

## LM25069 Positive Low Voltage Power Limiting Hot Swap Controller

Check for Samples: [LM25069](#)

### FEATURES

- Operating Range: +2.9V to +17V
- In-rush Current Limit for Safe Board Insertion into Live Power Sources
- Programmable Maximum Power Dissipation in the External Pass Device
- Adjustable Current Limit
- Circuit Breaker Function for Severe Over-Current Events
- Internal High Side Charge Pump and Gate Driver for External N-channel MOSFET
- Adjustable Under-Voltage Lockout (UVLO) and Hysteresis
- Adjustable Over-Voltage Lockout (OVLO) and Hysteresis
- Initial Insertion Timer Allows Ringing and Transients to Subside After System Connection
- Programmable Fault Timer Avoids Nuisance Trips
- Active High Open Drain POWER GOOD Output
- Available in Latched Fault and Automatic Restart Versions

### APPLICATIONS

- Server Backplane Systems
- Base Station Power Distribution Systems
- Solid State Circuit Breaker

### PACKAGE

- VSSOP-10

### DESCRIPTION

The LM25069 positive hot swap controller provides intelligent control of the power supply voltage to the load during insertion and removal of circuit cards from a live system backplane or other "hot" power sources. The LM25069 provides in-rush current control to limit system voltage droop and transients. The current limit and power dissipation in the external series pass N-Channel MOSFET are programmable, ensuring operation within the Safe Operating Area (SOA). The POWER GOOD output indicates when the output voltage is within 1.3V of the input voltage. The input under-voltage and over-voltage lockout levels and hysteresis are programmable, as well as the initial insertion delay time and fault detection time. The LM25069-1 latches off after a fault detection, while the LM25069-2 automatically restarts at a fixed duty cycle. The LM25069 is available in a 10 pin VSSOP package.

### Typical Application

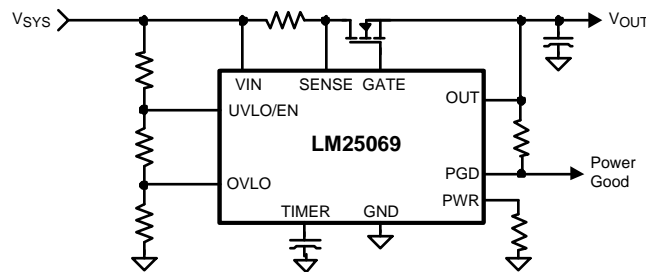


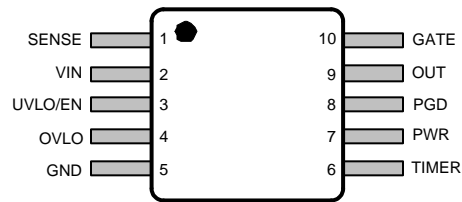
Figure 1. Positive Power Supply Control



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## Connection Diagram



**Figure 2. Top View  
10-Lead VSSOP**

### PIN DESCRIPTIONS

| Pin # | Name    | Description           | Applications Information   |
|-------|---------|-----------------------|--|
| 1     | SENSE   | Current sense input   | The voltage across the current sense resistor ( $R_S$ ) is measured from VIN to this pin. If the voltage across $R_S$ reaches 50mV the load current is limited and the fault timer activates.  |
| 2     | VIN     | Positive supply input | A small ceramic bypass capacitor close to this pin is recommended to suppress transients which occur when the load current is switched off.  |
| 3     | UVLO/EN | Under-voltage lockout | An external resistor divider from the system input voltage sets the under-voltage turn-on threshold. An internal 20 $\mu$ A current source provides hysteresis. The enable threshold at the pin is 1.17V. This pin can also be used for remote shutdown control. |
| 4     | OVLO    | Over-voltage lockout  | An external resistor divider from the system input voltage sets the over-voltage turn-off threshold. An internal 20 $\mu$ A current source provides hysteresis. The disable threshold at the pin is 1.16V.   |
| 5     | GND     | Circuit ground        |  |
| 6     | TIMER   | Timing capacitor      | An external capacitor connected to this pin sets the insertion time delay and the Fault Timeout Period. The capacitor also sets the restart timing of the LM25069-2.   |
| 7     | PWR     | Power limit set       | An external resistor connected to this pin, in conjunction with the current sense resistor ( $R_S$ ), sets the maximum power dissipation allowed in the external series pass MOSFET.   |
| 8     | PGD     | Power Good indicator  | An open drain output. When the external MOSFET $V_{DS}$ decreases below 1.3V, the PGD indicator is active (high). When the external MOSFET $V_{DS}$ increases above 1.9V the PGD indicator switches low.   |
| 9     | OUT     | Output feedback       | Connect to the output rail (external MOSFET source). Internally used to determine the MOSFET $V_{DS}$ voltage for power limiting, and to control the PGD indicator.  |
| 10    | GATE    | Gate drive output     | Connect to the external MOSFET's gate. This pin's voltage is limited at 19.5V above ground.  |



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

**Absolute Maximum Ratings<sup>(1)(2)(3)</sup>**

|                                    |                  |                 |
|------------------------------------|------------------|-----------------|
| VIN to GND <sup>(4)</sup>          |                  | -0.3V to 20V    |
| SENSE, OUT, PGD to GND             |                  | -0.3V to 20V    |
| UVLO to GND                        |                  | -0.3V to 20V    |
| OVLO to GND                        |                  | -0.3V to 20V    |
| VIN to SENSE                       |                  | -0.3V to +0.3V  |
| ESD Rating <sup>(5)</sup>          | Human Body Model | 2kV             |
| Storage Temperature                |                  | -65°C to +150°C |
| Junction Temperature               |                  | +150°C          |
| Lead Temperature (soldering 4 sec) |                  | +260°C          |

- (1) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not ensure specific performance limits. For ensured specifications and conditions see the Electrical Characteristics.
- (2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
- (3) For detailed information on soldering plastic VSSOP packages refer to the Packaging Databook available from Texas Instruments.
- (4) Current out of a pin is indicated as a negative number.
- (5) The human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin.

**Operating Ratings**

|                      |                |
|----------------------|----------------|
| VIN Supply Voltage   | +2.9V to 17V   |
| PGD Off Voltage      | 0V to 17V      |
| Junction Temp. Range | -40°C to +85°C |

**Electrical Characteristics**

Limits in standard type are for  $T_J = 25^\circ\text{C}$  only; limits in boldface type apply over the junction temperature ( $T_J$ ) range of  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ . Minimum and Maximum limits are ensured through test, design, or statistical correlation. Typical values represent the most likely parametric norm at  $T_J = 25^\circ\text{C}$ , and are provided for reference purposes only. Unless otherwise stated the following conditions apply:  $V_{IN} = 12\text{V}$ .

| Symbol                 | Parameter                                 | Conditions                                       | Min.         | Typ. | Max.         | Units |
|------------------------|---|--|--------------|------|--------------|-------|
| <b>Input (VIN pin)</b> |   |  |              |      |              |       |
| $I_{IN-EN}$            | Input Current, enabled                    | UVLO = 2V and OVLO = 0.7V, $V_{IN} = 14\text{V}$ |              | 1.6  | <b>2.4</b>   | mA    |
| $I_{IN-DIS}$           | Input Current, disabled                   | UVLO = 0.7V or OVLO = 2V                         |              | 1.0  | <b>1.6</b>   | mA    |
| POR                    | Power On Reset threshold at VIN           | VIN Increasing                                   |              | 2.6  | <b>2.8</b>   | V     |
| $POR_{HYS}$            | POR hysteresis                            | VIN decreasing                                   |              | 150  |              | mV    |
| <b>OUT pin</b>         |   |  |              |      |              |       |
| $I_{OUT-EN}$           | OUT bias current, enabled                 | OUT = VIN, Normal operation                      |              | 0.30 |              | μA    |
| $I_{OUT-DIS}$          | OUT bias current, disabled <sup>(1)</sup> | Disabled, OUT = 0V, SENSE = VIN                  |              | -12  |              |       |
| <b>UVLO, OVLO pins</b> |   |  |              |      |              |       |
| $UVLO_{TH}$            | UVLO threshold                            |  | <b>1.154</b> | 1.17 | <b>1.183</b> | V     |
| $UVLO_{HYS}$           | UVLO hysteresis current                   | UVLO = 1V  | <b>15</b>    | 20   | <b>26</b>    | μA    |
| $UVLO_{DEL}$           | UVLO delay                                | Delay to GATE high                               |              | 15   |              | μs    |
|                        |   | Delay to GATE low                                |              | 8.3  |              |       |
| $UVLO_{BIAS}$          | UVLO bias current                         | UVLO = 3V  |              |      | <b>1</b>     | μA    |
| $OVLO_{TH}$            | OVLO threshold                            |  | <b>1.142</b> | 1.16 | <b>1.185</b> | V     |
| $OVLO_{HYS}$           | OVLO hysteresis current                   | OVLO = 2V  | <b>-26</b>   | -20  | <b>-15</b>   | μA    |
| $OVLO_{DEL}$           | OVLO delay                                | Delay to GATE high                               |              | 16   |              | μs    |
|                        |   | Delay to GATE low                                |              | 8.2  |              |       |
| $OVLO_{BIAS}$          | OVLO bias current                         | OVLO = 1V  |              |      | <b>1</b>     | μA    |

- (1) OUT bias current (disabled) due to leakage current through an internal 1.0 MΩ resistance from SENSE to VOUT.

## Electrical Characteristics (continued)

Limits in standard type are for  $T_J = 25^\circ\text{C}$  only; limits in boldface type apply over the junction temperature ( $T_J$ ) range of  $-40^\circ\text{C}$  to  $+85^\circ\text{C}$ . Minimum and Maximum limits are ensured through test, design, or statistical correlation. Typical values represent the most likely parametric norm at  $T_J = 25^\circ\text{C}$ , and are provided for reference purposes only. Unless otherwise stated the following conditions apply:  $V_{IN} = 12\text{V}$ .

