TPD4162F
Square wave drive system
Brushless DC motor drive circuit

Reference Guide

RD043-RGUIDE-02

TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION

Contents

1. Introduction

This reference guide describes the specifications, usage, and operation of a square-wave drive type motor drive circuit that uses a brushless DC (BLDC) motor driver TPD4162F and Hall elements (Hall sensors).

The TPD4162F has a built-in IGBT and FRDs rated at up to 600 V by adopting the high breakdown voltage PWM method. Hall elements and Hall ICs can be used to drive BLDC motors directly. It also incorporates an over-current protection circuit, a thermal shutdown circuit, and an under-voltage protection circuit to save the time for circuit design.

TPD4162F uses surface-mount-type package named HSSOP31, which are smaller than conventional TPD4152K using DIP26 packages, enabling the PCB to be made smaller to save space and reduce costs.

And the new high breakdown-voltage SOI process reduces losses and improves efficiencies compared to the conventional product TPD4152K. In addition to the conventional current limiting function, the TPD4162F also incorporates an overcurrent protection function that can quickly protect against sudden increases in current generated when the motor is locked.

The applications described in this guide are designed so that the entire board can be housed in the motor case by taking advantage of the features of the HSSOP31 package, assuming use in 100 mm diameter motors, and thus contributing to the size reduction of the entire system. In terms of circuitry, the specifications are optimized for applications in AC200 V equipment.

Various design information such as circuit diagrams and board patterns described in this guide are provided as reference designs. Please refer to the link destinations below and use them as reference for actual design.

To download the TPD4162F reference design → Click Here

2. Specifications and appearance

2.1. Circuit specifications

Table 2.1 shows the specifications of the BLDC motor drive circuits described in this guide.

Table 2.1 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		

2.2. Circuit diagrams

Fig. 2.1 shows the TPD4162F application circuit using Hall elements.

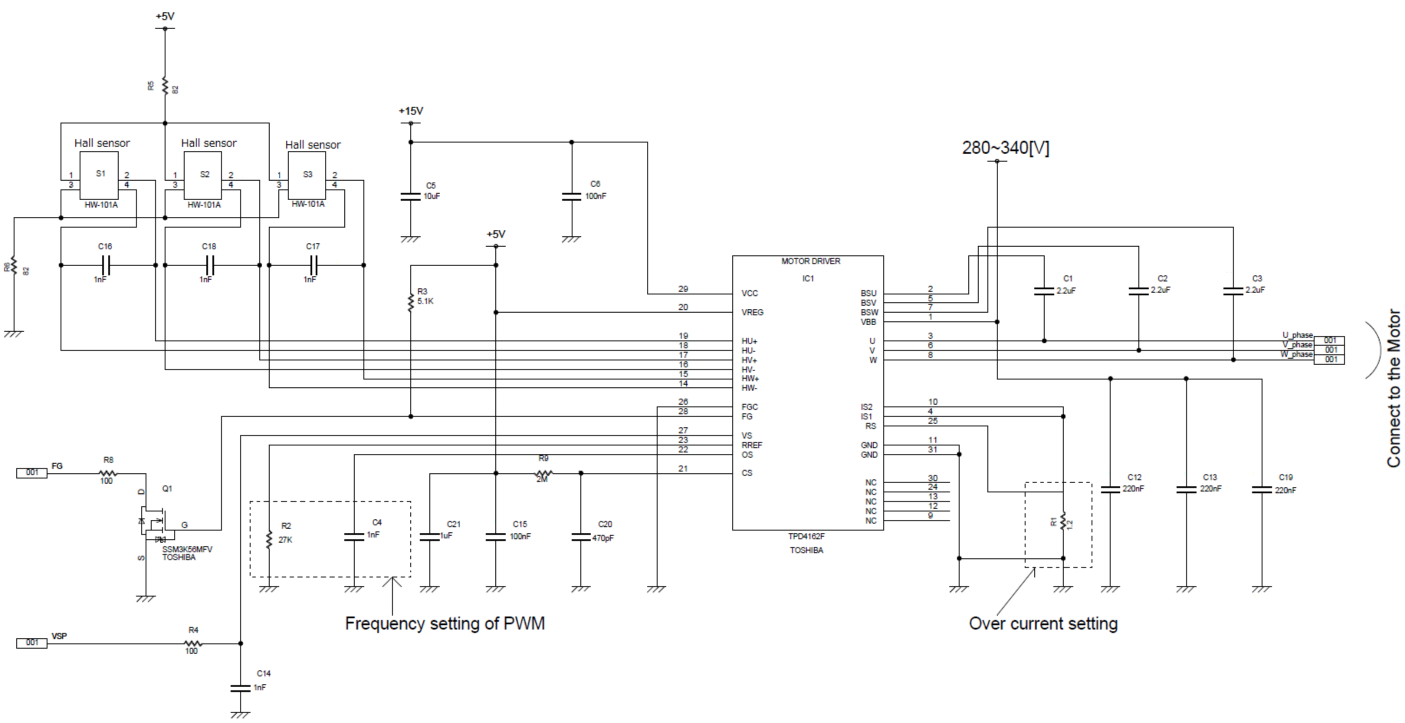


Fig. 2.1 TPD4162F application circuit

2.3. Bill of materials

Table 2.2 shows the bill of materials for this circuit.

