TPD4162F
Square-Wave Control Type
BLDC Motor Drive Circuit

Design guide

RD043-DGUIDE-02

TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION

Contents

1. Introduction

Toshiba high-voltage IPDs (Intelligent Power Devices) are products with built-in switching elements rated at up to 250-600 V and capable of driving direct brushless DC (BLDC) motors. The product lineup includes motor output, drive type (square-wave, sine-wave) and AC input voltage for application, etc., and the reference design is available for optimized design of each specification. Table 1.1 and Table 1.2 show the reference designs by application/motor specification.

Table 1.1 List of high-voltage IPD reference designs (Square-wave drive)

Motor output	40 W class	40 W class	40 W class
Silencing requirements	None	None	None
AC input voltage	100 V system	100 V/200 V system For regions with unstable power supply quality	100 V/200 V system For regions with unstable power supply quality
Recommended device	TPD4151F (250 V/1 A)	TPD4152F (600 V/0.7 A)	TPD4162F (600 V/0.7 A)
Remarks			Reduced-loss version of the TPD4152F
Reference design	Click Here	Click Here	Click Here
Reference Guide	RD020-RGUIDE-02	RD017-RGUIDE-02	This document RD043-RGUIDE-01

Table 1.2 List of high-voltage IPD reference designs (Sine-wave drive)

Motor output	60 W class	60 W class
Silencing requirements	Yes	Yes
AC input voltage	100 V/200 V system For regions with unstable power supply quality	100 V/200 V system For regions where power supply quality is stable
Recommended device	TPD4204F (600 V/2.5 A)	TPD4206F (500 V/2.5 A)
Recommended Motor Controller	TB6634FNG	TB6634FNG
Reference design	Click Here	Click Here
Reference Guide	RD018-RGUIDE-02	RD019-RGUIDE-02

High-voltage IPDs are available here → Click Here

2. Overview

In recent years, the importance of motors has risen dramatically as home appliances become more energy-efficient and automobiles become more electrically equipped. A motor is a generic term for devices that convert electrical energy into mechanical energy. A magnetic field generated by a current flowing through a coil attracts or repels a magnet and turns a rotor. The motors are largely divided into AC (alternating current) motors and DC (direct current) motors. Especially DC motors, the direction of the current must be controlled to rotate in either direction.

DC motors have a variety of types, for example, brushed DC motors are used for toys of car and train. This motor is often used because it is characterized by good controllability and efficiency, small size and low cost. A brushed DC motor has a brush to apply current to the windings. A windings is attached to the rotor of the motor, and a commutator is attached to the rotary shaft. The commutator is a rotary electric switch that periodically alternates the direction of the current. Using the fact that the contact between the commutator and the windings in the magnetic field, the brush on the power supply side is automatically switched by the rotation of the motor itself and a constant rotational force is generated by switching the direction of the current supplied by the commutator.

We often see a stepping motor, but the feature of this motor is its high accuracy. For example, high positioning accuracy required for industrial precision machines, stepping motors make this possible. Reproducibility is excellent, enabling the same movement repeatedly. It is also used in air conditioner louvers and other applications, and is a long-life, quiet motor.

On the other hand, the BLDC motors, which covered in this Design Guide, do not use brushes and commutators which are mechanical contacts, but instead use sensors and electronic circuits (usually referred to as "drive circuits") to switch currents. The evolution of semiconductors has made it possible to control the current through the drive circuit. Since the principle of BLDC motors rotation is similar to that of a brushed DC motor, the relationship between current, rotational force, voltage and rotational speed is almost the same as that of a brushed DC motor, while the structure is AC motor, so BLDC motor has superior points in both DC motor and AC motor. It is compact, high-power, and does not generate internal sparks or noise due to no brushes. Furthermore, it has a long life due to no brush wear, and has little conversion loss, so it is used in a variety of applications, from computers to home appliances. Table 2.1 shows the comparison of various motors.

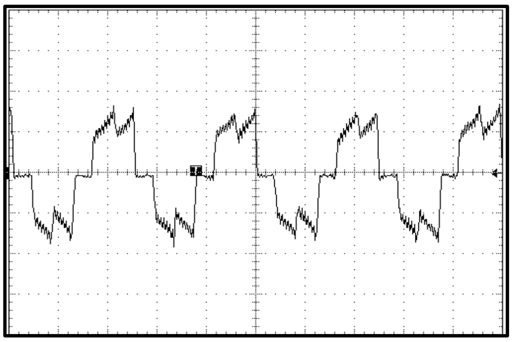
Table 2.1 Comparison of various motors

	AC Motor	Brush DC motors	Stepping motors	BLDC motors
Efficiency	40~80 %	60~80 %	60~70 %	80 % or more
Size	Large	Small	Medium	Small
Integrated Circuit	Not required	Not required	Required	Required
Life	Long	Short	Long	Long
Brush	No	Yes	No	No
Usage	Washing machines, Electric fans, Vacuum cleaners	Toys, Small appliances	Robots, Small appliances, Industrial precision machine	Air conditioner, Washing machine, Small appliances

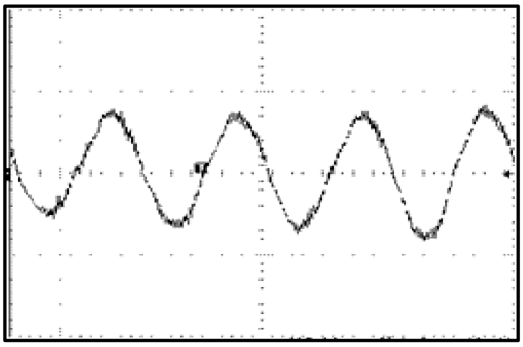
As previously mentioned, BLDC motors can operate efficiently due to their low conversion-loss characteristics. More efficient BLDC motors are becoming increasingly popular due to the recent rise in demand for energy saving in home appliances and other products.

BLDC motors are typically driven in three phases, requiring six switching elements.

The six switching elements can be energized in two ways: a square-wave drive (120 degrees energized) and a sine-wave drive (180 degrees energized). The square-wave drive method controls the motor winding current in a square waveform so that the energization period of each phase becomes 120 degrees. On the other hand, the sine-wave drive method controls the motor winding current in a sine wave form so that the energization period of each phase becomes 180 degrees. Fig.2.1 shows examples of the phase current waveforms of the square wave drive method and sine wave drive method.



(a) Square wave drive



(b) Sine wave drive

Fig. 2.1 Example of phase current waveform

Table 2.2 shows the features of the square-wave drive (120-degree energization) and sine-wave drive (180-degree energization) methods.

Table 2.2 Features of square-wave drive and sine-wave drive

	Square-wave drive (120 degrees energized)	Sine-wave drive (180 degrees energized)
Noise/Vibration	△	○
Efficiency	△	○
Design ease	Easy control, small mounting area	Complex control, large mounting area
Circuit configuration	Can be configured with IPD only	Composed of Motor Controller + IPD

The TPD4162F incorporates a PWM circuit, a three-phase distribution circuit, a level-shifted high-side drive circuit, a low-side drive circuit, an output IGBTs, and FRDs. Without an external motor controller IC, the TPD4162F with a square-wave drive can drive directly BLDC motor by inputs from a Hall element (Hall sensor) or Hall IC. Equipped with IGBTs and FRDs rated at up to 600 V, it can be applied to AC200 V system inputs. Various types of protection circuits including over-current protection circuits, thermal protection circuits, and under voltage protection circuits, are incorporated to contribute to save the time for peripheral circuit design. Regarding over-current protection, in addition to the conventional current limiting function, the TPD4162F has a function that enables high-speed protection against sudden current increases in case of the motor is locked.

This product offers a new compact surface-mount-type package named HSSOP31 that enables the control board to be configured in a compact and thin form, contributing to improved design flexibility and miniaturization of the motor when it is housed in the motor case.

This Design Guide describes applications and design precautions for BLDC motor driven by TPD4162F using Hall elements. For more information about the TPD4162F, please refer to the product datasheet.

To download the datasheet for TPD4162F → Click Here

3. Circuit design

3.1. Circuit specifications

Table 3.1 shows the specifications of the BLDC motor drive circuits described in this guide.

