High-Side Intelligent Power Switches for Industrial and Automotive Applications

FTF-AUT-F0179

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APR. 2014
Agenda

• Introduction and Agenda Review
• Market Environment
• Technology Review
• Product Review and Impact on Solutions
• Ecosystem and Design Support
• Session Review and Wrap-up
Session Introduction

• Freescale’s intelligent high side switches are designed to control a wide variety of loads in automotive and industrial systems. This presentation describes Freescale’s high side switch portfolio and roadmap, device features, potential applications and available design and support tools.

• By completing this 1h training, you will be able to:
  - Describe the capabilities of the products that will help you meet your design challenges, and how they can provide you a competitive/differentiating advantage
  - Determine which eXtreme Switch family fits your target market/application
Market Environment
Market and Trends for Energy Distribution

Energy Distribution with SmartPower

• **Today:**
  - Most applications use fuses / relays

• **Trend:**
  - Regulation; CO2 emissions
  - Reduce weight and size
  - Warranty extension: Need very robust design
  - More comfort: Silence/noise
  - Euro6 constraints
  - Fuse box not accessible
**SmartPower Benefits**

**SmartPower** device is a Power IC with some digital content. It interfaces between an MCU and a load.

“eXtreme Switch” is Freescale’s brand name for high-current “SmartPower”.

Why use SmartPower devices instead of relays?

- **Simple & Robust Design**
  - Self protection, diagnostic features

- **Switching Capability**
  - PWM capability
  - EMC, di/dt and dv/dt control

- **Power Dissipation**
  - Standby current few µA
  - No relay coil driver losses

- **Integration**
  - Lighter weight, smaller systems
## Relay Replacement Evolution

<table>
<thead>
<tr>
<th>Features</th>
<th>Relay</th>
<th>eXtreme Switch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load requiring &lt;1A</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>PWM</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Block reverse battery current</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Overcurrent management to protect wiring</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>H-bridge or ½ H-bridge topologies &gt; 10A</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
## eXtreme Switch Target Applications

<table>
<thead>
<tr>
<th>Auto/trucks application</th>
<th>Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>Halogen &amp; incandescent lamps, LEDs, Xenon HID, …</td>
</tr>
<tr>
<td>DC Motor</td>
<td>Fuel pump, wiper, fan, …</td>
</tr>
<tr>
<td>Solenoid</td>
<td>Xenon shutter, relay coil, …</td>
</tr>
<tr>
<td>Resistor</td>
<td>$0^\circ$ heater, seat heater, …</td>
</tr>
<tr>
<td>Power Distribution</td>
<td>Other modules or subcircuits</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Industrial application</th>
<th>Loads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>Halogen &amp; incandescent lamps, LEDs, Xenon</td>
</tr>
<tr>
<td>DC Motor</td>
<td>Electric doors, wiper, washer pump, machine inspection, vending machines, HVAC…</td>
</tr>
<tr>
<td>Inductive Loads</td>
<td>Solenoids, water and fluid control app, valve controllers for thermostats, home automation system</td>
</tr>
<tr>
<td>Power Distribution</td>
<td>PLC, low end robotic, industrial printing systems, POS terminal</td>
</tr>
</tbody>
</table>
Technology Review
What is an eXtreme Switch?

- High-side switch connected between supply and load
- A dual-chip solution in a package: most optimized (cost) for given current (so far)
- The eXtreme Switch limit of the load current is **1A-30A DC** and 150A transient. Loads are mostly bulbs, DC motors, solenoids or submodules
- eXtreme Switch devices are available for:
  - **Automotive** applications:
    - **12V systems** (45V technology): Lighting, “Main switch”, DC motor control
    - **24V systems** (65V technology): **General purpose** switch for **trucks**, buses and special engines
  - **Industrial** applications
eXtreme Switch Composition

SMARTMOS™

- Protection and diagnostic
  - Over temperature (175°C)
  - Over current shutdown
  - Over/under voltage
  - Short circuit
  - Reverse battery
  - Loss of ground/Vbat
  - Energy discharge protection

- SPI Interface
  - Easy connection to the uP
  - Programmability
  - Daisy chain using SPI
  - Programmable over current trip level
  - Watchdog
  - Embedded PWM module

Vertical Power Stage

- Best-in-class technology
  - Planar HD5 and TrenchFet LFET
  - 45V & 65V BV

- Protection in the power stage
  - Temperature sensor
  - Current sensor
  - Voltage sensor (Gen4)

