TPD2015FN
Application Notes

Overview

TPD2015FN is a high-side switch (8 channels) with MOSFET out. It can be driven directly from CMOS, TTL logic circuitry (MCUs, etc.) and is suitable for driving inductive and resistive loads such as industrial programmable logic controllers, motors and lamps in factory automation equipment, etc. This product has built-in overcurrent and over temperature protection functions, which contribute to improving the stability of the system. This guide explains detailed operations related to basic characteristics and protective functions, as well as precautions for use.

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1. Product comparison (TPD2005F, TPD2015FN)

Table 1.1 shows the main differences between each product. TPD2005F is our conventional product. It is an 8-channel output high-side switch. TPD2015FN will be a product that is smaller and has improved properties by reviewing the wafer process and packaging. The main improvement points are the expansion of the operating temperature range up to 110 °C and on-resistance has been reduced to 46%. SSOP30 (0.65 mm pitch) package size reduces the mounting area by approximately 30% from the conventional SSOP24 (1.0 mm pitch).

Table 1.1 Product comparison table

Item	TPD2005F	TPD2015FN
Operating Temperature T_{opr}	-40 to 85 °C	-40 to 110 °C
On-resistance R_{ON} @ V_{IN} = 5 V, I_{OUT} = 0.5 A, T_j = 25 °C	1.2 Ω (max)	0.55 Ω (max)
Overcurrent protection	Current clamping system	PWM system
Over temperature protection	160 °C	175 °C
Power Dissipation	1.2 W	1.8 W
Single pulse energy	10 mJ (min)	30 mJ (min)
Output leakage current @ V_{DD} = 40 V, V_{IN} = 0 V, T_j = 25 °C	100 µA (max)	1 µA (max)
Package	SSOP24 (1.0 mm pitch)	SSOP30 (0.65 mm pitch)
Package size	13.0 mm × 8.0 mm	9.7 mm × 7.6 mm

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2. Power supply voltage

2.1. Operating range of power supply voltage

Table 2.1 Operating range of power supply voltage

Item	Symbol	Operating Power Supply Voltage Range	Absolute maximum rating	Unit
Power voltage for driving	$V_{DD(opr)}$	8 to 40	40	V

The absolute maximum rating is a standard that must not be exceeded instantaneously.

2.2. Power on/off method

Apply V_{DD} and after the voltage reaches 8 V or more, apply the control input signal V_{IN}. Also, set the control input terminal to 0 V when the power is turned on. The control input sequence is shown below.
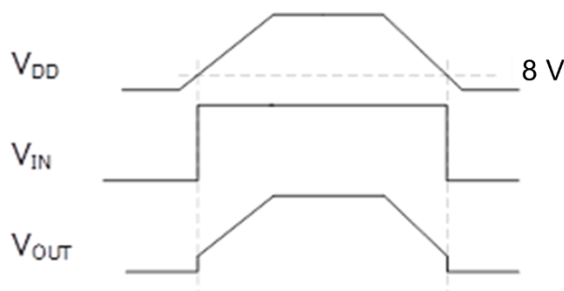

Fig. 2.1 Control Input Sequence

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3. Operation waveform

3.1. Normal operation waveform

As an example of normal operation, Fig. 3.1 and 3.2 show operating waveforms and measurement circuit diagrams. This product absorbs the back electromotive force to the minus side that occurs when an inductive load turns off without exceeding the withstand voltage of the element by turning on the output slightly. In Fig. 3.1, We can see that the output is clamped at a voltage of about -1.3 V. Current is supplied to the load from the OUT terminal during this period.

Ch1 : $V_{IN1 \text{ to } 8}$
5 V/div

Ch2 : $V_{OUT1 \text{ to } 8}$
5 V/div

Ch3 : $I_{OUT1 \text{ to } 8}$
100 mA/div

24 V

-1.3 V

2 ms/div

Fig. 3.1 Normal operation waveform

Fig. 3.2 Example of normal operation circuit

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4. Control input

4.1. IN1 to IN8 pins

This product has input terminals IN1 to IN8, and these input terminals correspond to output terminals OUT1 to OUT8, respectively, and each channel can be controlled independently. Each input pin has a built-in 300 kΩ (typ.) pull-down resistor, and when the input pin is open, it is in the Low state. Since the input voltage V_{IH} is 2.0 V (min), it is possible to control not only 5.0 V MCUs but also 3.3 V MCUs. For detailed electrical characteristics, please refer to the data sheet of this product. Please leave the NC pin open to prevent short-circuiting with adjacent terminals.
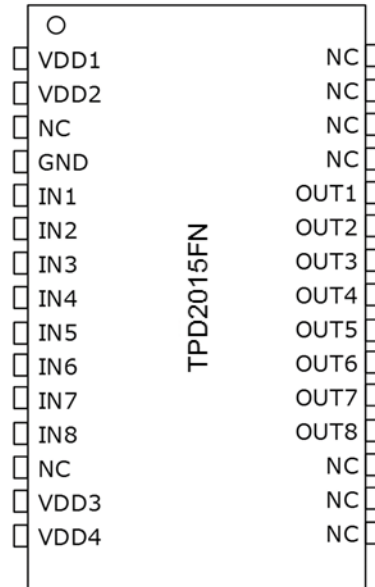
VDD1	NC
VDD2	NC
NC	NC
GND	NC
IN1	OUT1
IN2	OUT2
IN3	OUT3
IN4	OUT4
IN5	OUT5
IN6	OUT6
IN7	OUT7
IN8	OUT8
NC	NC
VDD3	NC
VDD4	NC