Table 3. 1 BLDC motor drive circuitry specifications

Parameter	Symbol	Value	Unit
Operating power voltage	V_{BB}	280~340	V
	V_{CC}	15	V
PWM on-duty ratio	PWMMIN	0	%
	PWMMAX	100	%
PWM frequency	f_C	20	kHz
Speed control voltage range	V_S	0 ~ 6.5	V
Current limit operating voltage	V_R	0.5	V
Over-current protection operating voltage	V_{CS}	0.7	V
Motor diameter to be used	-	100	mm
Hall element	HW-101A manufactured by Asahi Kasei		

3.2. Application circuit

Fig. 3.1 shows the TPD4162F application circuit using Hall elements.

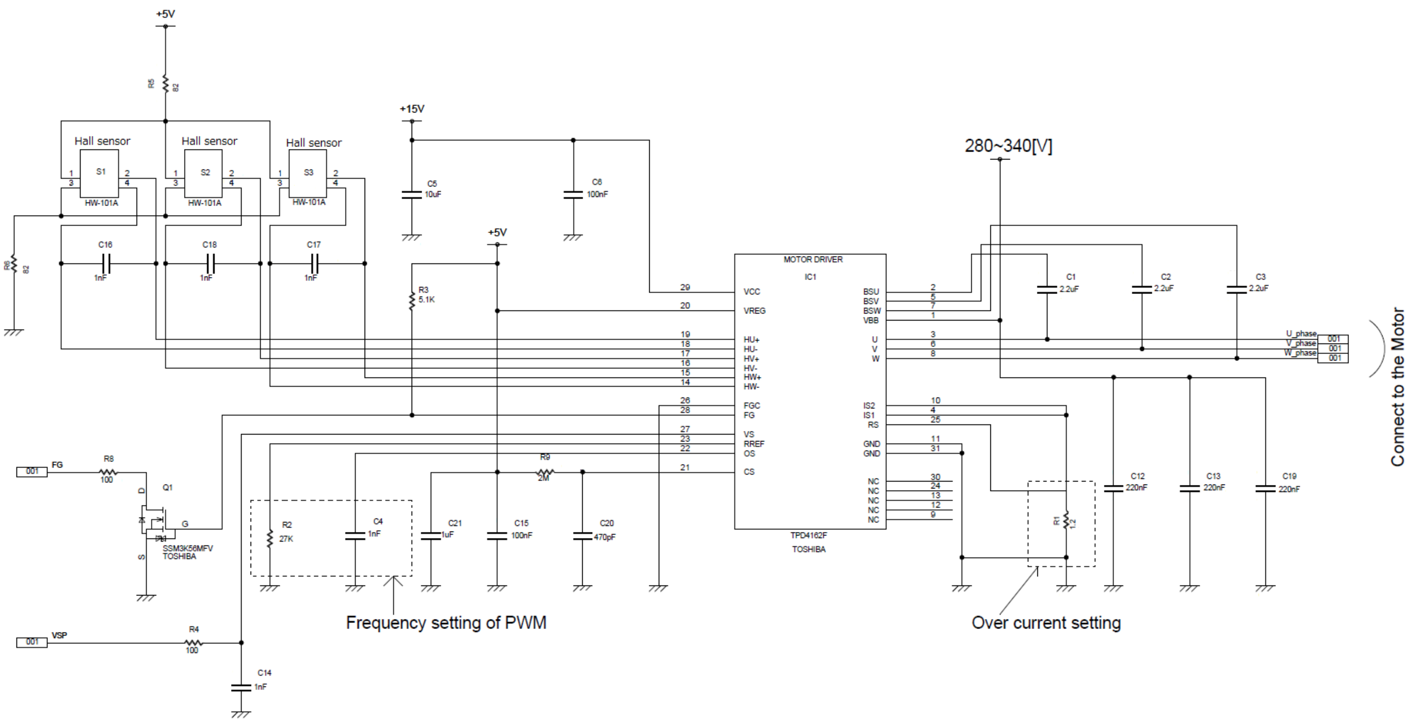
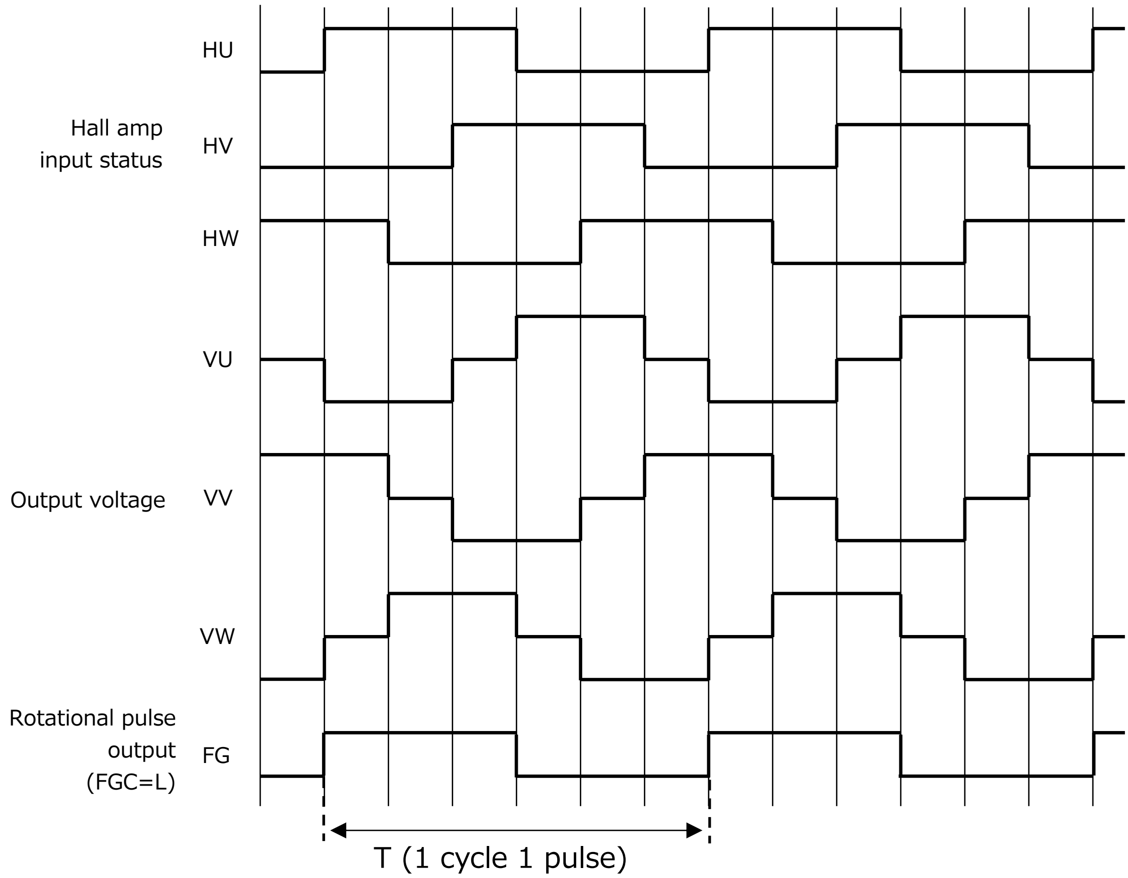


Fig. 3.1 TPD4162F application circuit

3.3. Calculation of motor speed

Fig.3.2 shows the timing chart.

In the application circuit of this guide, the FGC pin is set to "L". Therefore, the rotation pulse output is 1 pulse for the electrical angle of 360 °.



NOTE: The Hall amp input state "H" indicates the state of $H*_{+} > H*_{-}$. (*: U/V/W)

Fig. 3.2 Timing chart

From the timing chart, the motor speed can be calculated using the following formula by measuring the time for one cycle of the rotation pulse output to obtain the frequency. The calculation formula and calculation example are shown below.

$$R_S = 60 \times 2 \times \frac{F}{P} \quad (rpm)$$

R_S: Motor speed   T: Rotational pulse period   P: Motor pole count   F: Frequency=1/T

Calculation example: When a 12-pole motor is used and a result of 100 Hz is obtained from the rotation pulse output.

$$R_S = 60 \times 2 \times \frac{100}{12} = 1000 \quad (rpm)$$

Note that when the FGC pin is set to "H", three pulses are output for an electrical angle of 360 °. Therefore, calculate F in the above equation using the frequency of the rotation pulse output divided by 3.

