Overview

The TPD7107F is an N-channel MOSFET gate driver IC for 1-channel output high-side switches. A high-current high-side switch can be easily configured by combining this product with an N-channel MOSFET with a 40V breakdown voltage. The boosting method for driving the N-channel MOSFET uses a charge pump circuit, so it can be used with 100% duty cycle. In addition, the IC has a built-in capacitor for the charge pump so that peripheral components can be reduced. Protecting and monitoring the MOSFET enables the building of highly secure systems.
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1. Compare products (TPD7107F, TPD7106F, TPD7104AF)

The following table shows the main differences between our 1-channel high-side N-channel MOSFET gate driver ICs. The features of our product lineup include highly safe protective functions such as reverse power connection protection and GND disconnection protection. Also, for how to control the external MOSFET during these protective operations, select the optimum products according to the necessity of the functions from the table below.

Table 1.1  Product comparison

<table>
<thead>
<tr>
<th>Item</th>
<th>TPD7107F</th>
<th>TPD7106F</th>
<th>TPD7104AF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wafer process</td>
<td>BiCD0.13</td>
<td>BiCD0.13</td>
<td>BiCD0.13</td>
</tr>
<tr>
<td>Power Supply Voltage (DC)</td>
<td>26 V</td>
<td>27 V</td>
<td>24 V</td>
</tr>
<tr>
<td>Power Supply Voltage (Pulse)</td>
<td>36 V(t≤400ms)</td>
<td>40 V(t≤500ms)</td>
<td>40 V(t≤300ms)</td>
</tr>
<tr>
<td>Output source current</td>
<td>100 μA</td>
<td>10 mA</td>
<td>100 μA</td>
</tr>
<tr>
<td>Output sink current</td>
<td>5 mA / 230mA (Note2)</td>
<td>0.4 A</td>
<td>5 mA</td>
</tr>
<tr>
<td>Reverse Battery protection method (Note1)</td>
<td>MOSFET ON</td>
<td>MOSFET OFF</td>
<td>MOSFET OFF</td>
</tr>
<tr>
<td>GND open protection.</td>
<td>✓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Package.</td>
<td>WSON10A</td>
<td>SSOP16</td>
<td>PS-8</td>
</tr>
</tbody>
</table>

Note1: Difference in external MOSFET operation when the power is reversed.

MOSFET ON: To reduce losses, the MOSFET is turned on and current flows.  
MOSFET OFF: MOSFET and apply current to the MOSFET body diodes. To interrupt the current, connect an additional driver IC+ MOSFET so that the drain and drain are connected.

Note2: Refer to 4.2 Output Sink Current.
2. 1ch Output High Side Switch Outline

The high-side switch is a switch circuit in which a switching element such as a MOSFET is arranged on the power supply side, and an inductive load or a resistive load is connected to the GND side to adjust the current supplied to the load. This is a gate driver IC that drives the N-channel MOSFET that constitutes the high-side switch.

The high-side switches used in various applications are used in a wide current range of several hundred mA to several hundred A. In particular, a low on-resistance MOSFET is used for loads with large currents. We have a lineup of MOSFET that supports a variety of current ratings, so you can use this product in conjunction with them. It is also designed for automotive applications, so it has a variety of protection functions and a diagnostic function that provides feedback to the microcontroller. This guide mainly explains the basic characteristics, protection functions, and diagnostic functions, as well as their operation.

![Schematic view of high-side switch](image)

Table 2.1 List of recommended MOSFET

<table>
<thead>
<tr>
<th>ID(A)</th>
<th>to 50A</th>
<th>to 100A</th>
<th>to 150A</th>
<th>to 200A</th>
<th>to 250A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended device N-channel MOSFET 40V</td>
<td>TK50S04K3L</td>
<td>TK100S04N1L</td>
<td>TPWR7904PB</td>
<td>TK200F04N1L</td>
<td>TKR74F04PB</td>
</tr>
<tr>
<td></td>
<td>XPN3R804NC</td>
<td>TK80S03K3L</td>
<td>TPHR7904PB</td>
<td>TK1R4F04PB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TK35S04K3L</td>
<td>TK65S04N1L</td>
<td>TPW1R104PB</td>
<td>TK1R5R04PB</td>
<td></td>
</tr>
</tbody>
</table>

According to the load current.
3. Power supply voltage

3.1. Operation range of power supply voltage

<table>
<thead>
<tr>
<th>Item</th>
<th>Symbol</th>
<th>Operating ranges</th>
<th>Maximum Ratings</th>
<th>unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating supply voltage</td>
<td>VDD</td>
<td>5.75 to 26</td>
<td>40</td>
<td>V</td>
</tr>
</tbody>
</table>

The operating power supply voltage range is as shown in Table 3.1. However, to protect the external MOSFET and to protect this product from malfunction and damage, this product has a built-in protection function when the power supply voltage is abnormal.