Table 2.2 Bill of materials

Item	Part	Quantity	Value	Part name	Manufacturer	Description	Package Name	Standard Dimensions mm (inch)
1	IC1	1	-	TPD4162F	TOSHIBA	IPD	HSSOP31	11.93 x 17.5
2	Q1	1	-	SSM3K56MFV	TOSHIBA	MOSFET	VESM	1.2 x 1.2
3	S1,S2,S3	3		HW-101A	AKM	Hall element	4SOP	2.9 x 2.9
4	R1	1	1.2 Ω	ERJ1TRQF1R2U	Panasonic	1 W ±1 %		6.4 x 3.2 (2412)
5	R2	1	27 kΩ			100 mW ±1 %		1.6 x 0.8 (0603)
6	R3	1	5.1 kΩ			100 mW ±5 %		1.6 x 0.8 (0603)
7	R4,R8	1	100 Ω			100 mW ±5 %		1.6 x 0.8 (0603)
8	R5,R6	2	82 Ω			100 mW ±5 %		1.6 x 0.8 (0603)
9	R9	1	2 MΩ			250 mW ±1 %		2.0 x 1.2 (0805)
10	C1,C2,C3	3	2.2 μF			Ceramic, 25 V, ±10 %		2.0 x 1.2 (0805)
11	C4,C14	2	1 nF			Ceramic, 25 V, ±5 %		1.6 x 0.8 (0603)
12	C5	1	10 μF			Ceramic, 25 V, ±10 %		2.0 x 1.2 (0805)
13	C6,C15	2	100 nF			Ceramic, 25 V, ±10 %		1.6 x 0.8 (0603)
14	C12,C13, C19	3	220 nF			Ceramic, 630 V, ±10 %		4.5 x 3.2 (1812)
15	C16,C17, C18	3	1 nF			Ceramic, 50 V, ±10 %		1.6 x 0.8 (0603)
16	C20	1	470 pF			Ceramic, 50 V, ±5%		1.6 x 0.8 (0603)
17	C21	1	1 μF			Ceramic, 25 V, ±10%		2.0 x 1.2 (0805)

2.4. Appearance of the PCB and its mounting on the motor

In this guide, we designed a board to be mounted on a motor with a diameter of 100 mm. Fig. 2.2 shows the BLDC motor drive circuit board.

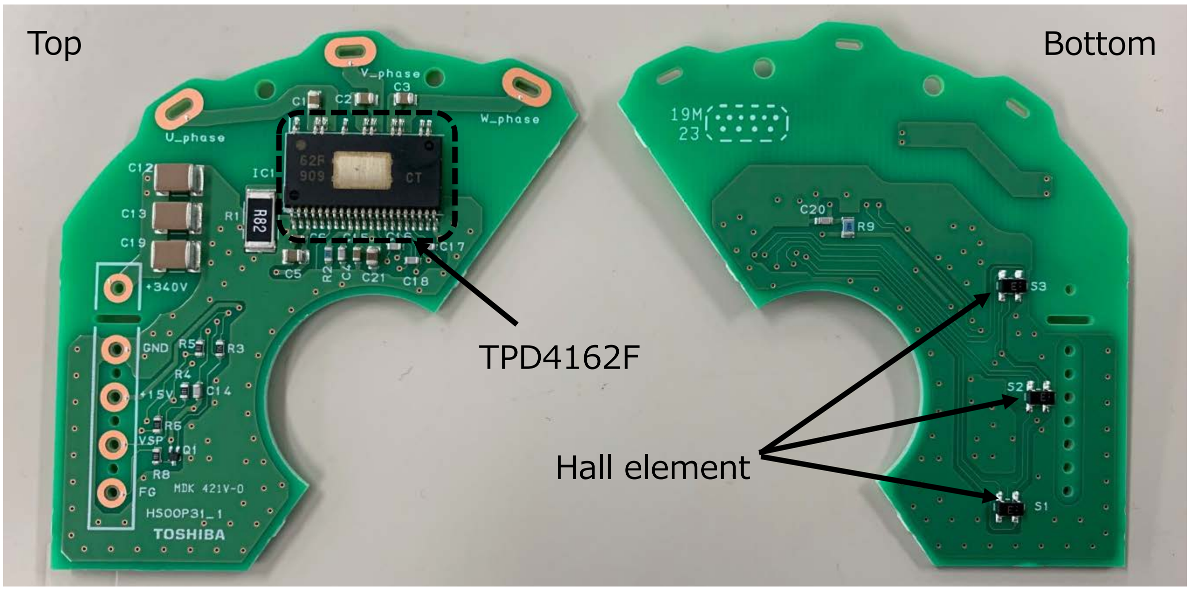


Fig. 2.2 BLDC motor drive circuit board

Fig. 2.3 shows the appearance of this board when it is mounted on a 100 mm diameter motor. Note that the motor in this photo is a dummy mock-up.

