relays. This illustrates a 10x higher lifetime switching cycle for the semiconductor over the mechanical counterpart.

![Switching Cycles Comparison](image)

**Figure 3. Switching Cycles Comparison**

To construct the solid state relay using 2 MOSFETs, either the drains or the sources are tied together. This is to prevent current flow through the body diode of the MOSFETs when there is no conduction. Though the P-channel FETs drive circuit is easier to implement, high-power and cost-sensitive systems use N-channel FETs for its lower $R_{ds, on}$ and lower cost. The diagram in Figure 4 shows the cutoff switch consisting of three blocks: the level-shifter, the bias supply, and the driver/power switch.

The third portion of the circuit is the low-side driver configured as a high-side driver where the output of the level-shifted signal from the MCU drives UCC27524A-Q1 (dual low-side driver with enable function capability). Tying the driver's outputs together allows this topology to meet the fast turn-on/off requirements of such applications by doubling the drive current. This topology allows the low-side driver, referenced to the drain of the lower MOSFET, to disconnect the battery from the rest of the circuit during any fault conditions effectively protecting the system from damage. This discrete solution provides high power handling capability (>500W) often required in automotive applications.

![Low-side driver as high-side switch](image)

**Figure 4. Low-side driver as high-side switch**

In summary, this tech note demonstrates a way to replace relays with MOSFETs and low-side gate drivers to solve design constraints associated with mechanical relays. This solution is more viable for its robustness, reliability and performance over time in high power automotive applications.

**Related Documentation**

- UCC27524A1-Q1 product folder
- UCC27524A1-Q1 datasheet
- UCC27528-Q1 product folder
- UCC27532-Q1 product folder
- SN6501-Q1 product folder
## Revision History

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

<table>
<thead>
<tr>
<th>Changes from Original (November 2018) to A Revision</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Changed “Figure 1”</td>
<td>1</td>
</tr>
<tr>
<td>• Changed “Section 3 isolated bias supply to section 2 Isolated bias”</td>
<td>2</td>
</tr>
</tbody>
</table>