

LV-IPD

(Low Voltage Intelligent Power Device)

Application Notes

Overview

This document is an application note describing the types, I/O specifications, protective and diagnostic functions, properties, and usage precautions from the features of the Toshiba Low-Voltage Intelligent Power Device [LV-IPD] products.

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1. Product Lineup Introduction

1.1. Low voltage intelligent power device

An intelligent power device is a product equipped with a diagnostic output function that mainly applies current to resistive loads and inductive loads, shuts off the current when an abnormal state of the load occurs, and feeds back the abnormal state to a microcomputer or other device. It is used in sets that require high quality and reliability, such as in ECU (Electrical Control Unit of cars).

Low voltage IPD (Intelligent Power Device) and IPS (Intelligent Power Switch) used in automotive and industrial applications are synonymous. We call it IPD, but it is also called IPS, Smart Power Driver, SMARTMOS, Smart MOSFET, Protected MOSFET, etc.

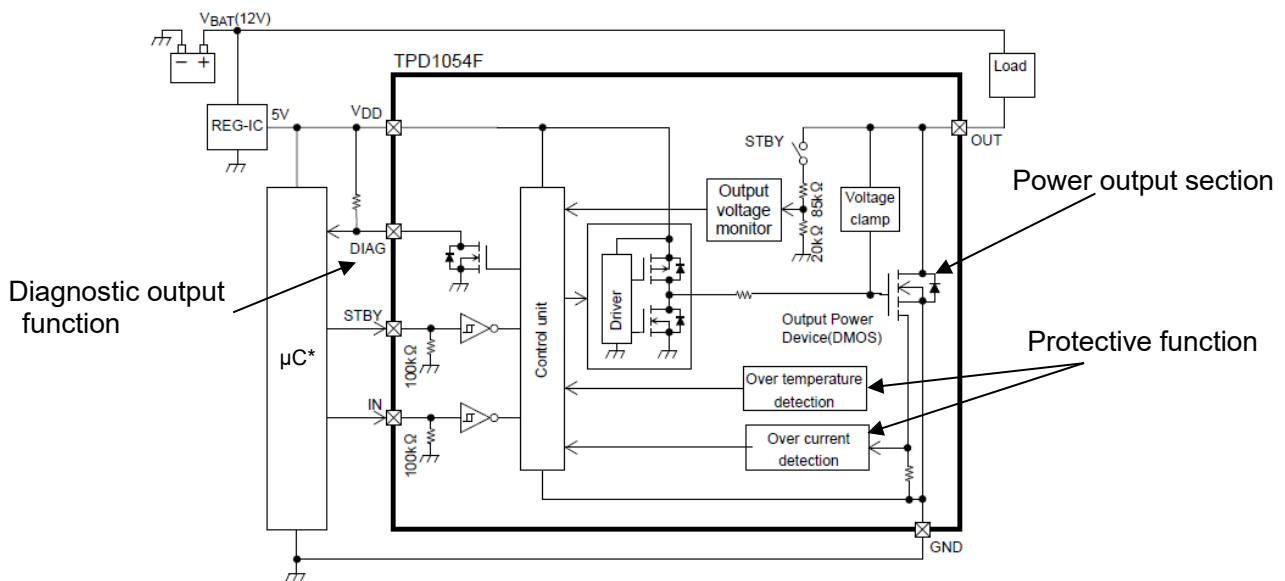


Fig. 1.1 Low-side switch TPD1054F (example)

*) μC : Micro Controller

1.2. Product type

Product functions include high-side switches, low-side switches, and gate driver products.

1.2.1. High-side switch

A power switch located on the power supply side (upstream) with respect to the load (LOAD) is called a high-side switch. Major applications include single-phase motors, solenoids, and makeup relays. It can be driven directly from CMOS or TTL logic circuitry (such as a microcomputer) and has a variety of built-in protective functions. Products with a diagnostic function feedback information to a microcomputer or other device to respond to abnormal conditions. Even if the load is short-circuited to GND, the abnormal status of the overcurrent can be judged.

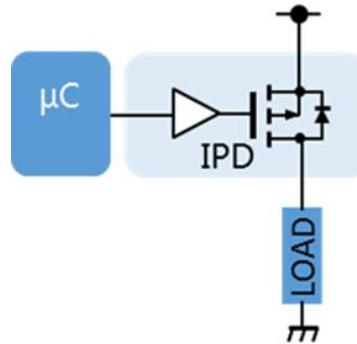


Fig. 1.2 Outline of high-side switch

1.2.2. Low Side Switch

A power switch located GND (downstream) of the load (LOAD) is called a low-side switch. Major applications include single-phase motors, solenoids, and makeup relays. It can be driven directly from CMOS or TTL logic circuitry (such as a microcomputer) and has a variety of built-in protective functions. Products with a diagnostic function feedback information to a microcomputer or other device to respond to abnormal conditions. The high-side switch features a lower total system cost.

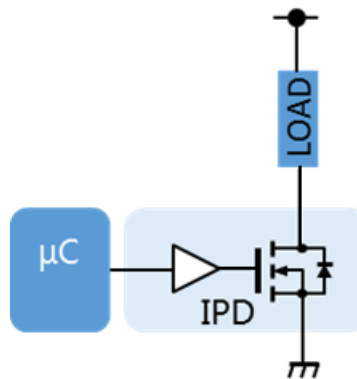


Fig. 1.3 Outline of low-side switch

1.2.3. Gate driver

Gate drivers drive the gates of power devices such as MOSFET. Fig. 1.4 shows an inverter drive for a three-phase brushless DC motor. In addition to our three-phase brushless DC motors, we also offer products that drive H-bridge motors and single-phase motors.

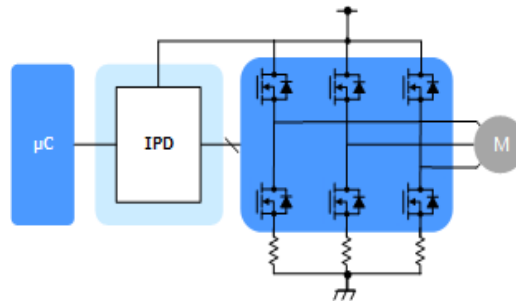


Fig. 1.4 Outline of gate driver

1.3. Product name description

Naming of our IPD products is performed according to the following rules.

Example: TPD1054F

<u>TPD</u>	<u>10</u>	<u>54</u>	<u>F</u>
term 1	term 2	term 3	(term 4) term 5

Table 1.1 Description of product names

Term	Meaning	Remarks
term 1	Represents Toshiba Intelligent Power Device products.	"TPD"
term 2	10 to 19:1 output or 2 outputs power switch (per chip)	-
	20 to 29:Multi-output power switch.	
	40 to 49:Bridge output power switch	
	70:Low-side gate driver	
	71:High-side gate driver	
	72:Bridge gate driver	
term 3	Additional two-digit number from 00 to 99	-
term 4	Alphabetically ordered (from A) changes that cannot be written up to term 3	For package changes, refer to the back of term 5.
term 5	Represents type of envelope. F: Surface-Mount Type FN: Flat Package 2 Directions (0.65μm Pitch)	-

1.4. Product Lineup

Currently, IPD offered by us will be in the following lineup (as of December 2022).