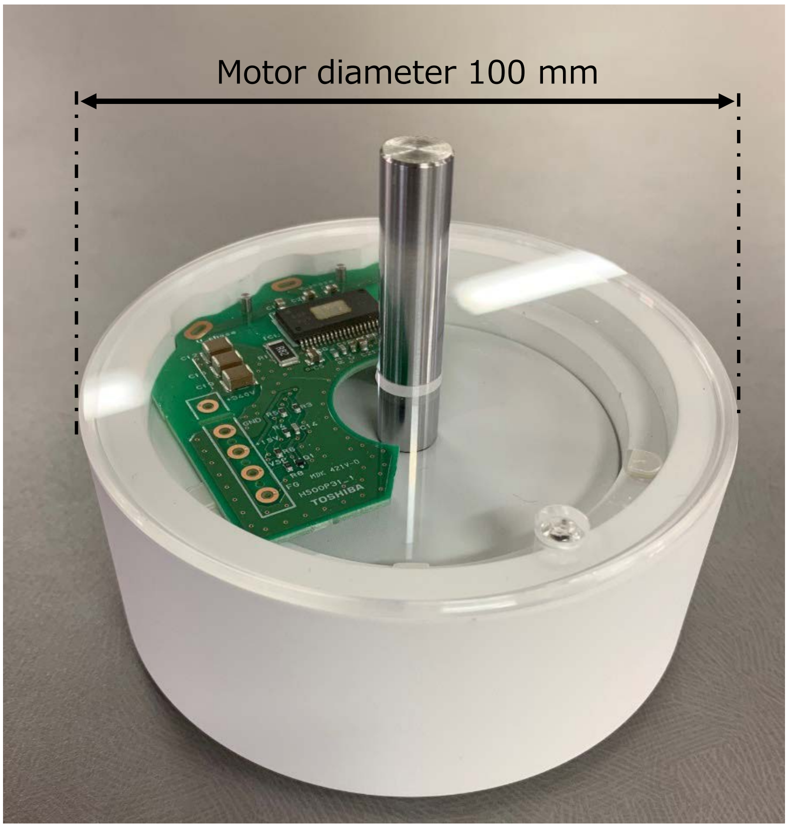


Fig. 2.3 Image of the BLDC motor drive circuit board on a motor

Fig. 2.4 shows a photograph comparing to a board using conventional DIP26 mounted products (TPD4152K).

Both are 100 mm diameters of the motor board and the peripheral circuits are almost the same. However, the TPD4162F of the HSSOP31 packages is placed as close as possible to the U-, V-, and W-phase outputs together with the peripheral components, and the board area is reduced to less than half.

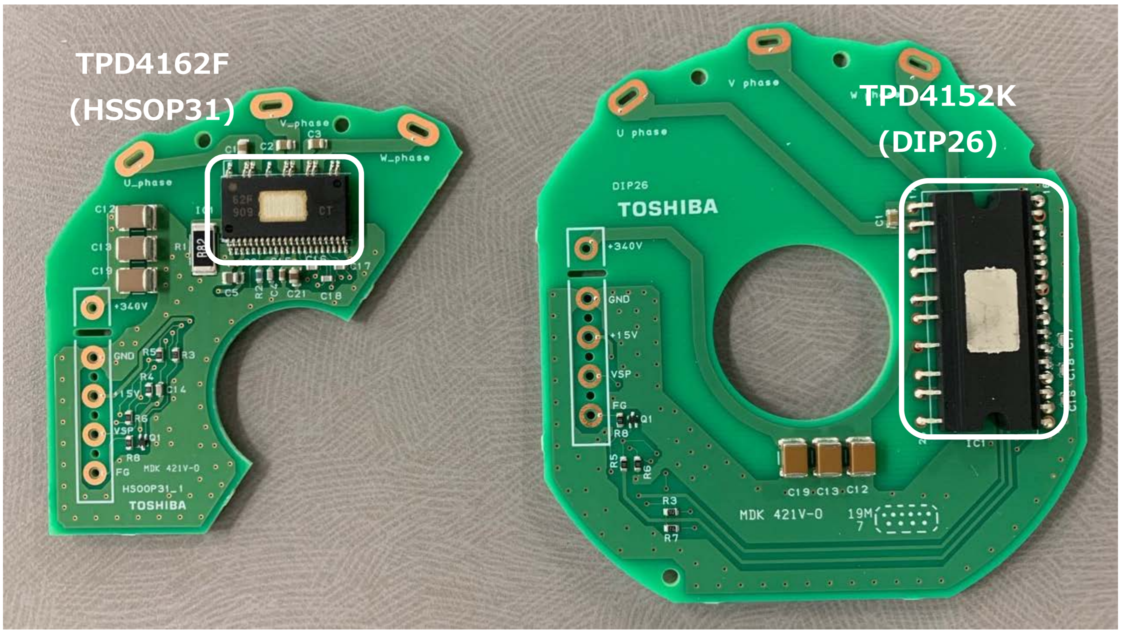


Fig. 2.4 Comparisons with DIP26 products BLDC motor drive circuit board

2.5. PCB pattern diagram

Fig. 2.5 and Fig. 2.6 shows BLDC motor drive circuit board. This board is a double-sided board configuration on the top (part mounting surface excluding the Hall element) and the bottom.