3.2. Overvoltage protection

- When the voltage of a VDD terminal is more than the over voltage detection threshold (VOV), the off-driver usually operates and the external FET turns off. After that, if the VDD terminal voltage is less than the over voltage threshold voltage, the external FET is driven again.
  - In the case of VIN=H and VDD>VOV, the off-driver operates after the mask time of TOV (200us max) (VGATE=H to L).
  - In the case of VDD>VOV and VIN=L to H, it keeps VGATE=L.

3.3. Undervoltage protection

- When VDD terminal voltage is less than VUV3 (2.7V (typ.)), the rapid off-driver operates, carry out latch-off of the external FET, and outputs H state to DIAG.
- In case VDD<VUV5, the off-driver operates and VDD goes up. After that, if VDD is more than VUV5, the off-driver will change to normal operation (TDIAG).
- Even if VDD terminal voltage falls under the conditions of VGATE=H, VGATE keeps H state, and external FET will be ON in VDD>VUV3. (Low-voltage extension operation)
- There is a Latch clear standby time (TLATCH) after returning to the normal operation from the low voltage.

![Figure 3.1 The abnormalities in power supply voltage.](image-url)
3.4. The power activation method

After applying V_{DD} and reaching the predetermined voltage (5.75V) or higher, set the STBY pin to the High state. In addition, the IN pin should be in the low state at power-on. The control input sequence is shown below.

![Control input sequence diagram](image)

Figure 3.2 Control input sequence
4. Output current

4.1. Output source current

The source current output from the GATE pin is output from the internal charge pump circuit. Figure 4.1 shows the GATE pin voltage (red) at \(V_{DD}=5\,\text{V}\) and the gate-source voltage (blue) applied to the MOSFET. To ensure a gate-to-source voltage of 10V or greater, the source current must be limited to approximately 180\(\mu\text{A}\) or less. For ambient temperature and other design-margins, connect an external resistor of 100k\(\Omega\) or more between MOSFET gate and source.

![Gate voltage load regulation (V_{DD}=5\text{V})](image)

Figure 4.1  Gate voltage load regulation (\(V_{DD}=5\text{V}\))

4.2. Output sink current

The output sink current of the GATE pin is 5mA at the absolute maximum rating. However, when an error is detected, the rapid off-driver operates and a sink current of 230mA (rapid off time 100\(\mu\text{s}\)) is generated and then the low state is maintained with a 5mA off-driver. Figure 4.2 shows the turn-off waveform at normal off and Figure 4.3 shows the turn-off waveform at rapid off. Excessive stress is applied to the MOSFET when overcurrent or short circuit occurs. In such an abnormal situation, the quick off driver operates to shut off the MOSFET in a short time, preventing the MOSFET from being destroyed.
Figure 4.2  Gate voltage turn off waveforms at the time of normal operation
External MOSFET: TPWR7904PB

Figure 4.3  Gate voltage turn off waveforms at the time of abnormal operation
External MOSFET: TPWR7904PB
5. Control input

5.1. STBY terminal input
This terminal is used to control the product to the standby state. By setting to the Low state, the internal circuit is stopped and the mode transitions to low current consumption mode. The GATE pin and DIAG pin maintain the Low state. In the standby state, each protection function and the diagnostic output function are stopped. A pull-down resistor is incorporated, so it is in the standby state when it is open. By setting to the High state, the standby state is canceled.

5.2. IN terminal input
By setting the IN pin to the High state, the GATE pin outputs a boosted voltage and applies a bias to the gate of the external MOSFET. In addition to the control to turn on/off the MOSFET, it is also used as a signal to reset the inside of the IC by setting the IN pin to the Low state after the protection function operates. Since a pull-down resistor is internally incorporated, the IN pin is in the Low state when it is open.