Table 1.2 Product Lineup

Function	Product name	Product overview (number of outputs × on-resistance / package / etc.)	
High-side switch	TPD1052F	1 output × 0.8 Ω / PS8 / AEC-Q100 qualified	
	TPD1055FA	1 output × 0.12 Ω / WSON10 / AEC-Q100 qualified	
	TPD2015FN	8 outputs × 0.55 Ω / SSOP30	
Low-side switch	TPD1044F	1 output × 0.6 Ω / PS8 / AEC-Q100 qualified	
	TPD1054F	1 output × 0.8 Ω / PS8 / AEC-Q100 qualified	
	TPD1058FA	1 output × 0.1 Ω / WSON10 / AEC-Q100 qualified	
	TPD2017FN	8 outputs × 0.55 Ω / SSOP30	
Gate driver	for high-side switch	TPD7104AF	1 output / PS8 / AEC-Q100 qualified
		TPD7106F	1 output / SSOP16 / AEC-Q100 qualified
		TPD7107F	1 output / WSON10 / AEC-Q100 qualified
	for motor	TPD7211F	Half-bridge output / PS8 / for automotive applications
		TPD7212FN	3-phase 6 outputs / SSOP30 / AEC-Q100 qualified
		TPD7212F	3-phase 6 outputs / WQFN32 / AEC-Q100 qualified

2. PIN ASSIGNMENT

2.1. I/O pins

This section explains the main I/O control terminals of IPD referring to TPD1054F of the low-side switch. Besides the power / GND terminals, the input terminals have terminals for on/off control and stand-by control, and the output terminals have terminals for connecting loads and for transmitting diagnostics to the outside.

TPD1054F (low-side switch) example

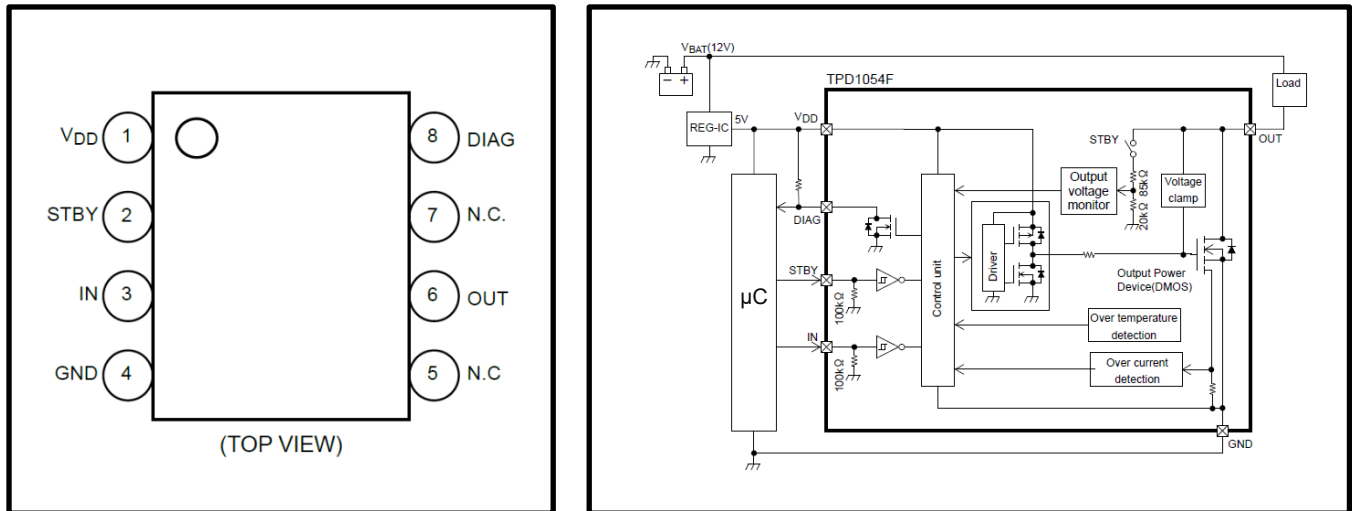


Fig. 2.1 TPD1054F Pin Layout and Block Diagram

Table 2.1 Pin Description (TPD1054F)

Pin name	PIN ASSIGNMENT
V _{DD}	Power supply pin. Used by applying a voltage within the specified range at the terminals used to operate the control circuit inside this product. (Depending on the product, the power supply terminal of the power output section may also be used.)
STBY	Terminal for standby input. The standby current consumption can be reduced by inputting STBY = "L". (Preset or not depending on the product)
IN	Input pin. Turns the output on / off by input V _{IN} =H / L.
GND	Ground terminal.
N.C	No Connection
OUT	Output pin. A load is connected between this terminal and the power supply for use. (For low-side switch products)
DIAG	Diagnostic output pin. This pin is used to feed back the normal / abnormal status of the product to the MCU. Pull up to the control power supply (5 V or 3.3 V).

* Input / control / output system terminals may differ depending on the product.

3. Protective function

Describes the protective functions of the circuitry built into IPD.

3.1. Overcurrent protection function

The specific operation of the overcurrent protection function compares the reference voltage with the voltage generated by the resistive element for current detection inside the product, and judges that the generated voltage is in an overcurrent state when the voltage exceeds the reference voltage, and shuts off the output. Fig. 3.1 shows the operation waveform when the overcurrent protection function of the low-side switch product is activated. Immediately after the input voltage becomes H (on control), the output voltage is L (on state). However, after an overcurrent judgement, the output voltage transitions to H and shifts to the off operation, the output current attenuates. The overcurrent judgment is canceled after a certain period. If an overcurrent judgment occurs again, the overcurrent judgment to cancellation are repeated as shown in the figure. (Refer to descriptions in Sections 6.7 and 6.8.)

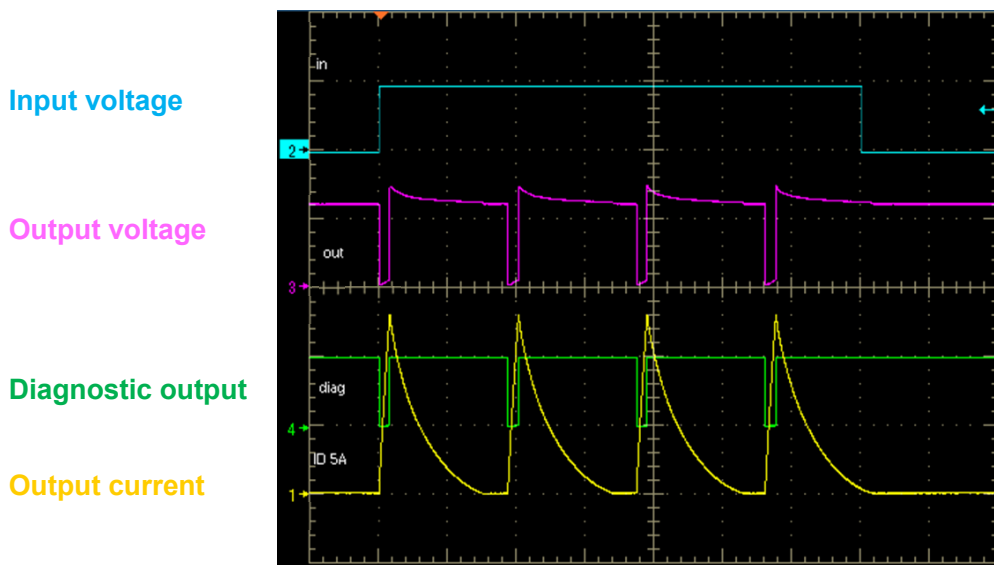


Fig. 3.1 Overcurrent Protection Function

3.2. Overheat protection function

The determination of the temperature that requires overheat protection is made by monitoring the forward voltage (V_F) of the temperature sensing diode located on the chip. V_F has a temperature coefficient of about $-2\text{mV}/^\circ\text{C}$. When V_F falls below the reference voltage by comparing the internal reference voltage with V_F , it is judged that an overheat condition has occurred due to a temperature rise, and the protective function of the element is activated. Fig. 3.2 shows the operation waveform when the overheat protection function is activated.