3.4. Method of rotation control

The TPD4162F changes the on-duty ratio of the PWM signals by input a DC-voltage to the V_S terminals and can control the rotation speed. Fig. 3.3 shows the relation between the V_S pin voltages and the on-duty ratios of PWM signal.

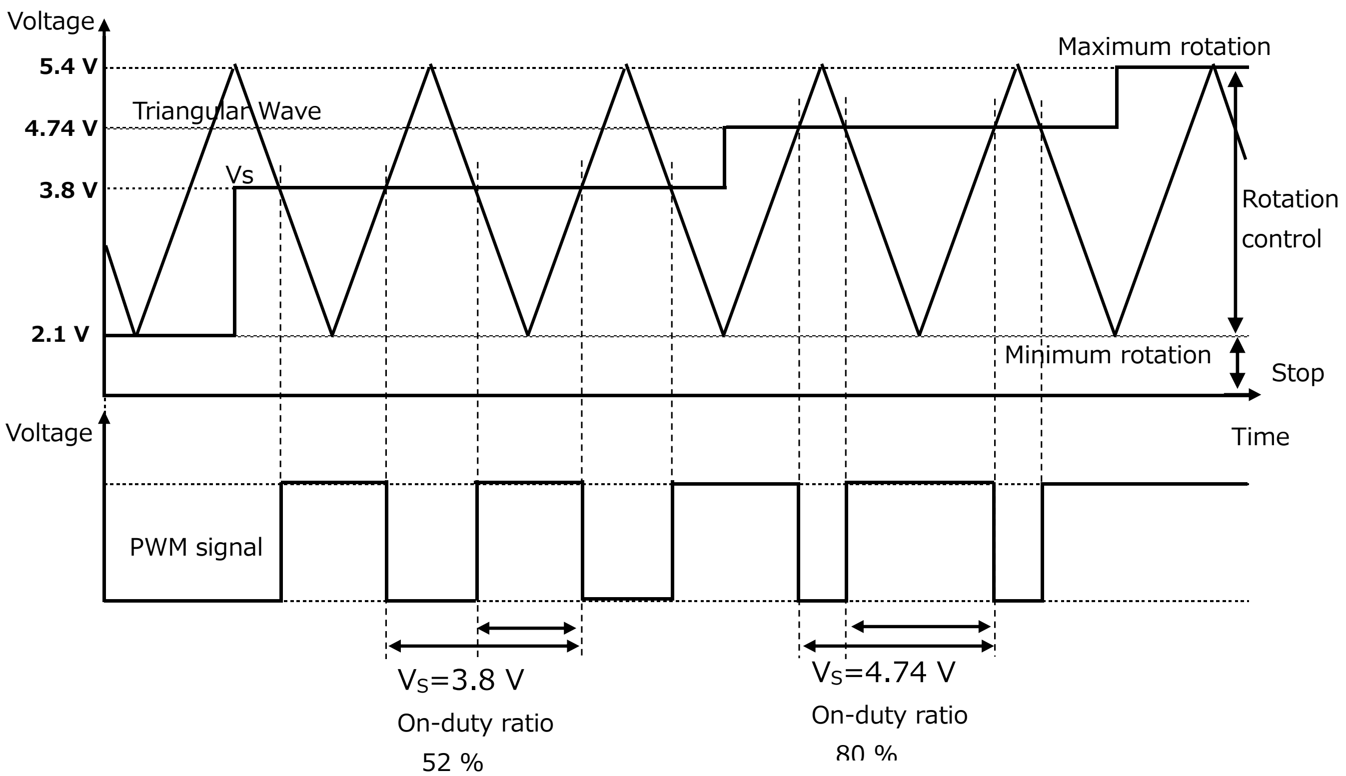


Fig. 3.3 Rotational speed control by V_S voltages

The V_S pin voltage is compared with triangular wave by the internal comparator to generate PWM signal. The motor speed is controlled by the on-duty ratio of this PWM signal. As shown in the Fig. 3.3, the triangular wave amplitudes at a voltage of 2.1 V to 5.4 V. Therefore, the on-duty ratio of the PWM can be changed by changing the voltage at the V_S pin within this range. When the V_S pin voltage is 5.4 V, the on-duty ratio of PWM signal is 100 %, and the motor speed is at its maximum.

The frequency of the triangular wave is determined by the combination of external C4 and R2. The calculation formula is as follows. For typical external constants (C4=1000 pF, R2=27 kΩ) used in the application circuits in this guide, the frequency is 20. 8 kHz.

$$f_C = \frac{0.65}{C4 \times (R2 + 4250)} = \frac{0.65}{1000 \times 10^{-12} \times (27 \times 10^3 + 4250)} = \quad 20800 \quad (H_z)$$

C4: 1000 pF, R2: 27 kΩ

An example of calculating the motor speed is shown below.

Let's assume that the max. motor speed (PWM-signal on-duty ratio = 100 %) is 1000 rpm with loads, and that a triangular wave of 20. 8 kHz is generated at R2=27 ks and C4=1000 pF.

If V_S=3.8 V at this time, the on-duty ratio of the PWM signal is 52 % as shown below.

$$On-duty\ ratio = \frac{V_S - Minimum\ amplitude\ voltage}{Maximum\ amplitide\ voltage - Minimum\ amplitude\ voltage} = \frac{3.8-2.1}{5.4-2.1} = 0.52$$

The motor speed at this time can be obtained by the following formula. In this case, the motor speed is 520 rpm.

$$Motor\ speed = Maximum\ motor\ speed \times On-duty\ ratio = 1000 \times 0.52 = 520 \quad (rpm)$$

※ There are some motor characteristics variation so please check the actual motor for the exact rotational speed.

3.5. Hall element and Hall IC

Hall elements, Hall ICs, and Hall Linear ICs are sensors for detecting the rotor position in a motor which uses the Hall effect. Hall effect is a phenomenon in which electromotive force is generated in the direction perpendicular to the current flow and the magnetic field when a magnetic field is applied in the direction perpendicular to the current flow through the substance. Using this effect, non-contact type sensors that convert and output changes in the magnetic field into electrical signals are Hall elements, Hall ICs, and Hall linear ICs. It is important to select the sensors in order to optimize total system. This guide describes in detail the design when using Hall elements.

3.5.1. Design with Hall element

Hall elements have a wide variety of types and characteristics, so please use them after confirming the specification of the Hall element to be used.

Design the Hall element so that the maximum input current and ambient temperature are within the safe operating area (SOA) shown in Fig. 3.4. It is recommended to insert a Hall bias resistor, as there is a risk of breakage if it is used exceeding the SOA.

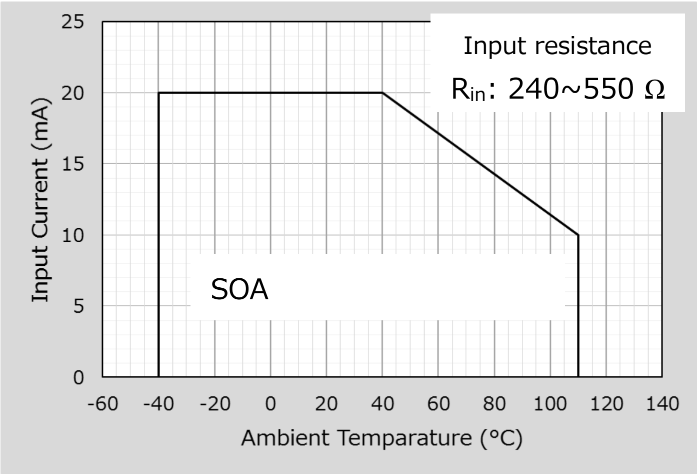


Fig. 3.4 Safe operating area (SOA) of HW-101A

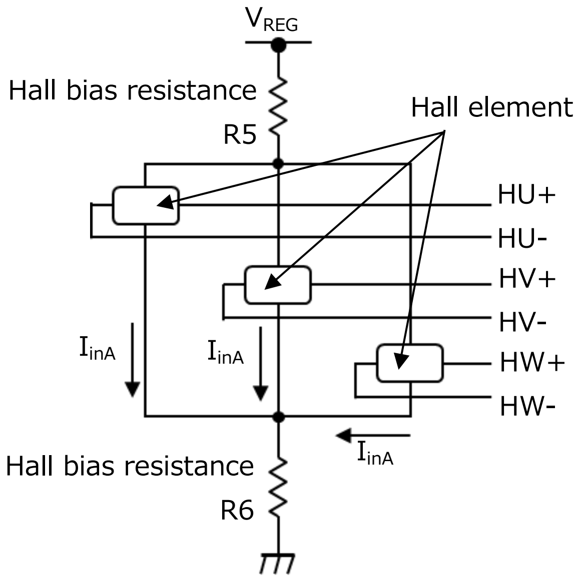


Fig. 3.5 Hall bias resistance

Example of hole bias calculation

Examples of calculations when using HW-101A manufactured by Asahi Kasei are shown below. In this application circuit, three Hall elements are connected in parallel as shown in Fig. 3.5, and one Hall bias resistor is inserted on the power supply side and the GND side respectively.

