Application Circuits of TPD4152F Square-Wave Control Type of BLDC Motor Driver

Reference Guide

RD017-RGUIDE-02

TOSHIBA ELECTRONIC DEVICES & STORAGE CORPORATION

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0. Introduction

Incorporating 250- to 600-V switching devices, Toshiba's intelligent power devices (IPDs) can directly drive a brushless DC (BLDC) motor. Toshiba offers various IPDs that meet a wide range of requirements, including a motor's output power, the control method (square wave vs sine wave), and the AC input voltage of the application. Toshiba provides a reference design for each type of application to help you create the optimal design. Table 0.1 lists the reference designs for different applications and motors. Consult an appropriate reference design.

Table 0.1 Reference designs for high-voltage IPDs

Motor output	≤ 30 W	≤ 30 W	≤ 60W	≤ 60W
Quiet operation	N/R	N/R	Required	Required
Commutation	Square-wave	Square-wave	Sine-wave	Sine-wave
AC input voltage	100-127 V	100-240 V For countries or regions with unstable power distribution	100-240 V For countries or regions with unstable power distribution	100-240 V For countries or regions with stable power distribution
Recommended IPD	TPD4151F (250 V / 1 A)	TPD4152F (600 V / 0.7A)	TPD4204F (600 V / 2.5A)	TPD4206F (500 V / 2.5A)
Recommended PWM controller	N/R	N/R	TB6634FNG	TB6634FNG
Reference design	Click Here	Click Here	Click Here	Click Here
Reference Guide	RD020-RGUIDE-02	This document	RD018-RGUIDE-02	RD019-RGUIDE-02

For Toshiba's high-voltage IPDs → Click Here

1. Overview

A motor is a generic name of machine designed to convert electric energy into mechanical energy. When an electric current flows through a motor's coil, magnetic fields are produced. The rotor of the motor spins as magnets in the rotor are attracted and repelled by the magnetic fields. The direction of motor rotation can be changed by controlling the direction of the electric current.

In line with the low power consumption requirement of home appliances and increasing vehicle electrification, the importance of motors is growing dramatically. There are various kinds of motors. For example, brushed direct-current (DC) motors are commonly used in automotive applications, toy trains and so on. Nowadays, brushed DC motors are the most widely used due to their excellent controllability, high efficiency, ease of size reduction, and low price. Stepping motors, which are also in widespread use, are characterized by their high accuracy. For example, industrial precision machines require high positioning accuracy, which is enabled by stepping motors. In addition, stepping motors ensure repeatability of movement. The stepping motors found in air-conditioner louvers also feature long service life and quiet operation.

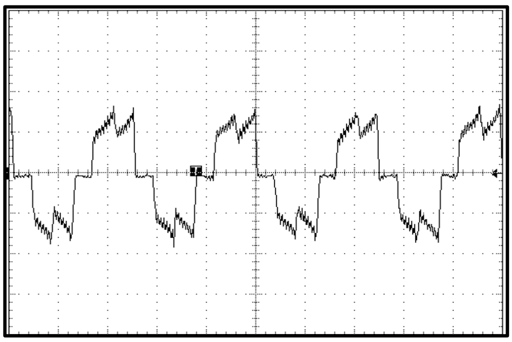
Brushed DC motors use brushes to send electric currents to coils. A motor's rotor has several coils, and a commutator is attached on the motor shaft. The commutator is a rotating electrical switch that reverses the current direction in the rotor coils periodically. The commutator is connected to the coils rotating inside magnetic fields. As a coil rotates, it makes contact with one brush on the power supply side. At this point, the commutator reverses the direction of current through the coil. The commutation sequence is controlled to produce an even torque.

In contrast, BLDC motors do not use any brush (i.e., mechanical contactor) or commutator to change the current direction. Instead, BLDC motors rely on sensors and electronic circuits (collectively called a "driver"). Current commutation using an electronic motor driver was enabled by the progress of semiconductor devices. Being similar in the principle of operation, brushed and BLDC motors have almost the same current-to-torque and voltage-to-rpm relationships. However, as the structure of BLDC motors is similar to that of alternating-current (AC) motors, BLDC motors provide the combined advantages of both DC and AC motors. BLDC motors are small, provide high output power, generate no internal spark or noise due to brushes, have a long service life being free from mechanical wear, and exhibit low energy loss. Therefore, BLDC motors are widely used for various applications including computers and home appliances. Table 1.1 compares various types of motors.