Power Package

- PQFN low cost power package
  - 0.5 mm thick lead frame
  - Die soldered attached
  - Rthj-c < 0.5°C/W

- SOICeP32 and 54
  - Designed for high power
  - Large al wire capability
  - Pb-free compliancy
eXtreme Switch Product Features Evolution

Gen3

- SPI interface for programmability, full diagnostics
- Full diagnostic, no real time fault management needed
- High power density
- Extremely low sleep state current
- Multi-step over current strategy with auto-restart
- Robust and reliable solution with failsafe operation
- Specific configuration for bulbs, HID, LED
- Easy PWM management, EMC optimized
- Embedded PWM function with optimized slew rates
- Outputs under full control and protected in case of MCU damage
- External or Internal watchdog with failsafe management

Gen3L

- LFET technology introduction significantly reduces on-resistance
- Higher over current thresholds to accommodate newest lamps
- Option for dual in SOIC with exposed thermal pad (EVL compliant)

Gen4

- Intended for a complete and scalable family in term of software and footprint
- Provides diagnostics for light emitting diodes (LEDs) with an enhanced current sense precision with synchronization pin
- Combines flexibility through daisy chainable 5.0 MHz SPI, extended digital and analog feedback, safety and robustness
- Integrates an enhanced PWM module with 8 bits duty cycle capability and pre-scaler per output
- This family is packaged in a Pb-Free power-enhanced SOICep package with exposed pad and ELV compliant.
Main Differences Between 12V and 24V Vehicular Systems

- Operating profile for trucks might be 300,000 km/y
- Wire harness for 24V system is often much longer than in passenger vehicles
- Potentially up to 20 meters from module to load (up to 40 m with a trailer)
- Potentially up to 20 meters from battery to module (for a distributed architecture)
- Increases wiring inductance and the possibility of wiring harness faults
- 24V systems have more loads than 12V systems and more of those loads are motors and solenoids
- Motors are often PWMed at ~1 kHz from 5% to 100% whereas lighting is PWMed at 100 to 200 Hz
- Vehicular transient specifications are more severe in 24V systems

<table>
<thead>
<tr>
<th></th>
<th>12V System</th>
<th>24V System</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Dump (5b)</td>
<td>41V</td>
<td>58V</td>
<td>-600V at ECU level</td>
</tr>
<tr>
<td>Fast negative transient pulse (1)</td>
<td>-100V</td>
<td>-450V...-600V*</td>
<td>-600V on Vpwr</td>
</tr>
<tr>
<td>Fast positive transient pulse (2a)</td>
<td>+100V</td>
<td>+50V*</td>
<td>Load required</td>
</tr>
<tr>
<td>Burst negative pulses (3a)</td>
<td>-150V</td>
<td>-200V</td>
<td></td>
</tr>
<tr>
<td>Burst positive pulses (3b)</td>
<td>+100V</td>
<td>+200V</td>
<td></td>
</tr>
<tr>
<td>Operating voltage range</td>
<td>4V to 20V</td>
<td>8V to 36V</td>
<td></td>
</tr>
<tr>
<td>Under voltage</td>
<td>4.1V typ. (4.5V max)</td>
<td>7V</td>
<td></td>
</tr>
<tr>
<td>Over voltage</td>
<td>32V typ. (28V min)</td>
<td>40V min*</td>
<td>input customer helpfull</td>
</tr>
<tr>
<td>Reverse battery</td>
<td>-16V</td>
<td>-28V</td>
<td></td>
</tr>
<tr>
<td>Cranking (Pulse 4)</td>
<td>4.5 or 5.0V</td>
<td>8V*</td>
<td></td>
</tr>
<tr>
<td>Supply voltage clamp</td>
<td>47V</td>
<td>60V</td>
<td></td>
</tr>
</tbody>
</table>
eXtreme Switch Product Numbering

**Part Number**

**MC**
- **QUALIFICATION STATUS**
  - **PC**: PRE-QUALIFICATION, ENGINEERING SAMPLES
  - **MC**: FULLY QUALIFIED
  - **SC**: CUSTOM DEVICE