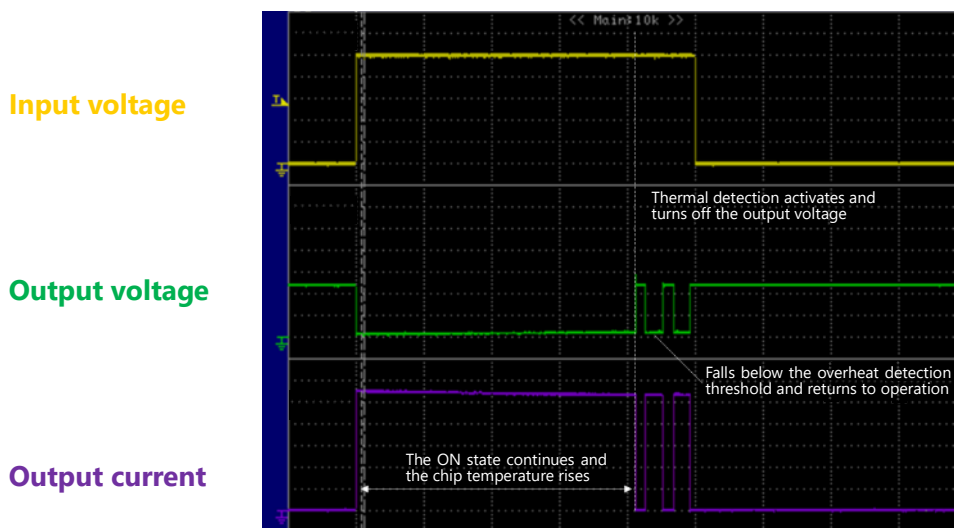


Fig. 3.2 Overheat Protection Function

3.3. Active clamp (low side switch product example)

Active clamping is a function that absorbs energy by suppressing voltage caused by back EMF energy generated when switching control of an inductive load to less than the withstand voltage of the element. When the drain-source voltage exceeds a certain value due to the back-EMF energy of the inductance, the output DMOS is turned on to regenerate the energy. The current can be cut off at high speed because the regenerative voltage is higher than the regenerative voltage at forward voltage using a diode. Overcurrent protection and overheat protection cannot be activated during the active clamp operation. Design the product so that the specified energy and maximum rated temperature are not exceeded.

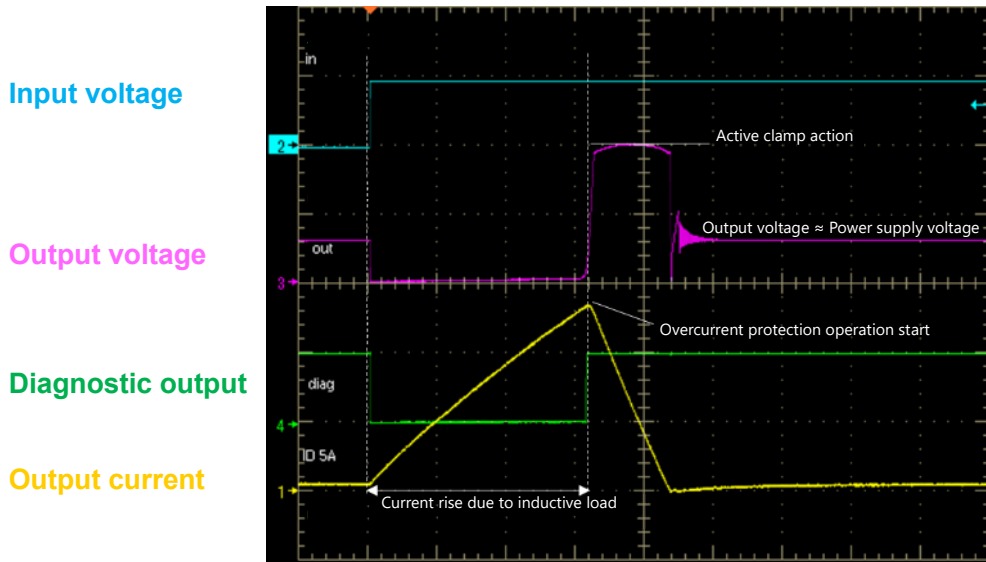


Fig. 3.3 Active Clamp Function

3.4. Power Reverse Connection Protection (Gate Driver Product Example)

3.4.1. Protected by keeping MOSFET on-state

The product TPD7107F maintains MOSFET controlled by the product in the on-state to protect the product and MOSFET in order to reduce the loss of external MOSFET when the power is reversed.

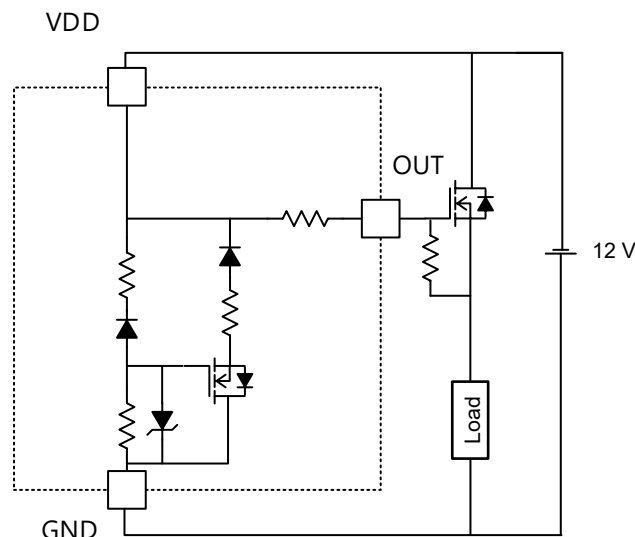


Fig. 3.4 Power Supply Reverse Connection Protection (MOSFET on)

3.4.2. Protected by keeping MOSFET off-state

The product TPD7104AF protects the product and MOSFET by keeping MOSFET controlled by the product off when the power is reversed and by interrupting the current. When used in conjunction with a load switch, MOSFET that performs on/off control during normal operation as shown in Fig. 3.6 and the circuit configuration of the reverse-connection protective MOSFET should be designed to be connected in series.

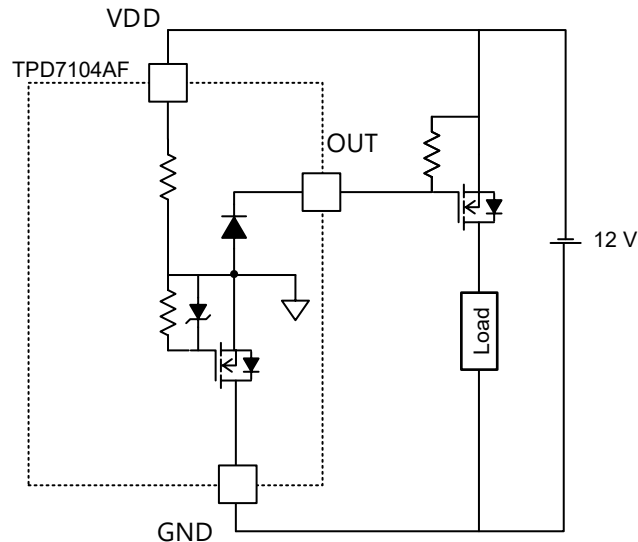


Fig. 3.5 Power Supply Reverse Connection Protection (MOSFET off)