TPD2015FN

Fig. 4.1 Pin assignments

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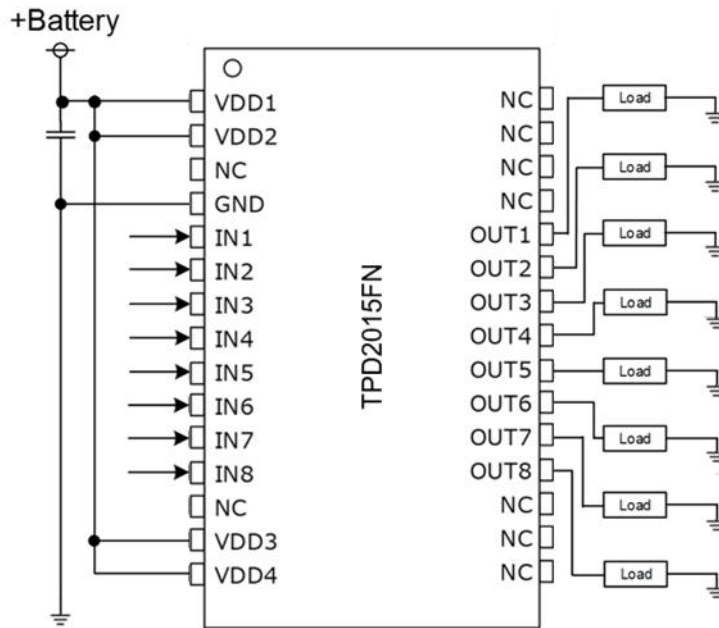## 5. Application circuit example

Fig. 5.1 Application circuit example

NOTE : Connect the power supply capacitor as close to the IC as possible.

Precautions for use
- Apply a voltage of 40 V or less to the + Battery.
- A resistive load or an inductive load is assumed in the load section. However, connect a load with a minimum value of 1.0 A or less, which is the minimum value for overcurrent detection.
- IN1 to IN8 are assumed to be 3.3 V or 5.0 V MCUs or TTLs. Do not apply voltage exceeding the absolute maximum rating.

(1) Capacitor for power supply terminal
Connect a capacitor as close as possible between V_{DD} and GND pins of the ICs.

Table 5.1 Recommended values (capacitors for power supply terminals)