| Symbol                         | Parameter                               | Conditions   | Min.        | Typ. | Max.        | Units         |
|--------------------------------|---|--|-------------|------|-------------|---------------|
| <b>Power Limit (PWR pin)</b>   |   |  |             |      |             |               |
| $PWR_{LIM-1}$                  | Power limit sense voltage (VIN-SENSE)   | SENSE-OUT = 12V, $R_{PWR} = 69.8\text{ k}\Omega$                   | <b>19</b>   | 25   | <b>31</b>   | mV            |
| $PWR_{LIM-2}$                  |   | SENSE-OUT = 6V, $R_{PWR} = 34.8\text{ k}\Omega$                    | <b>19</b>   | 25   | <b>31</b>   | mV            |
| $I_{PWR}$                      | PWR pin current                         | $V_{PWR} = 2.5\text{V}$  |             | -15  |             | $\mu\text{A}$ |
| $R_{SAT(PWR)}$                 | PWR pin impedance when disabled         | UVLO = 0.7V  |             | 140  |             | $\Omega$      |
| <b>Gate Control (GATE pin)</b> |   |  |             |      |             |               |
| $I_{GATE}$                     | Source current                          | Normal Operation   | <b>-27</b>  | -20  | <b>-13</b>  | $\mu\text{A}$ |
|                                | Sink current                            | UVLO = 1V  | <b>1.5</b>  | 2    | <b>2.7</b>  | mA            |
|                                |   | VIN - SENSE = 150 mV or VIN < POR, $V_{GATE} = 5\text{V}$          | <b>160</b>  | 260  | <b>375</b>  | mA            |
| $V_{GATE}$                     | Gate output voltage in normal operation | GATE voltage with respect to ground                                | <b>18</b>   | 19.5 | <b>21</b>   | V             |
| <b>Current Limit</b>           |   |  |             |      |             |               |
| $V_{CL}$                       | Threshold voltage                       | VIN-SENSE voltage  | <b>45</b>   | 50   | <b>55</b>   | mV            |
| $t_{CL}$                       | Response time                           | VIN-SENSE stepped from 0 mV to 80 mV                               |             | 15   |             | $\mu\text{s}$ |
| $I_{SENSE}$                    | SENSE input current                     | Enabled, SENSE = OUT   |             | 23   |             | $\mu\text{A}$ |
|                                |   | Disabled, OUT = 0V   |             | 12   |             |               |
|                                |   | Enabled, OUT = 0V  |             | 62   |             |               |
| <b>Circuit Breaker</b>         |   |  |             |      |             |               |
| $V_{CB}$                       | Threshold voltage                       | VIN - SENSE  | <b>75</b>   | 95   | <b>110</b>  | mV            |
| $t_{CB}$                       | Response time                           | VIN - SENSE stepped from 0 mV to 150 mV, time to GATE low, no load |             | 0.19 | <b>0.36</b> | $\mu\text{s}$ |
| <b>Timer (TIMER pin)</b>       |   |  |             |      |             |               |
| $V_{TMRH}$                     | Upper threshold                         |  | <b>1.6</b>  | 1.72 | <b>1.85</b> | V             |
| $V_{TMRL}$                     | Lower threshold                         | Restart cycles (LM25069-2)   | <b>0.9</b>  | 1.0  | <b>1.1</b>  | V             |
|                                |   | End of 8th cycle (LM25069-2)                                       |             | 0.3  |             | V             |
|                                |   | Re-enable Threshold (LM25069-1)                                    |             | 0.3  |             | V             |
| $I_{TIMER}$                    | Insertion time current                  |  | <b>-7.5</b> | -5.5 | <b>-3.5</b> | $\mu\text{A}$ |
|                                | Sink current, end of insertion time     | TIMER pin = 2V   | <b>1.5</b>  | 2    | <b>2.5</b>  | mA            |
|                                | Fault detection current                 |  | <b>-110</b> | -80  | <b>-50</b>  | $\mu\text{A}$ |
|                                | Fault sink current                      |  | <b>1.6</b>  | 2.5  | <b>3.4</b>  | $\mu\text{A}$ |
| $DC_{FAULT}$                   | Fault Restart Duty Cycle                | LM25069-2 only   |             | 0.67 |             | %             |
| $t_{FAULT}$                    | Fault to GATE low delay                 | TIMER pin reaches the upper threshold                              |             | 20   |             | $\mu\text{s}$ |
| <b>Power Good (PGD pin)</b>    |   |  |             |      |             |               |
| $PGD_{TH}$                     | Threshold measured at SENSE-OUT         | Decreasing   |             | 1.3  | <b>1.9</b>  | V             |
|                                |   | Threshold Hysteresis   |             | 0.6  |             |               |
| $PGD_{VOL}$                    | Output low voltage                      | $I_{SINK} = 2\text{ mA}$   |             | 15   | <b>30</b>   | mV            |
| $PGD_{IOH}$                    | Off leakage current                     | $V_{PGD} = 17\text{V}$   |             |      | <b>1</b>    | $\mu\text{A}$ |

### Typical Performance Characteristics

Unless otherwise specified the following conditions apply:  $T_J = 25^\circ\text{C}$ ,  $V_{IN} = 12\text{V}$

**VIN Pin Input Current vs. VIN**

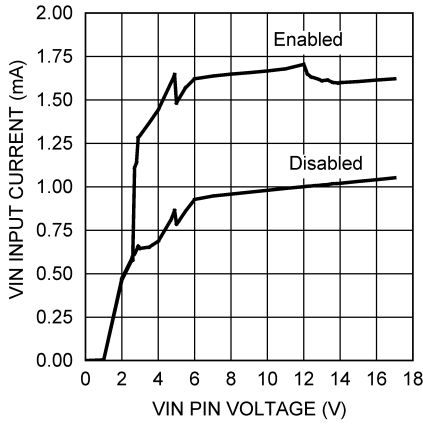


Figure 3.

**SENSE Pin Input Current**

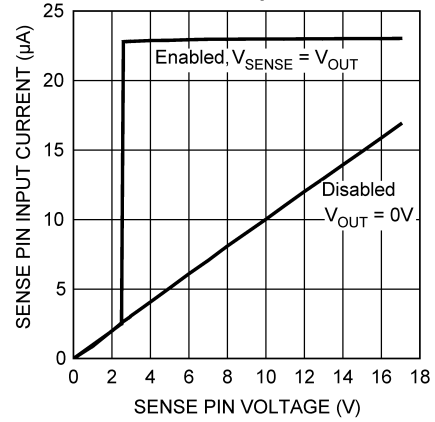


Figure 4.

**OUT Pin Input Current**

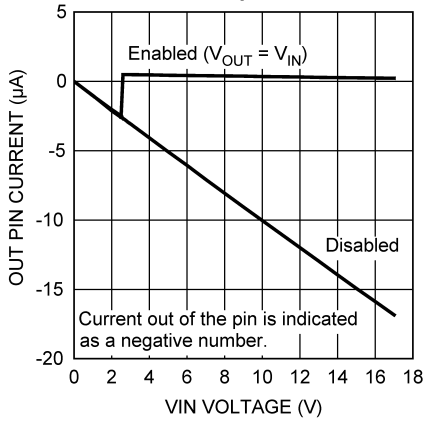


Figure 5.

**GATE Pin Voltage**

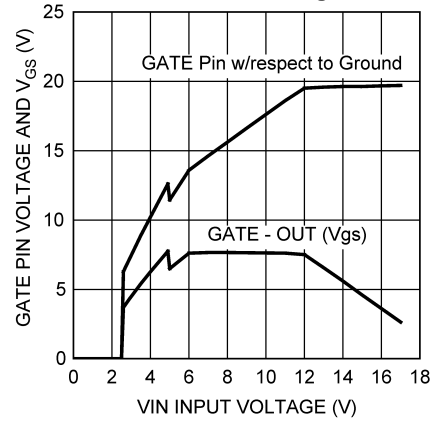


Figure 6.

**GATE Pin Source Current**

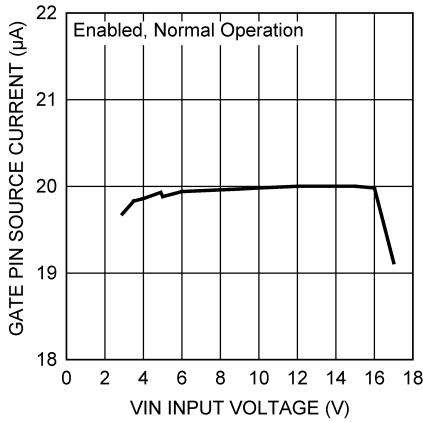


Figure 7.

**MOSFET Power Dissipation Limit**

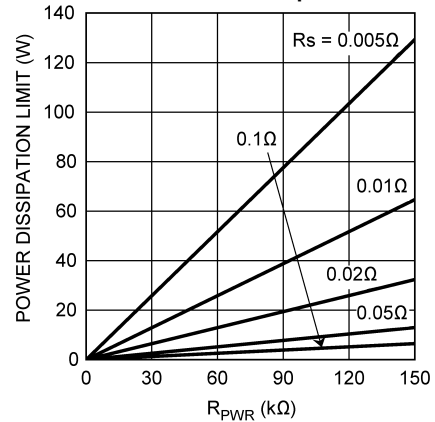


Figure 8.

**Typical Performance Characteristics (continued)**

Unless otherwise specified the following conditions apply:  $T_J = 25^\circ\text{C}$ ,  $V_{IN} = 12\text{V}$

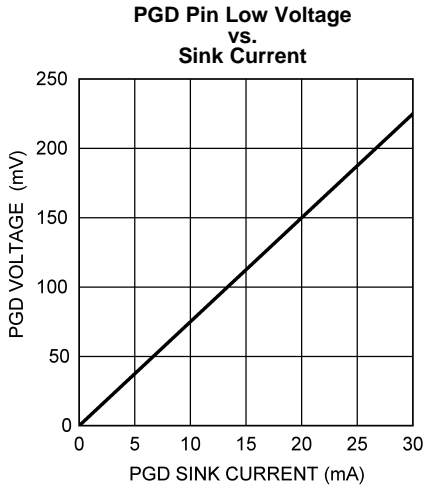


Figure 9.

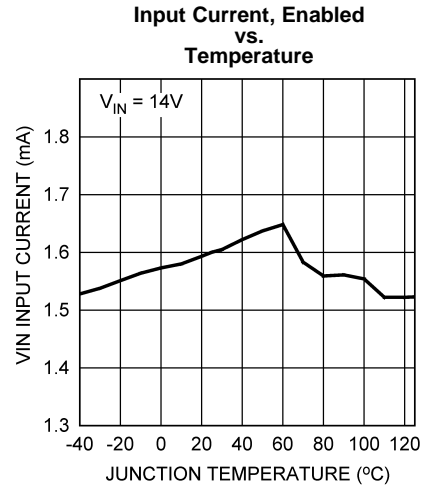


Figure 10.

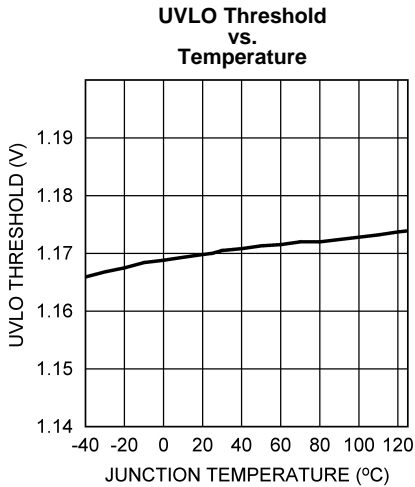


Figure 11.

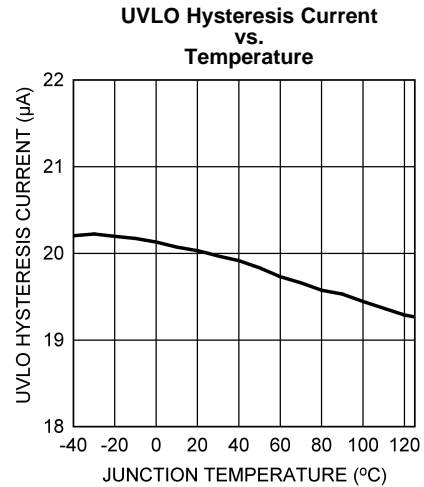


Figure 12.

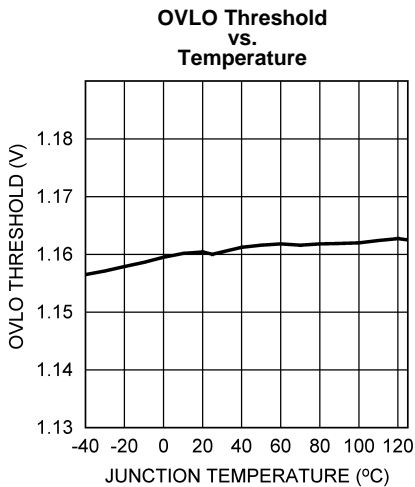


Figure 13.

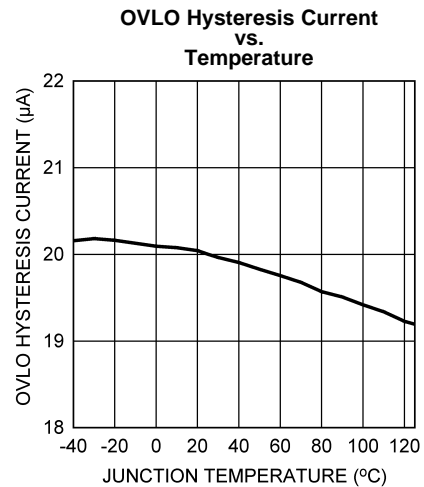


Figure 14.