5.3. MIRROR - SHUNT terminal input
A differential amplifier for sensing the load current is built-in and its input terminal. Connect the MIRROR terminal to the source terminal of the external MOSFET. Connect the SHUNT terminal to the load-side of the outputs. Connect a shunt resistor between the MIRROR and SHUNT terminals.
6. The example of an application circuit

- Q1: N-channel MOSFET / 40V
- D1,D2: CRZ16
- R1: 47kΩ
- R2: 10kΩ
- R3,R4,R5: 100Ω
- R6: 200kΩ
- R7: 1mΩ/4W
- C1: 10nF/12V
- C2: 0.22μF/50V
- C3: 220pF/50V

Note1: Please connect the capacitor for power supplies near the IC as much as possible.

Figure 6.1 The example of an application circuit

Precautions for use
- For overvoltage protection between gate and source in Q1, connect the Zener diode in both directions (Zener voltage 16V). Connect a pull-down resistor R6, as Q1 may malfunction if the IC's GATE terminal becomes high-impedance due to a break in the circuit.
- For the shunt resistor R7 used for sensing the current, select the resistance value and power dissipation considering the maximum load current and loss. The $V_{\text{DIAG}}$ of voltage output to the ADC can be calculated by the following equation.

\[
V_{\text{DIAG}} = I_D \cdot R7 \cdot \left( \frac{R2}{R3} \right)
\]

- Place capacitor C1 between $V_{\text{DD}}$ and GND and capacitor C3 between MIRROR-SHUNT as close as possible to IC.
7. Protect function

7.1. Protection for reverse battery connection

Figure 7.1 shows the power supply reverse connection operation conditions. GND is connected to the VDD, VDD terminal on the load side, and evaluation is performed in the reverse connection state. The VGS in Q1 was measured when VDD was applied 0V to -26V. The VGS rises linearly up to -16V, and the VGS is about 15V when VDD is around -18V, and the MOSFETQ1 is turned on sufficiently.

![Figure 7.1](image1)

**Figure 7.1** Reverse battery connection operating condition

![Figure 7.2](image2)

**Figure 7.2** Reverse battery operation (VDD vs Q1 VGS)
7.2. Active clamp operation

Figure 7.3 shows the active clamp check circuit conditions. Connect an inductive load of 50μH to the load and input control signals to IN (Pulse width = 300μs). Because of normal operation, analogue voltage is output to the DIAG. However, since only 50μH is connected, current increases and overcurrent protection operates. Then, the induced voltage by the inductive load of 50μH is generated, the VDS of the external MOSFET rises, and it enters the active clamping operation at about 36.4V.

![Figure 7.3 Active clamp operation](image)

Ch1: $V_{\text{DIAG}}$ (2pin) 5.0V/div
Ch2: $V_{\text{DD}}$ (10pin) 10.0V/div
Ch4: $V_{\text{DS}}$ 10.0V/div (diff)
Ch3: $V_{\text{IN}}$ (5pin) 5.0V/div 40μs/div

clamp voltage = 36.4V
Active clamp
Over current detected

*Figure 7.4 Active clamp operation ($V_{\text{DD}}$=16V, IN: pulse width = 300μs, L load = 50μH)*
7.3. Load current sensing in normal operation

Fig. 7.5 shows the actual measured values assuming that the X-axis is the load current and the Y-axis is the analog voltage of the DIAG. In the low-current range below the 1A, the voltage across the shunt resistor is also small, so the sense amplifier input offset becomes dominant, causing a relative error. When the 1A is exceeded, it becomes 10% or less and approaches the theoretical values. The guaranteed input offset of the sense amplifier is ±2mV.

![Figure 7.5  Current sense characteristic](image-url)
7.4. Load opening detection

Figure 7.7 shows the output waveform when the load is disconnected (load open). The V_{DIAG} has an intermediate voltage of 2.75V and outputs the voltage at the time of detecting a load disconnection. When the IN terminal is set to L \rightarrow, it shifts to the normal operation mode after 12.5ms (T_{DIAG}). When the IN terminal is set to \rightarrow L, the load disconnection detecting mode is adopted again.