Item	Recommended value	Remarks
V_{DD} – GND	0.1 to 1 µF	Ceramic capacitors

6. Protection features

6.1. Over temperature protection

Over temperature protection of this product turns off all outputs from OUT1 to OUT8 when TSD (175 °C typ.) or more is reached in order to protect the system from heat generation due to loss during operation and rise in ambient temperature. increase. Fig. 6.1 shows the operating waveforms when Ta=25 °C. Fig. 6.2 is an example of a test circuit when operating OUT3 to OUT6 with a current load of about 1.4 A, at which overcurrent protection does not operate, in order to generate loss in this product. Approximately 2.8 s after the output is turned on, over temperature protection is activated and the output is turned off. When the over temperature protection is activated, the output is turned off to reduce loss, and when Tj drops by the hysteresis ΔT_{SD} (20 °C typ.), the output returns to the on state. However, if the factor that activates the overheat protection is not eliminated, Tj will rise again and the overheat protection will activate → the output will turn off → Tj will decrease → the output will turn on repeatedly. Since the stability of the system and the reliability of the IC are concerned when the over temperature protection state continues for a long time, it is necessary to provide a fail-safe function as a system when the protection function is activated.
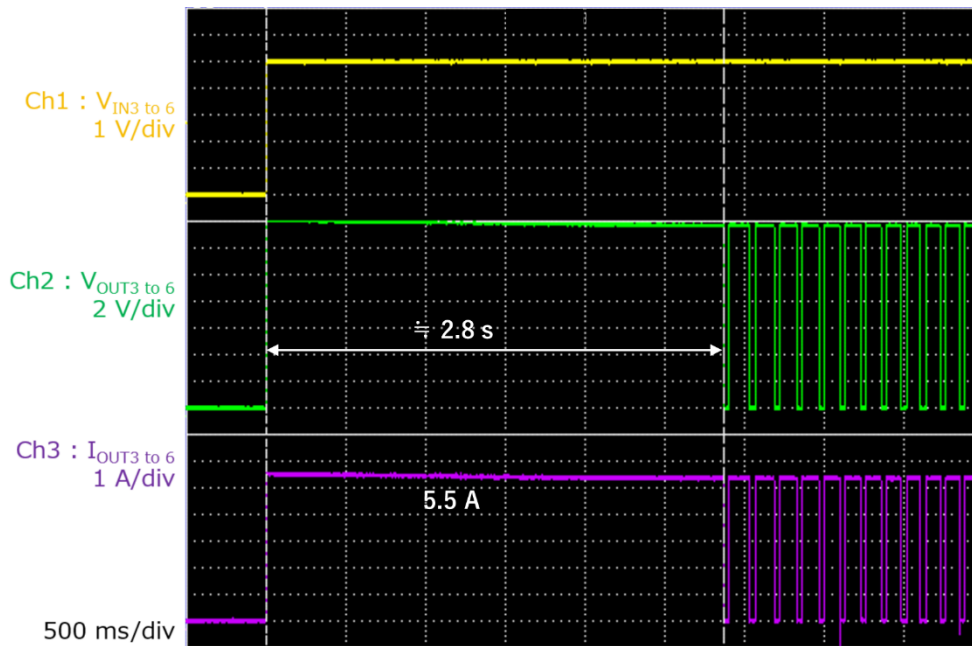
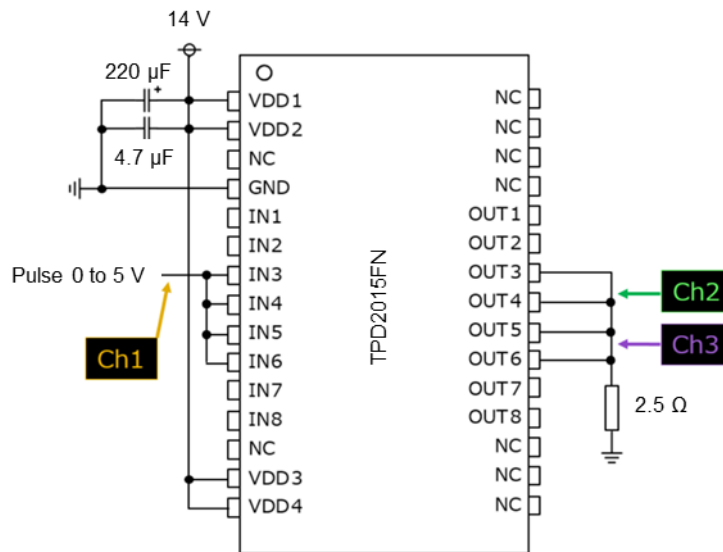**Fig. 6.1 Waveform of over temperature protection operation**

Fig. 6.2 Example of over temperature protection test circuit

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6.2. Overcurrent protection

Overcurrent protection of this product is a function that limits the output voltage and output current when an overcurrent occurs due to a load short circuit, etc., to prevent damage to this product and peripheral devices. There are generally two cases of conditions under which a load short circuit occurs. This section describes the case (6.2.1) in which the load is shorted while the Product is in the ON state, and the case (6.2.2) in which the Product transitions from OFF to ON while the load is in the shorted state.