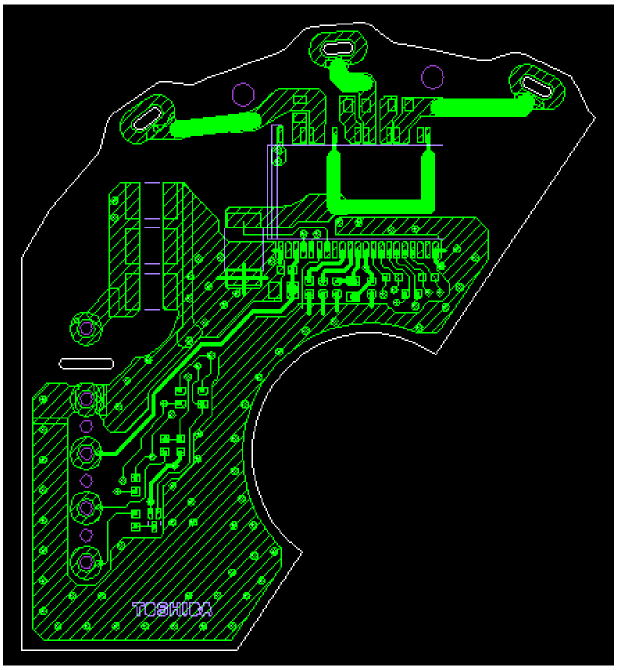


Fig. 2.5 BLDC motor drive circuit board diagram (Top side)

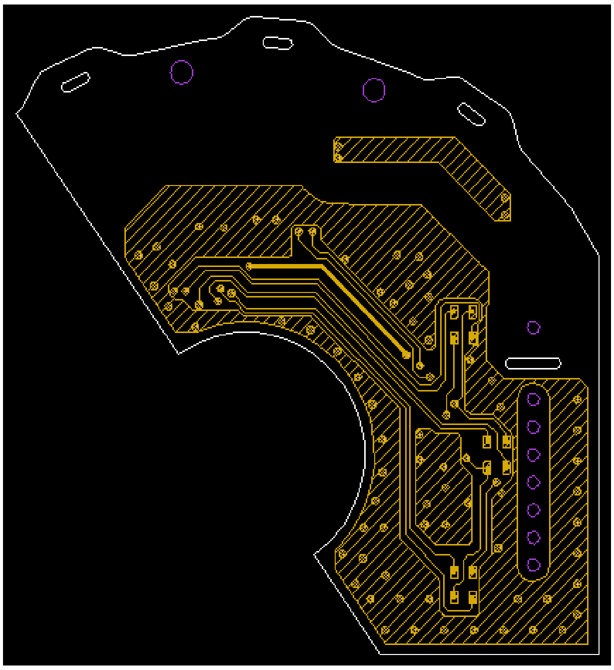
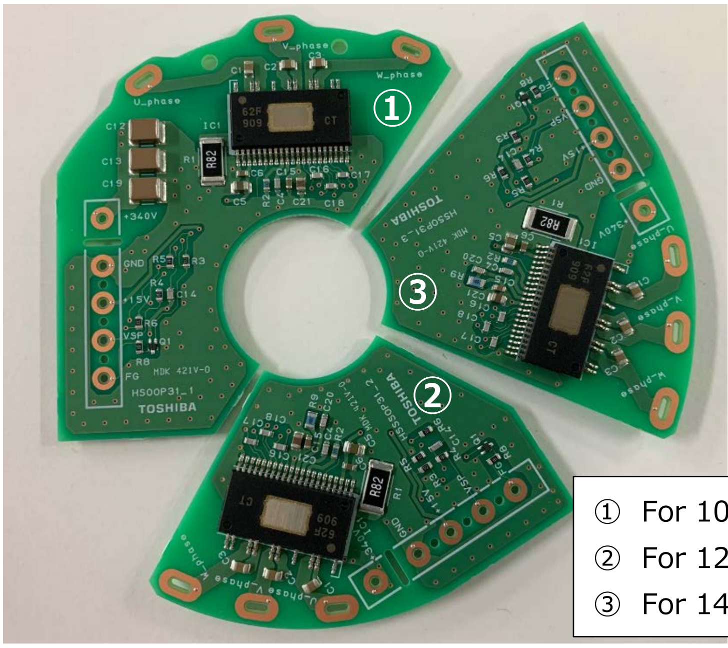


Fig. 2.6 BLDC motor drive circuit board diagram (Bottom side)

2.6. Board for motors other than 100 mm diameter (reference)

For your reference, we will introduce the 100 mm diameter motor circuit boards as well as the 120 mm and 140 mm diameter motor drive circuit boards. Fig. 2.7 shows an example of three types of board, including 100 mm board. The circuit board shown in ① in this figure is for the 100 mm diameter motor described so far, and ② is for the 120 mm diameter motor and ③ is for the 140 mm diameter motor.