- Design conditions

  Use the V_{REG} terminal for the HW-101A power supply: 5 V (typ.)

  Operating Temperature Range: -40 °C to 110 °C

  R5 and R6 accuracy: ±5 %

In order to obtain the maximum characteristics at 110 °C, the center value sets 5 mA so that the input current I_{inA} to the Hall element is kept at the maximum value of 10 mA within the SOA, and the input resistance (R_{in}) value of the Hall element is calculated as the maximum value of 550 Ω which is the maximum value of the specification. In addition, R5 and R6 should be the same values because it is recommended that the bias voltage of no-excitation be set to $V_{REG}/2$.

If the input resistor of the Hall element is R_{in}, the voltage V_H generated at both ends of each Hall element is calculated as follows:

$$V_H = R_{in} \times I_{inA} = 550 \times 5 \times 10^{-3} = 2.75 \ (V)$$

Since R5 and R6 are the same value, the voltage drop V_R generated by the Hall bias resistors R5 and R6 is obtained by subtracting this value from the V_{REG} value =5 V and dividing it by 2.

$$V_R = \frac{V_{REG} - V_H}{2} = \frac{5 - 2.75}{2} = 1.125 \ (V)$$

Since the current obtained by combining the I_{inA} of the Hall elements flows through R5 and R6, the values of R5 and R6 are as follows.

$$R5 = R6 = \frac{V_R}{3 \times I_{inA}} = \frac{1.125}{3 \times 5 \times 10^{-3}} = 75\ (\Omega)$$

Next, confirm from the HW-101A specifications that the SOA is not exceeded in the worst case of the selected resistor. Because it is a worst case check, each value is calculated using the minimum and maximum values where the current increases.

Fig. 3.6 shows the temperature characteristics of the input resistance (R_{in}) of Hall elements.

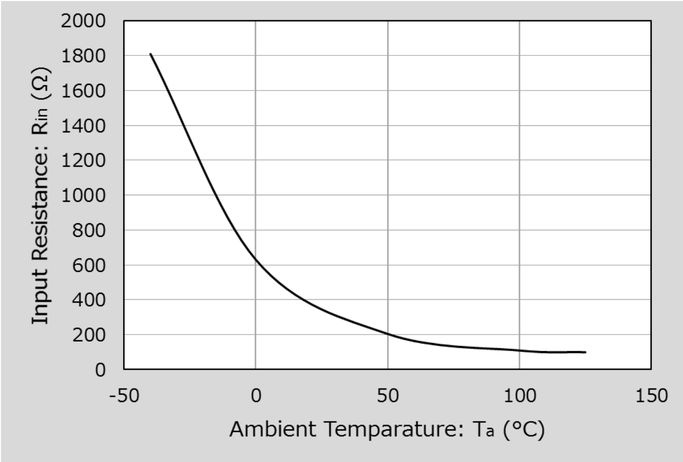


Fig. 3.6 Input resistance to temperature characteristics of HW-101A

From Fig. 3.6, the R_{in} is lowest at an ambient temperature of 110 °C and the minimum value (R_{in_min}) is 100 Ω. Since R5 and R6 have a resistive accuracy of ±5 %, the minimum value (R_{min}) is 71.3 Ω. On the other hand, the maximum value of V_{REG} (V_{REG_max}) is 5.5 V from the specification. Use these values to determine the maximum value of the input current (I_{inA_max}) of the Hall elements.

In Fig. 3.5, the series resistance R_H which is total resistance value from V_{REG} to GND is obtained by adding resistors consisting of three Hall elements connected in parallel to R5 and R6. On the other hand, one-third of the current flowing through R5 and R6 flows through the Hall elements, so the I_{inA_max} can be obtained as shown in the following equation.

$$I_{inA\_max} = \frac{1}{3} \times \frac{V_{REG\_max}}{2 \times R_{min} + \frac{R_{in\_min}}{3}} = \frac{1}{3} \times \frac{5.5}{2 \times 71.3 + \frac{100}{3}} \cong 10.4\ (mA)$$

From this result, when R5 and R6 are 75 Ω, the current must be reduced because the SOA may be exceeded when the ambient temperature is 110 °C. In this section, the values of R5 and R6 are assumed to be 82 Ω from the E24 series for ease of obtaining parts.

Calculate the I_{in_max} when R5 and R6 are 82 r ease of obtaininR_{min} of R5 and R6 is 77.9 Ω.

$$I_{inA\_max} = \frac{1}{3} \times \frac{V_{REG\_max}}{2 \times R_{min} + \frac{R_{in\_min}}{3}} = \frac{1}{3} \times \frac{5.5}{2 \times 77.9 + \frac{100}{3}} \cong 9.7\ (mA)$$

From this result, if R5 and R6 are 82 Ω, R5 and R6 are determined to be 82 Ω, because it is confirmed that they are within the SOA in the ambient temperature range of-40 to 110°C.

※ Those equations are examples. Please design the system in the actual operating temperature range and confirm with the actual unit.

3.5.2. Design with Hall IC

Although the TPD4162F is compatible with Hall elements, Hall ICs can also be used. However, depending on the specification of the Hall IC, an external voltage conversion circuit is required. In this case, design so that the amplitude of the signal input to the Hall amplifier is 0.7 V or less for Low level and 3.7 V or more for High level. Also, to prevent misreading, the reference voltage should be 1/2 of the input voltage.

Fig. 3.7 shows an example of a voltage conversion circuit, and Fig. 3.8 shows the output waveform (input waveform for H+) of the voltage conversion circuit.

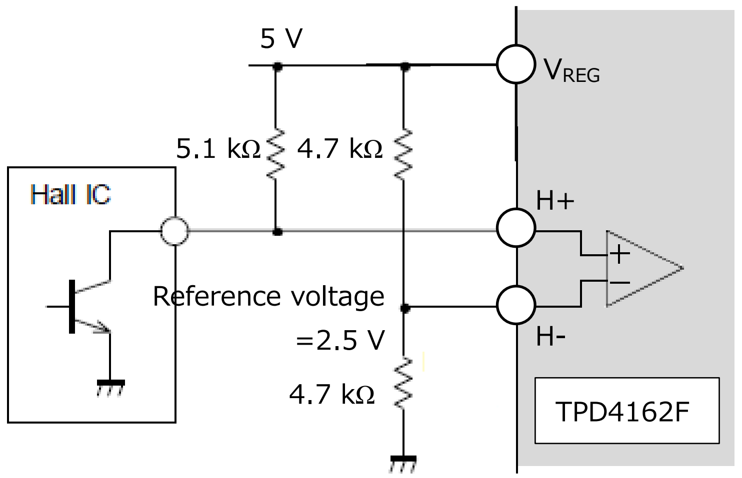


Fig. 3.7 Voltage conversion circuit example

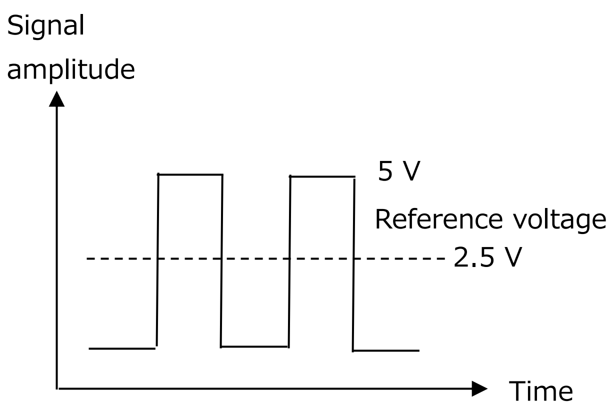


Fig. 3.8 Example of voltage conversion output waveform

In Fig. 3.7, the output pins of the Hall IC are pulled up to the V_{REG} pin (5 V output) of the TPD4162F by a resistor, and the High (5 V) and Low (0 V) signals from the output of the Hall IC are input to the H+ pin of the TPD4162F. Since the negative side of the Hall amplifier is biased at a V_{REG} / 2=2.5 V obtained by dividing the V_{REG}, signals amplifying at 0 to 5 V are input to the Hall amplifier based on 2.5 V.