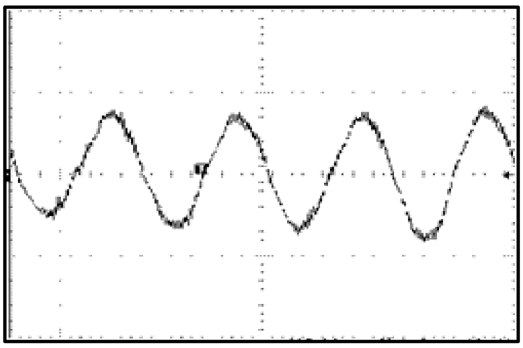
Table 1.1 Comparison of various types of motors

	Brushed DC motors	Brushless DC motors	Stepping motors	AC motors
Efficiency	60 to 80%	≥80%	60 to 70%	40 to 80%
Size	Small	Small	Medium	Large
Electronic circuit	N/R	Required	Required	N/R
Service life	Short	Long	Long	Long
Brushes	Y	N	N	N
Applications	Toys, small home appliances	Air conditioners, washing machines, small home appliances	Robots, small home appliances, industrial precision machines	Washing machines, electric fans, vacuum cleaners

As described above, BLDC motors can operate at high efficiency due to low energy conversion loss. In recent years, manufacturers of home appliances and other consumer products have been under pressure to further reduce their power consumption, driving the widespread use of efficient BLDC motors. For example, a three-phase BLDC motor is commutated using six switching devices. There are two major control techniques for three-phase BLDC motors: 120-degree square-wave control and 180-degree sine-wave control. A square-wave control technique generates square motor winding currents in such a manner as to energize each phase winding for 120 electrical degrees whereas a sine-wave control technique controls sine-wave currents to energize each phase winding for 180 electrical degrees. Figure 1.1 shows examples of phase currents for square- and sine-wave control.



(A) Square-wave control



(b) Sine-wave control

Figure 1.1 Phase current examples

Table 1.2 summarizes the characteristics of 120-degree square-wave control and 180-degree sine-wave control.

Table 1.2 Characteristics of square-wave and sine-wave control

	Square-wave (120-degree) control	Sine-wave (180-degree) control
Noise/vibration	Moderate	Low
Efficiency	Moderate	Excellent
Ease of design	Simple control, small board area	Complicated control, large board area
Other	Configurable only with an IPD	Composed of a PWM controller and an IPD

The TPD4152F incorporates a PWM controller, a three-phase distribution circuit, a level-shifting high-side driver, a low-side driver, and output IGBT/fast-recovery-diode (FRD) pairs. The TPD4152F can directly drive a BLDC motor, without the need for an external PWM controller IC, using square-wave control based on inputs from Hall sensors or a Hall IC. Since the integrated IGBTs and FRDs have a maximum rated voltage of 600 V, the TPD4152F can be used for motor applications with a 200-240 VAC input. In addition, the TPD4152F incorporates overcurrent protection, thermal shutdown, and undervoltage protection, which make it possible to reduce design resource of peripheral circuits.

Housed in the small HSSOP31 surface-mount package, the TPD4152F helps reduce the size and thickness of a motor control board, providing greater flexibility in incorporating the board into a motor casing and thereby reducing the size of the motor assembly.

This reference guide describes applications of the TPD4152F and design considerations for driving a BLDC motor with the TPD4152F together with Hall sensors or a Hall IC.

For details of the TPD4152F, see the datasheet.

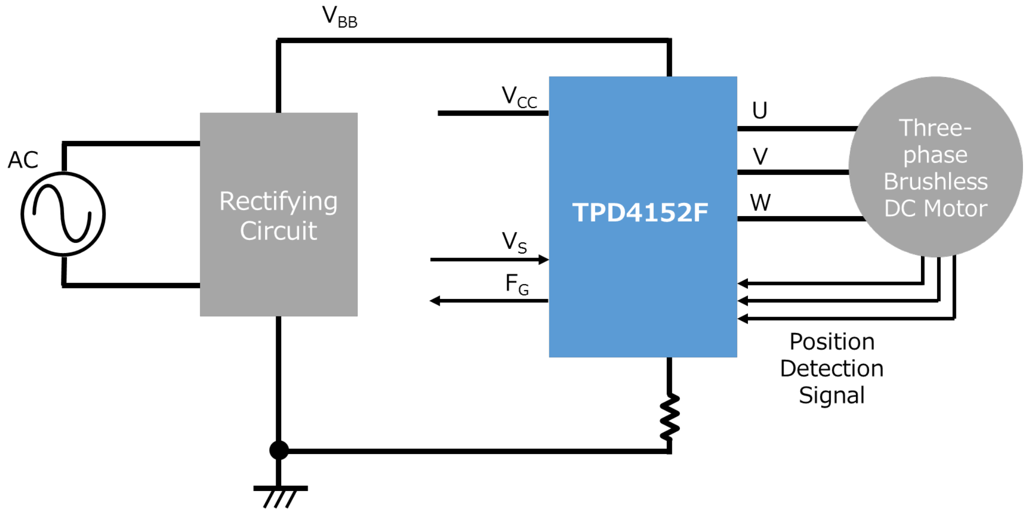
To download the datasheet for the TPD4152F → Click Here

1.1. Target applications

Applications using a motor with an output power of 30 W or less (motor control in inverter systems)

- Air conditioners (indoor and outdoor unit fans)
- Air purifier fans
- Washing machine pumps

Circuit example



2. Application circuit example and the bill of materials

2.1. Application circuit example

Figure 2.1 shows an application circuit example for using a Hall IC whereas Figure 2.2 shows an example for using Hall sensors.