**Typical Performance Characteristics (continued)**

Unless otherwise specified the following conditions apply:  $T_J = 25^\circ\text{C}$ ,  $V_{IN} = 12\text{V}$

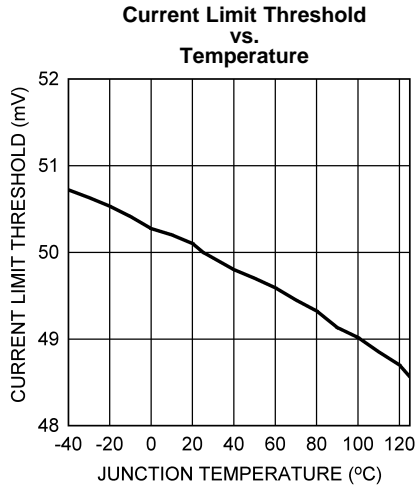


Figure 15.

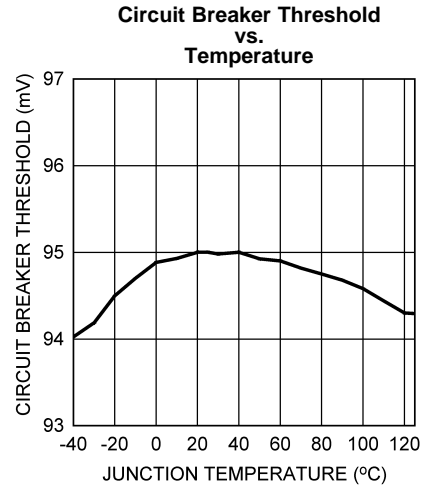


Figure 16.

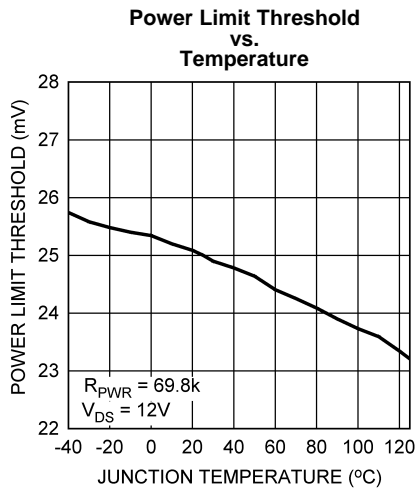


Figure 17.

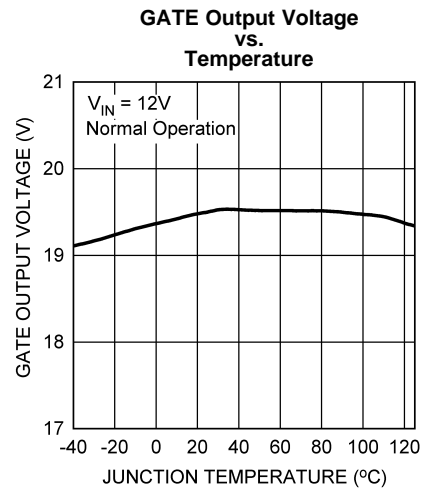


Figure 18.

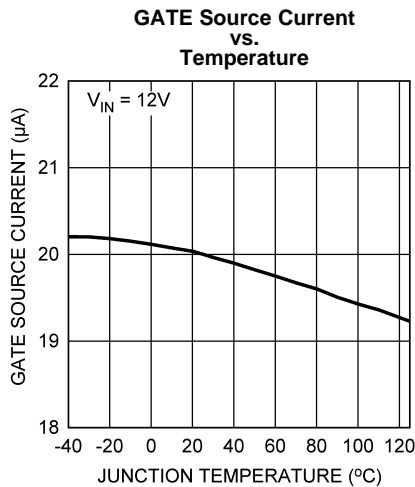


Figure 19.

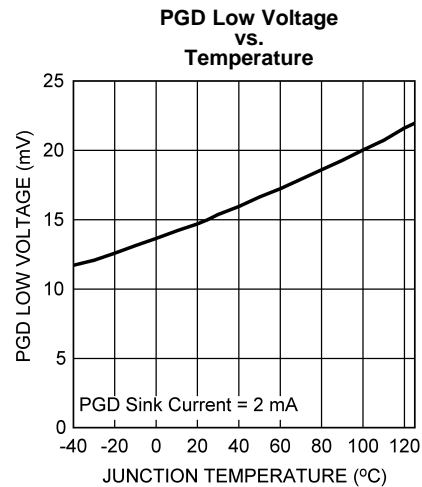


Figure 20.

Block Diagram

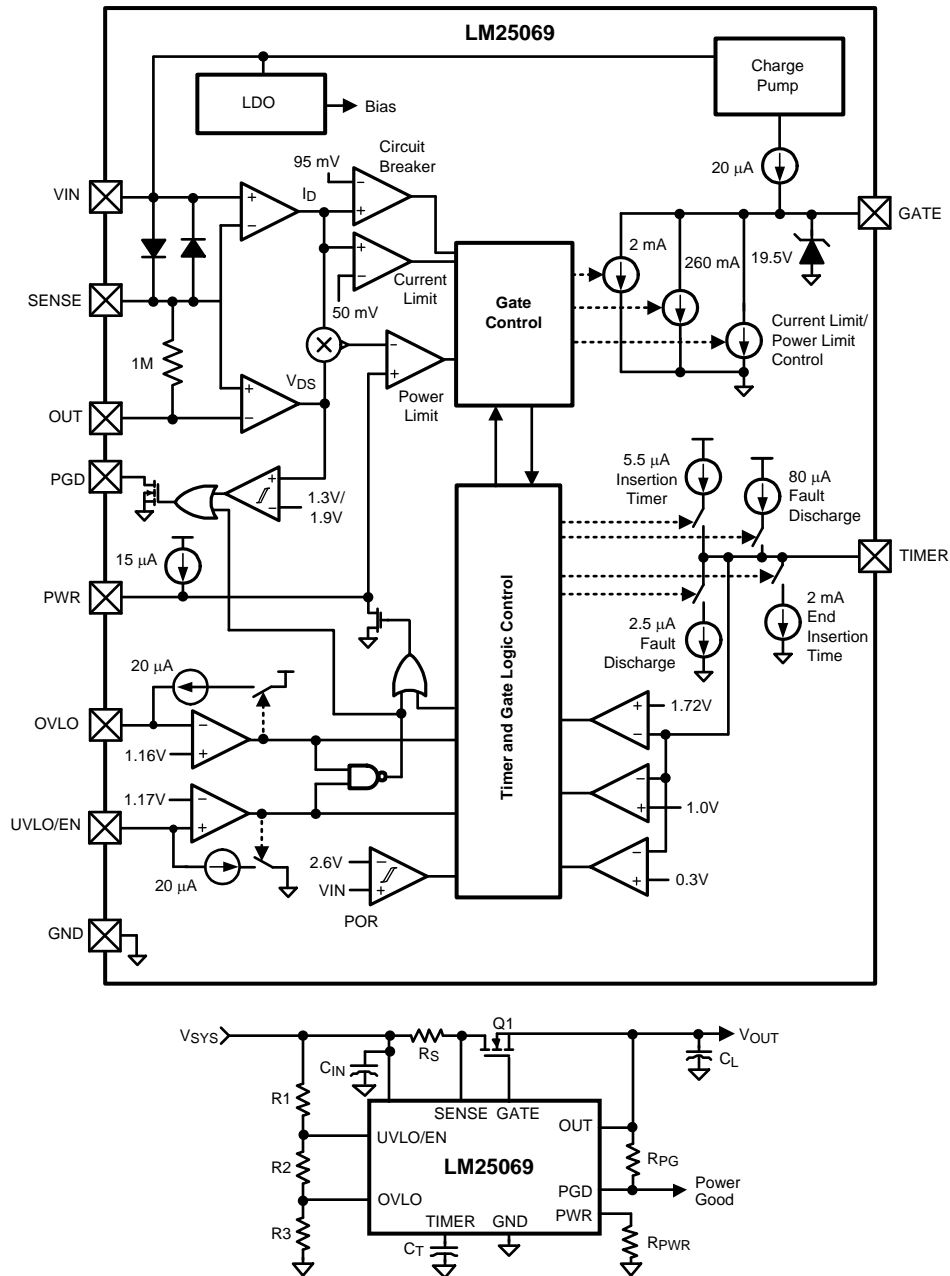


Figure 21. Basic Application Circuit



## FUNCTIONAL DESCRIPTION

The LM25069 is designed to control the in-rush current to the load upon insertion of a circuit card into a live backplane or other "hot" power source, thereby limiting the voltage sag on the backplane's supply voltage, and the  $dV/dt$  of the voltage applied to the load. Effects on other circuits in the system are minimized, preventing possible unintended resets. A controlled shutdown when the circuit card is removed can also be implemented using the LM25069. In addition to a programmable current limit, the LM25069 monitors and limits the maximum power dissipation in the series pass device to maintain operation within the device Safe Operating Area (SOA). Either current limiting or power limiting for an extended period of time results in the shutdown of the series pass device. In this event, the LM25069-1 latches off until the circuit is re-enabled by external control, while the LM25069-2 automatically restarts with defined timing. The circuit breaker function quickly switches off the series pass device upon detection of a severe over-current condition. The Power Good (PGD) output pin indicates when the output voltage is within 1.3V of the system input voltage ( $V_{SYS}$ ). Programmable under-voltage lock-out (UVLO) and over-voltage lock-out (OVLO) circuits enable the LM25069 when the system input voltage is between the desired thresholds. The typical configuration of a circuit card with LM25069 hot swap protection is shown in Figure 22.