Fig.3.8 shows the voltage conversion output waveform (=input waveform for H+) in this example.

Those are just an example. When designing an actual system, please carefully check the output specifications of the Hall IC to be used and design an appropriate circuit.

3.6. Current-limit function

The current limit function shuts down high-side IGBT to suppress an increase current when the output current increases and exceeds due to a temporary overload, etc. The timing chart below shows the operation of the current limit function when the V-phase is operating on the high side and the U-phase is operating on the low side.

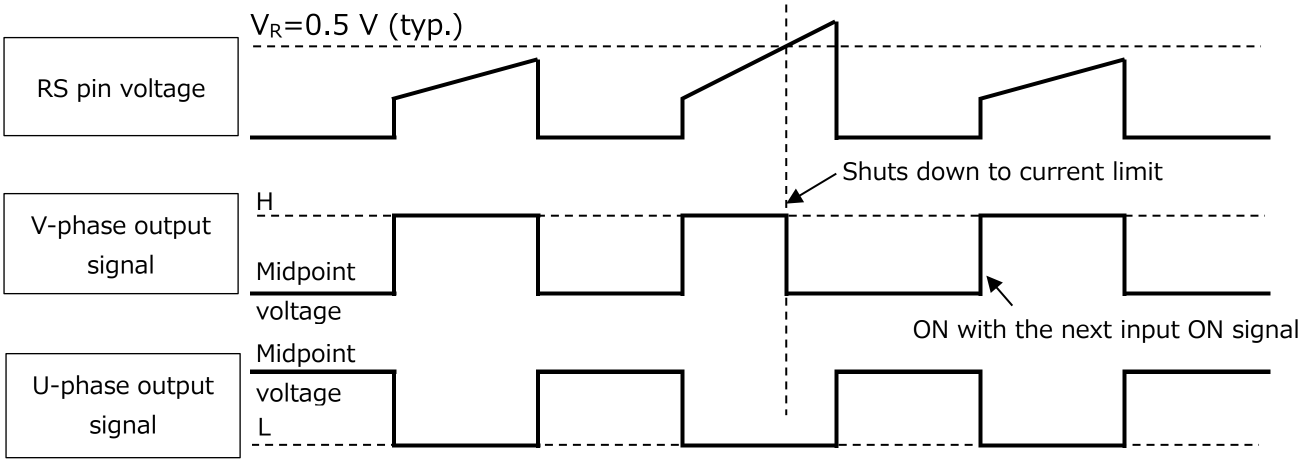


Fig.3.9 Timing chart in current limit operation

At RS pin (over-current detection pin), when the voltage exceeds the current limit voltage V_R=0.5 V (typ.), the TPD4162F operates and shuts down the high-side IGBT until the next ON input signal. During this time, the regenerative current flows through the body diodes of the output IGBT of the other phases, so the motor does not stop, but the current supplied from the power supply is reduced.

The RS pin is directly connected to the IS1 and IS2 pins, and an external resistor for detecting current is connected between the RS-terminal and GND. The current flowing through each phase of the motor is output from the IS1 and IS2 pins as is. This current is converted to voltage by an external resistor and detected. Therefore, the detection current is set by the external resistor R1 of the RS pin.

The detected current must not exceed the absolute maximum rating of the output current (0.7 A). Therefore, the value of the external resistor R1 should be determined from the detected current of the over-current protection operating at a higher V_{CS} than the V_R. How to set R1 is explained in the next section which describes the over-current protection function. Since R1=1.2 Ω is used in this application circuit, the current limit detection current I_R is as follows.

$$I_R = \frac{V_R}{R1} = \frac{0.5}{1.2} \cong 0.417 \quad (A)$$

I_R: Current limit detection current

V_R: Current limit operating voltage=0.5 V (typ.)

3.7. Over-current protection function

The over-current protection function shuts down the high-side / low-side IGBT of the output for all phases when a motor lock or the like occurs due to an external factor. The over-current protection function operates when the RS pin voltage exceeds the over-current protection voltage V_{CS}=0.7 V (typ.). The timing chart below shows the case where the over-current protection operates when the V-phase is operating on the high side and the U-phase is operating on the low side.

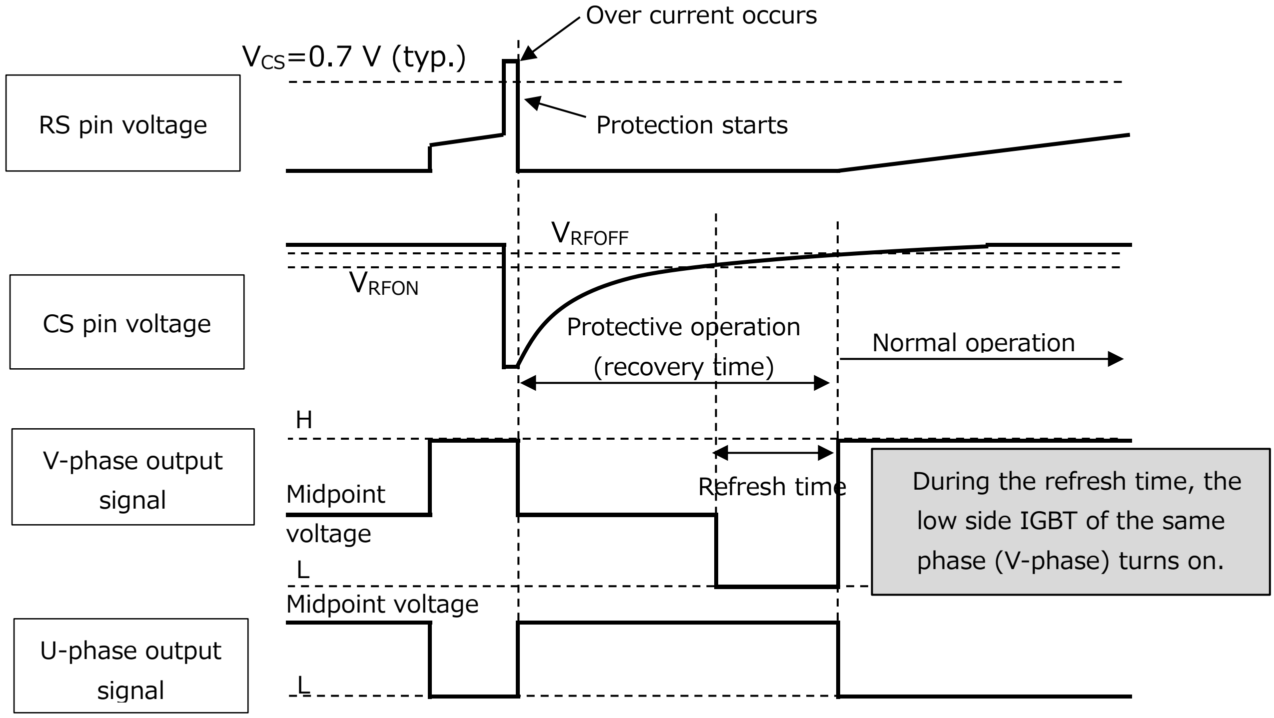


Fig.3.10 Timing chart for over-current protection operation

The over-current protection function shuts down the high-side / low-side IGBT of the output of all phases when the RS-terminal voltage rises rapidly and the V_{CS} is reached prior to the current limit function operating.

The RS pin voltage drops to nearly 0 V because current no longer flows when the protection operation starts, but the protection operation continues until the external capacitor of the CS pin (over-current protection pin) is charged and V_{RFOFF} reached the threshold. This capacitor is used to set the recovery time from the start of protection to the return to normal operation. Although the capacitor is charged during normal operation, it is discharged at the same time as the over-current is detected, and charging starts at the start of protection.