Figure 7.6 Load Disconnection Detection Evaluation Conditions

Figure 7.7 Load disconnection detected (V_{DD}=12V, IN=0 to 3.3V, R_{load}=open)
7.5. $V_{DD}$ short detection

Figure 7.9 shows each output waveform at the time of a short to power fault. In the circuit diagram, the drain and source of Q1 are short-circuited to reproduce the short to power operation and check the diagnostic output at that time. When a load disconnection is detected, a voltage of 2.75V is output, but when the short to power is detected, a 5V is output to enable the microcontroller to recognize the short to power.

![Circuit Diagram](image)

Figure 7.8 Measurement condition of $V_{DD}$ short detection.

![Waveform Chart](image)

Figure 7.9 $V_{DD}$ short detection ($V_{DD}$=12V, IN=0 to 3.3V, Q1 drain-source shorted).
7.6. GND disconnection detection

Figure 7.10 shows the measurement circuit. GND disconnection detection is a function that maintains off so that an external MOSFET does not operate when the GND line of this product is disconnected. When the GND on the IC side is opened, the GND terminal (it display on Ch2) of the IC floats and the voltage rises. The $V_{GS}$ of external MOSFET is monitored with the differential probe and turns off ($\approx 0V$) at approximately $450\mu s$. Since the $V_{GS}$ has dropped below $V_{th}$, the external MOSFET turns off and cuts off the current to the GND.

![Figure 7.10 GND Disconnection Detection](image)

**Figure 7.10**  GND Disconnection Detection

![Figure 7.11 GND Disconnection Detected (V_{DD}=12V, IN=3.3V, with GND pin open asynchronously)](image)

**Figure 7.11**  GND Disconnection Detected ($V_{DD}=12V$, $IN=3.3V$, with GND pin open asynchronously)
7.7. Abnormal external MOSFET drain-source voltage

When a gate bias is applied to an external MOSFET, but an abnormal potential occurs between the drain and source, an H-state is output from the diagnostic output to indicate an error. Figure 7.12 is an evaluation condition that deliberately reproduces the drain-source anomaly. A 220 Ω (R8) is deliberately inserted between the VDD (12V) and the drain of Q1, and a 100 Ω load resistor is connected. This unit monitors the VDD•SHUNT voltages. Figure 7.13 shows the evaluation results. When a pulse is input to the IN terminal and the turn-on operation is performed, a normal bias is applied to the VGS. However, since 220 Ω is connected to the R8, the SHUNT terminal voltage is about 3.9V without an increase. The VDD•SHUNT voltage is about 8.1V, and the IC detects an abnormal drain-source voltage. The detection time is about 13.5ms.

In the case where a drain-to-source voltage error and low-voltage detection (UV5) occur simultaneously, this device determines that a load is short-circuited, performs rapid OFF operation without waiting for the detection time, and outputs the H-state to the diagnostic output DIAG pin.

![Figure 7.12 FET drain to source voltage abnormality](image)

![Figure 7.13 FET drain to source voltage abnormality](image)

(VDD=12V, IN=0 to 3.3V, pulse width 20ms, Rload = 100Ω, R8=220Ω)
8. Evaluation board

We prepare evaluation boards that mount MOSFET and other peripheral devices. You can check the function under actual load and the protection diagnosis function.

![Evaluation board (TPD7107F)](image)

**Figure 8.1** Evaluation board (TPD7107F)

**Figure 8.2** Evaluation board schematic.

Note1: Unimplemented parts: Q2,Q3,U5,TP12,D6,D7,C7,R7,R8

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9. Points to note in the description

1. Block diagram
   Functional blocks, circuits, constants, etc. in the block diagram may be partially omitted or simplified to explain the functions.

2. Equivalent circuit
   The equivalent circuit may be partially omitted or simplified to illustrate the circuit.

10. Points to Remember on Handling of ICs

10.1. Precautions for use

1. The absolute maximum rating is the standard which must exceed no one value of two or more rating even the instant. It cannot exceed to any of two or more rating. When the absolute maximum rating is exceeded, it may become the cause of destruction, damage, and degradation, and it may be injured by the burst and combustion.

2. Since current sensing voltages and more than diagnostic output voltage may be outputted to the DIAG output by the injection of the power supply, interception condition (rising and bringing down), the input condition (MIRROR, SHUNT) to current sense amplifier, etc., please confirm problem existence by the set in the case of use. Also, please give me the measure by the capacitor etc. if needed.
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