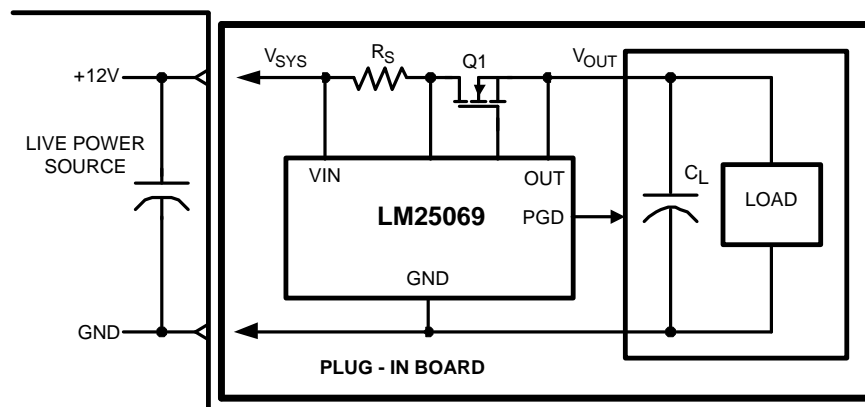


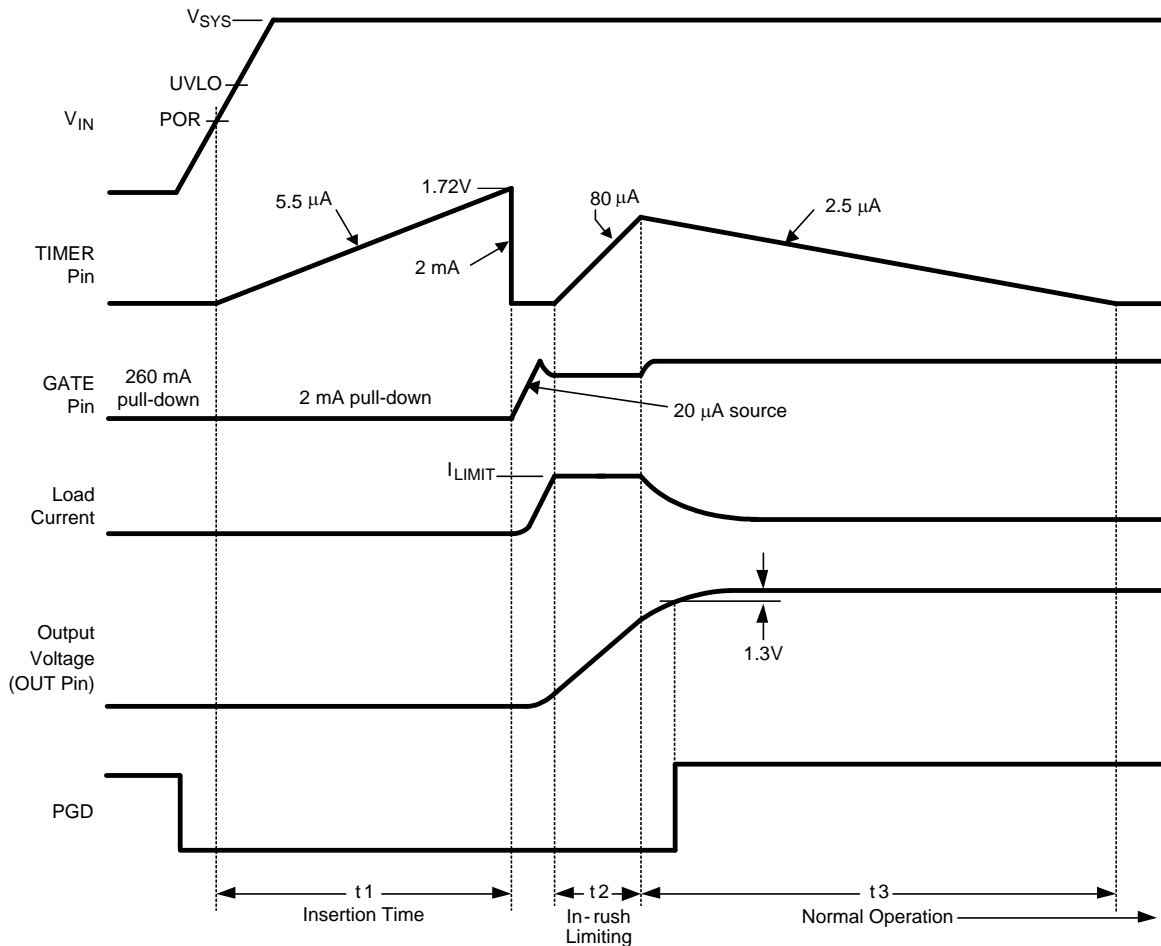
Figure 22. LM25069 Application

### Power Up Sequence

The VIN operating range of the LM25069 is +2.9V to +17V, with a transient capability to 20V. Referring to the Block Diagram and Figure 21 and Figure 23, as the voltage at VIN initially increases, the external N-channel MOSFET (Q1) is held off by an internal 260 mA pull-down current at the GATE pin. The strong pull-down current at the GATE pin prevents an inadvertent turn-on as the MOSFET's gate-to-drain (Miller) capacitance is charged. Additionally, the TIMER pin is initially held at ground. When the VIN voltage reaches the POR threshold the insertion time begins. During the insertion time, the capacitor at the TIMER pin ( $C_T$ ) is charged by a 5.5  $\mu$ A current source, and Q1 is held off by a 2 mA pull-down current at the GATE pin regardless of the VIN voltage. The insertion time delay allows ringing and transients at VIN to settle before Q1 is enabled. The insertion time ends when the TIMER pin voltage reaches 1.72V.  $C_T$  is then quickly discharged by an internal 2 mA pull-down current. The GATE pin then switches on Q1 when  $V_{SYS}$  exceeds the UVLO threshold. If  $V_{SYS}$  is above the UVLO threshold at the end of the insertion time, Q1 switches on at that time. The GATE pin charge pump sources 20  $\mu$ A to charge Q1's gate capacitance. The maximum voltage at the GATE pin is limited by an internal 19.5V zener diode.

As the voltage at the OUT pin increases, the LM25069 monitors the drain current and power dissipation of MOSFET Q1. In-rush current limiting and/or power limiting circuits actively control the current delivered to the load. During the in-rush limiting interval ( $t_2$  in Figure 23) an internal 80  $\mu$ A fault timer current source charges  $C_T$ . If Q1's power dissipation and the input current reduce below their respective limiting thresholds before the TIMER pin reaches 1.72V the 80  $\mu$ A current source is switched off, and  $C_T$  is discharged by the internal 2.5  $\mu$ A current sink ( $t_3$  in Figure 23). The in-rush limiting interval is complete when the voltage at the OUT pin increases to within 1.3V of the input voltage ( $V_{SYS}$ ), and the PGD pin switches high.

If the TIMER pin voltage reaches 1.72V before in-rush current limiting or power limiting ceases (during  $t_2$ ), a fault is declared and Q1 is turned off. See the [Fault Timer & Restart](#) section for a complete description of the fault mode.



**Figure 23. Power Up Sequence (Current Limit only)**

### Gate Control

A charge pump provides the voltage at the GATE pin to enhance the N-Channel MOSFET's gate. During normal operating conditions ( $t_3$  in [Figure 23](#)) the gate of Q1 is held charged by an internal 20  $\mu\text{A}$  current source. The voltage at the GATE pin (with respect to ground) is limited by an internal 19.5V zener diode. See the graph [GATE Pin voltage](#). Since the gate-to-source voltage applied to Q1 could be as high as 19.5V during various conditions, a zener diode with the appropriate voltage rating must be added between the GATE and OUT pins if the maximum  $V_{GS}$  rating of the selected MOSFET is less than 19.5V. The external zener diode must have a forward current rating of at least 260 mA.

When the system voltage is initially applied, the GATE pin is held low by a 260 mA pull-down current. This helps prevent an inadvertent turn-on of the MOSFET through its drain-gate capacitance as the applied system voltage increases.

During the insertion time ( $t_1$  in [Figure 23](#)) the GATE pin is held low by a 2 mA pull-down current. This maintains Q1 in the off-state until the end of  $t_1$ , regardless of the voltage at  $V_{IN}$  or UVLO.

Following the insertion time, during  $t_2$  in [Figure 23](#), the gate voltage of Q1 is modulated to keep the current or power dissipation level from exceeding the programmed levels. While in the current or power limiting mode the TIMER pin capacitor is charging. If the current and power limiting cease before the TIMER pin reaches 1.72V the TIMER pin capacitor then discharges, and the circuit enters normal operation.

If the in-rush limiting condition persists such that the TIMER pin reached 1.72V during  $t_2$ , the GATE pin is then pulled low by the 2 mA pull-down current. The GATE pin is then held low until either a power up sequence is initiated (LM25069-1), or until the end of the restart sequence (LM25069-2). See the [Fault Timer & Restart](#) section.

If the system input voltage falls below the UVLO threshold, or rises above the OVLO threshold, the GATE pin is pulled low by the 2 mA pull-down current to switch off Q1.

### Current Limit

The current limit threshold is reached when the voltage across the sense resistor  $R_S$  (VIN to SENSE) reaches 50 mV. In the current limiting condition, the GATE voltage is controlled to limit the current in MOSFET Q1. While the current limit circuit is active, the fault timer is active as described in the [Fault Timer & Restart](#) section. If the load current falls below the current limit threshold before the end of the Fault Timeout Period, the LM25069 resumes normal operation. For proper operation, the  $R_S$  resistor value should be no larger than 200 m $\Omega$ . Higher values may result in instability in the current limit control loop.

### Circuit Breaker

If the load current increases rapidly (e.g., the load is short-circuited) the current in the sense resistor ( $R_S$ ) may exceed the current limit threshold before the current limit control loop is able to respond. If the current exceeds approximately twice the current limit threshold ( $95 \text{ mV}/R_S$ ), Q1 is quickly switched off by the 260 mA pull-down current at the GATE pin, and a Fault Timeout Period begins. When the voltage across  $R_S$  falls below 95 mV the 260 mA pull-down current at the GATE pin is switched off, and the gate voltage of Q1 is then determined by the current limit or the power limit functions. If the TIMER pin reaches 1.72V before the current limiting or power limiting condition ceases, Q1 is switched off by the 2 mA pull-down current at the GATE pin as described in the [Fault Timer & Restart](#) section.

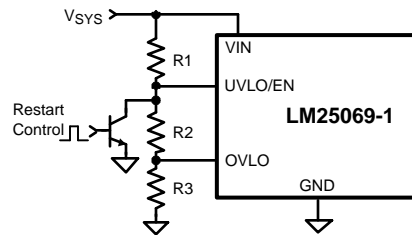
### Power Limit

An important feature of the LM25069 is the MOSFET power limiting. The Power Limit function can be used to maintain the maximum power dissipation of MOSFET Q1 within the device SOA rating. The LM25069 determines the power dissipation in Q1 by monitoring its drain-source voltage (SENSE to OUT), and the drain current through the sense resistor (VIN to SENSE). The product of the current and voltage is compared to the power limit threshold programmed by the resistor at the PWR pin. If the power dissipation reaches the limiting threshold, the GATE voltage is modulated to regulate the current in Q1. While the power limiting circuit is active, the fault timer is active as described in the [Fault Timer & Restart](#) section.

### Fault Timer & Restart

When the current limit or power limit threshold is reached during turn-on or as a result of a fault condition, the gate-to-source voltage of Q1 is modulated to regulate the load current and power dissipation in Q1. When either limiting function is activated, an 80  $\mu\text{A}$  fault timer current source charges the external capacitor ( $C_T$ ) at the TIMER pin as shown in [Figure 25](#) (Fault Timeout Period). If the fault condition subsides during the Fault Timeout Period before the TIMER pin reaches 1.72V, the LM25069 returns to the normal operating mode and  $C_T$  is discharged by the 2.5  $\mu\text{A}$  current sink. If the TIMER pin reaches 1.72V during the Fault Timeout Period, Q1 is switched off by a 2 mA pull-down current at the GATE pin. The subsequent restart procedure then depends on which version of the LM25069 is in use.

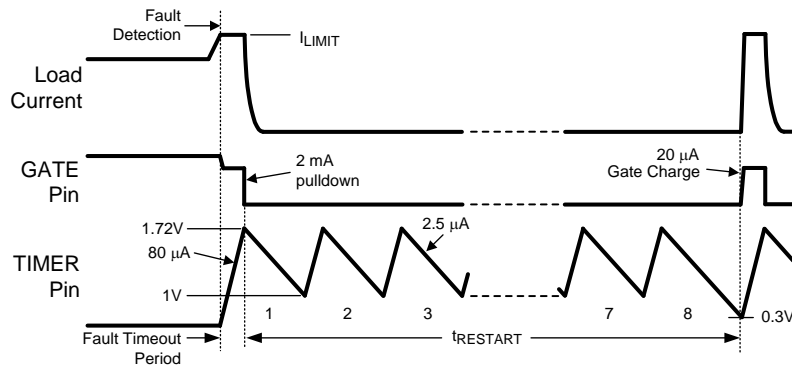
The LM25069-1 latches the GATE pin low at the end of the Fault Timeout Period.  $C_T$  is then discharged to ground by the 2.5  $\mu\text{A}$  fault current sink. The GATE pin is held low by the 2 mA pull-down current until a power up sequence is externally initiated by cycling the input voltage ( $V_{\text{SYS}}$ ), or momentarily pulling the UVLO pin below its threshold with an open-collector or open-drain device as shown in [Figure 24](#). The voltage at the TIMER pin must be less than 0.3V for the restart procedure to be effective.