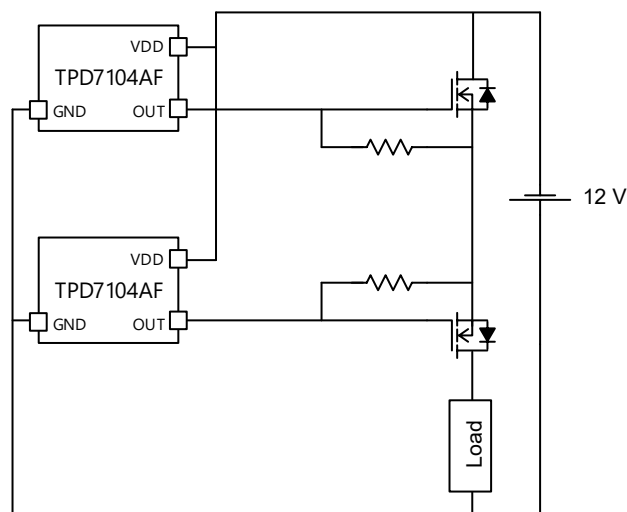


Fig. 3.6 Configuration in Combination with Load switch

4. Diagnostic function

The diagnostic function operates, for example, when the overcurrent protection operation, overheat protection operation, or the load becomes open (the output pin is in the high-impedance state). Specific operation of the diagnostic function is to provide information to the MCU by combining "H" and "L" signals from the diagnostic outputs (DIAG pins) for normal and abnormal conditions. By processing the signal input to IPD product and the signal output by the diagnostic function with a logic circuit or the like, abnormal conditions occurring in MOSFET or the like controlled by IPD product can be judged. For information on the specific diagnostic functions of each product, refer to the information contained in each data sheet.

4.1. Current sense function

The current flowing through the load is detected by reading the differential voltage generated in the shunt resistor (R_S) using the built-in current sense amplifier, outputting it as an analog voltage corresponding to the preset gain (resistive ratio: R_2/R_1), and reading it through an external A/D converter.

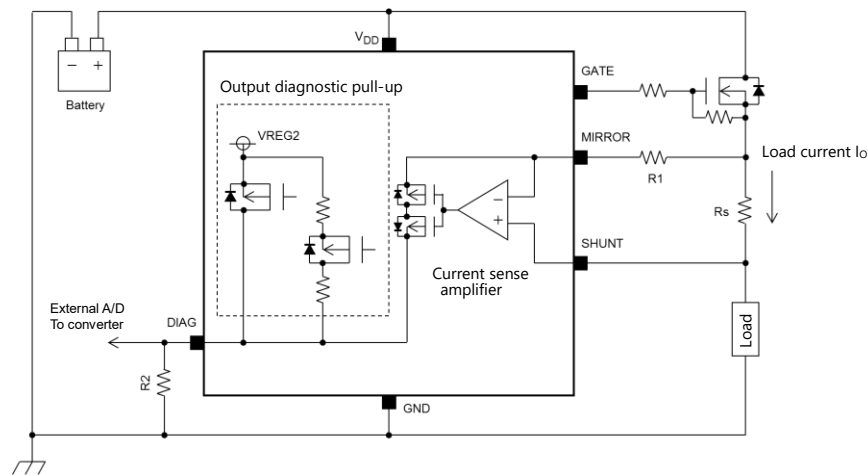


Fig. 4.1 Current Sense Amplifier Circuit

The load current sensing output voltage output from the diagnostic terminal (DIAG pin) is calculated using Equation 4.1 below.

$$V_{DIAG} = \frac{R_2}{R_1} \times (R_S \times I_O + V_{IO}) \quad \text{(Equation 4.1)}$$

V_{DIAG} : DIAG pin output voltage
 I_O : Load current
 V_{IO} : Input offset voltage

4.2. Disconnection Detection Function

The disconnection (load-open) detection function detects contact failure at the connector part of ECU and disconnection of the harness.

The load open detection function is divided roughly into the following two types.

1. When the output stage transistor is off, the output terminal voltage is monitored and the output voltage is equal to or higher than the set value, the load is determined to be open.
2. When the output stage transistor is on, the current flowing through the output stage transistor is monitored, and when the output current falls below the set value, the load is determined to be open.

Many of our IPD for high-side switches output terminals when the output stage transistor of 1. is off. It employs a type that monitors the voltage and detects the load open.

When the input V_{IN} of the on/off control = L (output off), the output stage transistor is controlled to be off, and the effect of the current in the path from Charge pump to OUT terminal is small. Therefore, the output voltage (V_{OUT}) is determined by the division voltage of $R1$ and the external resistor R_L . When this voltage V_{OUT} exceeds the threshold of the Schmitt inverter ($SINV$), the load is judged to be open, and "H" is output to DIAG terminal, and the load is transmitted to the microcomputer.

$$V_{OUT} = \frac{R_L}{R_L + R1} \times V_{DD} \geq V_{IH_{SINV}} \quad (\text{Equation 4.2})$$

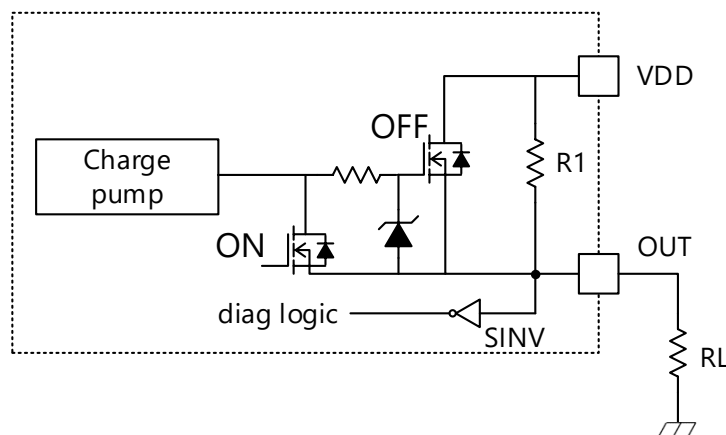


Fig. 4.2 Outline of Disconnection Detection Circuit

4.3. Overcurrent detection function

The overcurrent detection function operates when a current exceeding the specified value flows through the output stage transistor, and transmits the protection and diagnosis results of the product itself to the microcomputer, etc.

As shown in Fig. 4.3, a transistor (Q2) with a constant ratio (1/N) and an output stage drum (Q1) are configured to detect the overcurrent, and the current (I_S) of 1/N flows through the transistor is controlled at the same gate potential. The comparator compares the constant current (I_{REF}) for comparison with the reference voltage ($R2 \times I_{REF}$) generated by the resistor R2 and the potential ($R1 \times I_S$) generated by the detection path, determines whether the current is within the normal current range or the overcurrent state, and protects the product and outputs diagnostic data.

- Ratio of current to I_S and I_{OUT}

$$I_{OUT} : I_S = N : 1 \quad (\text{Equation 4.3})$$

$$I_S = I_{OUT} / N \quad (\text{Equation 4.4})$$

- Overcurrent detection condition

$$R1 \times I_S \geq R2 \times I_{REF} \quad (\text{Equation 4.5})$$

$$I_S \geq \frac{R2}{R1} \times I_{REF} \quad (\text{Equation 4.6})$$

From Equations 4.6 and 4.4, the overcurrent detection-value I_{OC} is as follows.

$$I_{OC} \geq \frac{R2}{R1} \times N \times I_{REF} \quad (\text{Equation 4.7})$$

For example, if the product is designed with the following figures,

$R1 = 1 \text{ k}\Omega$, $R2 = 4 \text{ k}\Omega$, $N = 20000$, $I_{REF} = 60 \mu\text{A}$

The overcurrent detection I_{OC} is as follows and is used as a reference for determining the overcurrent status.

$$I_{OC} \geq \frac{4 \text{ k}\Omega}{1 \text{ k}\Omega} \times 20000 \times 60 \mu\text{A} = 4.8 \text{ A} \quad (\text{Equation 4.8})$$