**XS**
- **ON-RESISTANCE**
  - 22 = 22 mΩ
  - 50 = 50 mΩ

**4**
- **FAMILY**
  - XS = eXtreme SWITCH

**2**
- **GENERATION**
  - 3 = Gen 3
  - 4 = 24V family
  - 5 = Gen 4

**00**
- **NUMBER OF OUTPUTS**
  - 2 = 2 outputs
  - 4 = 4 outputs
  - 5 = 5 outputs

**B**
- **ON-RESISTANCE, SMALLEST OUTPUTS**
  - 00 = All output identical

**EK**
- **PACKAGE DESIGNATOR**
  - EK: Lead free SOIC
  - FK: Lead free PQFN

**R2**
- **TAPE AND REEL**
  - R2: TAPE AND REEL

**Revision**
- __ = revision A
- B = upgraded control die
- BA = fastest device
Product Review and Impact on Solutions
**Extended operating voltage range:**
In extended mode, the functionality is guaranteed but not the electrical parameters specified

- **12V Products:** 4.0 to 28V (vs. 6.0 to 20V)
- **24V Products:** 6.0 to 58V (vs. 8.0 to 36V)
# Extreme Switch IMM Product Family

## 12V Family Devices

<table>
<thead>
<tr>
<th>Generation</th>
<th>Part Number</th>
<th>Outputs # and On-Resistance</th>
<th>Total Outputs</th>
<th>Package</th>
<th>Low Operating Voltage</th>
<th>High Operating Voltage</th>
<th>Pin to Pin Compatibility</th>
<th>SW Compatibility</th>
<th>Status / Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen3L</td>
<td>MC07XSC200EK</td>
<td>Dual 7mΩ</td>
<td>2</td>
<td>32-pin SOICEP</td>
<td>6V</td>
<td>20V</td>
<td>-</td>
<td>✓</td>
<td>In Production</td>
</tr>
<tr>
<td>Gen3L</td>
<td>MC10XSC425EK</td>
<td>Dual 10mΩ, Dual 25mΩ</td>
<td>4</td>
<td>32-pin SOICEP</td>
<td>6V</td>
<td>20V</td>
<td>-</td>
<td>✓</td>
<td>In Production</td>
</tr>
<tr>
<td>Gen4</td>
<td>MC07XSF517EK</td>
<td>Triple 7mΩ, Dual 17mΩ</td>
<td>5</td>
<td>54-pin SOICEP</td>
<td>7V</td>
<td>18V</td>
<td>-</td>
<td></td>
<td>In Production</td>
</tr>
<tr>
<td>Gen4</td>
<td>MC17XSF500EK</td>
<td>Penta 17mΩ</td>
<td>5</td>
<td>32-pin SOICEP</td>
<td>7V</td>
<td>18V</td>
<td>-</td>
<td></td>
<td>In Production</td>
</tr>
<tr>
<td>Gen4</td>
<td>MC40XSF500</td>
<td>Penta 40mΩ</td>
<td>5</td>
<td>32-pin SOICEP</td>
<td>7V</td>
<td>18V</td>
<td>-</td>
<td></td>
<td>In Production</td>
</tr>
<tr>
<td>Gen4</td>
<td>MC08XSF421</td>
<td>Dual 88mΩ, Dual 21mΩ</td>
<td>4</td>
<td>32-pin SOICEP</td>
<td>7V</td>
<td>18V</td>
<td>✓</td>
<td></td>
<td>Launch 04/2014</td>
</tr>
<tr>
<td>Gen4</td>
<td>MC17XSF400</td>
<td>Quad 17mΩ</td>
<td>4</td>
<td>32-pin SOICEP</td>
<td>7V</td>
<td>18V</td>
<td>✓</td>
<td></td>
<td>Launch 04/2014</td>
</tr>
<tr>
<td>Gen4</td>
<td>MC25XSF300</td>
<td>Triple 25mΩ</td>
<td>3</td>
<td>32-pin SOICEP</td>
<td>7V</td>
<td>18V</td>
<td>✓</td>
<td></td>
<td>Launch 04/2014</td>
</tr>
<tr>
<td>Gen4</td>
<td>MC10XSF325</td>
<td>Dual 10mΩ, Single 25mΩ</td>
<td>3</td>
<td>32-pin SOICEP</td>
<td>7V</td>
<td>18V</td>
<td>✓</td>
<td></td>
<td>Launch 04/2014</td>
</tr>
<tr>
<td>Gen4</td>
<td>MC10XSF700</td>
<td>Dual 10mΩ</td>
<td>2</td>
<td>32-pin SOICEP</td>
<td>7V</td>
<td>18V</td>
<td>✓</td>
<td></td>
<td>Launch 04/2014</td>
</tr>
<tr>
<td>Gen4</td>
<td>MC10XSF225</td>
<td>Single 10mΩ, Single 25mΩ</td>
<td>2</td>
<td>32-pin SOICEP</td>
<td>7V</td>
<td>18V</td>
<td>✓</td>
<td></td>
<td>Launch 04/2014</td>
</tr>
</tbody>
</table>