**Figure 24. Latched Fault Restart Control**

The LM25069-2 provides an automatic restart sequence which consists of the TIMER pin cycling between 1.72V and 1V seven times after the Fault Timeout Period, as shown in Figure 25. The period of each cycle is determined by the 80  $\mu$ A charging current, and the 2.5  $\mu$ A discharge current, and the value of the capacitor  $C_T$ . When the TIMER pin reaches 0.3V during the eighth high-to-low ramp, the 20  $\mu$ A current source at the GATE pin turns on Q1. If the fault condition is still present, the Fault Timeout Period and the restart cycle repeat.

The Fault Timeout Period during restart cycles is approximately 18% shorter than the initial fault timeout period which initiated the restart cycle. This is due to the fact that the TIMER pin transitions from 0.3V to 1.72V after each restart time, rather than from ground.



**Figure 25. Restart Sequence (LM25069-2)**

### Under-Voltage Lock-Out (UVLO)

The series pass MOSFET (Q1) is enabled when the input supply voltage ( $V_{SYS}$ ) is within the operating range defined by the programmable under-voltage lockout (UVLO) and over-voltage lock-out (OVLO) levels. Typically the UVLO level at  $V_{SYS}$  is set with a resistor divider (R1-R3) as shown in Figure 21. Referring to the Block Diagram when  $V_{SYS}$  is below the UVLO level, the internal 20  $\mu$ A current source at UVLO is enabled, the current source at OVLO is off, and Q1 is held off by the 2 mA pull-down current at the GATE pin. As  $V_{SYS}$  is increased, raising the voltage at UVLO above its threshold the 20  $\mu$ A current source at UVLO is switched off, increasing the voltage at UVLO, providing hysteresis for this threshold. With the UVLO pin above its threshold, Q1 is switched on by the 20  $\mu$ A current source at the GATE pin if the insertion time delay has expired. See the Applications Section for a procedure to calculate the values of the threshold setting resistors (R1-R3). The minimum possible UVLO level at  $V_{SYS}$  can be set by connecting the UVLO pin to VIN. In this case Q1 is enabled after the insertion time.

### Over-Voltage Lock-Out (OVLO)

The series pass MOSFET (Q1) is enabled when the input supply voltage ( $V_{SYS}$ ) is within the operating range defined by the programmable under-voltage lockout (UVLO) and over-voltage lock-out (OVLO) levels. If  $V_{SYS}$  raises the OVLO pin voltage above its threshold Q1 is switched off by the 2 mA pull-down current at the GATE pin, denying power to the load. When the OVLO pin is above its threshold, the internal 20  $\mu$ A current source at OVLO is switched on, raising the voltage at OVLO to provide threshold hysteresis. When  $V_{SYS}$  is reduced below the OVLO level Q1 is enabled. See the Applications Section for a procedure to calculate the threshold setting resistor values.

## Shutdown Control

The load current can be remotely switched off by taking the UVLO pin below its threshold with an open collector or open drain device, as shown in Figure 26. Upon releasing the UVLO pin the LM25069 switches on the load current with in-rush current and power limiting.

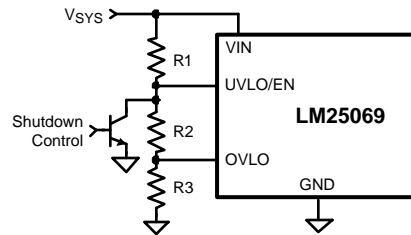


Figure 26. Shutdown Control

## Power Good Pin

The Power Good indicator pin (PGD) is connected to the drain of an internal N-channel MOSFET capable of sustaining 17V in the off-state, and transients up to 20V. An external pull-up resistor is required at PGD to an appropriate voltage to indicate the status to downstream circuitry. The off-state voltage at the PGD pin can be higher or lower than the voltages at VIN and OUT. PGD is switched high when the voltage from SENSE to OUT (the external MOSFET's  $V_{DS}$ ) decreases below 1.3V. PGD switches low when the MOSFET's  $V_{DS}$  is increased past 1.9V. If the UVLO pin is taken below its threshold or the OVLO pin taken above its threshold, to disable the LM25069, PGD switches low within 10  $\mu$ s without waiting for the voltage at OUT to fall. The PGD output pin is high when the voltage at VIN is less than 1.6V.

## Application Information (Refer to Figure 21)

### CURRENT LIMIT, $R_S$

The LM25069 monitors the current in the external MOSFET (Q1) by measuring the voltage across the sense resistor ( $R_S$ ), connected from VIN to SENSE. The required resistor value is calculated from:

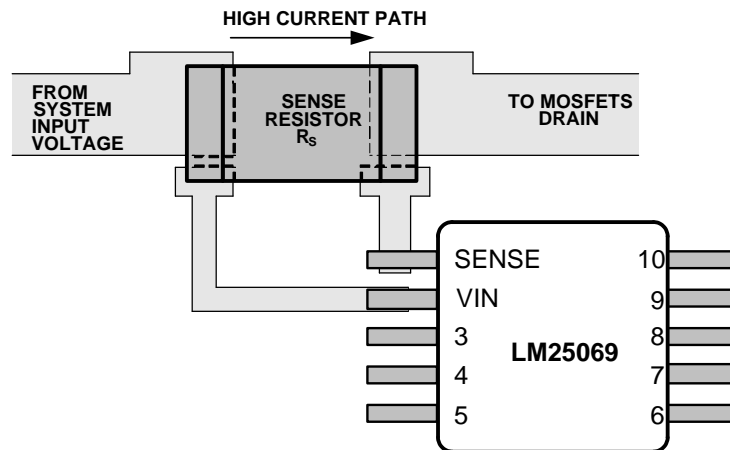
$$R_S = \frac{50 \text{ mV}}{I_{LIM}}$$

where

- $I_{LIM}$  is the desired current limit threshold (1)

If the voltage across  $R_S$  reaches 50 mV, the current limit circuit modulates the gate of Q1 to regulate the current at  $I_{LIM}$ . While the current limiting circuit is active, the fault timer is active as described in the [Fault Timer & Restart](#) section. For proper operation,  $R_S$  must be no larger than 200 m $\Omega$ .

While the maximum load current in normal operation can be used to determine the required power rating for resistor  $R_S$ , basing it on the current limit value provides a more reliable design since the circuit can operate near the current limit threshold continuously. The resistor's surge capability must also be considered since the circuit breaker threshold is approximately twice the current limit threshold. Connections from  $R_S$  to the LM25069 should be made using Kelvin techniques. In the suggested layout of [Figure 27](#) the small pads at the lower corners of the sense resistor connect only to the sense resistor terminals, and not to the traces carrying the high current. With this technique, only the voltage across the sense resistor is applied to VIN and SENSE, eliminating the voltage drop across the high current solder connections.



**Figure 27. Sense Resistor Connections**

## POWER LIMIT THRESHOLD

The LM25069 determines the power dissipation in the external MOSFET (Q1) by monitoring the drain current (the current in  $R_S$ ), and the  $V_{DS}$  of Q1 (SENSE to OUT pins). The resistor at the PWR pin ( $R_{PWR}$ ) sets the maximum power dissipation for Q1, and is calculated from the following equation:

$$R_{PWR} = 2.32 \times 10^5 \times R_S \times P_{FET(LIM)}$$

where

- $P_{FET(LIM)}$  is the desired power limit threshold for Q1
  - $R_S$  is the current sense resistor described in the [Current Limit](#) section
- (2)

For example, if  $R_S$  is 10 m $\Omega$ , and the desired power limit threshold is 20W,  $R_{PWR}$  calculates to 46.4 k $\Omega$ . If Q1's power dissipation reaches the threshold Q1's gate is modulated to regulate the load current, keeping Q1's power from exceeding the threshold. For proper operation of the power limiting feature,  $R_{PWR}$  must be  $\leq 150$  k $\Omega$ . While the power limiting circuit is active, the fault timer is active as described in the [Fault Timer & Restart](#) section. Typically, power limit is reached during startup, or if the output voltage falls due to a severe overload or short circuit.

The programmed maximum power dissipation should have a reasonable margin from the maximum power defined by the FET's SOA chart if the LM25069-2 is used since the FET will be repeatedly stressed during fault restart cycles. The FET manufacturer should be consulted for guidelines.

If the application does not require use of the power limit function the PWR pin can be left open.

The accuracy of the power limit function at turn-on may degrade if a very low value power dissipation limit is set. The reason for this caution is that the voltage across the sense resistor, which is monitored and regulated by the power limit circuit, is lowest at turn-on when the regulated current is at minimum. The voltage across the sense resistor during power limit can be expressed as follows:

$$V_{SENSE} = I_L \times R_S = \frac{R_{PWR}}{2.32 \times 10^5 \times V_{DS}} = \frac{R_S \times P_{FET(LIM)}}{V_{DS}}$$

where

- $I_L$  is the current in  $R_S$
  - $V_{DS}$  is the voltage across Q1
- (3)

For example, if the power limit is set at 20W with  $R_S = 10$  mohms, and  $V_{DS} = 15$ V the sense resistor voltage calculates to 13.3 mV, which is comfortably regulated by the LM25069. However, if a lower power limit is set lower (e.g., 2W), the sense resistor voltage calculates to 1.33 mV. At this low level noise and offsets within the LM25069 may degrade the power limit accuracy. To maintain accuracy, the sense resistor voltage should not be less than 5 mV.

## TURN-ON TIME

The output turn-on time depends on whether the LM25069 operates in current limit, or in both power limit and current limit, during turn-on.

**A) Turn-on with current limit only:** The current limit threshold ( $I_{LIM}$ ) is determined by the current sense resistor ( $R_S$ ). If the current limit threshold is less than the current defined by the power limit threshold at maximum  $V_{DS}$  the circuit operates at the current limit threshold only during turn-on. Referring to [Figure 30a](#), as the load current reaches  $I_{LIM}$ , the gate-to-source voltage is controlled at  $V_{GSL}$  to maintain the current at  $I_{LIM}$ . As the output voltage reaches its final value, ( $V_{DS} \approx 0V$ ) the drain current reduces to its normal operating value. The time for the OUT pin voltage to transition from zero volts to  $V_{SYS}$  is equal to:

$$t_{ON} = \frac{V_{SYS} \times C_L}{I_{LIM}}$$

where

- $C_L$  is the load capacitance (4)

For example, if  $V_{SYS} = 12V$ ,  $C_L = 1000 \mu F$ , and  $I_{LIM} = 1A$ ,  $t_{ON}$  calculates to 12 ms. The maximum instantaneous power dissipated in the MOSFET is 12W. This calculation assumes the time from  $t_1$  to  $t_2$  in [Figure 30a](#) is small compared to  $t_{ON}$ , and the load does not draw any current until after the output voltage has reached its final value, and PGD switches high ([Figure 28](#)). If the load draws current during the turn-on sequence ([Figure 29](#)), the turn-on time is longer than the above calculation, and is approximately equal to:

$$t_{ON} = -(R_L \times C_L) \times \ln \left[ \frac{(I_{LIM} \times R_L) - V_{SYS}}{(I_{LIM} \times R_L)} \right]$$

where

- $R_L$  is the load resistance (5)

The Fault Timeout Period must be set longer than  $t_{ON}$  to prevent a fault shutdown before the turn-on sequence is complete.