① For 100 mm diameter motor
② For 120 mm diameter motor
③ For 140 mm diameter motor

Fig. 2.7 Example of three types of board

Fig. 2.8 and Fig. 2.9 show the appearance and component arrangement of the board ② and board ③ shown in Fig. 2.7.

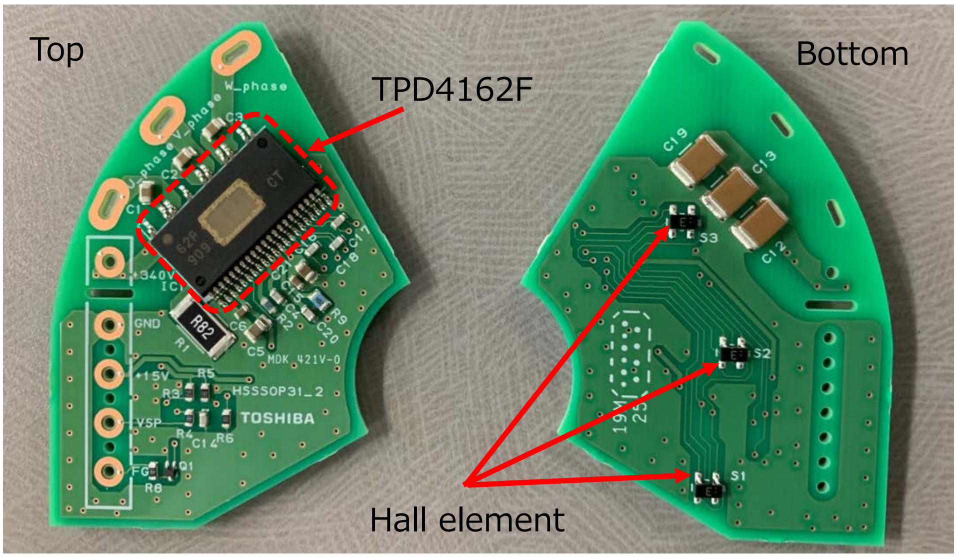


Fig. 2.8 Drive circuit board for 120 mm diameter motor

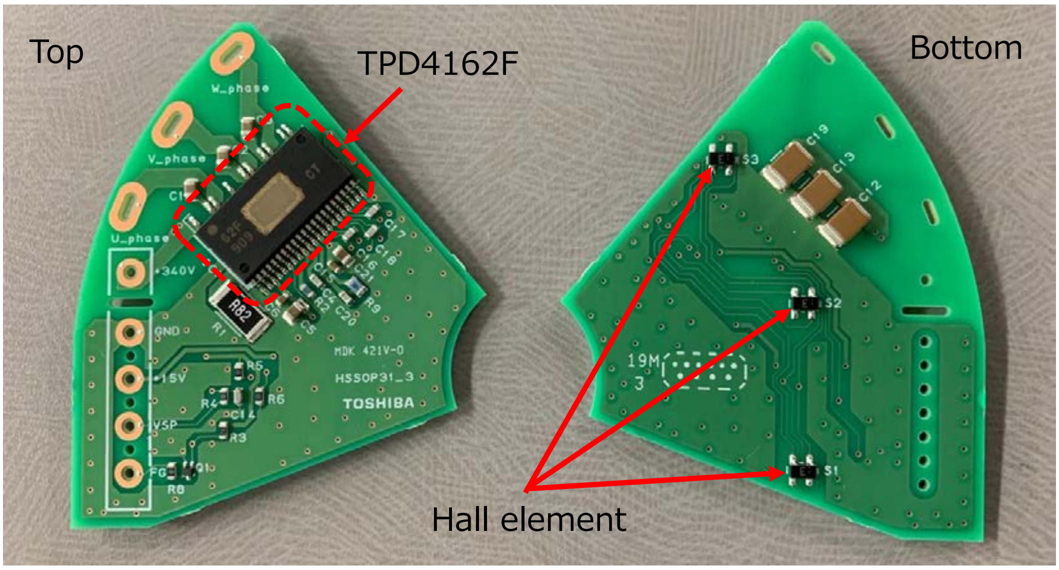


Fig. 2.9 Drive circuit board for 140 mm diameter motor

3. Operation procedure

3.1. Connecting to an external device

Fig. 3.1 shows the external connection pins of this application circuit board.