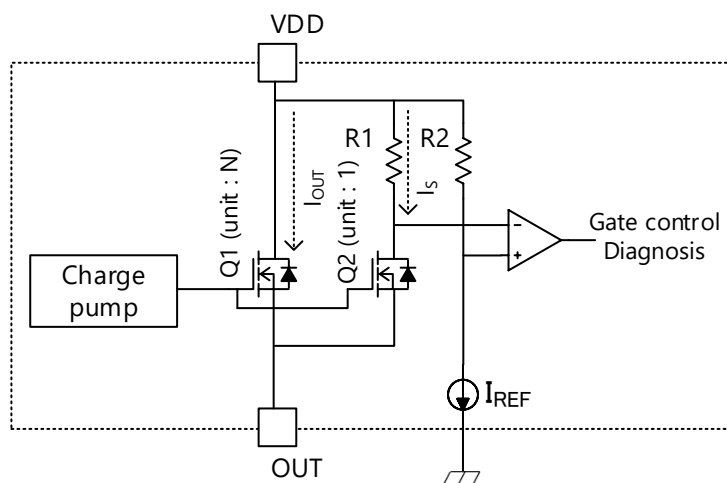


Fig. 4.3 Overcurrent Detection Circuit Schematic

5. Absolute maximum rating

Table 5.1 shows the values of the items of absolute maximum ratings referring to the product TPD1058FA. Absolute Maximum Ratings are standards that do not exceed any one value of multiple ratings instantaneously or instantaneously.

Cannot be exceeded for any of multiple ratings. Exceeding the absolute maximum ratings may cause breakage, damage or deterioration and may result in injury due to explosion or combustion.

Table 5.1 Absolute Max. Ratings (TPD1058FA)

Item	Symbol	Terminal	Rating	Unit	Remarks
Power supply voltage	V _{DD}	V _{DD}	-0.3 to 6	V	-
Input voltage	V _{IN} , V _{STBY}	IN, STBY	-0.3 to 6	V	-
Diagnostic output voltage	V _{DIAG}	DIAG	-0.3 to 6	V	-
Diagnostic output current	I _{DIAG}	DIAG	5	mA	-
Output voltage	V _{OUT}	OUT	-0.3 to 40	V	N-channel DMOS of drain-source tolerance 60 V is used.
Output current	I _{OUT}	OUT	Internally limited (Note)	A	-
Power Dissipation	P _D	-	1.84	W	-
Active clamp tolerance (single engine)	E _{AS}	-	95	mJ	-
Active clamping current	I _{AR}	OUT	6	A	-
Operating temperature	T _{opr}	-	-40 to 125	°C	-
Channel temperature	T _{ch}	-	150	°C	-
Storage temperature	T _{stg}	-	-40 to 150	°C	-

Note : The output current is limited by the overcurrent protection function. Under normal operating conditions, the range will be within the range where the overcurrent detection value or less can be used.

6. ELECTRICAL CHARACTERISTICS

Table 6.1 lists the electrical characteristics (partially excerpted) referring to the product TPD1058FA.

Table 6.1 Electrical Characteristics (TPD1058FA)

Characteristics	Symbol	Pin	Test conditions	Min	Typ.	Max	Unit
Output clamp voltage	$V_{(CL)DSS}$	OUT	$I_{OUT}=1mA, V_{STBY}=5V, V_{IN}=0V$	40	46	60	V
Operating supply voltage	$V_{DD(opr)}$	V_{DD}	-	4.5	5	5.5	V
Under voltage protection	$V_{DD(UV)}$	V_{DD}	-	2.5	2.9	3.5	V
Supply current	I_{DD1}	V_{DD}	$V_{STBY}=0V, V_{IN}=0V, V_{DD}=5V$	-	0	10	μA
	I_{DD2}	V_{DD}	$V_{STBY}=5V, V_{IN}=0V, V_{DD}=5V$	-	0.61	2	mA
	I_{DD3}	V_{DD}	$V_{STBY}=5V, V_{IN}=5V, V_{DD}=5V$	-	0.62	5	mA
Output leakage current	I_{OL1}	OUT	$V_{STBY}=V_{IL}, V_{IN}=V_{IL}, V_{OUT}=8 \text{ to } 16V$	-	-	10	μA
	I_{OL2}	OUT	$V_{STBY}=V_{IH}, V_{IN}=V_{IL}, V_{OUT}=8 \text{ to } 16V$	-	160	300	μA
High-level input voltage	V_{IH}	IN,STBY	-	2.0	-	-	V
Low-level input voltage	V_{IL}	IN,STBY	-	-	-	0.8	V
High-level input current	I_{IH}	IN,STBY	$V_{IN}(V_{STBY})=5V, V_{DD}=5V$	-	50	200	μA
Low-level input current	I_{IL}	IN,STBY	$V_{IN}(V_{STBY})=0V, V_{DD}=5V$	-1	-	1	μA
Diagnostic output leakage current	I_{DH}	DIAG	$V_{DIAG}=5V$	-	-	3	μA
Diagnostic output voltage	V_{DL}	DIAG	$I_{DIAG}=+1mA$	-	0.01	0.2	V
Output resistance	$R_{DS(ON)1}$	OUT	$I_{OUT}=+2A, T_{ch}=25^{\circ}C, V_{DD}=5V, V_{STBY}=V_{IH}, V_{IN}=V_{IH}$	-	0.07	0.10	Ω
	$R_{DS(ON)2}$	OUT	$I_{OUT}=+2A, T_{ch}=-40 \text{ to } 125^{\circ}C, V_{DD}=5V, V_{STBY}=V_{IH}, V_{IN}=V_{IH}$	-	-	0.16	Ω
Over temperature detection	T_{OT}	-	$V_{STBY}=V_{IH}, V_{IN}=V_{IH}$	150	172	200	$^{\circ}C$
	ΔT_{OT}	-		-	12	-	
Over current detection	I_{OC}	OUT	$V_{STBY}=V_{IH}, V_{IN}=V_{IH}, V_{DD}=5V$	6	13	-	A
Over current protection operation time	$t_{OFF-DUTY}$	OUT	$V_{BAT}=12V, R_L=0.1\Omega, V_{DD}=5V, V_{STBY}=V_{IH}, V_{IN}=V_{IH}$	3	7	12	ms
Load open detection resistor	R_{op}	OUT	$V_{STBY}=V_{IH}, V_{IN}=V_{IL}, V_{OUT}=8 \text{ to } 16V$	10	300	1000	k Ω
	ΔR_{op}	OUT	$V_{STBY}=V_{IH}, V_{IN}=V_{IL}, V_{OUT}=8 \text{ to } 16V$	-	40	-	k Ω

6.1. Out-Clamp Voltage ($V_{(CL)DSS}$)

TPD1058FA incorporates an active clamp circuit and describes the output-voltage $V_{(CL)DSS}$ at which the active clamp operates. This indicates the clamping voltage. However, the active clamping operation is loss and the allowable energy value is not specified. Therefore, it is required to use the product within OUT terminal voltage 60 V.

6.2. Operating Power Supply Voltage ($V_{DD(opr)}$)

The operating power supply voltage indicates the range of voltage conditions when the following electrical characteristics and various protection functions are satisfied.

6.3. Output Leak Current (I_{OL})

The output leakage current specifies the leakage current when MOSFET of the output stage is off-state. The leakage current varies depending on the input conditions. I_{OL2} is 160 μA (typ.) due to the operating condition of the diagnostic circuitry and so on.