6.2.1. Load short-circuited after IC is turned on

Fig. 6.4 is an example of a test circuit to reproduce a load short circuit while the product is on. I used it as a switching element to short-circuit Q1 (23 mΩ typ.).When the load is short-circuited (Q1 is turned on) while this product is on, the overcurrent detection value IOC of this product is 1.5 A typ.As shown in Fig. 6.3, the IOUT current may flow up to about 16 A due to the delay of the overcurrent detection circuit operation. However, the time during which the current is generated is only a few microseconds. Therefore, the possibility of device destruction or melting is extremely low. The overcurrent protection circuit of this product adopts the PWM method for the purpose of reducing the loss of the IC itself, and the overcurrent protection operation time is 3.0 ms typ. In Fig. 6.3, it can be confirmed that normal operation resumes after about 2.9 ms, and that the output is turned off after the short-circuit state is detected.
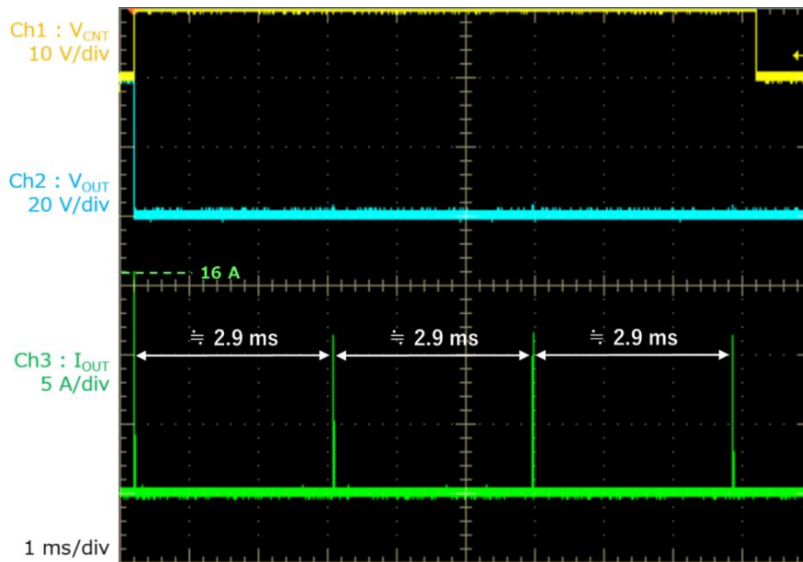
Fig. 6.3 Waveform of overcurrent protection operation (Load short-circuited after IC is turned on)
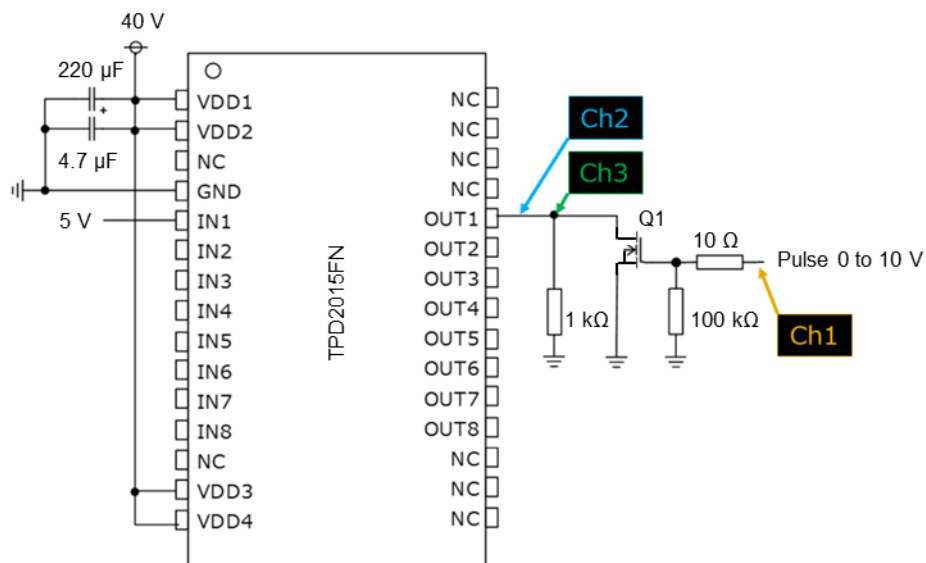
Fig. 6.4 Example of overcurrent protection test circuit (Load short-circuited after IC is turned on)

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6.2.2. IC on after load short circuit

In Fig. 6.6 is an example of a test circuit for reproducing the state of transition from off to on after the load of this product is short-circuited. A control signal is input to the IN1 terminal while the OUT1 terminal is shorted to GND. Figure 6.5 shows the operating waveforms when the input is in the H state and the output is turned on. As mentioned above, the I_{OUT} current rises to about 11.5 A due to the delay in the operation of the overcurrent detection circuit. However the time during which the current is generated is only a few microseconds, so the possibility of device destruction or melting is extremely low.
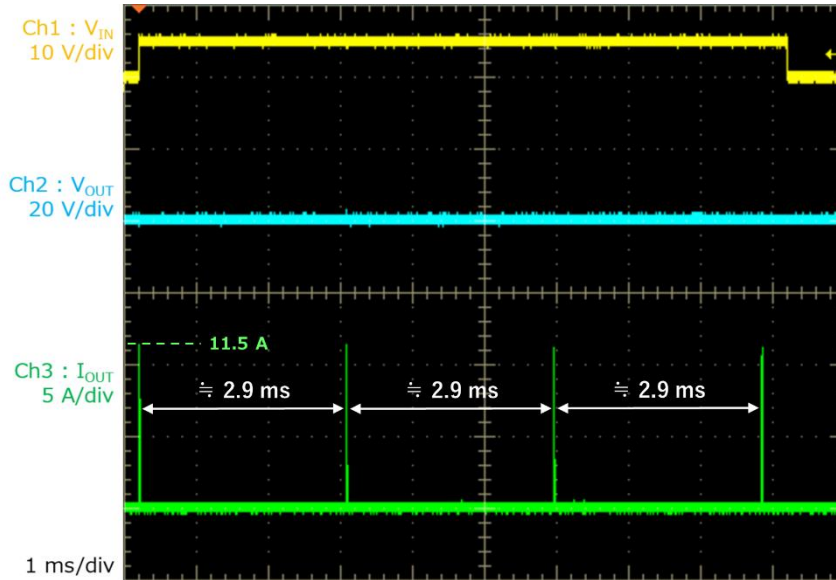
Fig. 6.5 Waveform of overcurrent protection operation (IC on after load short circuit)
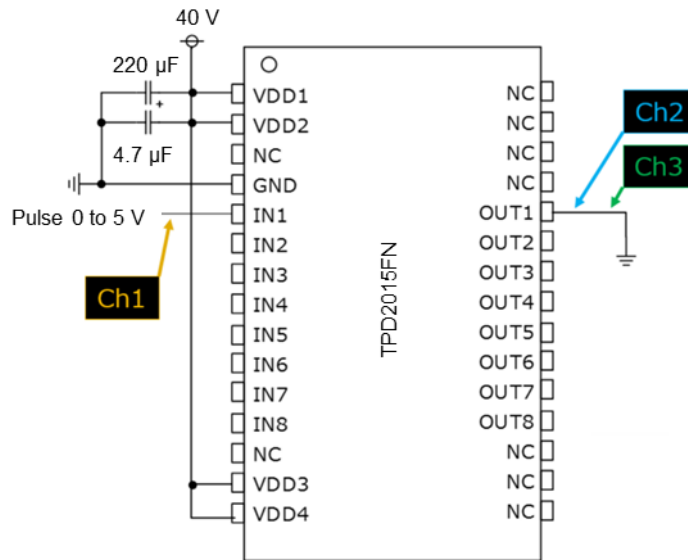
Fig. 6.6 Example of overcurrent protection test circuit (IC on after load short circuit)