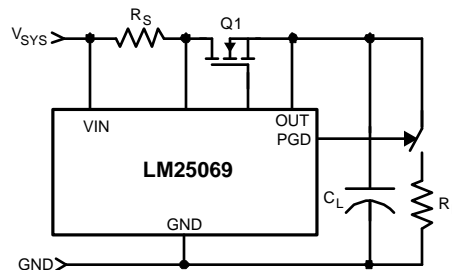


Figure 28. No Load Current During Turn-On

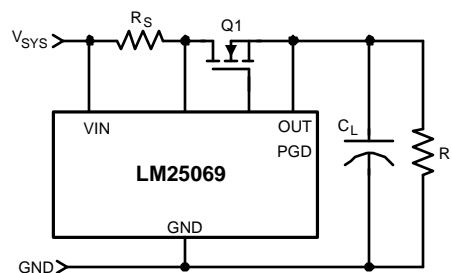
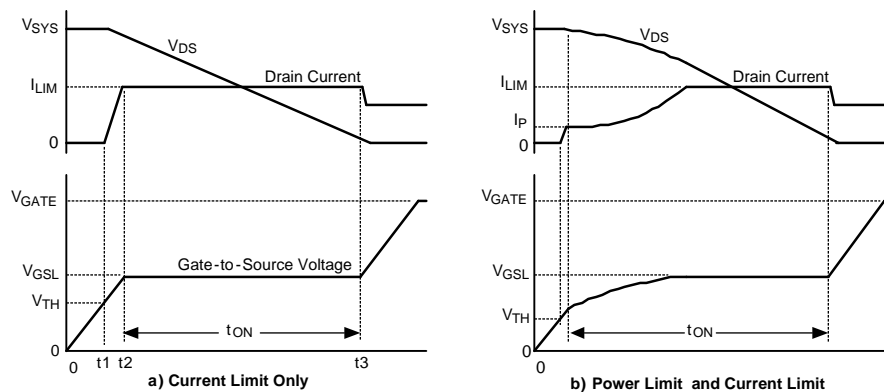


Figure 29. Load Draws Current During Turn-On

**B) Turn-on with power limit and current limit:** The maximum allowed power dissipation in Q1 ( $P_{FET(LIM)}$ ) is defined by the resistor at the PWR pin, and the current sense resistor  $R_S$ . See the [POWER LIMIT THRESHOLD](#) section. If the current limit threshold ( $I_{LIM}$ ) is higher than the current defined by the power limit threshold at maximum  $V_{DS}$  ( $P_{FET(LIM)}/V_{SYS}$ ) the circuit operates initially in the power limit mode when the  $V_{DS}$  of Q1 is high, and then transitions to current limit mode as the current increases to  $I_{LIM}$  and  $V_{DS}$  decreases. See [Figure 30b](#). Assuming the load ( $R_L$ ) is not connected during turn-on, the time for the output voltage to reach its final value is approximately equal to:

$$t_{ON} = \frac{C_L \times V_{SYS}^2}{2 \times P_{FET(LIM)}} + \frac{C_L \times P_{FET(LIM)}}{2 \times I_{LIM}^2} \quad (6)$$

For example, if  $V_{SYS} = 12V$ ,  $C_L = 1000 \mu F$ ,  $I_{LIM} = 1A$ , and  $P_{FET(LIM)} = 10W$ ,  $t_{ON}$  calculates to  $\approx 12.2$  ms, and the initial current level ( $I_p$ ) is approximately 0.83A. The Fault Timeout Period must be set longer than  $t_{ON}$ .



**Figure 30. MOSFET Power Up Waveforms**

## MOSFET SELECTION

It is recommended that the external MOSFET (Q1) selection be based on the following criteria:

- The  $BV_{DSS}$  rating should be greater than the maximum system voltage ( $V_{SYS}$ ), plus ringing and transients which can occur at  $V_{SYS}$  when the circuit card, or adjacent cards, are inserted or removed.
- The maximum continuous current rating should be based on the current limit threshold ( $50 \text{ mV}/R_S$ ), not the maximum load current, since the circuit can operate near the current limit threshold continuously.
- The Pulsed Drain Current spec ( $I_{DM}$ ) must be greater than the current threshold for the circuit breaker function ( $95 \text{ mV}/R_S$ ).
- The SOA (Safe Operating Area) chart of the device, and the thermal properties, should be used to determine the maximum power dissipation threshold set by the  $R_{PWR}$  resistor. The programmed maximum power dissipation should have a reasonable margin from the maximum power defined by the FET's SOA chart if the LM25069-2 is used since the FET will be repeatedly stressed during fault restart cycles. The FET manufacturer should be consulted for guidelines.
- $R_{DS(on)}$  should be sufficiently low that the power dissipation at maximum load current ( $I_{L(max)}^2 \times R_{DS(on)}$ ) does not raise its junction temperature above the manufacturer's recommendation.

If the circuit's input voltage is at the low end of the LM25069's operating range ( $< 3.5V$ ), or at the high end of the operating range ( $> 14V$ ), the gate-to-source voltage applied to the MOSFET by the LM25069 is less than 5V, and can approach 1V in a worst case situation. See the graph "[GATE Pin voltage](#)". The selected device must have a suitable Gate-to-Source Threshold Voltage.

The gate-to-source voltage provided by the LM25069 can be as high as 19.5V at turn-on when the output voltage is zero. At turn-off the reverse gate-to-source voltage will be equal to the output voltage at the instant the GATE pin is pulled low. If the device chosen for Q1 is not rated for these voltages, an external zener diode must be added from its gate to source, with the zener voltage less than the device maximum  $V_{GS}$  rating. The zener diode's working voltage protects the MOSFET during turn-on, and its forward voltage protects the MOSFET during shutoff. The zener diode's forward current rating must be at least 260 mA to conduct the GATE pull-down current when a circuit breaker condition is detected.



## TIMER CAPACITOR, C<sub>T</sub>

The TIMER pin capacitor (C<sub>T</sub>) sets the timing for the insertion time delay, fault timeout period, and restart timing of the LM25069-2.

**A) Insertion Delay** - Upon applying the system voltage (V<sub>SYS</sub>) to the circuit, the external MOSFET (Q1) is held off during the insertion time (t<sub>1</sub> in [Figure 23](#)) to allow ringing and transients at V<sub>SYS</sub> to settle. Since each backplane's response to a circuit card plug-in is unique, the worst case settling time must be determined for each application. The insertion time starts when VIN reaches the POR threshold, at which time the internal 5.5 μA current source charges C<sub>T</sub> from 0V to 1.72V. The required capacitor value is calculated from:

$$C_T = \frac{t_1 \times 5.5 \mu\text{A}}{1.72\text{V}} = t_1 \times 3.2 \times 10^{-6} \quad (7)$$

For example, if the desired insertion delay is 250 ms, C<sub>T</sub> calculates to 0.8 μF. At the end of the insertion delay, C<sub>T</sub> is quickly discharged by a 2 mA current sink.

**B) Fault Timeout Period** - During in-rush current limiting or upon detection of a fault condition where the current limit and/or power limit circuits regulate the current through Q1, the fault timer current source (80 μA) switches on to charge C<sub>T</sub>. The Fault Timeout Period is the time required for the voltage at the TIMER pin to transition from ground to 1.72V, at which time Q1 is switched off. If the LM25069-1 is in use, the required capacitor value is calculated from:

$$C_T = \frac{t_{\text{FAULT}} \times 80 \mu\text{A}}{1.72\text{V}} = t_{\text{FAULT}} \times 4.65 \times 10^{-5} \quad (8)$$

For example, if the desired Fault Timeout Period is 17 ms, C<sub>T</sub> calculates to 0.8 μF. When the Fault Timeout Period expires, the LM25069-1 latches the GATE pin low until a power-up sequence is initiated by external circuitry. If the LM25069-2 is in use, the Fault Timeout Period during restart cycles is approximately 18% shorter than the initial fault timeout period which initiated the restart cycles since the voltage at the TIMER pin transitions from 0.3V to 1.72V. Since the Fault Timeout Period must always be longer than the turn-on-time, the required capacitor value for the LM25069-2 is calculated using this shorter time period:

$$C_T = \frac{t_{\text{FAULT}} \times 80 \mu\text{A}}{1.42\text{V}} = t_{\text{FAULT}} \times 5.63 \times 10^{-5} \quad (9)$$

For example, if the desired Fault Timeout Period is 17 ms, C<sub>T</sub> calculates to 0.96 μF. When the Fault Timeout Period of the LM25069-2 expires, a restart sequence starts as described below ([Restart Timing](#)). Since the LM25069 normally operates in power limit and/or current limit during a power-up sequence, the Fault Timeout Period **MUST** be longer than the time required for the output voltage to reach its final value. See the [TURN-ON TIME](#) section

**C) Restart Timing** For the LM25069-2, after the Fault Timeout Period described above, C<sub>T</sub> is discharged by the 2.5 μA current sink to 1.0V. The TIMER pin then cycles through seven additional charge/discharge cycles between 1V and 1.72V as shown in [Figure 25](#). The restart time ends when the TIMER pin voltage reaches 0.3V during the final high-to-low ramp. The restart time, after the Fault Timeout Period, is equal to:

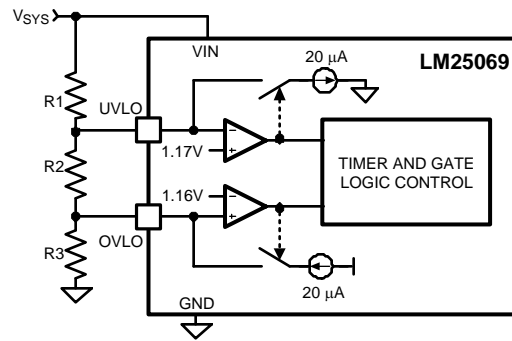
$$t_{\text{RESTART}} = C_T \times \left[ \frac{7 \times 0.72\text{V}}{2.5 \mu\text{A}} + \frac{7 \times 0.72\text{V}}{80 \mu\text{A}} + \frac{1.42\text{V}}{2.5 \mu\text{A}} \right] \\ = C_T \times 2.65 \times 10^6 \quad (10)$$

For example, if C<sub>T</sub> = 0.8 μF, t<sub>RESTART</sub> = 2.12 seconds. At the end of the restart time, Q1 is switched on. If the fault is still present, the fault timeout and restart sequence repeats. The on-time duty cycle of Q1 is approximately 0.67% in this mode.

## UVLO, OVLO

By programming the UVLO and OVLO thresholds the LM25069 enables the series pass device (Q1) when the input supply voltage (V<sub>SYS</sub>) is within the desired operational range. If V<sub>SYS</sub> is below the UVLO threshold, or above the OVLO threshold, Q1 is switched off, denying power to the load. Hysteresis is provided for each threshold.

**Option A:** The configuration shown in [Figure 31](#) requires three resistors (R1-R3) to set the thresholds.



**Figure 31. UVLO and OVLO Thresholds Set By R1-R3**

The procedure to calculate the resistor values is as follows:

- Choose the upper UVLO threshold ( $V_{UVH}$ ), and the lower UVLO threshold ( $V_{UVL}$ ).
- Choose the upper OVLO threshold ( $V_{OVH}$ ).
- The lower OVLO threshold ( $V_{OVL}$ ) cannot be chosen in advance in this case, but is determined after the values for R1-R3 are determined. If  $V_{OVL}$  must be accurately defined in addition to the other three thresholds, see [Option B](#) below.