There are two types of thresholds: the first threshold at which the bootstrap capacitor starts charging to operate the high-side IGBT and the second threshold at which charging ends and normal operation starts. A series of operations to charge bootstrap capacitors is called refresh operation.

When the CS-pin voltage reaches the refresh operation starting voltage V_{RFON}, the low side IGBT of the same phase as the high side IGBT which was operating just before the over-current protection operated turns on, and charging of the bootstrap capacitor starts. Subsequently, when the CS pin voltage reaches the refresh operation stop voltage V_{RFOFF}, IGBTs of the all phases start normal operation according to the input signal.

When calculating the detected current for over-current protection, the accuracy of the resistor to be used and the maximum value of the V_{CS} must be considered. The maximum value of the V_{CS} (V_{CS_max}) is specified as 0.76 V. The maximum value of the detected current (I_{CS_max}) is 0.7 A, which is the absolute maximum rating of the output current, and the accuracy of the external resistor to be used is assumed to be ± 5%. The I_{CS} becomes largest when the V_{CS} is the largest and the external resistor R1 is the smallest-5 %, so R1 at that time can be calculated as follows:

$$I_{CS\_max} = \frac{V_{CS\_max}}{0.95 \times R1}$$

$$\mathrm{R1} = \frac{V_{CS\_max}}{0.95 \times I_{CS\_max}} = \frac{0.76}{0.95 \times 0.7} \cong 1.14 \quad (\Omega)$$

From this calculation result, it can be said that R1 should be 1.14 Ω or more if the maximum value of the detected current is 0.7 A or less. In this section, select a resistor of 1.2 Ω for the E24 series, taking into account the ease of parts availability.

3.8. Caution when Circuit Design

1) The capacity of the bootstrap capacitors (C1, C2, C3) depends on the drive conditions of the motor. In addition, the IC operates up to the V_{BS} under-voltage protection voltage (V_{BS}UVD=3 V (typ.)), but it is recommended that the voltage across the capacitor be 13.5 V or more in order to keep the loss of the output IGBT small. Note that the stress voltages of the capacitors are V_{CC}. Provide adequate derating.

2) The frequency of the triangular wave is determined by the combination of C4 and R2, but the error factor specific to the IC is about 10 %. In addition, note that consideration must be given to the stray capacitance of the board.

3) The reference current of the charge/discharge circuit of the triangular wave is made by R2. However, if the value of R2 is too small and the current exceeds the current capacity of the IC's internal circuit, the triangular wave will be distorted. Set R2 to 9 kΩ or more.

4) The FG pin has an open-drain structure. When the FG terminal is not used, connect it to GND.

5) If noise is observed at the output of the Hall element, add a capacitor between the Hall amp input terminals of each phase.

6) Use an indium-antimony Hall element and set the peak output voltage to 300 mV or higher.

4. Board design

4.1. Board pattern design work

Creepage distance

Secure appropriate creepage distances according to the safety standards of the required specifications. Table 4.1 shows the creepage distances used on the circuit board. Since the required creepage distance varies depending on the environment, material, material contamination, humidity, altitude (atmospheric pressure), etc., the operating environment should be considered thoroughly.

Table 4.1 Minimum design creepage distance

Target line 1	Target line 2	Creepage distance between target line 1 and target line 2
V_{BB}	GND	4.0 mm
Three-phase wire (U, V, W)	GND	4.0 mm

Current capacity

Each pattern on the board must have a pattern width that prevents the temperature rise or voltage drop caused by the wiring resistance from causing problems when the maximum current flows.

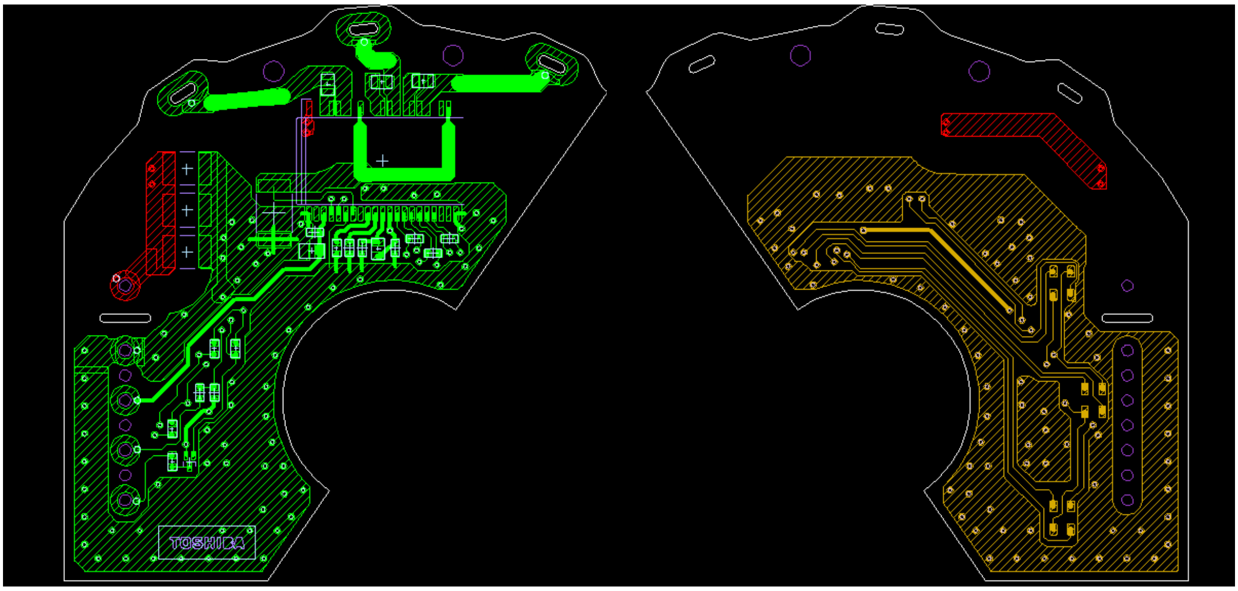


Fig.4.1 Pattern layout diagram

4.2. Hall element pattern design

Installation position

Since the installation position of the Hall element varies depending on the number of poles of the rotor and the position of the stator, the arrangement must be determined according to the motor used. Since the output of the Hall element is proportional to the magnetic flux density, it is also affected by the vertical direction of the board and the stator. This board has a 8-pole rotor. Fig. 4.2 shows the Hall elements layout in this case.

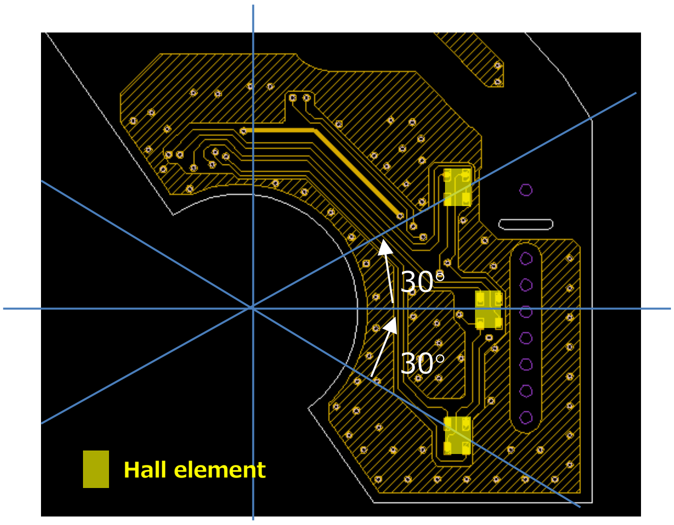


Fig. 4.2 Hall elements layout diagram

4.3. Caution when board design

1) The triangular wave oscillator circuit for generating PWM signals is equipped with C4 and R2 external circuits to charge and discharge very small currents. Therefore, if it is affected by noise, it may cause distortion or malfunction of the triangular wave. To avoid this, when mounting the IC on a board, take measures such as placing external components near the IC terminals and separating them from wires that carry large currents.

2) Place the bypass capacitor of the power supply near the IC's pins to increase the noise suppression effect.