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7. Power dissipation

As shown in Table 7.1 and Figure 7.1, the power consumed by this product can be divided into two parts: the power consumed on a regular basis and the power consumed by the transistors in the output section. The breakdown of losses in Table 7.1 is calculated using the formula below, but the loss during the back electromotive force period is much larger than the conduction loss and switching loss. Considering the thermal resistance value ($R_{th (j-a)}$) described in the data sheet, do not exceed the specified junction temperature (Tj).

$$P_{Constant\ loss} = I_{DD(ON)} \times V_{DD(opr)} \quad (6\text{-}1)$$

$$P_{Conduction\ loss} = I^2 \times R_{DSON} \quad (6\text{-}2)$$

$$P_{Switching\ loss} = \frac{1}{6} \times V_{OUT} \times I_{load} \times (tON + tOFF) \times f_{pwm} \quad (6\text{-}3)$$

$$P_{Reverse\ power\ loss} = 0.473 \times V_{(CL)OUT} \times I_{load} \times \left(\frac{tw}{1/f_{PWM}}\right) \quad (6\text{-}4)$$

$$t_w = 3.6\ (ms) \quad \text{…Value based on actual measurements}$$

Table 7.1 Loss breakdown ($V_{DD(opr)}$ = 24 V, f_{PWM} = 50 Hz, Duty = 50 %, I_{load} = 0.48 A)

	item	V (V)	$V_{(CL)OUT}$ (V)	I_{Load} (mA)	R_{DSON} (Ω)	duty (%)	tON (μs)	tOFF (μs)	L (mH)	f_{PWM} (Hz)	ch 数	Loss (W)
A	Constant loss	24		4.2							1	0.1008
	Conduction loss			480	0.55	50%					1	0.0634
B	Switching loss	24		480		50%	10	6		50	1	0.0017
	Reverse power loss		-1.3	480					50	50	1	1.0339
	total											1.1998
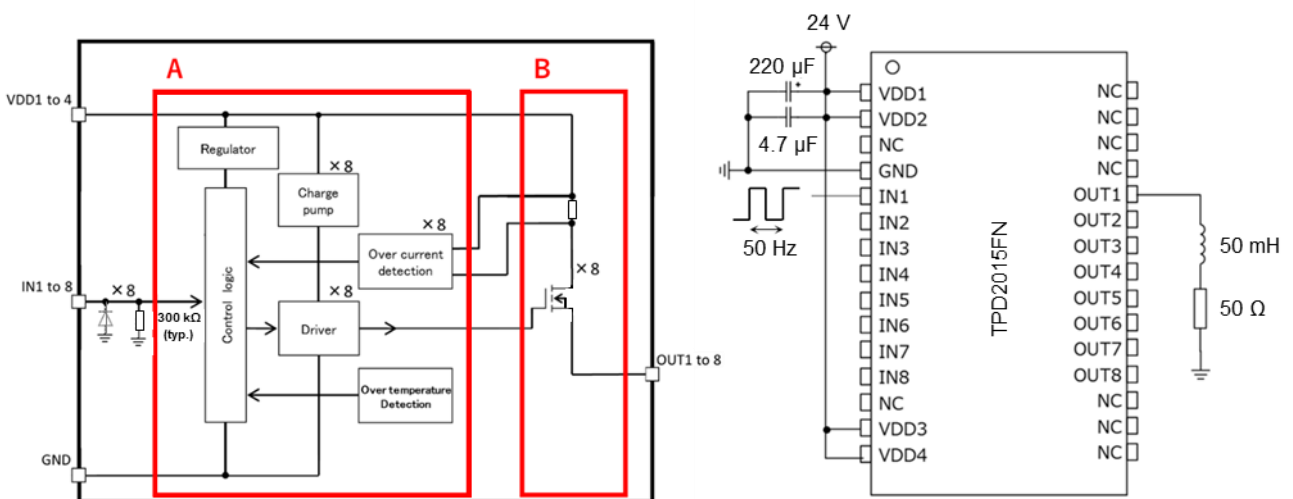
Fig. 7.1 Internal block diagram and external connection conditions example