## 36V Family Devices

<table>
<thead>
<tr>
<th>Generation</th>
<th>Part Number</th>
<th>Outputs # and On-Resistance</th>
<th>Total Outputs</th>
<th>Package</th>
<th>Low Operating Voltage</th>
<th>High Operating Voltage</th>
<th>Pin to Pin Compatibility</th>
<th>SW Compatibility</th>
<th>Status / Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen2</td>
<td>MC06XSD200FK</td>
<td>Dual 6mΩ</td>
<td>2</td>
<td>24-pin PQFN</td>
<td>8V</td>
<td>36V</td>
<td>✓</td>
<td>✓</td>
<td>In production</td>
</tr>
<tr>
<td>Gen2</td>
<td>MC10XSD200FK</td>
<td>Dual 10mΩ</td>
<td>2</td>
<td>24-pin PQFN</td>
<td>8V</td>
<td>36V</td>
<td>✓</td>
<td>✓</td>
<td>In production</td>
</tr>
<tr>
<td>Gen2</td>
<td>MC10XSD200FK</td>
<td>Dual 10mΩ</td>
<td>2</td>
<td>24-pin PQFN</td>
<td>8V</td>
<td>36V</td>
<td>✓</td>
<td>✓</td>
<td>In production</td>
</tr>
<tr>
<td>Gen2</td>
<td>MC22X34200BEK</td>
<td>Dual 22mΩ</td>
<td>2</td>
<td>32-pin SOICEP</td>
<td>8V</td>
<td>36V</td>
<td>✓</td>
<td>✓</td>
<td>Launch 03/2014</td>
</tr>
<tr>
<td>Gen2</td>
<td>MC50X34200BEK</td>
<td>Dual 50mΩ</td>
<td>2</td>
<td>32-pin SOICEP</td>
<td>8V</td>
<td>36V</td>
<td>✓</td>
<td>✓</td>
<td>Launch 03/2014</td>
</tr>
</tbody>
</table>

## Main Switch Devices

<table>
<thead>
<tr>
<th>Generation</th>
<th>Part Number</th>
<th>Outputs # and On-Resistance</th>
<th>Total Outputs</th>
<th>Package</th>
<th>Low Operating Voltage</th>
<th>High Operating Voltage</th>
<th>Pin to Pin Compatibility</th>
<th>SW Compatibility</th>
<th>Status / Launch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen2</td>
<td>MC34981</td>
<td>Single 4mΩ, 60kHz</td>
<td>1</td>
<td>16-pin PQFN</td>
<td>6V</td>
<td>27V</td>
<td>-</td>
<td>-</td>
<td>In production</td>
</tr>
</tbody>
</table>
22A / 14V Gen4 Penta eXtreme Switches
MC07XS6517 / MC17XS6500

Scalable family of 22A/14V programmable penta high-side switches with wide-range diagnostic current sensing and lowest Rdson for up to 30% smaller PCB and 50% lower component count

Differentiating Points:

- **Robustness**: Unique over-current latch-off protection, full digital and accurate analog diagnostics, and protection features with embedded failsafe mode
- **Integration**: Five configurable low Rdson channels with daisy-chainable SPI
- **Density**: Thermally enhanced package for affordable high switch count modules with up to 30% lower power, 30% smaller PCB footprint and 50% fewer components
- **Accuracy**: Advanced current sensing over temperature and supply voltage range allowing accurate current monitoring from 27mA to 22A
- **Scalability**: Pin and SW driver compatible family
- **Best thermal efficiency**: Lowest Rdson in penta configuration

![Figure 1. Penta High Side Simplified Application Diagram](image)

**Typical Applications**

**Transportation**
- 12V lighting from high beam to LEDs

**Industrial**
- High current / highly inductive loads (solenoids)
- DC motor control
- Factory automation PLC
- Industrial lighting
### Product features:

- **Penta**: $3 \times 7 \, \text{m}\Omega + 2 \times 17 \, \text{m}\Omega$ or Penta $5 \times 17 \, \text{m}\Omega$
- Operating voltage range of **6.0 V to 18 V** with sleep current < 5.0 $\mu$A
- **Flexibility** Xenon / LED / Halogen (up to 11A, 22A)
- Lighting: from 25 Hz to 400 Hz
- **Daisy chainable 16-bit 5 MHz SPI**: control over-current profiles, PWM duty-cycles, output-ON and -OFF open load detections, thermal shut-down and fault reporting
- **Individually** programmable external PWM signal with **8-bit** duty cycle control.
- Channel round shaping for **excellent EMC behavior**
- Enhanced output current sense (down to 27.5 mA) with programmable synchronization signal, ±5°C temperature and ±1% battery voltage feedback
- Watchdog and **failsafe mode**
- **External** smart power switch control
- **Compatible** PCB footprint and SPI software driver among the family
- Current sense precision resistor **can be shared** among many devices
High Power Robustness Assessment: Gen4

Tests performed at hot temp.

<table>
<thead>
<tr>
<th>Short-circuit case</th>
<th>Battery voltage</th>
<th>Supply Line</th>
<th>Load Line</th>
<th>Cycles w/o failure</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turn-on into a short-circuit condition</td>
<td>16V</td>
<td>5.0 μH / 10 mΩ</td>
<td>5.0 μH / 50 mΩ</td>
<td>500k</td>
<td>AECQ100-12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0 μH / 20 mΩ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short-circuit in on-state</td>
<td>14V</td>
<td>0.3 m / 2.5 mm²</td>
<td>5.0 μH / 50 mΩ</td>
<td>500k</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5.0 m / 2.5 mm²</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.0 μH / 20 mΩ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>On-state overload 95% OCHI1/2/3 levels</td>
<td>16V</td>
<td>0.3 m / 2.5 mm²</td>
<td>0.3 m / 1.0 mm²</td>
<td>500k</td>
<td></td>
</tr>
</tbody>
</table>
NXP eXtreme Switch
Dual 6 mΩ – Dual 10 mΩ – Dual 20 mΩ – Dual 22 mΩ -Dual 50 mΩ

Scalable, programmable family of 24V/36V SPI-driven, dual-channel, smart high-side switches with lowest RDSon for up to a 30% board reduction

Differentiating Points:

- **Robustness**: Unique over-current latch-off protection, full digital & analog diagnostic and protection features with embedded failsafe mode
- **Integration**: Unique daisy-chainable SPI control for dual low RDSon channels in a single package
- **Accuracy**: 5X better current sensing accuracy over temperature & supply voltage range with unique accurate temperature sensing capability
- **Scalable**: Compatible PCB footprint and SPI software driver among the 36V product family
- **Lowest Rds on in Dual Configuration**: 20% smaller PCB due to lower power dissipation when using 12A/channel or 24A/dual in a thermally enhanced package

Typical Applications

- **Transportation 12 / 24V**
  - 24V lighting and capacitive loads
  - Valves
  - DC motors
- **Industrial**
  - High current / highly inductive loads (solenoids)
  - DC motor control
  - Factory automation
Product features:

- **Dual** 6, 10, 20, 22, 50 mΩ high side switches with possible parallel output mode
- Operating voltage range: 8V to 36V. Extended range: 6V to 58V. Sleep mode current < 10 µA
- **Flexibility** for resistive/capacitive/inductive loads (up to 1 kHz)
- 3.3 V and 5.0 V compatible 16-bit daisy chainable SPI control
- **Programmable** over-current profiles, channel control including PWM duty-cycles (8-bit), output-ON and OFF open load detections and fault reporting
- Individually **programmable internal/external PWM clock signals**
- **Temperature sensing** (±5°C) & over temperature shutdown for each channel
- Synchronous / asynchronous accurate current (±10%) sensing
- External current sense precision resistor shared among devices
- Watchdog and **failsafe mode**
- Hard or soft short-circuit + over temperature protection with safe auto-retry
- Selectable slew rates to improve EMC performances