5. Product overview

5.1. Overview

The TPD4162F is a BLDC motor driver using high-voltage PWM control. It is fabricated using a high-voltage SOI process. The device contains PWM circuit, 3-phase decode circuit, level shift high-side driver, low-side driver, IGBT outputs, FRDs, over-current, and current limit and under-voltage protection circuits, and a thermal shutdown circuit. It is easy to control a BLDC motor by applying a signal from a motor controller and a Hall element / Hall IC to the TPD4162F.

Overview

- High voltage power side and low voltage signal side terminal are separated.
- Bootstrap circuits give simple high-side supply.
- Bootstrap diodes are built-in.
- PWM and 3-phase decode circuit are built-in.
- Pulse-per-revolution output:
  FGC=High: 3 pulses/electrical angle 360 °
  FGC=Low : 1 pulse/electrical angle 360 °
- 3-phase bridge output using IGBTs
- FRDs are built-in.
- Included over-current and current limit and under-voltage protection, and thermal shutdown.
- The package is a surface mount type 31 pin package.
- Compatible with Hall element input and Hall IC input.

5.2. Product appearance and topside marking

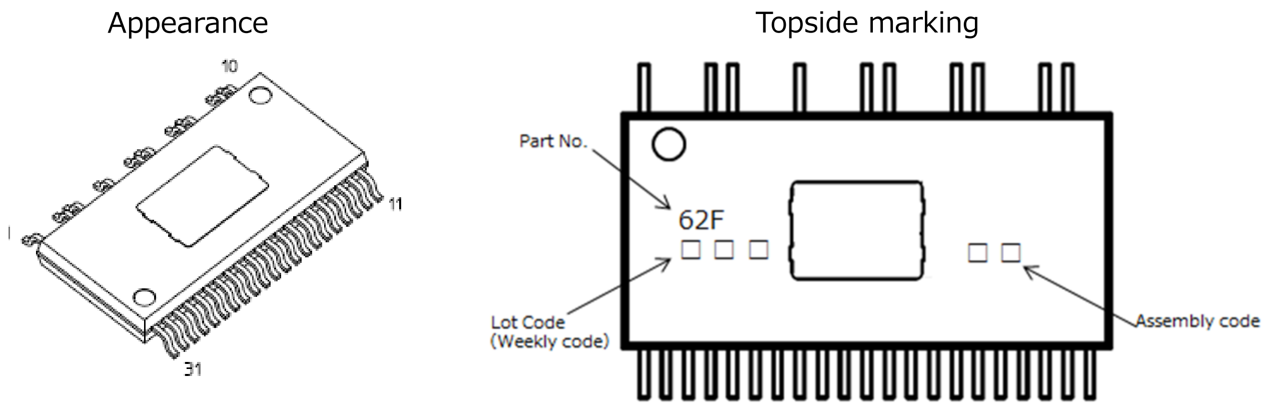


Fig. 5.1 Appearance and topside marking of TPD4162F

5.3. Internal circuit block diagram

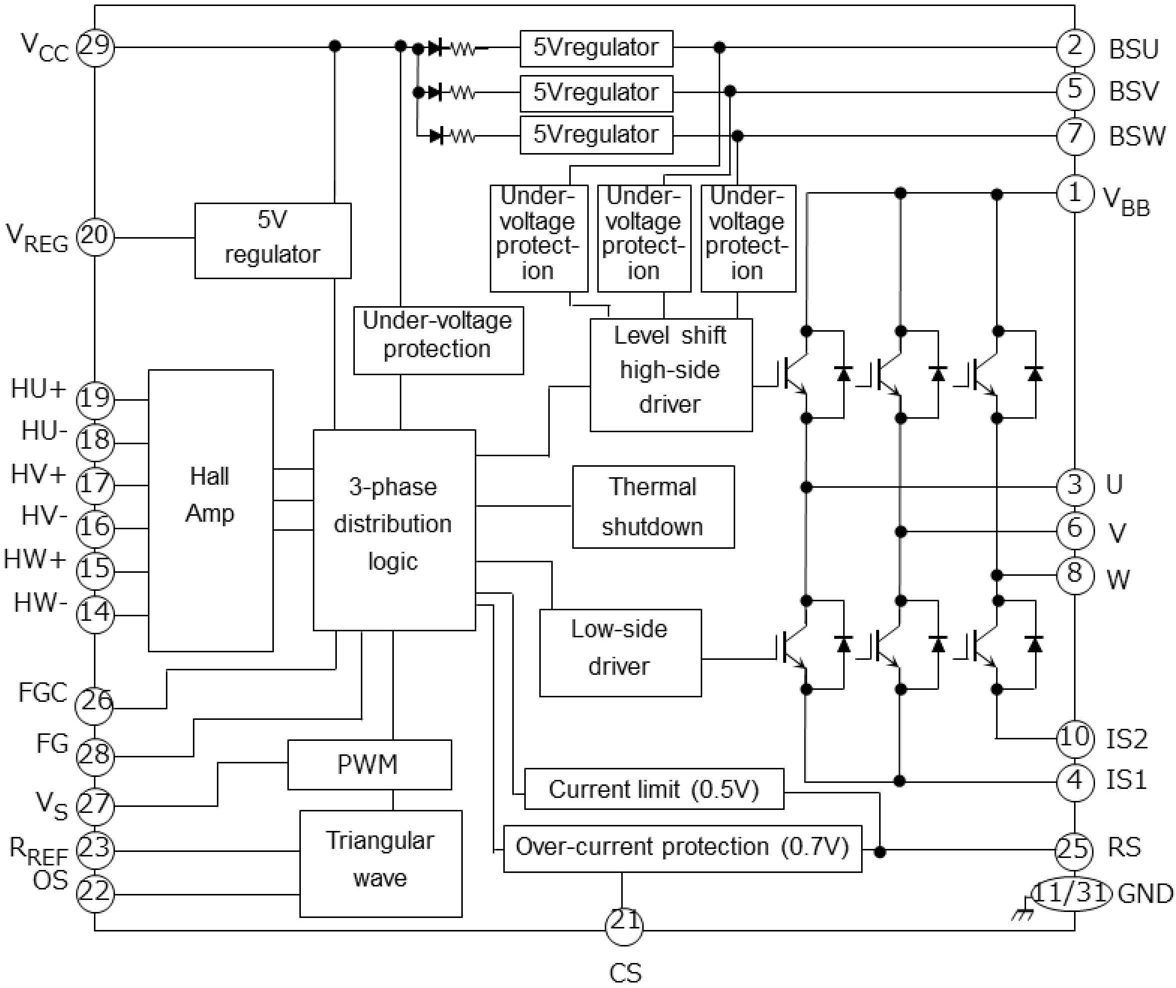


Fig. 5.2 TPD4162F internal circuit block diagram

5.4. Pin assignment

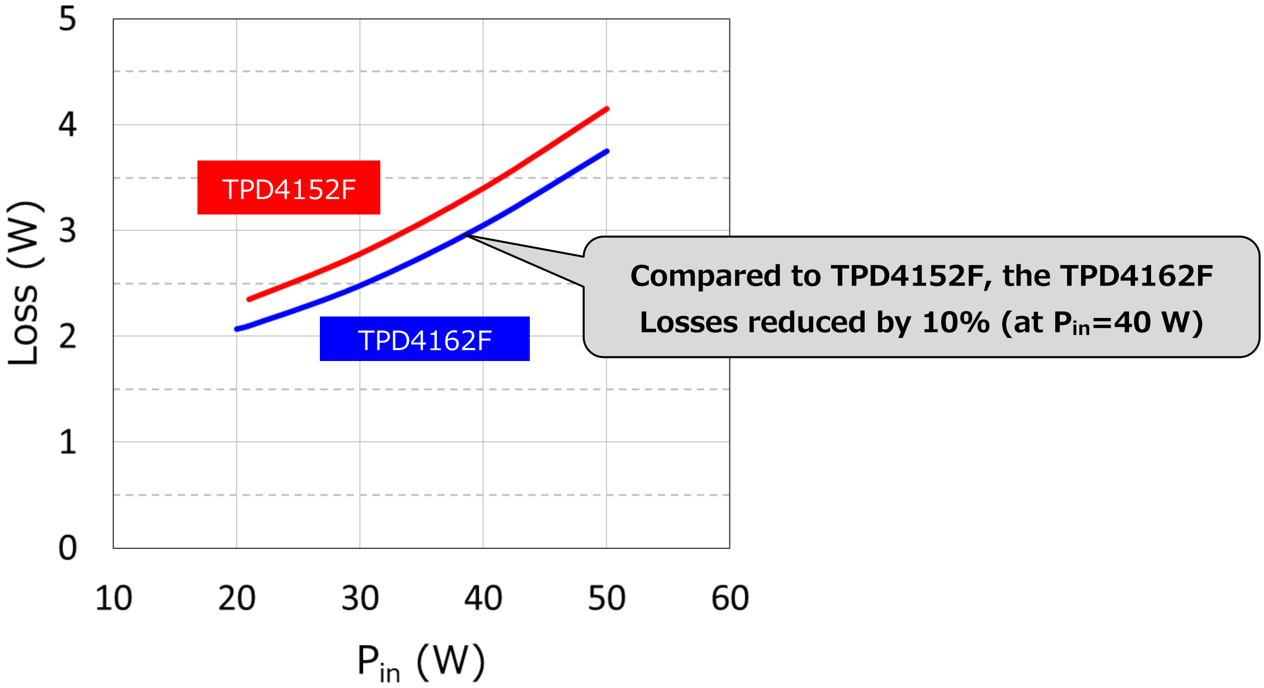
Table 5.1 TPD4162F pin descriptions

Terminal number	Terminal symbol	PIN DESCRIPTION
1	V_{BB}	High voltage power supply input pin
2	BSU	U-phase bootstrap capacitor connecting pin
3	U	U-phase output pin
4	IS1	IGBT emitter/FRD anode pin
5	BSV	V-phase bootstrap capacitor connecting pin
6	V	V-phase output pin
7	BSW	W-phase bootstrap capacitor connecting pin
8	W	W-phase output pin
9	NC	Unused pin, which is not connected to the chip internally
10	IS2	IGBT emitter/FRD anode pinl
11	GND	Ground pin
12	NC	Unused pin, which is not connected to the chip internally
13	NC	Unused pin, which is not connected to the chip internally
14	HW-	W-phase Hall element signal input pin (Hall IC can be used)
15	HW+	W-phase Hall element signal input pin (Hall IC can be used)
16	HV-	V-phase Hall element signal input pin (Hall IC can be used)
17	HV+	V-phase Hall element signal input pin (Hall IC can be used)
18	HU-	U-phase Hall element signal input pin (Hall IC can be used)
19	HU+	U-phase Hall element signal input pin (Hall IC can be used)
20	V_{REG}	5 V regulator output pin
21	CS	Over-current protection detection pin
22	OS	PWM triangular wave oscillation frequency setup pin (Connect a capacitor to this pin)
23	R_{REF}	PWM triangular wave oscillation frequency setup pin (Connect a resistor to this pin)
24	NC	Unused pin, which is not connected to the chip internally
25	RS	Input for current limit and over-current protection detection pin
26	FGC	FG pulse count select (High or open:3 ppr, Low:1 ppr)
27	V_S	Speed control signal input pin (PWM reference voltage input pin)
28	FG	Rotation pulse output pin
29	V_{CC}	Control power supply pin
30	NC	Unused pin, which is not connected to the chip internally
31	GND	Ground pin

5.5. Loss characteristic

TPD4162F uses a new high breakdown-voltage SOI-process to reduce losses and improve efficiencies over conventional products.

Fig. 5.3 shows a graph comparing the losses of the TPD4162F and the conventional product TPD4152F. It can be seen that the TPD4162F is reduced by 0.4 W when the input power at Pin=40 W compared to the TPD4152F.



Condition: V_{BB}=280 V, V_{CC}=15 V, V_S=4 V, f_s=20 kHz, T_a = 25 °C, No-fan, Heat sink less

Fig. 5.3 Loss characteristics (Compared to TPD4152F)

Terms of Use

This terms of use is made between Toshiba Electronic Devices and Storage Corporation (“We”) and Customer who downloads or uses this Reference Design. Customer shall comply with this terms of use. This Reference Design means all documents and data in order to design electronics applications on which our semiconductor device is embedded.

Section 1. Restrictions on usage

1. This Reference Design is provided solely as reference data for designing electronics applications. Customer shall not use this Reference Design for any other purpose, including without limitation, verification of reliability.
