Motor Technologies 3: Protection Features
TI Precision Labs – Motor Drivers

Presented and prepared by Aaron Barrera
Overview

• Protection Features Summary

• Common Protection Features
  – VM undervoltage (UVLO)
  – Charge pump undervoltage (CPUV)
  – Overcurrent Protection (OCP)
  – Thermal warning / shutdown (OTW/ OTSD)

• Other Protection Features

• Examples:
  – DRV8872
  – DRV8343S-Q1
Protection Features Summary

- TI’s Motor Drivers come equipped with a variety of smart protection circuits that protects the motor and power MOSFETs when an unsafe condition is detected
  - Action(s) taken: disable MOSFETs and/or charge pump, report a fault condition

Smartly turning off the FETs protects the motor!

DRV8842 – DC Motor Driver IC
Protection Features Summary (cont.)

Protection Features can vary by:

**Motor Type**
- Brushed-DC
- Brushless-DC
- Stepper

**Family**
- DRV8x
- DRV10x
- DRV3x

**Interface**
- Hardware
- Serial Peripheral Interface (SPI)
Protection Features Summary (cont.)

Fault Reporting / Actions Taken

**Hardware**

- **nFAULT** driven low
- Default configurations
- No indication of which fault occurred
- Often automatic retry until fault condition is cleared

**Serial Peripheral Interface (SPI)**

- **nFAULT** driven low
- Set operating parameters
- Reads out fault diagnostic information
- Configurable fault response

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**8.6.1.1 FAULT Status Register**

FAULT Status Register (Address = 0x00) [reset = 0x00]

FAULT Status is shown in Figure 45 and described in Table 16.

<table>
<thead>
<tr>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAULT</td>
<td>GDF</td>
<td>CPUV</td>
<td>UVLO</td>
<td>OCP</td>
<td>OTW</td>
<td>OTSD</td>
<td>OL_SHT</td>
</tr>
<tr>
<td>R-0b</td>
<td>R-0b</td>
<td>R-0b</td>
<td>R-0b</td>
<td>R-0b</td>
<td>R-0b</td>
<td>R-0b</td>
<td>R-0b</td>
</tr>
</tbody>
</table>
Common Protection Features
Supply Undervoltage Lockout (UVLO)

- Supply voltage falls lower than the $V_{UVLO}$ falling threshold
  - Determined by $V_{UVLO}$ and $V_{UVLO,HYS}$
  - Re-enable drivers after supply > $V_{UVLO,rising}$

\[
\begin{align*}
V_M &< V_{UVLO} \\
\text{MOSFETs, charge pump} &\text{Disabled, nFAULT low}
\end{align*}
\]
Supply Undervoltage Lockout (UVLO)

- Supply voltage falls lower than the $V_{UVLO}$ falling threshold
  - Determined by $V_{UVLO}$ and $V_{UVLO,HYS}$
  - Re-enable drivers after supply > $V_{UVLO,rising}$
Charge pump undervoltage (CPUV)

- Charge pump voltage (VCP) falls lower than the CPUV threshold voltage of the charge pump
  - MOSFETs are disabled, nFAULT is driven low
  - Waits until CPUV condition is cleared
Charge pump undervoltage (CPUV)

- Charge pump voltage (VCP) falls lower than the CPUV threshold voltage of the charge pump
  - MOSFETs are disabled, nFAULT is driven low
  - Waits until CPUV condition is cleared

\[
\begin{align*}
V_{CP} &< V_{CPUV} \quad \text{MOSFETs disabled, nFAULT low} \\
V_{CP} &> V_{CPUV} \quad \text{MOSFETs enabled, nFAULT high}
\end{align*}
\]
Overcurrent Protection (OCP)

- Detects motor short conditions and protects system from damage
  - Analog current limit
  - Digital threshold and deglitch
  - Sense pin overvoltage

\[ I_{DS} > I_{OCP} \]

MOSFETS disabled, nFAULT low

Exceeds \( I_{OCP} \) after \( t_{OCP} \), OCP fault is detected

\[ t_{OCP} \]

\[ t \ (\text{ns}) \]
**OCP on a Gate Driver**

**V_{DS} Overcurrent Protection (VDS_OCP)**

Source-drain voltage monitored by dedicated pins, compared to threshold for OCP

$$V_{DS} > V_{DS\_OCP}$$

OCP fault detected

**V_{SEN} Overcurrent Protection (VSEN_OCP)**

Internal CSAs can compare voltage across shunt resistor to threshold for OCP

$$V_{SEN} > V_{SEN\_OCP}$$

OCP fault detected

MOSFETs disabled, nFAULT low
Thermal warning / shutdown (OTW/OTSD)

- **Overtemperature Warning (OTW)**
  - Devices continues to function
  - Only featured on some devices
- **Overtemperature Shutdown (OTSD)**
  - nFAULT driven low, MOSFETs and charge pump is disabled

\[ I_{LOAD} = 1 \text{ A} \]

\[ T_{OTW} - T_{HYS} \]

\[ T_{OTSD} \]

\[ T_{HYS} \]
Thermal warning / shutdown (OTW/OTSD)

- **Overtemperature Warning (OTW)**
  - Devices continues to function
  - Only featured on some devices

- **Overtemperature Shutdown (OTSD)**
  - nFAULT driven low, MOSFETs and charge pump is disabled

**Equations**

\[ T_{J} > T_{OTW} \]
\[ T_{OTSD} - T_{HYS} \]
\[ I_{LOAD} = 2 \, A \]
Thermal warning / shutdown (OTW/OTSD)

- **Overtemperature Warning (OTW)**
  - Devices continues to function
  - Only featured on some devices

- **Overtemperature Shutdown (OTSD)**
  - nFAULT driven low, MOSFETs and charge pump is disabled

\[ T_{J} > T_{OTW}, \text{ OTSD fault} \]

\[ T_{J} < T_{OTW} - T_{HYS}, \text{ Normal operation resumes} \]

\[ I_{LOAD} = 3 \, \text{A} \]
<table>
<thead>
<tr>
<th>Protection Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overvoltage Protection</td>
</tr>
<tr>
<td>Gate driver fault</td>
</tr>
<tr>
<td>Open Load Detection</td>
</tr>
<tr>
<td>Short-to-battery / short-to-ground</td>
</tr>
<tr>
<td>Dead Time</td>
</tr>
<tr>
<td>MOSFET $dV/dt$ Turn On Protection</td>
</tr>
</tbody>
</table>
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