Few external components required
# eXtreme Switch Features and Benefits

<table>
<thead>
<tr>
<th>Features</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest Rdson in thermally enhanced package</td>
<td>Best thermal efficiency for 30% smaller footprint and best module longevity with 30% lower power dissipation</td>
</tr>
<tr>
<td>Programmable dynamic threshold over-current and over-temperature detection limits</td>
<td>Optimized fault protection</td>
</tr>
<tr>
<td>Accurate temperature (±5 °C) and synchronous / asynchronous current (±10%) sensing</td>
<td>Advanced load diagnostics</td>
</tr>
<tr>
<td>Compatible devices and flexible load management from high current (HID, 65W lamps) to low current LEDs</td>
<td>Hardware reuse across multiple applications and quick-turn flexibility for tuning designs with ambiguous load requirement</td>
</tr>
<tr>
<td>Programmable fault auto-retry</td>
<td>Auto recovery for transient faults</td>
</tr>
<tr>
<td>Watchdog and protected output in failsafe mode</td>
<td>Ready for an SIL-B compliant module design</td>
</tr>
<tr>
<td>Selectable slew rate</td>
<td>Optimize EMI vs. efficiency tradeoff</td>
</tr>
<tr>
<td>Individually programmable internal/external PWM signals</td>
<td>Offloads MCU for software design simplicity &amp; PPM reduction</td>
</tr>
<tr>
<td>16-bit daisy chainable SPI control</td>
<td>BOM component &amp; cost savings by eliminating series SPI resistors between MCU and device</td>
</tr>
</tbody>
</table>

**Freescale**
eXtreme Switches Product Differentiation

Programmable penta high-side switches with wide-range diagnostic current sensing and lowest $R_{Dson}$ for up to 30% smaller PCB and 50% lower component count

### Robustness
- **Embedded intelligence and safety**
  - External or internal watchdog with fail safe management
  - Multi-step configurable over-current latch protection
  - Reduces wire harness size & increases protection

### Integration
- **Lighter weight, smaller systems**
  - Embedded PWM module simplifies MCU interface
  - Full diagnostics for multiple switches thru single SPI bus
  - Thermal efficient design enables smaller package

### Flexibility
- **Design re-use across multiple applications**
  - Configurable over-current for different load types & sizes
  - Embedded diagnostics & fault management simplifies SW
  - Software & footprint compatibility family
Ecosystem and Design Support
Application Diagram for Front Lights

5V Regulator
VCC Clamp

Main MCU
SI
CSI
SCLK
RST
CLK
A/D1
TRIG1
A/D2
GND

Gen4
SI
VCC
VBAT
CP
CSI
SCLK
SO
RST
CLK
CSNS
SYNC
LIMP
IN1
IN2
IN3
IN4
OUT1
OUT2
OUT3
OUT4
OUT5
OUT6
GND

Smart Power
IN4
IN3
IN2
IN1
LIMP
SYNC
CSNS
CLK
RST
SO
SCLK
CSI
SI
VCC
VBAT
CP

Watchdog
VBAT
LIMP
IN5
IN6
IN7
GND

Parking Light
Flasher
Low Beam
Fog Light
High Beam
Spare

20V

VCC
GND

VCC Clamp

VBAT RIGHT

VBAT LEFT
24V eXtreme Switch Application Diagram
**Extreme Switch Target Applications**

**Auto External Lighting**

<table>
<thead>
<tr>
<th>Car Application</th>
<th>Low &amp; High beam Fog lights</th>
<th>Low &amp; High beam Fog lights</th>
<th>Stop, Flasher Back drive lights</th>
<th>Stop, Flasher Back drive lights</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>H1, H3, H4, H7, H9</td>
<td>Xenon HID</td>
<td>P27W, P21W</td>
<td>P21W+R10W</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of lamp</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family</td>
<td>Product</td>
<td>Primary output</td>
<td>Secondary output</td>
<td>LED-arrays</td>
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<tr>
<td>Gen3</td>
<td>MC15XS3400</td>
<td>4°15 mΩ</td>
<td>-</td>
<td>√</td>
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<td>MC10XS3412</td>
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<td>√</td>
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<td>MC10XS3435</td>
<td>2°10 mΩ, 2°35 mΩ</td>
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<td></td>
<td>MC10XS3600</td>
<td>3°10 mΩ, 2°35 mΩ</td>
<td>√</td>
<td>√</td>
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<tr>
<td></td>
<td>MC35XS3600</td>
<td>5°35 mΩ</td>
<td>X</td>
<td>X</td>
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</tbody>
</table>

**Gen3L**
- MC09XS3400: 4°09 mΩ, -
- MC06XS3617: 3°06 mΩ, 2°17 mΩ
- MC10XS3200: 2°10 mΩ, 2°25 mΩ
- MC07XS3200: 2°7 mΩ, -

**Gen4**
- MC07XS6517: 3°7 mΩ, 2°17 mΩ
- MC17XS6500: 5x17mΩ, -

- Customer looks for integration
- Customer is willing to have a single module capable of driving either LED (low current) or standard lamp (high current) on the same output
eXtreme Switch Available Documentation