The part enclosed in red is the input terminal. Connect the high-voltage DC power supply to the V_{BB} terminal and the control DC power supply to the V_{CC} terminal respectively. In addition, input DC voltage to the V_S terminal as a signal for controlling the rotational speed.

The part enclosed in blue is the output terminal. Connect the U, V, and W phases of the motor to each of the U, V, and W terminals, respectively. In addition, a pulse signal for rotation speed detection is output to the FG terminal.

Use a power supply, load device, cable, lead wire, and connectors that meet the specifications in Table 2.1.

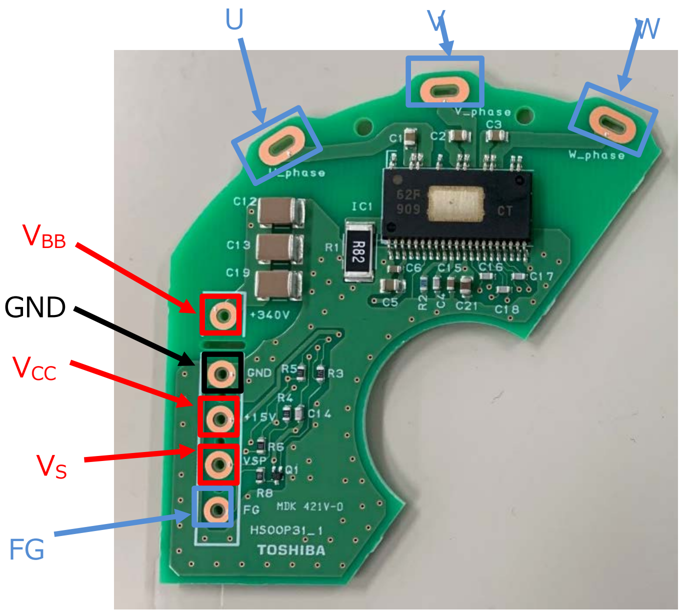


Fig. 3.1 BLDC motor driver external connection pins

Fig. 3.2 shows an example of the connection between this board and an external device.

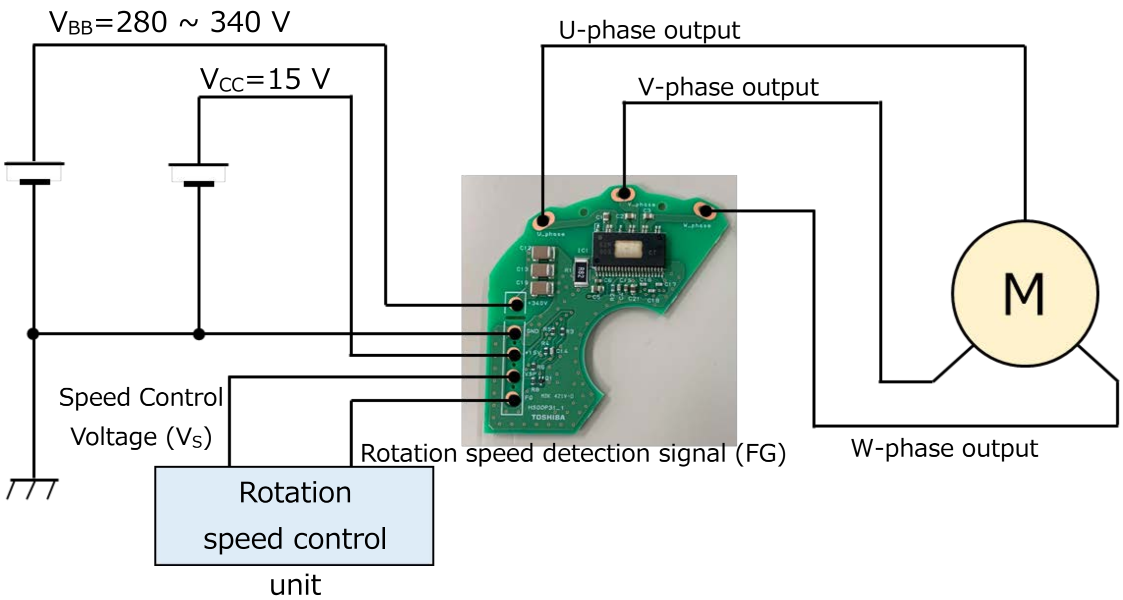


Fig. 3.2 Examples of the connection

3.2. Start and stop

Ensure that all of the following pin voltages are 0V prior to start of the power supply.

V_{BB} terminal, V_{CC} terminal, V_S terminal, U terminal, V terminal, W terminal

[Start Procedure]

1. Apply control DC voltages to the V_{CC}
2. Apply high voltage DC voltages to the V_{BB}

   (The order of 1. and 2. can be switched.)
3. Increase the DC voltage for speed control at the V_S terminal gradually from 0 V (VV_SOFF or less) until the motor reaches the predetermined speed.

[Stop procedure]

The procedure is reversed to starting.

1. Slowly lower the DC voltage for speed control at the V_S terminal until the motor stops (all IGBT are off).
2. Shut off the high voltage DC voltage of the V_{BB}
3. Cut off the DC voltage for control of the V_{CC} terminal.