2. Customer shall not use this Reference Design for sale, lease or other transfer.
3. Customer shall not use this Reference Design for evaluation in high or low temperature, high humidity, or high electromagnetic environments.
4. This Reference Design shall not be used for or incorporated into any product or system whose manufacture, use, or sale is prohibited under any applicable laws or regulations.

Section 2. Limitations

1. We reserve the right to make changes to this Reference Design without notice.
2. This Reference Design should be treated as a reference only. WE ARE NOT RESPONSIBLE FOR ANY INCORRECT OR INCOMPLETE DATA AND INFORMATION.
3. Semiconductor devices can malfunction or fail. When designing electronics applications by referring to this Reference Design, Customer is responsible for complying with safety standards and for providing adequate designs and safeguards for their hardware, software and systems which minimize risk and avoid situations in which a malfunction or failure of semiconductor devices could cause loss of human life, bodily injury or damage to property, including data loss or corruption. Customer must also refer to and comply with the latest versions of all relevant our information, including without limitation, specifications, data sheets and application notes for semiconductor devices, as well as the precautions and conditions set forth in the "Semiconductor Reliability Handbook".
4. Designing electronics applications by referring to this Reference Design, Customer must evaluate the whole system sufficiently. Customer is solely responsible for applying this Reference Design to Customer's own product design or applications. WE ASSUME NO LIABILITY FOR CUSTOMER'S PRODUCT DESIGN OR APPLICATIONS.
5. WE SHALL NOT BE RESPONSIBLE FOR ANY INFRINGEMENT OF PATENTS OR ANY OTHER INTELLECTUAL PROPERTY RIGHTS OF THIRD PARTIES THAT MAY RESULT FROM THE USE OF THIS REFERENCE DESIGN. NO LICENSE TO ANY INTELLECTUAL PROPERTY RIGHT IS GRANTED BY THIS TERMS OF USE, WHETHER EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE.
6. THIS REFERENCE DESIGN IS PROVIDED "AS IS". WE (a) ASSUME NO LIABILITY WHATSOEVER, INCLUDING WITHOUT LIMITATION, INDIRECT, CONSEQUENTIAL, SPECIAL, OR INCIDENTAL DAMAGES OR LOSS, INCLUDING WITHOUT LIMITATION, LOSS OF PROFITS, LOSS OF OPPORTUNITIES, BUSINESS INTERRUPTION AND LOSS OF DATA, AND (b) DISCLAIM ANY AND ALL EXPRESS OR IMPLIED WARRANTIES AND CONDITIONS RELATED TO THIS REFERENCE DESIGN, INCLUDING WITHOUT LIMITATION, WARRANTIES OR CONDITIONS OF FUNCTION AND WORKING, WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, ACCURACY OF INFORMATION, OR NONINFRINGEMENT.

Section 3. Terms and Termination

It is assumed that Customer agrees to any and all this terms of use if Customer downloads or uses this Reference Design. We may, at its sole and exclusive discretion, change, alter, modify, add, and/or remove any part of this terms of use at any time without any prior notice. We may terminate this terms of use at any time and without any cause. Upon termination of this terms of use, Customer shall eliminate this Reference Design. Furthermore, upon our request, Customer shall submit to us a written confirmation to prove elimination of this Reference Design.

Section 4. Export Control

Customer shall not use or otherwise make available this Reference Design for any military purposes, including without limitation, for the design, development, use, stockpiling or manufacturing of nuclear, chemical, or biological weapons or missile technology products (mass destruction weapons). This Reference Design may be controlled under the applicable export laws and regulations including, without limitation, the Japanese Foreign Exchange and Foreign Trade Act and the U.S. Export Administration Regulations. Export and re-export of this Reference Design is strictly prohibited except in compliance with all applicable export laws and regulations.

Section 5. Governing Laws

This terms of use shall be governed and construed by laws of Japan, without reference to conflict of law principle.

Section 6. Jurisdiction

Unless otherwise specified, Tokyo District Court in Tokyo, Japan shall be exclusively the court of first jurisdiction for all disputes under this terms of use.