6.4. High-level input voltage (V_{IH}), Low-level input voltage (V_{IL})

V_{IH} : 2.0 V (min) means that for $V_{IN} \geq 2.0$ V, V_{IN} must be entered as "High", whereas V_{IL} : 0.8 V (max) means that V_{IN} must be entered as "Low" by $V_{IN} \leq 0.8$ V. (The actual value of the input terminal threshold is located between 0.8 to 2.0 V.)

6.5. Output-on Resistor ($R_{DS(ON)}$)

The output on-resistance is the value of the on-resistance of the output stage transistor when it is turned on. It is specified under the following two conditions: normal temperature (25°C) and total temperature range.

6.6. Over temperature detection (T_{OT})

Detects an overheat condition for the purpose of protecting the product, circuit, and internal elements against temperature rise caused by loss during product use, etc. The temperature is determined by monitoring the forward voltage V_F of the temperature-sensing diodes located on the chip. Although the overheat detection protection function is activated at temperatures higher than the sensing temperature, do not rely on the overheat detection function at the time of design, in consideration of power dissipation and thermal resistance value, in order to realize a safe design.

6.7. Overcurrent detection (I_{OC})

To cope with the excessive current value in the event of an abnormality or the like, an overcurrent detection mechanism composed of a detection path and a comparison circuit with the specified judgment voltage is incorporated so that the current value of the output stage transistor can be detected. After an overcurrent judgment, turn the input control ON to OFF, or cancel the judgment state after a certain period of time has elapsed (see Section 6.8). If the overcurrent judgement is made again after the reset, the overcurrent judgement to reset is repeated.

6.8. Overcurrent Protection Time ($T_{OFF-DUTY}$)

The overcurrent protection operation time is the period during which the output stage transistor is kept off for a certain period after detection of an overcurrent. Even if the output stage transistor is turned off and falls below the judgment value for overcurrent, the overcurrent judgment will not be cleared at that point. After the overcurrent protection operation time, the effect at the time of overcurrent is eliminated, and then the overcurrent judgment is canceled so that the tester shifts to the normal operation state.

7. Package lineup

This section describes the packages and shapes of the low voltage IPD.

7.1. WSON10

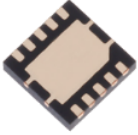
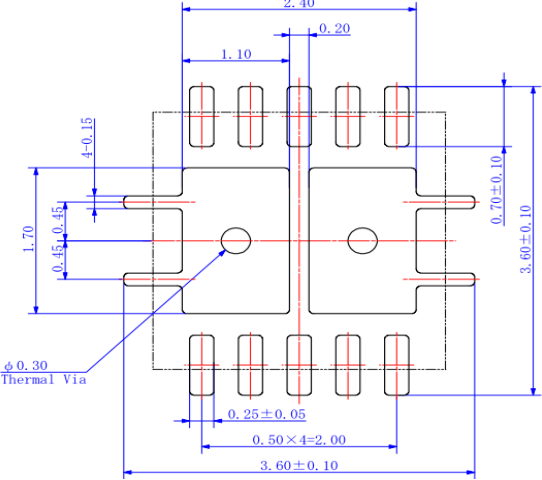
Dimension 3.0x3.0mm	Land Pattern Dimensions for reference only Unit: mm	Product name
		<p>TPD1055FA TPD1058FA</p>

Fig. 7.1 WSON10 Package information

7.2. WSON10A


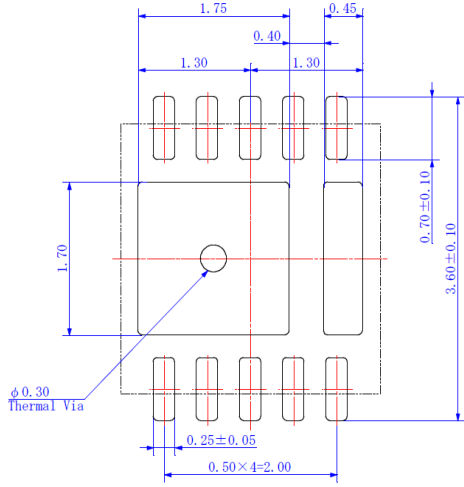
Dimension 3.0x3.0mm	Land Pattern Dimensions for reference only Unit: mm	Product name
		<p>TPD7107F</p>

Fig. 7.2 WSON10A Package information

7.3. WQFN32

Dimension	Land Pattern Dimensions for reference only Unit: mm	Product name
5.0x5.0mm		TPD7212F

Fig. 7.3 WQFN32 Package information

7.4. PS-8

Dimension	Land Pattern Dimensions for reference only Unit: mm	Product name
2.8x2.9mm		TPD1052F TPD1054F TPD7211F TPD7104AF

Fig. 7.4 PS-8 Package information

7.5. SSOP16


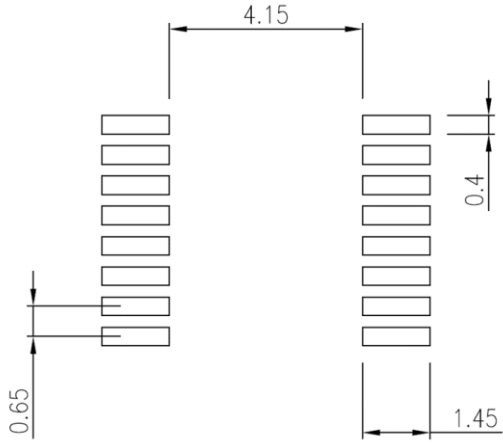
Dimension 5.0x6.4mm	Land Pattern Dimensions for reference only Unit: mm	Product name
		<p>TPD7106F</p>

Fig. 7.5 SSOP16 Package information

7.6. SSOP30


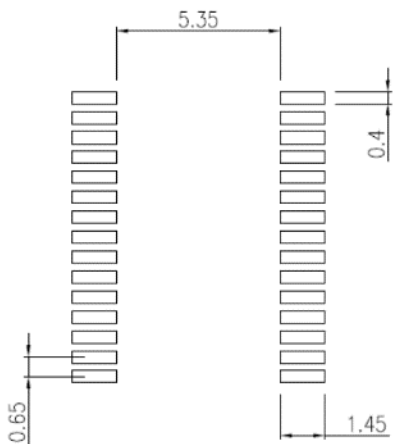
Dimension 9.7x7.6mm	Land Pattern Dimensions for reference only Unit: mm	Product name
		<p>TPD2015FN TPD2017FN TPD7212FN</p>

Fig. 7.6 SSOP30 Package information

8. Application Circuit (Example of Application Circuit Required for External Countermeasures)

8.1. Inductance Load Drive (High Side Switch Product Example)

If an inductive load (solenoid or motor) is used in a product for which the energy tolerance is not specified, measures must be taken with external components as shown in the figure below. If the product has no built-in active clamp circuit, application of a negative voltage to the output terminal may cause malfunction due to the operation of the parasitic element inside the product, or deterioration or breakdown due to exceeding the withstand voltage of the internal element. To prevent this, a freewheeling diode (FWD) is connected in parallel to the inductive load to regenerate the back EMF energy and clamp the output terminal voltage at approximately -0.7V (Fig. 8.1). However, since the regenerative current flows for a long time when FWD is connected, controllability issues arise when PWM control is performed. If OUT terminal has a negative voltage rating with a built-in output clamping circuit, the current flowing through the inductive load can be turned off quickly by regeneration with a FWD + Zener diode. This improves controllability during PWM control (Fig. 8.2).

8.1.1. Countermeasure Circuit 1

A diode is connected between OUT-GND. Select a diode with a withstand voltage equal to or greater than the power supply voltage.

