Battery Main Switch

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Agenda

- System Overview and Requirements
- Relay = ideal Component?
- Semiconductor Selection
- Reference Design development
- Precharging
- Conclusion
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Battery System

+200V

-200V

Power

12V

CAN Bus

Communi -cation

Main Switch

Block 10
Block 8
Block 9
Block 8
Block 7
Block 6
Block 5
Block 4
Block 3
Block 2
Block 1

Master

SPI to 2 wire

Current Sensor

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Main Switch Requirements

- Safe Disconnection

- Voltage: 200 – 500V

- Charge Current:
  - Continuous 100A
  - Peak (10s): 250A

- Load Current:
  - Continuous 150A
  - Peak (10s) 350A
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Relay Arcing

Welded Contacts after disconnection with high current

No Coil current!
Relay – a real ideal switch?

- Contact aging after switch-off (210V / 205A)
  - $R_{on} = \text{really } 0\Omega$?
- Condensation of vaporized metal parts at the wall
  - Isolation resistance really $\infty$?

Source: Panasonic
## Relay or Semiconductor-What is better?

<table>
<thead>
<tr>
<th>Feature</th>
<th>Relay</th>
<th>Semiconductor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lifetime</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
<tr>
<td><strong>Reaction time</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
<tr>
<td><strong>Module weight</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
<tr>
<td><strong>Module height</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
<tr>
<td><strong>Component Cost</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
<tr>
<td><strong>System Cost</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
<tr>
<td><strong>Experience</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
<tr>
<td><strong>Vibration robustness</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
<tr>
<td><strong>Noise</strong></td>
<td>![Relay]</td>
<td>![Semiconductor]</td>
</tr>
</tbody>
</table>
Main Switch
Current rise after Short Circuit

# Current [A] vs Time [ms]

- **Fuse blows**
- **Reaction time with Semiconductor**
- **Reaction time with Relay**
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Switching Elements
Voltage Drop over Current

![Graph showing voltage drop over current for different elements: IGBT, Diode, IGBT+Diode, 1Mosfet, 4Mosfet, Relay, and Relays old?](graph)

- **Parallel**: Indicates the relationship between current and voltage drop for parallel elements.
- **Aging**: Shows the impact of aging on the voltage drop.

**Axes**:
- **Vertical Axis**: Voltage Drop [V]
- **Horizontal Axis**: Current [A]

Note: The graph compares the voltage drop for different switching elements at varying currents, highlighting the contrast between new and old relays.
MosFET Evolution
Better Ron Resistance

- Improvement factor 15 within 20 years
- Assumption: available silicon chip technology in the actual TO247 package device

![Graph showing the reduction in Ron over time]

- 6400W @150A
- 427W @150A
- Today
Power Dissipation

- Configuration 8P/3S (8 MosFets parallel and 3 in series)
- Temperature: 25°C
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Block Circuit

- **S1**
  - Voltage disconnect

- **S2**
  - Voltage disconnect (redundant)

- **S3**
  - Prevent from overcharge (only in charger fail mode)

- **D1**
  - Free Wheel diode for emergency switch-off

- **C1**
  - Input Buffer
Reference Design
Overload Handling

- Normal Operation (<400A):
  - 8 equal independent paths via Hall sensor
    - Check of current distribution possible
  - Board Temperature Measurement

- Overload Condition:
  - Fast Overcurrent in Hall Sensors
    - 3µs delay
    - 55A Threshold each > 440A in total
    - Interrupt in µC
    - Hardware Reset of Driver
  - Voltage drop over RDSon
    - Hardware switch-off
    - Threshold:
      - 650A @ 25°C
      - 400A @ 120°C
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Precharge Function

- **Task:** Charge of empty DC link Capacitor

- **Conventional:** Relay + Resistor

- **Solid State:** uses Existing Circuitry + Software
- Detection of
  - Short Circuit
  - Open Load

- Measurement of
  - Load current
  - Capacitance value of DC link
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**Past:** Two Relays mandatory as safety part; No semiconductors allowed

**Actual proposal:** One Relay for final interruption necessary

**Future:** Complete solid state solution under discussion
Savings in the System

- Mechanical Parameters
  - Size
  - Weight

- Parts
  - Relays
  - Fuse
  - Precharge Circuit

- Wiring diameter
- Noise Cancellation
- Replacement of Switchbox (and Batteries?) after Crash
ENERGY EFFICIENCY
MOBILITY
SECURITY

Innovative semiconductor solutions for energy efficiency, mobility and security.