The resistors are calculated as follows:

$$R1 = \frac{V_{UVH} - V_{UVL}}{20 \mu A} = \frac{V_{UV(HYS)}}{20 \mu A} \quad (11)$$

$$R3 = \frac{1.16V \times R1 \times V_{UVL}}{V_{OVH} \times (V_{UVL} - 1.17V)} \quad (12)$$

$$R2 = \frac{1.17V \times R1}{V_{UVL} - 1.17V} - R3 \quad (13)$$

The lower OVLO threshold is calculated from:

$$V_{OVL} = \frac{[(R1 + R2) \times ((1.16V) - 20 \mu A)] + 1.16V}{R3} \quad (14)$$

As an example, assume the application requires the following thresholds:  $V_{UVH} = 8V$ ,  $V_{UVL} = 7V$ ,  $V_{OVH} = 15V$ .

$$R1 = \frac{8V - 7V}{20 \mu A} = \frac{1V}{20 \mu A} = 50 \text{ k}\Omega \quad (15)$$

$$R3 = \frac{1.16V \times 50 \text{ k}\Omega \times 7V}{15V \times (7V - 1.17V)} = 4.64 \text{ k}\Omega \quad (16)$$

$$R2 = \frac{1.17V \times 50 \text{ k}\Omega}{(7V - 1.17V)} - 4.64 \text{ k}\Omega = 5.39 \text{ k}\Omega \quad (17)$$

The lower OVLO threshold calculates to 13.9V, and the OVLO hysteresis is 1.1V. Note that the OVLO hysteresis is always slightly greater than the UVLO hysteresis in this configuration. When the R1-R3 resistor values are known, the threshold voltages and hysteresis are calculated from the following:

$$V_{UVH} = 1.17V + [R1 \times (20 \mu A + \frac{1.17V}{(R2 + R3)})] \quad (18)$$

$$V_{UVL} = \frac{1.17V \times (R1 + R2 + R3)}{R2 + R3} \quad (19)$$

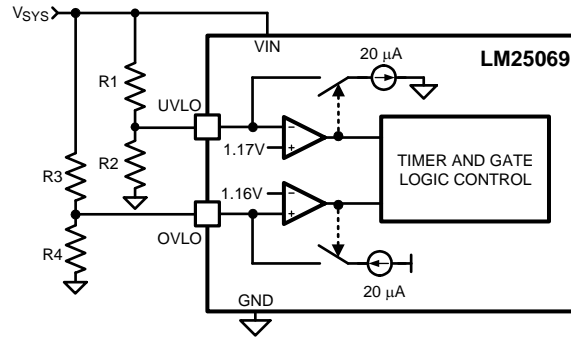
$$V_{UV(HYS)} = R1 \times 20 \mu A \quad (20)$$

$$V_{OVH} = \frac{1.16V \times (R1 + R2 + R3)}{R3} \quad (21)$$

$$V_{OVL} = [(R1 + R2) \times \frac{(1.16V) - 20 \mu A}{R3}] + 1.16V \quad (22)$$

$$V_{OV(HYS)} = (R1 + R2) \times 20 \mu A \quad (23)$$

**Option B:** If all four thresholds must be accurately defined, the configuration in [Figure 32](#) can be used.



**Figure 32. Programming the Four Thresholds**

The four resistor values are calculated as follows:

- Choose the upper and lower UVLO thresholds ( $V_{UVH}$ ) and ( $V_{UVL}$ ).

$$R1 = \frac{V_{UVH} - V_{UVL}}{20 \mu A} = \frac{V_{UV(HYS)}}{20 \mu A} \quad (24)$$

$$R2 = \frac{1.17V \times R1}{(V_{UVL} - 1.17V)} \quad (25)$$

- Choose the upper and lower OVLO threshold ( $V_{OVH}$ ) and ( $V_{OVL}$ ).

$$R3 = \frac{V_{OVH} - V_{OVL}}{20 \mu A} = \frac{V_{OV(HYS)}}{20 \mu A} \quad (26)$$

$$R4 = \frac{1.16V \times R3}{(V_{OVH} - 1.16V)} \quad (27)$$

As an example, assume the application requires the following thresholds:  $V_{UVH} = 8V$ ,  $V_{UVL} = 7V$ ,  $V_{OVH} = 15.5V$ , and  $V_{OVL} = 14V$ . Therefore  $V_{UV(HYS)} = 1V$ , and  $V_{OV(HYS)} = 1.5V$ . The resistor values are:

$$R1 = 50 \text{ k}\Omega, R2 = 10 \text{ k}\Omega$$

$$R3 = 75 \text{ k}\Omega, R4 = 6.07 \text{ k}\Omega$$

Where the R1-R4 resistor values are known, the threshold voltages and hysteresis are calculated from the following:

$$V_{UVH} = 1.17V + [R1 \times \frac{(1.17V + 20 \mu A)}{R2}] \quad (28)$$

$$V_{UVL} = \frac{1.17V \times (R1 + R2)}{R2} \quad (29)$$

$$V_{UV(HYS)} = R1 \times 20 \mu A \quad (30)$$

$$V_{OVH} = \frac{1.16V \times (R3 + R4)}{R4} \quad (31)$$

$$V_{OVL} = 1.16V + [R3 \times \frac{(1.16V - 20 \mu A)}{R4}] \quad (32)$$

$$V_{OV(HYS)} = R3 \times 20 \mu A$$

(33)

**Option C:** The minimum UVLO level is obtained by connecting the UVLO pin to VIN as shown in Figure 33. Q1 is switched on when the VIN voltage reaches the POR threshold ( $\approx 2.6V$ ). The OVLO thresholds are set using R3, R4. Their values are calculated using the procedure in Option B.

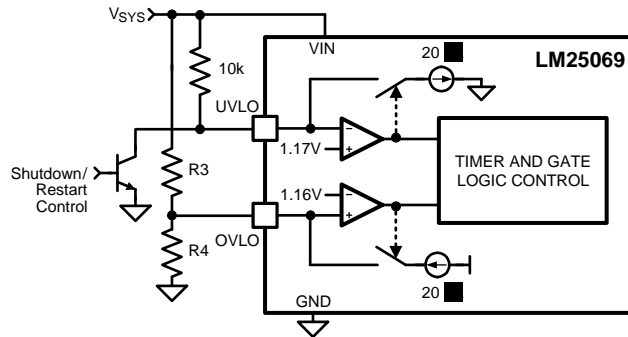


Figure 33. UVLO = POR with Shutdown/Restart Control

**Option D:** The OVLO function can be disabled by grounding the OVLO pin. The UVLO thresholds are set as described in Option B or Option C.

**POWER GOOD PIN**

During turn-on, the Power Good pin (PGD) is high until the voltage at VIN increases above  $\approx 1.6V$ . PGD then switches low, remaining low as the VIN voltage increases. When the voltage at OUT increases to within 1.3V of the SENSE pin ( $V_{DS} < 1.3V$ ), PGD switches high. PGD switches low if the  $V_{DS}$  of Q1 increases above 1.9V. A pull-up resistor is required at PGD as shown in Figure 34. The pull-up voltage ( $V_{PGD}$ ) can be as high as 17V, and can be higher or lower than the voltages at VIN and OUT.

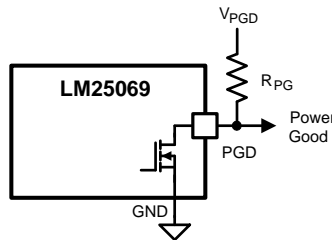


Figure 34. Power Good Output

If a delay is required at PGD, suggested circuits are shown in Figure 35. In Figure 35a, capacitor  $C_{PG}$  adds delay to the rising edge, but not to the falling edge. In Figure 35b, the rising edge is delayed by  $R_{PG1} + R_{PG2}$  and  $C_{PG}$ , while the falling edge is delayed a lesser amount by  $R_{PG2}$  and  $C_{PG}$ . Adding a diode across  $R_{PG2}$  (Figure 35c) allows for equal delays at the two edges, or a short delay at the rising edge and a long delay at the falling edge.

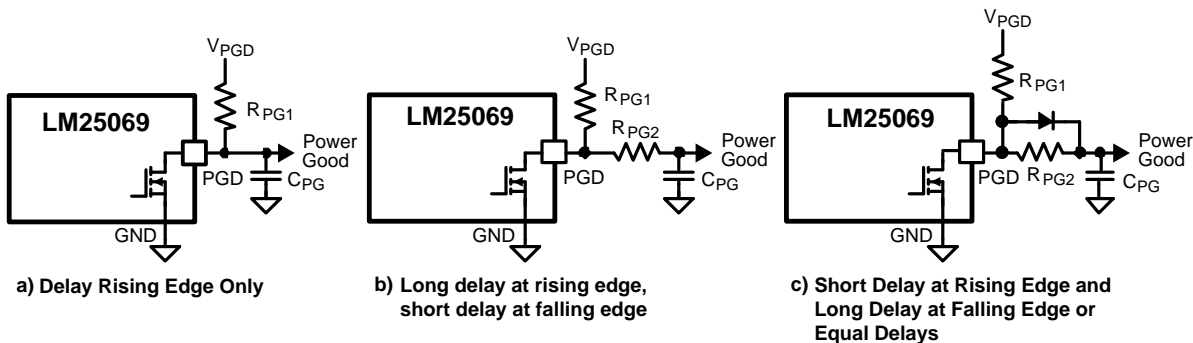


Figure 35. Adding Delay to the Power Good Output Pin

## Design-in Procedure

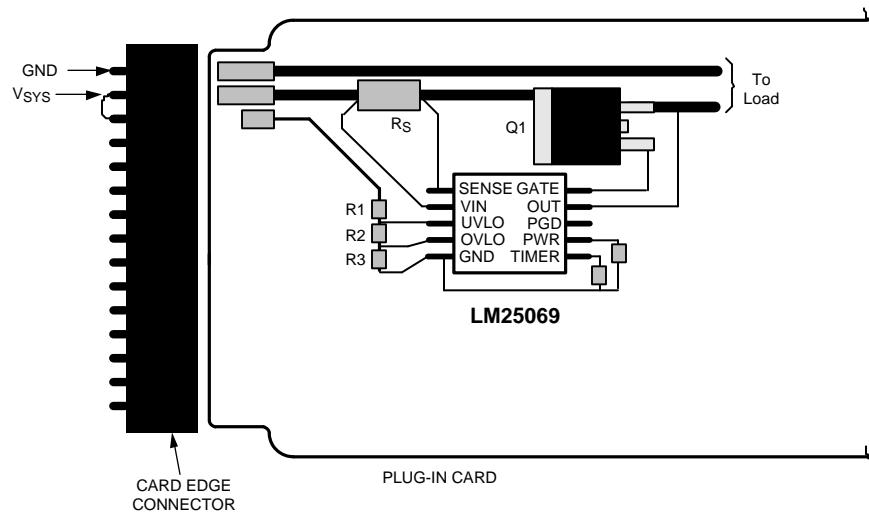
The recommended design-in procedure is as follows:

- Determine the current limit threshold ( $I_{LIM}$ ). This threshold must be higher than the normal maximum load current, allowing for tolerances in the current sense resistor value and the LM25069 Current Limit threshold voltage. Use equation 1 to determine the value for  $R_S$ .
- Determine the maximum allowable power dissipation for the series pass FET (Q1), using the device's SOA information. Use equation 2 to determine the value for  $R_{PWR}$ .
- Determine the value for the timing capacitor at the TIMER pin ( $C_T$ ) using equation 3 or equation 4. The fault timeout period ( $t_{FAULT}$ ) must be longer than the circuit's turn-on-time. The turn-on time can be estimated using the equations in the [TURN-ON TIME](#) section of this data sheet, but should be verified experimentally. Review the resulting insertion time, and restart timing if the LM25069-2 is used.
- Choose option A, B, C, or D from the [UVLO, OVLO](#) section of the Application Information for setting the UVLO and OVLO thresholds and hysteresis. Use the procedure for the appropriate option to determine the resistor values at the UVLO and OVLO pins.
- Choose the appropriate voltage, and pull-up resistor, for the Power Good output.

