Smart FET Protection Features
Agenda

- Current Limit
- Over Temperature Protection
- Over Voltage Protection
- ESD Protection
- Diagnostic Output
- High and Low Side Portfolio and Applications
SmartFET Capability

SmartFET enables integration of analog circuit elements in Power MOSFET devices for cost effective solutions.
Smart FET Protection Features

- ON Semiconductor’s Smart FET’s Feature 4 Main Protection Functions
  - Current Limit Protection
  - Over Temperature Protection
  - Overvoltage Protection
  - ESD Protection
- ON Semiconductor’s High Side NCV8460 Adds Diagnostic Features
  - Open Load Detection
Current Limit Protection

• Current from the Drain is mirrored into a smaller device anywhere from 1/200th to 1/1000th the size of the main power device

Figure 5. Simplified Current Limit Circuit
Current Limit Protection

- The current through the smaller device develops a voltage across $R_S$
- As $V_{RS}$ increases, a pulldown FET turns on, and pulls down on the voltage of the main power FET, which reduces output current
Current Limit Protection

• The current limit will vary with temperature
• As can be seen above, as the device heats up, current limit decreases
Over Temperature Protection

- On Semiconductor’s Smart FET’s include Over Temperature Protection, which shuts down the device when the temperature exceeds a predetermined threshold.
- If the TSD structure indicates a high temperature, the $T_{\text{LIM}}$ Pulldown device pulls the voltage down on the main power device.
Over Temperature Protection

- A reference voltage is compared to the TSD structure, a diode structure, located in the die’s ‘hot spot’
Over Temperature Protection

- Once the TSD structure indicates the temperature has dropped, the pulldown device turns off, allowing the main power device to turn back on.
- The typical hysteresis is 15 C.
Over Voltage Protection

- A Gate to Drain Zener Clamp provides overvoltage protection
- The clamp allows the Gate to turn on, spreading the energy more evenly across the active area
Over Voltage Protection

- Voltage across DUT is clamped during an inductive flyback event.
- When the input is turned off, the voltage across DUT increases until it reaches the clamp level, typically around 45 V.
ESD Protection

- Back to Back diodes on the Gate pin clamp the voltage to 13 V
- This combined with the internal series resistance allow a minimum of 4000 V Human Body Model and 400 V Machine Model ESD capability
- The Source and Drain are inherently protected through the device structure itself
Diagnostics

• The NCV8460 offers diagnostic features and a status pin
  – Normal Operation- Status Pin High

  ![Diagram of Normal Operation]

  – Undervoltage-
    • Status Pin Undefined
    • Output Turns Off

  ![Diagram of Undervoltage]
Diagnostics

- The NCV8460 offers diagnostic features and a status pin
  - Overvoltage
    - Status Pin Stays High
    - Output Shuts Off

- Over Temperature
  - Status Pin Goes Low
  - Output Turns Off
Diagnostics

• The NCV8460 offers diagnostic features and a status pin
  – Open Load With External Pull Up
    • Input High- Status Pin Goes Low When Open Load Detected
    • Input Low- Status Pin Goes Low When Open Load Detected

  \[\text{OPEN LOAD with external pull-up}\]
  \[
  \begin{array}{c}
  \text{INPUT} \\
  \text{LOAD VOLTAGE} \\
  \text{STATUS}
  \end{array}
  \begin{array}{c}
  \vdash \vdash \vdash \\
  V_{\text{OUT}}>V_{\text{OL}} \\
  V_{\text{OL}}
  \end{array}
  \]

  – Open Load Without External Pull Up
    • Input High- Status Pin Goes Low When Open Load Detected
    • Input Low- Status Pin Stays High Regardless of Load Condition

  \[\text{OPEN LOAD without external pull-up}\]
  \[
  \begin{array}{c}
  \text{INPUT} \\
  \text{LOAD VOLTAGE} \\
  \text{STATUS}
  \end{array}
  \begin{array}{c}
  \vdash \vdash \vdash \\
  \vdash \vdash \vdash \\
  \vdash \vdash \vdash
  \end{array}
  \]
## Potential Failure Modes and Mitigation Strategies