   (The order of 2. and 3. can be switched.)

3.3. Caution when use

1. Be sure to turn on / off the V_{CC}, V_{BB} while the V_S<VV_SOFF is on (all IGBTs = off). In this case, the order of V_{CC}, V_{BB} can be either first.

2. Be sure to gradually increase the V_S pin speed-control voltage from VV_SOFF or less (all IGBTs = off). If this voltage is steeply increased, the motor may not start.

3. If the V_{BB} lines are disconnected by relays, etc. while the motor is rotating, the regenerative energy of the motor will be lost and the IC may be damaged.

4. Note that if the motor is locked with the V_{BB} voltage low and the on-duty ratio 100%, the bootstrap voltage may drop due to the long high-side ON time immediately before the lock, which may make it impossible to restart after the lock is released.

   When the bootstrap voltage drops, the high-side output turns off due to the high-side under-voltage protection operation. However, if the V_{BB} voltage is low and the on-duty ratio is 100%, a level shift pulse for turning on the high-side output is not generated and restart is impossible. Level shift pulses cannot be generated because neither the edge of the Hall element output or the edge of the internal PWM signal that generates it exists due to the motor lock and the on-duty ratio 100% command.

   In this case, by forcibly turning the motor externally with the high-side power supply voltage recovered to a voltage 0.5 V higher than the under-voltage protection voltage value, or by setting the PWM on-duty ratio to less than 100 %, a level shift pulse is generated at the edges of these signals and the high-side output is turned ON, so the motor can be restarted.

To ensure that the system can be restarted after locking, limit the maximum value of the on-duty ratio to less than 100% on the motor specifications.

5. Be careful of electric shock when high voltage power is connected. In particular, the area around the V_{BB} and TPD4162F motors (red dotted area in Fig. 3.3) may be DC60 V or higher, which is dangerous. Never touch the high voltage power supply when it is connected, even if the motor is stopped.

   Also, even after the high-voltage power supply is stopped, electric charge may remain in the capacitor, which may cause an electric shock. When touching the board, make sure that the voltage of each part has dropped sufficiently.

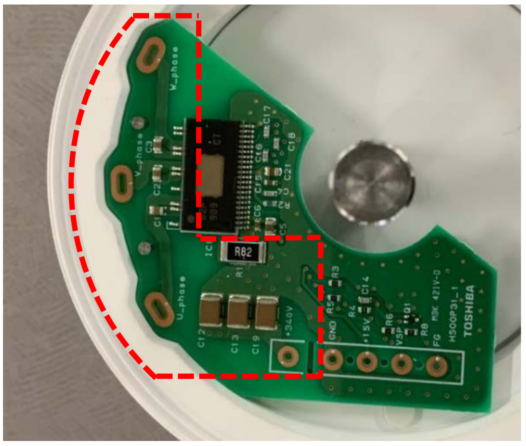
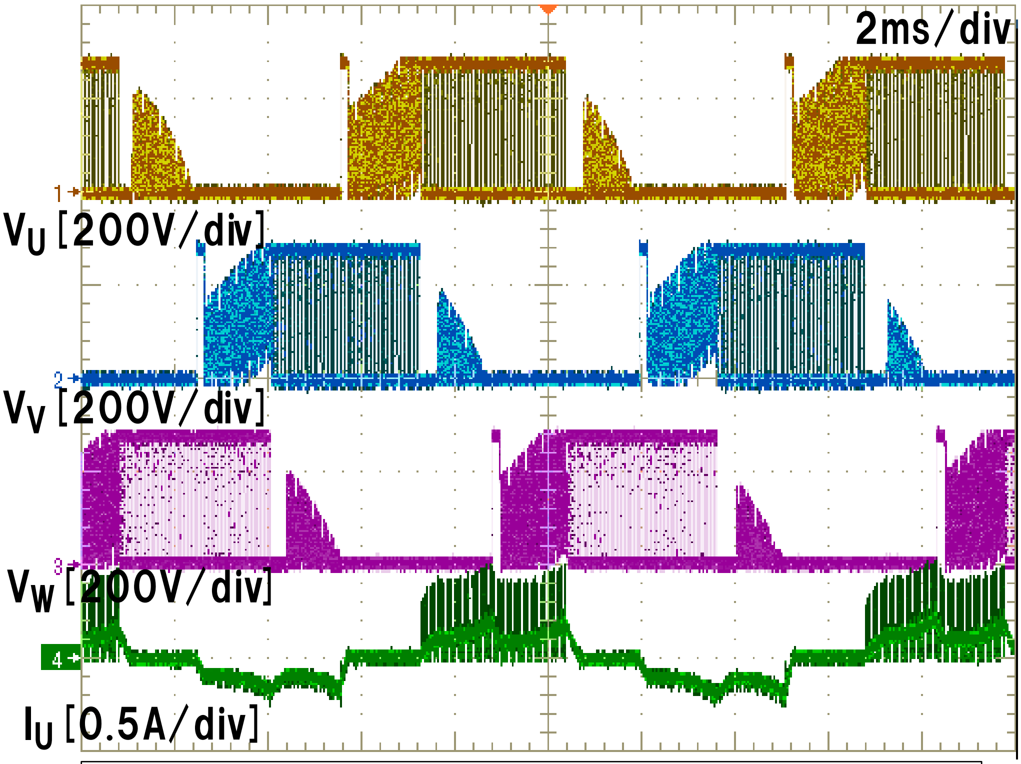