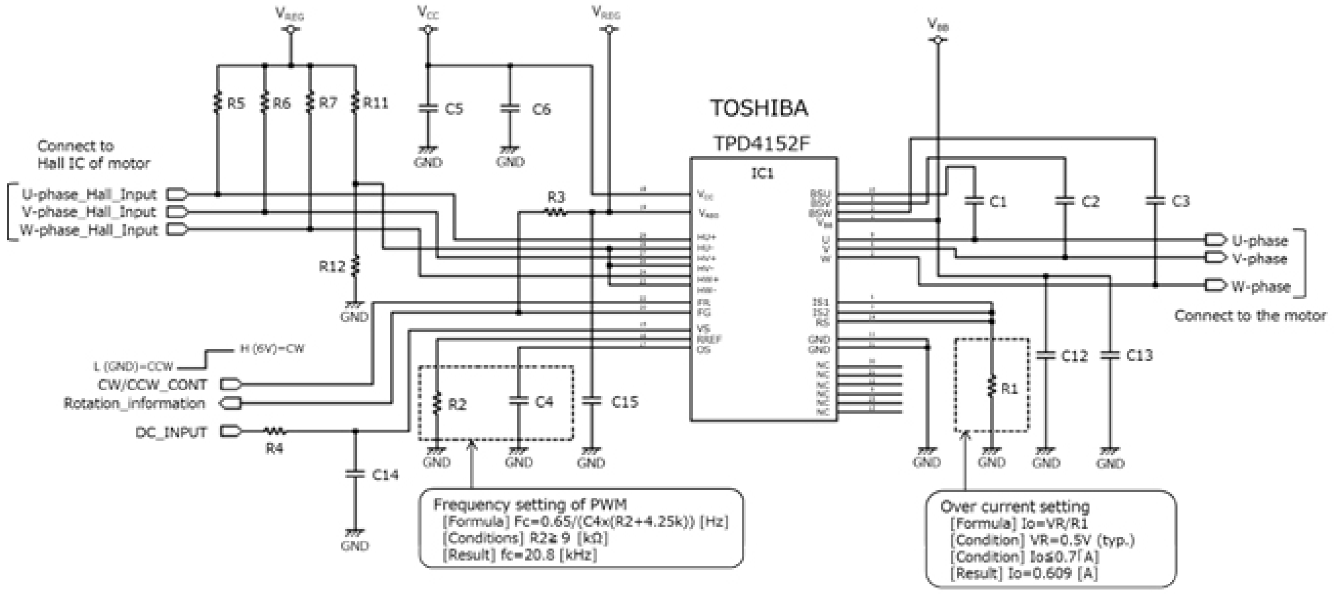


Figure 2.1 TPD4152F application circuit for using a Hall IC

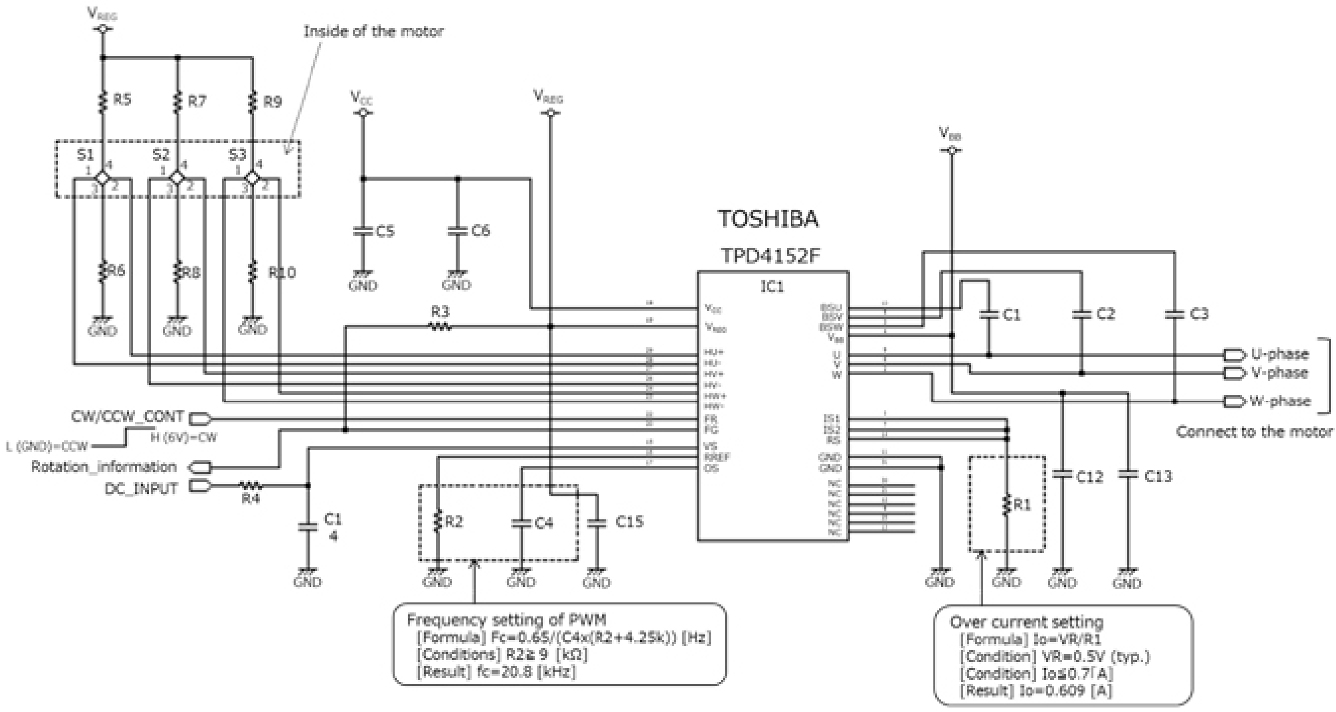


Figure 2.2 TPD4152F application circuit for using Hall sensors

2.2. Bill of materials

Table 2.1 Bill of materials for using a Hall IC (Figure 2.1)

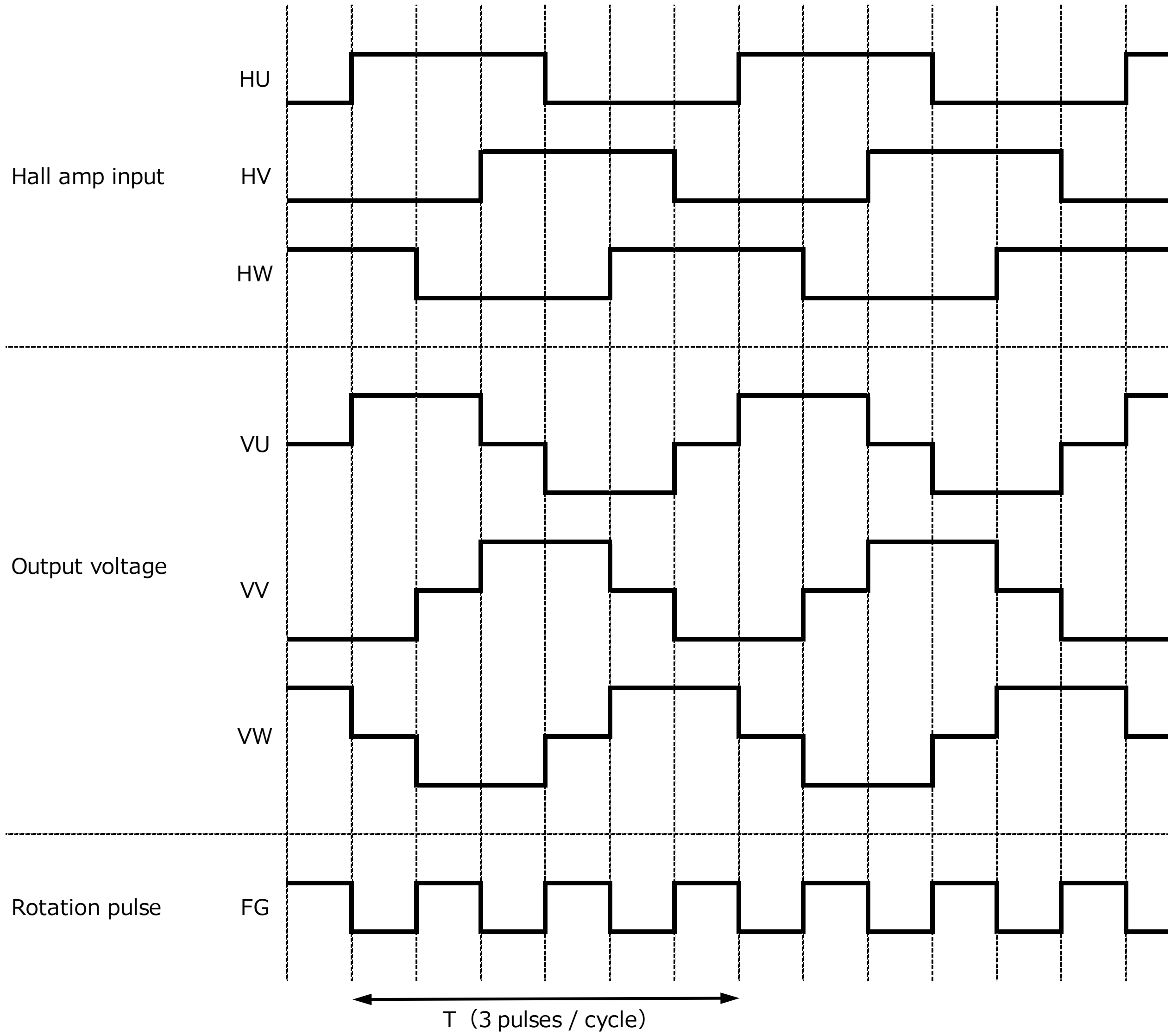
No.	Ref.	Qty	Value	Part Number	Manufacturer	Description	Packaging	Typical Dimensions mm (inches)
1	IC1	1	-	TPD4152F	TOSHIBA		HSSOP31	17.5 x 11.93
2	R1	1	820 mΩ	SL1TTER85F	KOA	1 W, ±1%	-	6.3 x 3.2 (2512)
3	R2	1	27 kΩ			200 mW, ±1%	-	1.6 x 0.8 (0603)
4	R3	1	5.1 kΩ			200 mW, ±5%	-	1.6 x 0.8 (0603)
5	R4	1	100 Ω			200 mW, ±5%	-	1.6 x 0.8 (0603)
6	R5, R6, R7	3	5.1 kΩ			200 mW, ±5%	-	1.6 x 0.8 (0603)
7	R11, R12	2	4.7 kΩ			200 mW, ±1%	-	1.6 x 0.8 (0603)
8	C1, C2, C3	3 Ω	2.2 μF			Ceramic, 25 V, ±10%	-	2.0 x 1.2 (0805)
9	C4, C14	2	1 nF			Ceramic, 25 V, ±10%	-	1.6 x 0.8 (0603)
10	C5	1	10 μF			Ceramic, 25 V, ±20%	-	1.6 x 0.8 (0603)
11	C6, C15	2	100 nF			Ceramic, 25 V, ±10%	-	1.6 x 0.8 (0603)
12	C12, C13	2	1 μF	ECQE6105KF	Panasonic	Polypropylene Film, 630V, ±10 %	DIP	