## PC Board Guidelines

The following guidelines should be followed when designing the PC board for the LM25069:

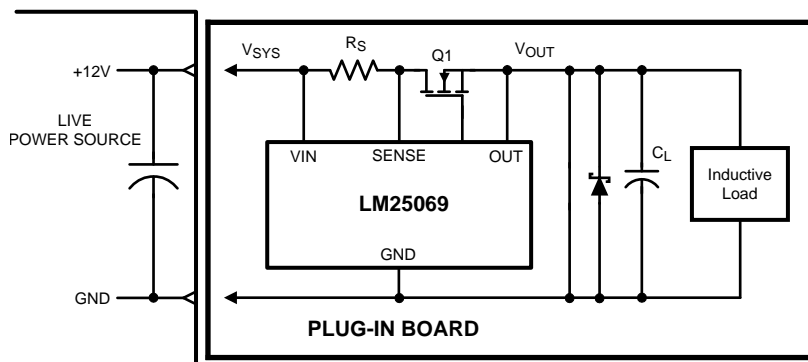
- Place the LM25069 close to the board's input connector to minimize trace inductance from the connector to the FET.
- Place a small capacitor (1000 pF) directly adjacent to the VIN and GND pins of the LM25069 to help minimize transients which may occur on the input supply line. Transients of several volts can easily occur when the load current is shut off.
- The sense resistor ( $R_S$ ) should be close to the LM25069, and connected to it using the Kelvin techniques shown in [Figure 27](#).
- The high current path from the board's input to the load (via Q1), and the return path, should be parallel and close to each other to minimize loop inductance.
- The ground connection for the various components around the LM25069 should be connected directly to each other, and to the LM25069's GND pin, and then connected to the system ground at one point. Do not connect the various component grounds to each other through the high current ground line.
- Provide adequate heat sinking for the series pass device (Q1) to help reduce stresses during turn-on and turn-off.
- The board's edge connector can be designed to shut off the LM25069 as the board is removed, before the supply voltage is disconnected from the LM25069. In [Figure 36](#) the voltage at the UVLO pin goes to ground before  $V_{SYS}$  is removed from the LM25069 due to the shorter edge connector pin. When the board is inserted into the edge connector, the system voltage is applied to the LM25069's VIN pin before the UVLO voltage is taken high.



**Figure 36. Recommended Board Connector Design**

### System Considerations

- Continued proper operation of the LM25069 hot swap circuit requires capacitance be present on the supply side of the connector into which the hot swap circuit is plugged in, as depicted in [Figure 22](#). The capacitor in the “Live Power Source” section is necessary to absorb the transient generated whenever the hot swap circuit shuts off the load current. If the capacitance is not present, inductance in the supply lines will generate a voltage transient at shut-off which can exceed the absolute maximum rating of the LM25069, resulting in its destruction.
- If the load powered by the LM25069 hot swap circuit has inductive characteristics, a Schottky diode is required across the LM25069’s output, along with some load capacitance. The capacitance and the diode are necessary to limit the negative excursion at the OUT pin when the load current is shut off. If the OUT pin transitions more than 0.3V negative the LM25069 will internally reset, interfering with the latch-off feature of the LM25069-1, or the restart cycle of the LM25069-2. See [Figure 37](#).



**Figure 37. Output Diode Required for Inductive Loads**

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**REVISION HISTORY**

| <b>Changes from Revision D (March 2013) to Revision E</b>  | <b>Page</b>        |
|--|--------------------|
| <hr/> <ul style="list-style-type: none"><li>• Changed layout of National Data Sheet to TI format .....</li></ul> | <a href="#">22</a> |

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**PACKAGING INFORMATION**

| Orderable Device   | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2)         | Lead/Ball Finish | MSL Peak Temp<br>(3) | Op Temp (°C) | Top-Side Markings<br>(4) | Samples                 |
|--------------------|---------------|--------------|-----------------|------|-------------|-------------------------|------------------|----------------------|--------------|--------------------------|-------------------------|
| LM25069PMM-1/NOPB  | ACTIVE        | VSSOP        | DGS             | 10   | 1000        | Green (RoHS & no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | -40 to 85    | SXNB                     | <a href="#">Samples</a> |
| LM25069PMM-2/NOPB  | ACTIVE        | VSSOP        | DGS             | 10   | 1000        | Green (RoHS & no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | -40 to 85    | SXLB                     | <a href="#">Samples</a> |
| LM25069PMME-1/NOPB | ACTIVE        | VSSOP        | DGS             | 10   | 250         | Green (RoHS & no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | -40 to 85    | SXNB                     | <a href="#">Samples</a> |
| LM25069PMME-2/NOPB | ACTIVE        | VSSOP        | DGS             | 10   | 250         | Green (RoHS & no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | -40 to 85    | SXLB                     | <a href="#">Samples</a> |
| LM25069PMMX-1/NOPB | ACTIVE        | VSSOP        | DGS             | 10   | 3500        | Green (RoHS & no Sb/Br) | CU SN            | Level-1-260C-UNLIM   |              | SXNB                     | <a href="#">Samples</a> |
| LM25069PMMX-2/NOPB | ACTIVE        | VSSOP        | DGS             | 10   | 3500        | Green (RoHS & no Sb/Br) | CU SN            | Level-1-260C-UNLIM   | -40 to 85    | SXLB                     | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

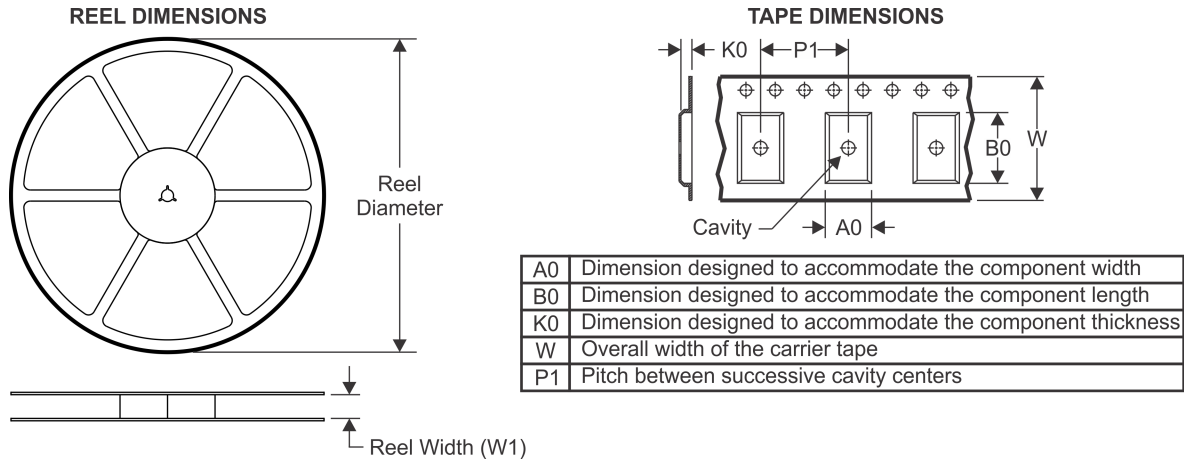
(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.



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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

| Device             | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|--------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM25069PMM-1/NOPB  | VSSOP        | DGS             | 10   | 1000 | 178.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM25069PMM-2/NOPB  | VSSOP        | DGS             | 10   | 1000 | 178.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM25069PMME-1/NOPB | VSSOP        | DGS             | 10   | 250  | 178.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM25069PMME-2/NOPB | VSSOP        | DGS             | 10   | 250  | 178.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM25069PMMX-1/NOPB | VSSOP        | DGS             | 10   | 3500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| LM25069PMMX-2/NOPB | VSSOP        | DGS             | 10   | 3500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |

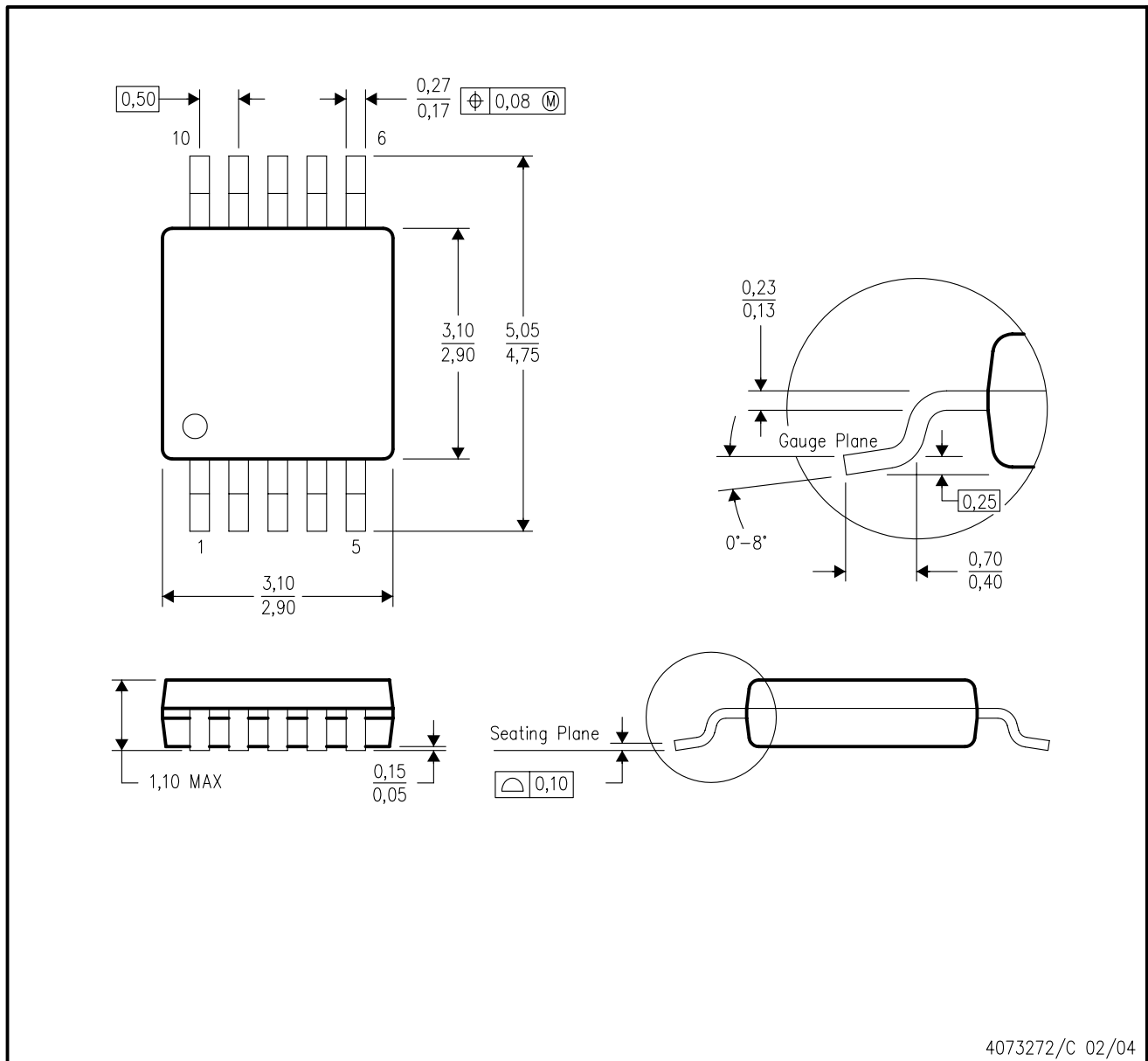
**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

| Device             | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|--------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM25069PMM-1/NOPB  | VSSOP        | DGS             | 10   | 1000 | 210.0       | 185.0      | 35.0        |
| LM25069PMM-2/NOPB  | VSSOP        | DGS             | 10   | 1000 | 210.0       | 185.0      | 35.0        |
| LM25069PMME-1/NOPB | VSSOP        | DGS             | 10   | 250  | 210.0       | 185.0      | 35.0        |
| LM25069PMME-2/NOPB | VSSOP        | DGS             | 10   | 250  | 210.0       | 185.0      | 35.0        |
| LM25069PMMX-1/NOPB | VSSOP        | DGS             | 10   | 3500 | 367.0       | 367.0      | 35.0        |
| LM25069PMMX-2/NOPB | VSSOP        | DGS             | 10   | 3500 | 367.0       | 367.0      | 35.0        |

DGS (S-PDSO-G10)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion.
  - D. Falls within JEDEC MO-187 variation BA.

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