Fig. 3. 3 BLDC motor drive circuits high-voltage area

4. Operation and characteristics

4.1. Operation waveform when the motor is driven

Fig. 4.1 shows the operation waveforms of U-, V-, and W-phase output voltages and U-phase output currents when the motor is actually driven using this applied circuit in the TPD4162F.



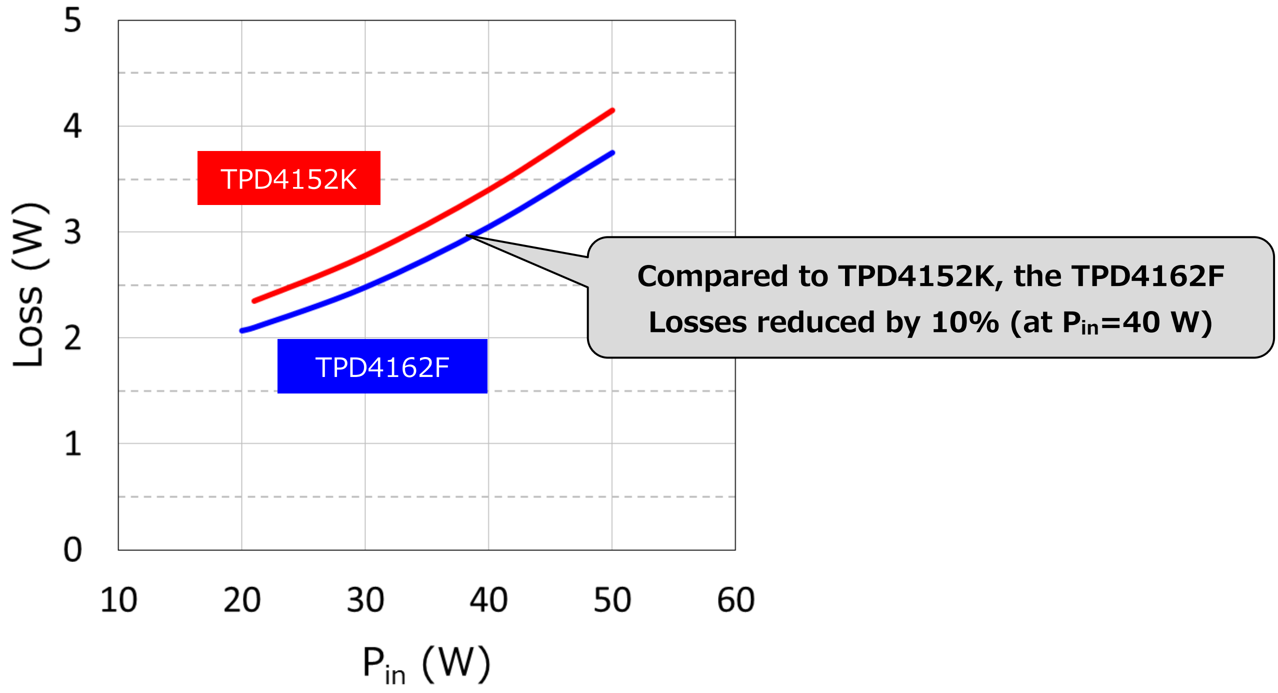
Measurement conditions: V_{BB} = 280 V, V_{CC} = 15 V, V_S = 4 V

Fig. 4.1 Operation waveforms

4.2. Other characteristics

TPD4162F has made packages smaller than conventional TPD4152K using DIP26 package products, and it has adopted a new high breakdown-voltage SOI process to reduce losses inside the IC, thereby curbing the effects of heat due to downsizing.

Fig. 4.2 shows the loss characteristics comparison with TPD4152K, a DIP26 product.



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. 4.2 Loss characteristics (compared with TPD4152K)

In addition, a table comparing TPD4162F and TPD4152K is shown below.

Table 4.1 TPD4162F and TPD4152K comparisons

Item	TPD4162F	TPD4152K
Maximum rating	600 V / 0.7 A	600 V / 0.7 A
Package	HSSOP31	DIP26
Current consumption (V_{BB}=450 V)	0.5 mA	0.5 mA
Current consumption (V_{CC}=15 V)	0.9 mA	2.3 mA
Output saturation voltage (I_C=0.5 A)	2.0 V	2.2 V
FRD forward voltage (I_F=0.5 A)	1.5 V	2.5 V

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