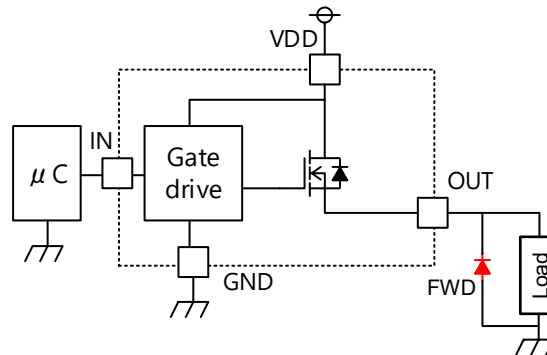


Fig. 8.1 Inductance Load countermeasure circuit1

8.1.2. Countermeasure Circuit 2

Zener diode was added to the circuit of Countermeasure 1. Energy regeneration time can be shortened.
* Confirm the negative voltage rating of OUT terminal of IPD before use.

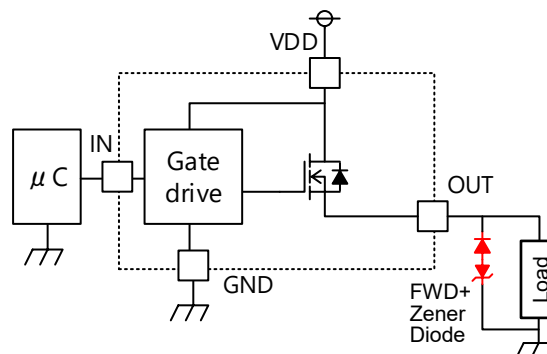


Fig. 8.2 Inductance Load countermeasure circuit 2

8.1.3. Countermeasure Circuit 3

A zener diode is connected between the power supply (VDD) and the power supply (OUT).
* Confirm the negative voltage rating of OUT terminal of IPD before use.

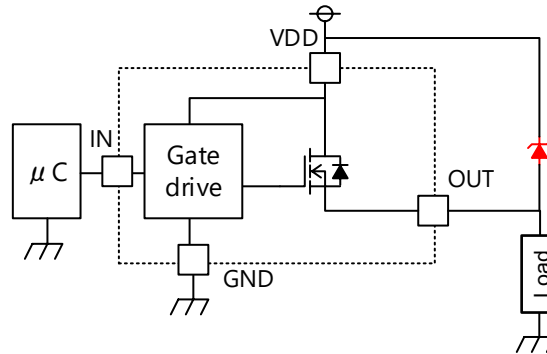


Fig. 8.3 Inductance Load countermeasure circuit 3

8.2. Power Reverse Connection Protection (Example of High Side Switch with Built-in Reverse Connection Protection)

If an inductance load (solenoid or motor) is used for a product for which the energy tolerance is not specified, external measures as shown in the figure below are required.

8.2.1. Countermeasure Circuit 1

Since only a small current such as consumed current flows through GND, a diode with a small power dissipation can be used. However, since a voltage drop equivalent to the forward voltage of the diode occurs, the input threshold is shifted. Pay attention to the heat at the current flowing from the load.

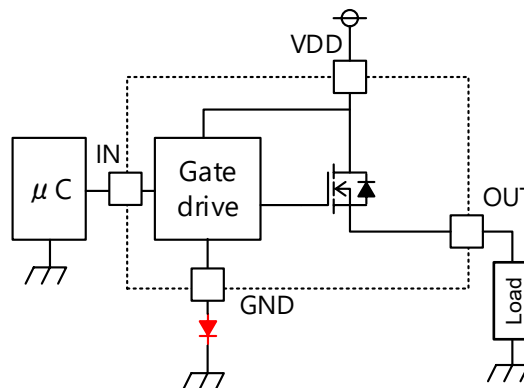


Fig. 8.4 Power Supply Reverse Connection Protection countermeasure circuit 1

8.2.2. Countermeasure Circuit 2

As a countermeasure circuit for reverse connection of the power supply, it is possible to also take countermeasures for the current flowing in from the load by connecting a diode on the path with the battery. However, since a diode is connected to the power line, a diode corresponding to the allowable loss is required.

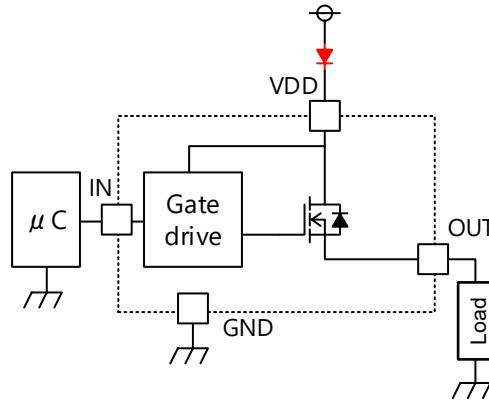


Fig. 8.5 Power Supply Reverse Connection Protection countermeasure circuit 2

8.2.3. Countermeasure Circuit 3

MOSFET diodes connected in the path with the battery of circuit 2 can reduce the voltage drop during normal operation. However, in this case, there are many external components, which increases the cost of the components.

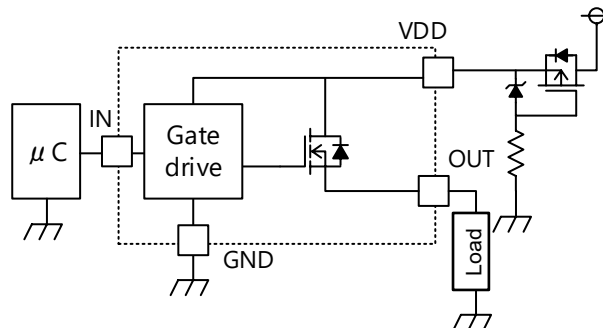


Fig. 8.6 Power Supply Reverse Connection Protection countermeasure circuit 3

9. Evaluation Boards

In order to make IPD product use easier to understand, we have prepared evaluation boards for basic operation checks for IPD product type.