Table 2.2 Bill of materials for using Hall sensors (Figure 2.2)

No.	Ref.	Qty	Value	Part Number	Manufacturer	Description	Packaging	Typical Dimensions mm (inches)
1	IC1	1	-	TPD4152F	TOSHIBA		HSSOP31	17.5 x 11.93
2	R1	1	820 mΩ	SL1TTER85F	KOA	1 W, ±1%	-	6.3 x 3.2 (2512)
3	R2	1	27 kΩ			200 mW, ±1%	-	1.6 x 0.8 (0603)
4	R3	1	5.1 kΩ			200 mW, ±5%	-	1.6 x 0.8 (0603)
5	R4	1	100 Ω			200 mW, ±5%	-	1.6 x 0.8 (0603)
6	R5, R6, R7 R8, R9, R10	2	300 Ω			200 mW, ±5%	-	1.6 x 0.8 (0603)
7	C1, C2, C3	3	2.2 µF			Ceramic, 25 V, ±10%	-	2.0 x 1.2 (0805)
8	C4, C14	2	1 nF			Ceramic, 25 V, ±10%	-	1.6 x 0.8 (0603)
9	C5	1	10 µF			Ceramic, 25 V, ±20%	-	1.6 x 0.8 (0603)
10	C6, C15	2	100 nF			Ceramic, 25 V, ±10%	-	1.6 x 0.8 (0603)
11	C12, C13	2	1 µF	ECQE6105KF	Panasonic	Polypropylene Film, 630 V, ±10%	DIP	
12	S1, S2, S3	3		HW-101A	ASK	Hall Sensor	4SOP	2.9 x 2.9

3. Control method

Figure 3.1 shows a timing chart for motor control.



Note: The High state of the Hall amplifier indicates a condition in which H*+ is greater than H*-. (*: U/V/W)

Figure 3.1 Timing chart

3.1. Calculating the rpm of a motor

The revolutions per minute (rpm) of a motor can be calculated by measuring the period of an output rotation pulse shown in Figure 3.1.

$$\mathrm{RS} = 60 \times 2 \times \frac{F}{P}$$

where:

RS: Motor rotation speed (rpm)
T/3: Rotation pulse period
P: Number of motor poles
F: Frequency (= 1/T)

Calculation example: When the frequency of the output rotation pulse for an eight-pole motor is measured to be 300 Hz

$$\mathrm{RS} = 60 \times 2 \times \frac{\frac{300}{3}}{8} = 1500\mathrm{rpm}$$

3.2. Controlling the rpm of a motor

The motor rpm can be controlled via the DC voltage applied to the V_S pin.
Figure 3.2 shows the relationship between the V_S voltage and the motor rpm.