• Datasheets
• Evaluation kit (EVB kit)
• Application notes:
  – PQFN PCB guidelines
  – EMC and fast transient pulses performance
  – IBIS Model File for Dual 24V High Side
  – Compact Thermal Model
  – Robustness performance
  – Training package
  – …
• Tools
  – Microsoft Excel® Thermal Calculator
  – Cadence Orcad® Behavioral Models
• Reference designs
Typical eSwitch EVB Kit Connected to SPIGEN Dongle

12V Power supply

PC via USB

SPI communication

KITUSBSPIDGLEVME

Load 1
Load 2
Load 3
Load 4
Load 5

KIT07XS6517EVB
eXtreme Switch Available Documentation

• Datasheets
• Evaluation kit (EVB kit)
• Application notes:
  − PQFN PCB guidelines
  − EMC and fast transient pulses performance
  − IBIS Model File for Dual 24V High Side
  − Compact Thermal Model
  − Robustness performance
  − Training package
  − …

• Tools
  − Microsoft Excel® Thermal Calculator
  − Cadence Orcad® Behavioral Models

• Reference designs
# Power Dissipation Calculator (Excel® based)

## Gen3, GEN3L, GEN4 and 24V eXtremeSwitch Partitioning and Thermal Estimates

### Conditions Table

<table>
<thead>
<tr>
<th>Condition</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Ambient temperature, ( T_a )</td>
<td>85</td>
<td>°C</td>
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<tr>
<td>Battery voltage, ( V_{batt} )</td>
<td>16</td>
<td>V</td>
</tr>
<tr>
<td>FPGA/N-Supply</td>
<td>29</td>
<td>C/W</td>
</tr>
<tr>
<td>Module Thermal Resistance</td>
<td>3</td>
<td>C/W</td>
</tr>
<tr>
<td>Total e-Switch Power Dissipation</td>
<td>2.2</td>
<td>W</td>
</tr>
<tr>
<td>Power Dissipated in other Drivers</td>
<td>1.0</td>
<td>W</td>
</tr>
<tr>
<td>Misc. Module Power</td>
<td>0.0</td>
<td>W</td>
</tr>
<tr>
<td>Total Module Power</td>
<td>3.2</td>
<td>W</td>
</tr>
<tr>
<td>Module Temp Rise</td>
<td>9.5</td>
<td>°C</td>
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<tr>
<td>Reverse Battery Voltage</td>
<td>14.0</td>
<td>V</td>
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</table>

### User Inputs

<table>
<thead>
<tr>
<th>Output Channel Name</th>
<th>Batt or Fuse</th>
<th>Proposed Device</th>
<th>Device channel #</th>
<th>Max Rds @25°C [mOhms]</th>
<th>Channel’s Min Inrush current limit [A]</th>
<th>Load’s Peak Inrush Current [A]</th>
<th>Load @16V [A]</th>
<th>Load Duty Cycle [%]</th>
<th>PWM Freq [Hz]</th>
<th>PWM Duty Cycle [%]</th>
<th>Slow Rate Setting</th>
<th>Slow Rate [µs]</th>
<th>Load ON</th>
<th>PWM ON</th>
<th>RMS Current @16V [A]</th>
<th>Estimated TJ [°C]</th>
<th>Rds@ Estimated TJ [mΩ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load #</td>
<td># MC20XS4200</td>
<td>#1</td>
<td>2</td>
<td>20</td>
<td>27.5</td>
<td>0.0</td>
<td>5.00</td>
<td>100%</td>
<td>100 Hz</td>
<td>100%</td>
<td>Low</td>
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<td>0</td>
<td>0.00 A</td>
<td>27.576</td>
<td>0.00 A</td>
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<tr>
<td>Load #</td>
<td># MC10XS4200</td>
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<td>10</td>
<td>55.0</td>
<td>0.0</td>
<td>5.00</td>
<td>100%</td>
<td>100 Hz</td>
<td>100%</td>
<td>Low</td>
<td>0.20</td>
<td>0</td>
<td>0</td>
<td>0.00 A</td>
<td>13.788</td>
<td>0.00 A</td>
</tr>
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<td>Load #</td>
<td># MC06XS4200</td>
<td>#3</td>
<td>1</td>
<td>6</td>
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<td>100%</td>
<td>100 Hz</td>
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<td>0</td>
<td>0</td>
<td>0.00 A</td>
<td>8.273</td>
<td>0.00 A</td>
</tr>
</tbody>
</table>

