Current Bidirectional Two-Quadrant

- Usually an active switch, controlled by terminal C
- Normally operated as two-quadrant switch:
  - can conduct positive or negative on-state current
  - can block positive off-state voltage
- provided that the intended on-state and off-state operating points lie on the composite i-v characteristic, then switch can be realized as shown

MOSFET Body Diode

- Power MOSFET characteristics
- Power MOSFET, and its integral body diode
- Use of external diodes to prevent conduction of body diode
Voltage-bidirectional Two-Quadrant

- Usually an active switch, controlled by terminal C
- Normally operated as two-quadrant switch:
  - can conduct positive on-state current
  - can block positive or negative off-state voltage
- provided that the intended on-state and off-state operating points lie on the composite i–v characteristic, then switch can be realized as shown
- The SCR is such a device, without controlled turn-off

Four-Quadrant Switches
Synchronous Rectifiers

Replacement of diode with a backwards-connected MOSFET, to obtain reduced conduction loss

Example Application

48V VEHICLE ELECTRICAL SYSTEM
Automobile 12V Power

Figure 3. Electrification of the Auto


48V Electrical System

12V/48V Electrical Architecture

Audi, "Electric biturbo and hybridization", 2014
AVL, "48V Mild Hybrid Systems"
Example 12/48 V Vehicle

System to Design

<table>
<thead>
<tr>
<th>Param</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_g$</td>
<td>12 V</td>
</tr>
<tr>
<td>$V_{out}$</td>
<td>48 V</td>
</tr>
<tr>
<td>$R_{out}$</td>
<td>48 Ω</td>
</tr>
<tr>
<td>$\Delta V_{out}$</td>
<td>0.1 V</td>
</tr>
</tbody>
</table>
Baseline Design

- Use TI WebBench (webench.ti.com) to get a baseline design

Device Parameters

Diode

MOSFET

Inductor

- $V_D = 0.05V$
- $D_D = 0.12$
- $T_1 = T_2$
- $R_D = \frac{V_D}{I_D}$
- $V_{gs} = 5V$
- $V_{gs} = 10V$
- $I_D = 1A$
- $R_{on} = 8m\Omega$
- 2 in parallel
- $R_{on} = 4m\Omega$
- $R_L = 1.96m\Omega$
Expected Behavior

Ideally:

$I_L = \frac{V}{R_D} = 4A$

$\Delta I_L = \frac{V}{C} \Delta T_S \sim \Delta I_L = 1A$