Calculation example: When the maximum speed of a loaded motor is 1000 rpm

A 20.8-kHz triangular wave is generated when R2 = 27 kΩ and C4 = 1 nF.

The PWM pulse width can be adjusted via the voltage applied to the V_S pin. When V_S = 3.8 V, the PWM duty cycle is 55%, which gives a motor speed of 550 rpm.

* The motor rpm should be measured using hardware since there is some error depending on the motor characteristics.

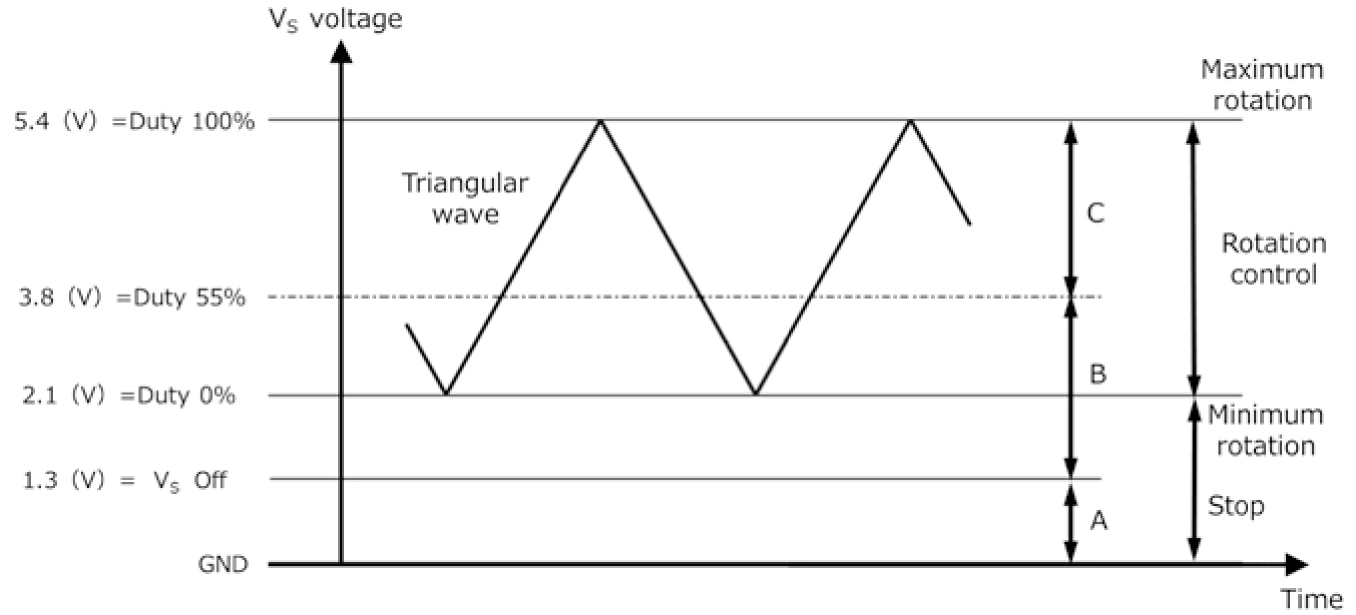


Figure 3.2 Controlling the motor rpm via the V_S voltage

The TPD4152F incorporates a bootstrap circuit that supplies power to the high-side drivers. When the V_S voltage is equal to or greater than 1.3 V (typical), the TPD4152F allows the output IGBTs to be turned on and off. At this time, while a high-side IGBT of a given phase is off, the bootstrap circuit turns on the corresponding low-side IGBT to charge the bootstrap capacitor associated with it. However, when the V_S voltage exceeds 3.8 V typical (i.e., the high-side duty cycle exceeds 55%), the TPD4152F keeps the corresponding low-side IGBT off in order to prevent cross conduction, or shoot-through, between the high-side and low-side IGBTs of the same phase. Even during this period, a regenerative current flows through the parallel diode of the low-side IGBT due to high-side PWM operation, charging the bootstrap capacitor. However, at a duty cycle of 100%, there is no regenerative current that charges the bootstrap capacitor. Therefore, the voltage of a bootstrap capacitor continually decreases during a PWM operation at a duty cycle of 100%. This voltage drop should be considered if the PWM duty cycle is set to 100%. Table 3.1 describes the charging of the bootstrap capacitor when the V_S pin is in different voltage ranges.