<table>
<thead>
<tr>
<th>Potential Failure Mode</th>
<th>Mitigation</th>
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<tbody>
<tr>
<td>Insufficient gate drive during fault condition</td>
<td>- Increase current source/sink capability of gate drive circuit  &lt;br&gt; - Increase gate drive voltage</td>
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<tr>
<td>Excessive $dV/dt$ at drain</td>
<td>- Increase series gate resistance  &lt;br&gt; - Filter or snubber circuits to eliminate fast edge transients  &lt;br&gt; - Reduce supply voltage</td>
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<tr>
<td>Excessive die temperature during SCIS operation</td>
<td>- Reduce load inductance  &lt;br&gt; - Reduce circuit parasitic inductance  &lt;br&gt; - Use lower clamp voltage device  &lt;br&gt; - Use device with proper energy rating  &lt;br&gt; - Decrease device duty cycle or frequency or both  &lt;br&gt; - Use parallel devices</td>
</tr>
<tr>
<td>Excessive die temperature during load dump or other transient event</td>
<td>- Increase load resistance  &lt;br&gt; - Improve transient thermal response via better thermal pathway or larger silicon active area  &lt;br&gt; - Use parallel devices</td>
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ON Semiconductor Low Side Portfolio

- NCV8401
  - 33 A Current Limit, 23 mOhm RDSOn, 42 V Clamp, and 175 C TSD
- NCV8402 and NCV8402 Dual
  - 2 A Current Limit, 165 mOhm RDSOn, 42 V Clamp, and 175 C TSD
- NCV8403
  - 15 A Current Limit, 53 mOhm RDSOn, 42 V Clamp, and 175 C TSD
- NCV8405
  - 6 A Current Limit, 90 mOhm RDSOn, 42 V Clamp, and 175 C TSD
- NCV8440
  - 95 mOhm RDSOn
  - 52 V Clamp Only, No TSD, or Current Limit
- NIMD6001 (Dual)
  - 110 mOhm RDSOn
  - No Clamp, TSD or Current Limit
  - Over Voltage Diagnostic Signal
Low Side Applications

- Split Cooling Valve Sensor- NCV8403
  - The Drain is used to drive a heater resistor to control a thermostat
  - As the resistive load heats up, the thermostat heats up causing it to be over-ridden
  - A $3\,\text{k}\Omega$ gate resistor is used to slew the switching speed.
Low Side Applications

- Lambda Sensor- NCV8403
  - A lambda sensor is a resistive load
  - The sensor measures the oxygen content in the exhaust gas
  - A 3 kΩ gate resistor is used to slew the switching speed
ON Semiconductor High Side Portfolio

- **NCV8450**
  - Released
  - 1 A Current Limit, 1 Ohm RDSOn
  - No Diagnostic Features
  - Cross to BTS4140
  - Voltage Clamped to 45 V, 175 C TSD

- **NCV8460**
  - Currently in Design
  - Diagnostic Features
    - On State Open Load Detection
    - Off State Open Load Detection
    - Diagnostic Output
  - Under Voltage and Over Voltage Shutdown
  - 9 A Current Limit, 60 mOhm RDSOn
  - Cross to VN750
  - Voltage Clamped to 42 V, 175 C TSD
High Side Applications

- Power Train Application- NCV8450
  - Evaporation Leak Detection Solenoid
High Side Applications

- Brake Light Application- NCV8450
  - Open Collector Hall Sensor Used to Drive NCV8450
Conclusion

• ON Semiconductor’s SmartFET offers 4 main protection functions
  – Current Limit
  – Over Temperature Protection
  – Over Voltage Protection
  – ESD Protection

• ON Semiconductors’ new NCV8460 adds a Diagnostic Output Feature
For More Information

- View the extensive portfolio of power management products from ON Semiconductor at [www.onsemi.com](http://www.onsemi.com)

- View reference designs, design notes, and other material supporting automotive applications at [www.onsemi.com/automotive](http://www.onsemi.com/automotive)