9.1. Evaluation board for high-side switch products

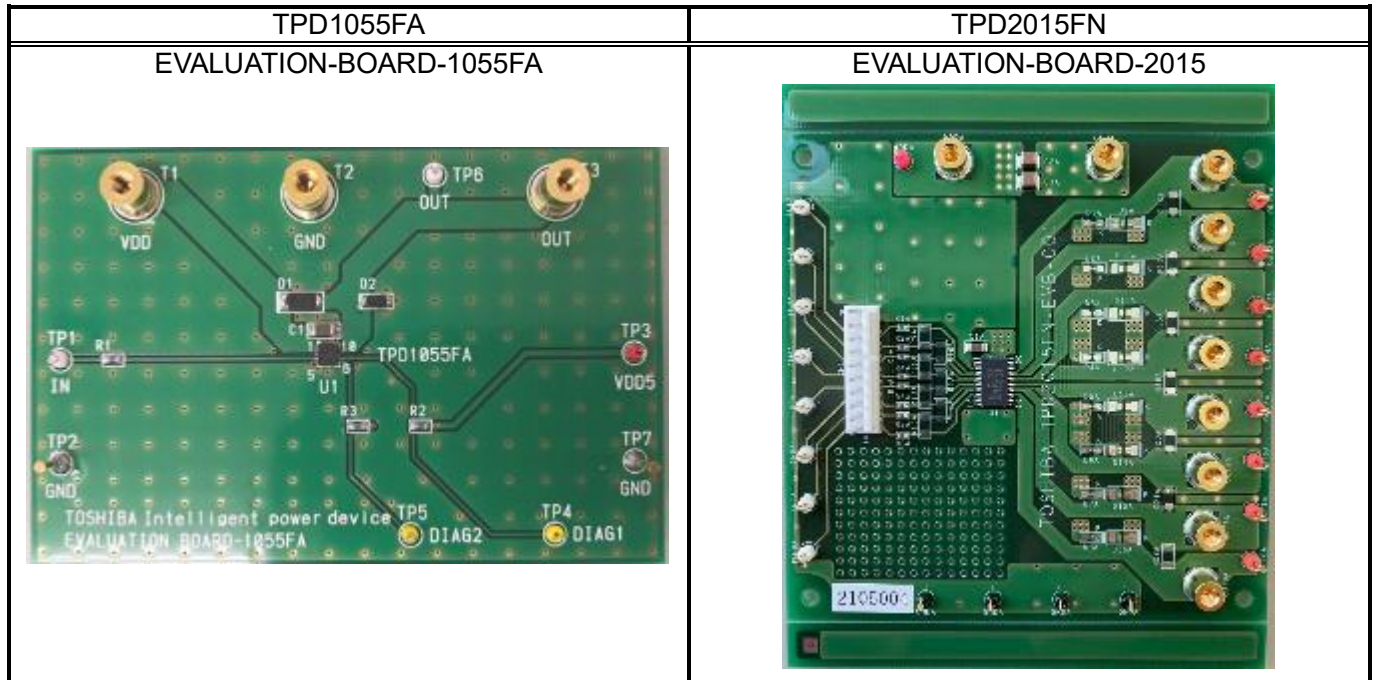


Fig. 9.1 Evaluation board for high-side switch products

9.2. Evaluation board for low-side switch products

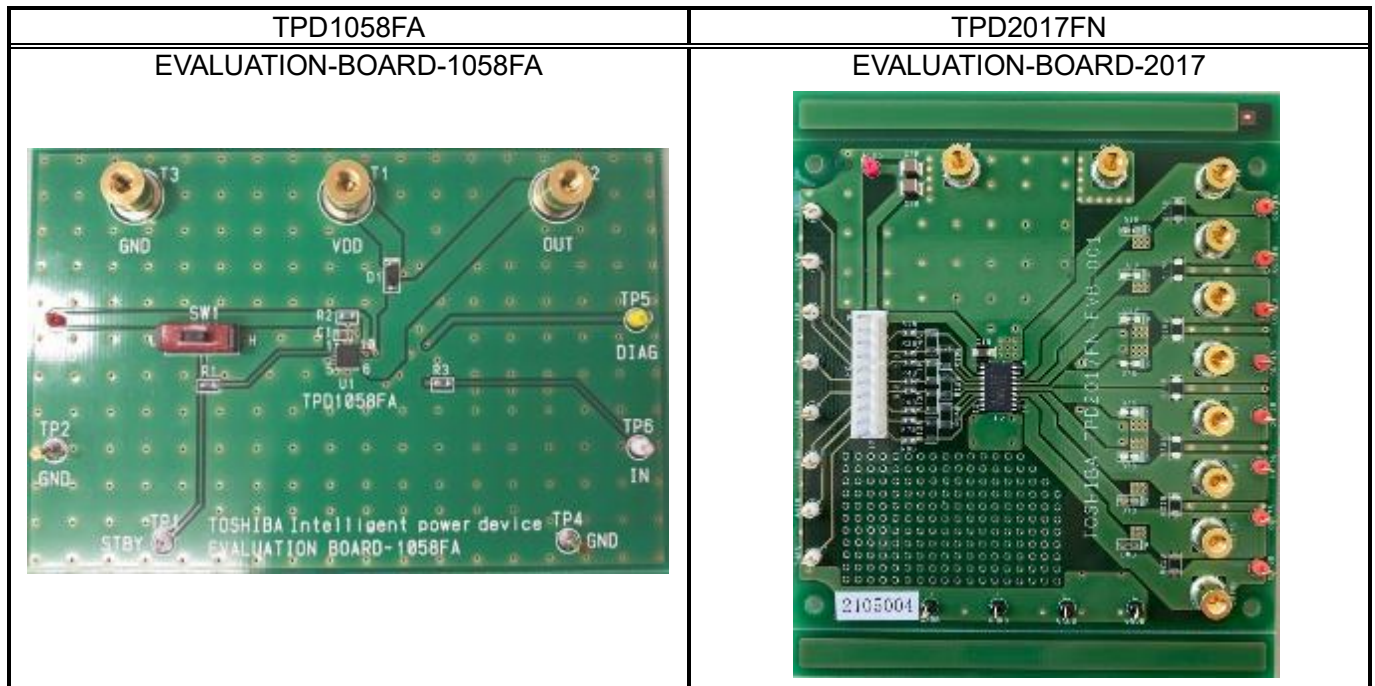


Fig. 9.2 Evaluation board for low-side switch products

9.3. Evaluation board for gate driver products


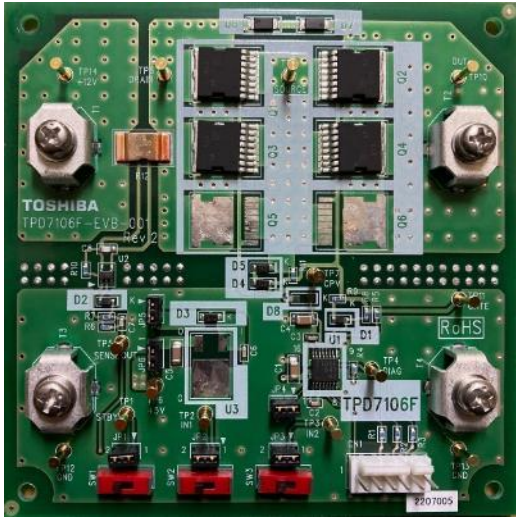

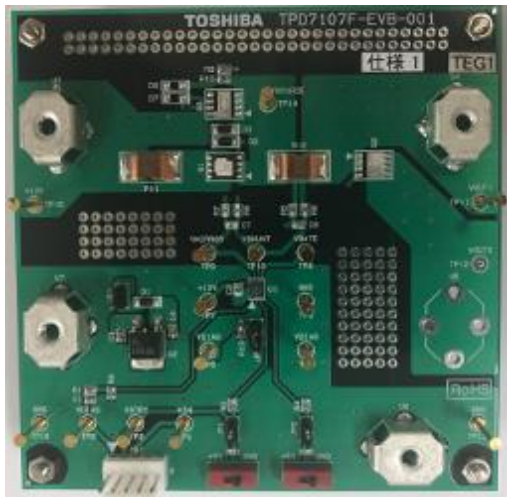
<p style="text-align: center;">TPD7104AF EVALUATION-BOARD-7104AF</p>  <p>The image shows the TPD7104AF evaluation board, a green PCB with various components including a central gate driver IC, several MOSFETs, and various passive components. It features four large silver heat sinks for the MOSFETs and a multi-pin connector at the bottom.</p>	<p style="text-align: center;">TPD7106F EVALUATION-BOARD-7106-2</p>  <p>The image shows the TPD7106F evaluation board, a green PCB with a central gate driver IC, multiple MOSFETs, and various passive components. It features four large silver heat sinks and a multi-pin connector at the bottom.</p>
<p style="text-align: center;">TPD7212FN EVALUATION-BOARD-7212FN</p>  <p>The image shows the TPD7212FN evaluation board, a green PCB with a central gate driver IC, multiple MOSFETs, and various passive components. It features four large silver heat sinks and a multi-pin connector at the bottom.</p>	<p style="text-align: center;">TPD7107F EVALUATION-BOARD-7107-DSOP</p>  <p>The image shows the TPD7107F evaluation board, a green PCB with a central gate driver IC, multiple MOSFETs, and various passive components. It features four large silver heat sinks and a multi-pin connector at the bottom.</p>

Fig. 9.3 Evaluation board for gate driver products

For detailed information on each evaluation board, please contact our web contact.

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