Table 3.1 Charging of bootstrap capacitors in different V_S voltage ranges

V_S voltage range	Output IGBT operation
A	Both the high-side and low-side IGBTs are off.
B	Charging operation range. While the high-side IGBT of a given phase is off, the corresponding low-side IGBT turns on periodically to charge the associated bootstrap capacitor.
C	No charging operation range. The output IGBTs are not charged. The high side performs a PWM operation as shown in the timing chart. When a high-side IGBT is off, charging operation by the corresponding low-side IGBT does not work.

3.3. Hall sensors and Hall ICs

The rotor position in a motor is detected using Hall sensors, a Hall IC, or a linear Hall IC, all of which are based on the Hall effect. When a magnetic field is applied perpendicular to a current flowing in an electrical conductor, a voltage difference is produced across the conductor, transverse to the current flow. This phenomenon is called the Hall effect. Hall sensors, Hall ICs, and linear Hall ICs are non-contact sensors that vary their output voltage in response to a magnetic field according to the Hall effect. It is important to select the sensors that best suit your application needs.

The next section describes the designing of a motor driver using Hall sensors in detail.

3.3.1. Using Hall sensors

There are various types of Hall sensors with different characteristics. Examine their specifications to select the optimal one. Hall sensors could burn up at high temperature, depending on their temperature characteristics. To prevent this problem, it is recommended to add Hall bias resistors as shown in Figure 3.3. Appropriate Hall bias resistors must be selected so that the maximum input current to the Hall sensor falls within its safe operating area, an example of which is shown in Figure 3.4. It is recommended to use resistors with the same value for R_A on the power supply side and R_B on the GND side.

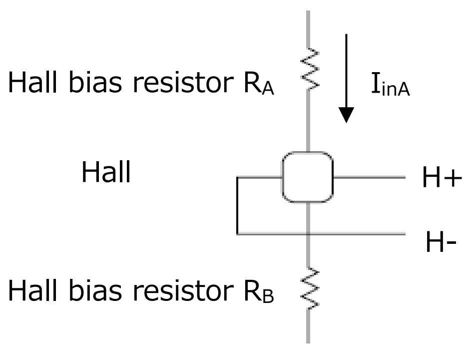


Figure 3.3 Hall bias resistors

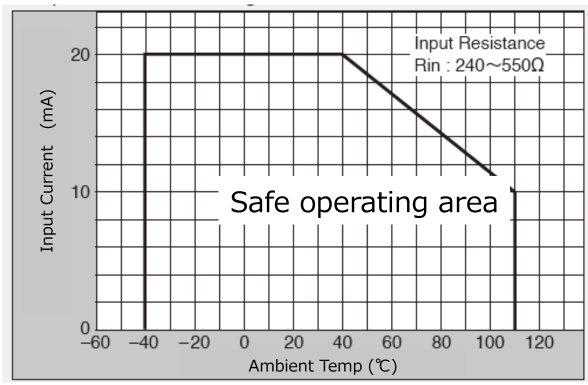


Figure 3.4 Temperature characteristics of a Hall sensor (HW-101A)

Calculating the Hall sensor bias current

The following exemplifies how to calculate the Hall sensor bias current for the HW-101A from Asahi Kasei Corporation.

- Design conditions
  The power supply from the V_{REG} pin is used for the HW-101A.
  Operating temperature range: -40 to 110°C
  R_A and R_B have a tolerance of ±5%.

The safe operating area shown in Figure 3.4 indicates that, at 110°C, the maximum current that provides the best performance is 10 mA. Therefore, we are going to use the center value, 5 mA, for this design example.

The values of the Hall bias resistors R_A and R_B can be calculated as follows:

$$R_A + R_B + R_{in} = \frac{V_{REG}}{I_{inA}}$$

where:

R_A, R_B: Hall bias resistors
R_{in}: Input resistance of the Hall sensor (see Figure 3.5)
I_{inA}: Input current to the Hall sensor
V_{REG}: Regulator output voltage

Hence, (R_A + R_B + R_{in}) is calculated to be 1000 Ω.

It is recommended to set the bias voltage across R_A and R_B to $\frac{V_{REG}}{2}$ when a motor is de-energized. Under this condition, R_A=R_B. Hence,

$2R+R_{in}$ = 1000 Ω
R_{in_Max}=500 Ω
2R = 1000-500 = 500 Ω
R = 500/2 = 250 Ω

Here, let's use resistors of the E24 series, considering availability. Therefore, R = 300 Ω. Next, it is necessary to determine whether the HW-101A operates inside its safe operating area with R = 300 Ω, referring to the HW-101A datasheet. The I_{inA} value becomes maximum when R_{in} is 100 Ω at 110°C (Figure 3.5), R_A and R_B are minimum, and V_{REG} is maximum. Hence:

$$I_{inA} = \frac{5.5}{285\times2+100} = 8.2 \text{ (mA)}$$

Therefore, the HW-101A falls inside the safe operating area over the temperature range from -40°C to 110°C.