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8. Evaluation board

8.1. Appearance of evaluation board

We prepare this product and an evaluation board that mounts peripheral devices. This function allows you to check the function and the protection diagnosis function at the actual load.
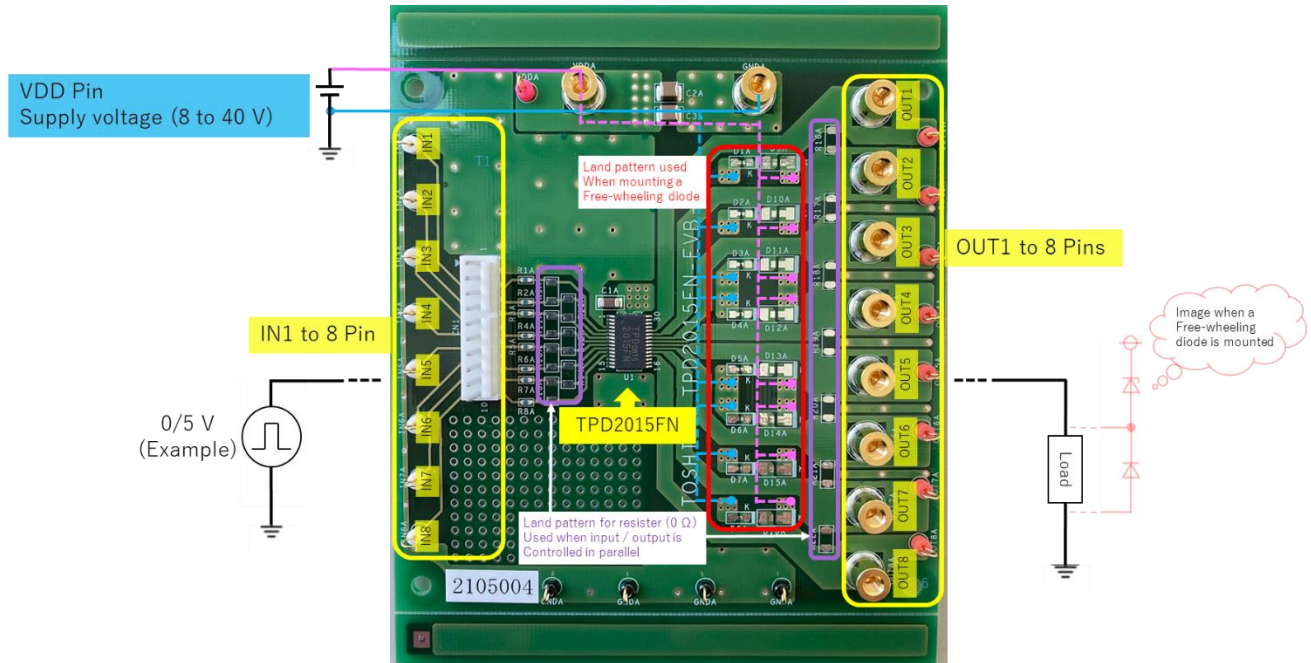
Fig. 8.1 External View of TPD2015FN evaluation board

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8.2. Connection diagrams
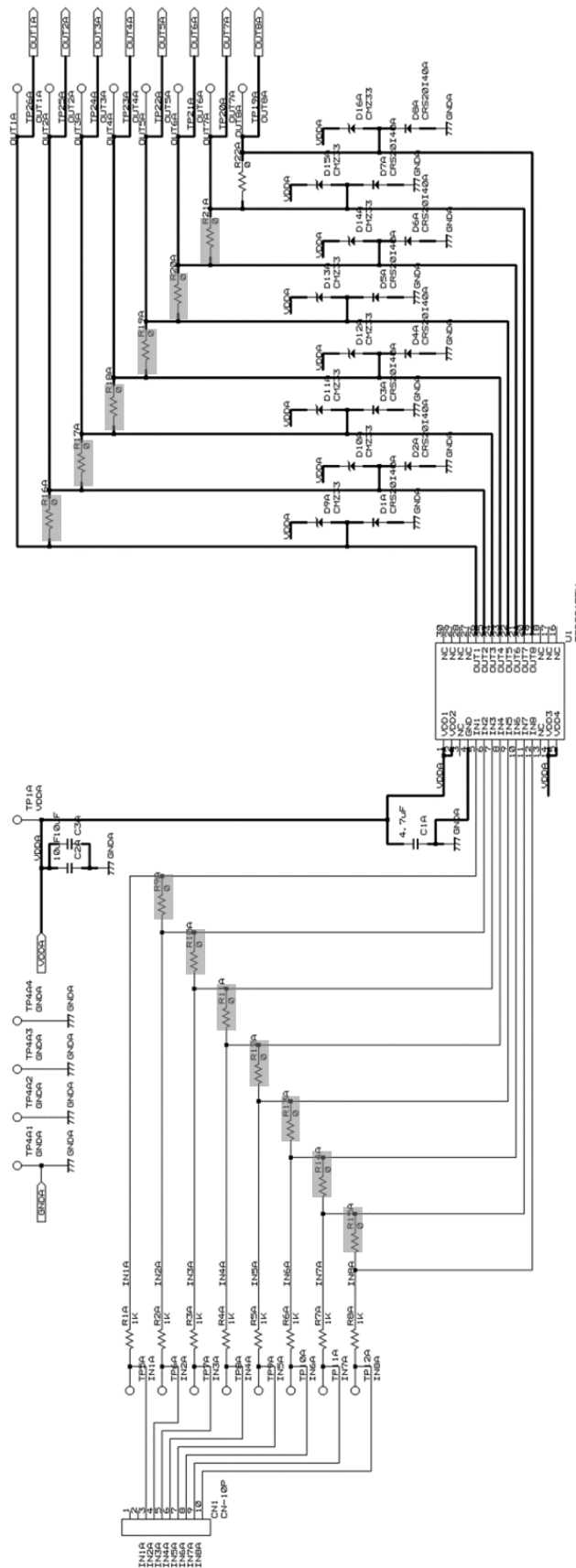
Fig. 8.2 TPD2015FN evaluation board connection diagram (CAD drawing)