Typical Rds(on) % of max rating

- Typical Rds(on) multiplier at 25°C: 1.00
- Typical Rds(on) multiplier at 150°C: 1.45
The behavioral model manages the **electrical** and **thermal** aspects **concurrently**. It allows evaluation of a device’s thermal performance under various conditions:

- Supply voltage
- PCB design layout
- Ambient temperature
- eXtreme Switch device type changes

**Parametric range steps** (over-current level, under-voltage threshold)

**The prediction of junction temperature elevation** is based on computing transient power dissipation on dedicated channel. The reciprocal influence of junction temperature and on-state resistance of channel is modeled.
eXtreme Switch Available Documentation

- Datasheets
- Evaluation kit (EVB kit)
- Application notes:
  - PQFN PCB guidelines
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  - Compact Thermal Model
  - Robustness performance
  - Training package
  - …
- Tools
  - Microsoft Excel® Thermal Calculator
  - Cadence Orcad® Behavioral Models
- Reference designs
24V Reference Design Board
Gen4 Reference Design Board

Loads
(Bulbs, LED, HID)

RefDesign Board

PC Interface

LabView

Freescale™

External Use | 37
36V eXtreme Switch Analog Tower System

Development KIT for devices compatible with industrial applications requirements:

Interact, Explore, Create with Tower Geeks Online Community (www.towergeeks.org)

Supported Software Design Resource: Processor Expert (MCU Driver Suite)

Available Sept. 2014
Session Review/ Wrap-up
Benefits of eXtreme Switches

- Robust Design: Provide robust design, intelligence and safety needed for 24V/12V applications
- Increased Integration: Increase integration to provide lighter, smaller systems
- Flexibility: Provide programmability and flexibility needed to control all aspects of loads

For automotive and industrial applications
For Additional Information

Freescale’s website
http://www.freescale.com/

Freescale’s analog website (useful PDFs plus links to other sites)
http://www.freescale.com/webapp/sps/site/homepage.jsp?code=ANALOGHOME
  About Freescale Analog
  Analog Technology Brochure (pdf)
  Analog Packaging Brochure (pdf)
  Analog Applications Brochure (pdf)
  Automotive Solutions Brochure (pdf)
  Analog Selector Guide (pdf)
  Automotive Selector Guide (pdf)
  SafeAssure Functional Safety
  Thermal Analysis of Semiconductor Systems (pdf)

High side switches, including eSwitches (parametric search & datasheets)
http://www.freescale.com/webapp/sps/site/taxonomy.jsp?nodeId=01435979968459

Analog Toolbox (evaluation kits, SPIGEN software, reference designs)

SPI Generator (SPIGen) Software
http://www.freescale.com/webapp/sps/site/prod_summary.jsp?code=SPIGEN
Q&A

Thank you for your attention
### eXtreme Switch – Intelligence and Safety

#### Protection Table

<table>
<thead>
<tr>
<th>Product Family</th>
<th>Part Number</th>
<th>Open load ON-OFF-LED</th>
<th>Load Shorted to Battery</th>
<th>Temperature pre-warning Flag</th>
<th>Analog meas.</th>
<th>Overtemp hysteresis (w/ Flag)</th>
<th>Overtemp shutdown (w/ Flag)</th>
<th>Ground loss - Reverse batt.</th>
<th>Load dump</th>
<th>Over / Under Voltage</th>
<th>ECU output short circuit</th>
<th>Load short circuit or overload latchoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>MC33981ABHFK / R2</td>
<td>A - -</td>
<td>x</td>
<td>-</td>
<td>X - -</td>
<td>X - -</td>
<td>X</td>
<td>X</td>
<td>41 V</td>
<td>x</td>
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<td>x</td>
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</tr>
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<td>41 V</td>
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<tr>
<td>24V</td>
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<tr>
<td>24V</td>
<td>MC22XS4200BFK / R2</td>
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<td>24V</td>
<td>MC50XS4200BFK / R2</td>
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<td>X</td>
<td>-</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- **A =** available with analog current measurement
- **"X" =** Feature available
- **"-" =** Feature not available

### Protection Features

**Intelligence**
- Protections, diagnostics SPI configurable

**Safety**
- In case of MCU failure, device protects all the system

**Intelligence & Safety**
- During system failure, Fail Safe mode can activate loads with full protection