8.3. Bill of materials

Table 8.1 BOM list

Parts number	Parts	Model number / Norm	Spec1	Spec2	Maker
U1	IPD	TPD2015FN	-	-	TOSHIBA
R1A to R8A	Chip resistance	RK73H1JTTD1001F	1 kΩ	0.125 W, ±1%	KOA
C1A	Ceramic capacitor	GRM31CR71H475KA12L	4.7 µF/50 V	±10%, X7R	Murata
C2A, C3A	Ceramic capacitor	GRM32ER71H106KA12L	10 µF/50 V	±10%, X7R	Murata
CN1	10-pole 1-row connector	22-23-2101	-	-	molex
-	Terminal	PB-1-G	-	-	MAC8
TP1A, TP4A1 to TP4A4, TP5A to TP12A, TP19A to TP26A	Monitor pin	-	-	-	MAC8

8.4. Board layout
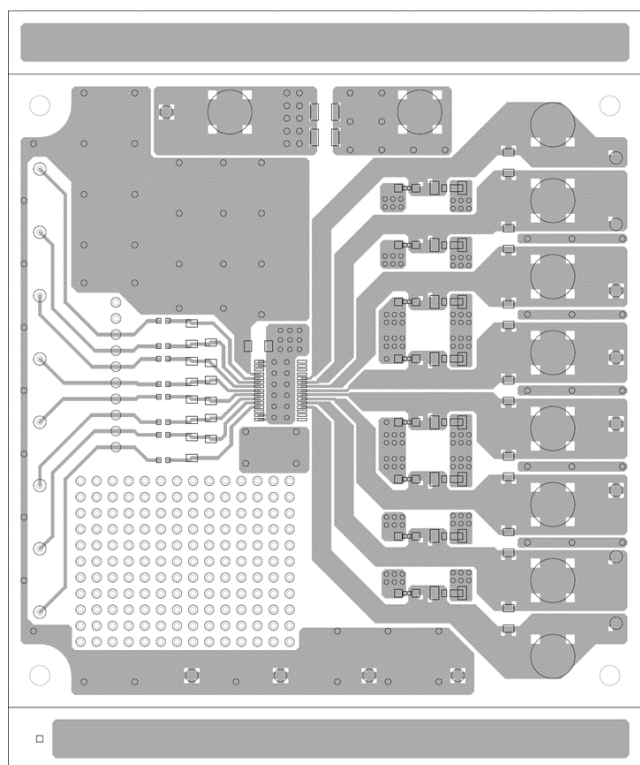
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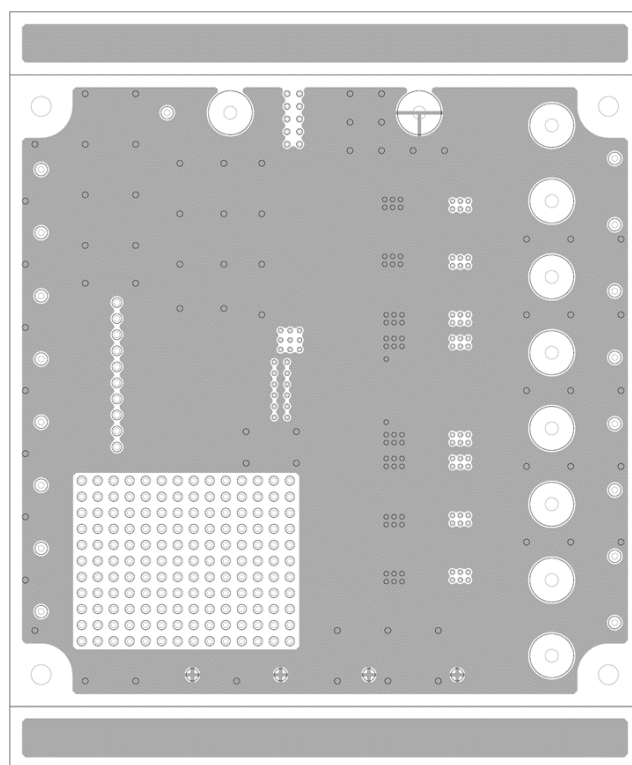
2nd layer
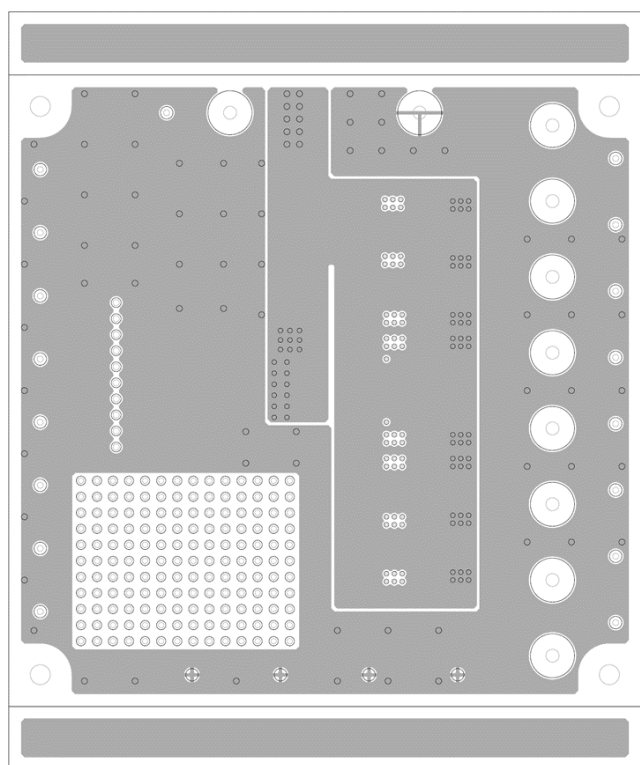
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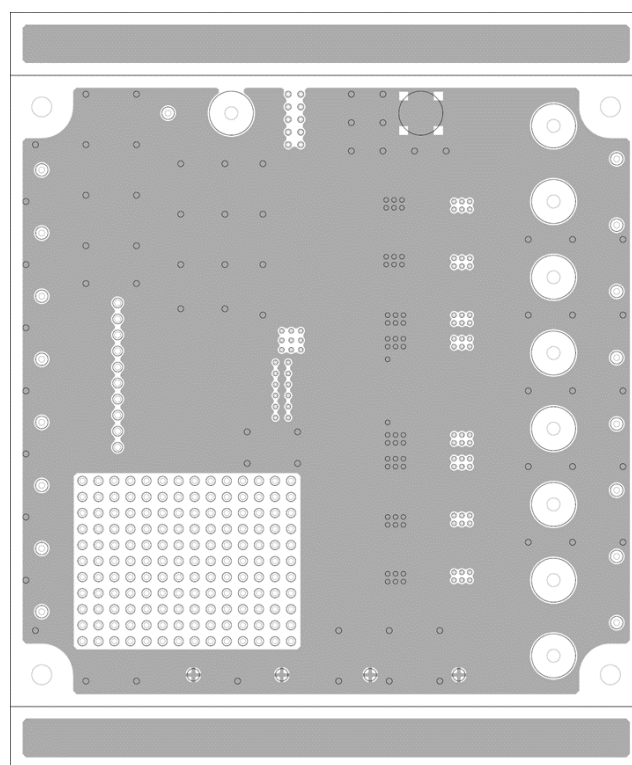
4th layer

Fig. 8.3 TPD2015FN evaluation board layout diagram

Points to note in the description

1. **Block diagram**
Function blocks, circuits, constants, etc. in the block diagram are partially omitted or simplified for explanation of functions.
2. **Equivalent circuit**
The equivalent circuit may be partially omitted or simplified for explanation of the circuit.

IC usage consideration

Notes on handing of ICs

(1) The absolute maximum ratings of a semiconductor device are a set of ratings that must not be exceeded, even for a moment.

(2) Use an appropriate power supply fuse to prevent large currents from continuing to flow in the event of an overcurrent or malfunction of the IC. The IC may be damaged due to use exceeding the absolute maximum ratings, incorrect wiring, or abnormal pulse noise induced by wiring or load. As a result, if a large current continues to flow through the IC, it may lead to smoking or ignition. Appropriate settings such as fuse capacity, blowing time, and insertion circuit position are required in order to minimize the effect of large current inflow and outflow during breakage.

Precautions for use

(1) Over-current protection circuit
The overcurrent protection circuit does not protect the IC in any case. After operation, promptly reset the overcurrent state.
If the absolute maximum rating is exceeded, the IC may be damaged or the over-current limit circuit may not operate properly or may be damaged before operation. In addition, if an overcurrent continues to flow for a long time after operation, the IC may be damaged due to heat generation, etc., depending on the use method and conditions.

(2) Thermal protection circuits
An over temperature protection circuit (usually a thermal shutdown circuit) does not protect the IC in any case. After operation, promptly reset the heating condition.
If the IC is used outside of the absolute maximum ratings, the over temperature protection circuit may not operate properly or the IC may be damaged before operation, depending on the usage and conditions.

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RESTRICTIONS ON PRODUCT USE

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