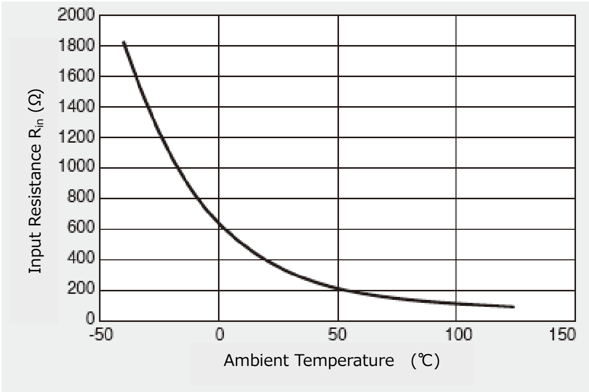


Figure 3.5 R_{in} vs temperature curve of the HW-101A

* Modify the design according to the temperature range in which the HW-101A is used and perform verification with actual hardware. The above calculation is intended merely as an example.

3.3.2. Using a Hall IC

In addition to Hall sensors, the TPD4152F allows the use of a Hall IC. When the Hall IC has an open-collector (or open-drain) output, pullup resistors must be added, as shown in Figure 3.6. In this case, the Hall amplifier inputs can be derived from the output of the voltage regulator (V_{REG}) incorporated in the TPD4152F. Figure 3.7 shows an example of the V_{REG} characteristics. Since the maximum Hall-amp common-mode input voltage of the TPD4152F is specified as 8 V, the maximum amplitude must be less than 8 V. The reference voltage should be one-half of the input voltage to ensure that the Hall IC output is read correctly.
The Hall IC shown in Figure 3.6 has an open-collector output. The pullup resistors are unnecessary when the Hall IC has a push-pull output.

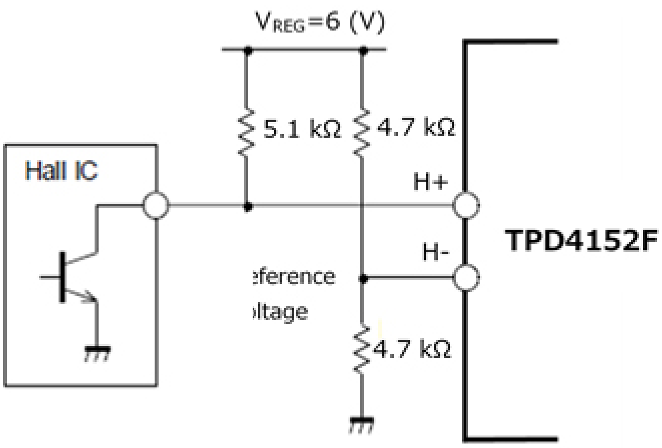


Figure 3.6 Pullup resistors

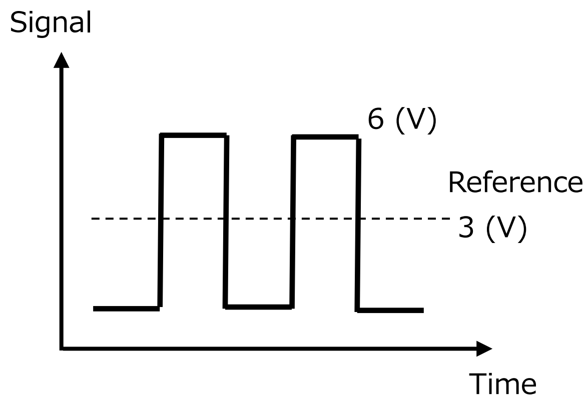


Figure 3.7 Example of output characteristics

4. Design considerations

- The required bootstrap capacitor value varies, depending on the motor drive conditions. Although the TPD4152F operates at above the V_{BS} undervoltage protection threshold, it is recommended to provide at least 13.5 V across the bootstrap capacitor in order to reduce the IGBT power loss. The capacitor is biased by V_{CC} and must be sufficiently derated.

- The overcurrent detection threshold is given by:

$$Io = \frac{V_R}{R1} \qquad \text{at } V_R = 0.5\text{ V (typical)}$$

  The maximum overcurrent detection threshold should be set to 0.7 A.

- In the application circuits shown in Figure 2.1 and Figure 2.2, the combination of C4 and R2 determines the PWM frequency. For example, when C4 = 1000 pF and R2 = 27 kΩ, the PWM frequency is roughly 20 kHz. The IC-intrinsic error is around 10%. The PWM frequency is approximated as follows. However, the stray capacitance of the printed circuit board should be taken into consideration.

$$f_c = \frac{0.65}{C4(R2+4.25k\Omega)} \quad \text{(Hz)}$$

  R2 produces a reference current for the PWM triangular wave charge/discharge circuit. If R2 is too small, the reference current exceeds the current-carrying capacity of the IC's internal circuit, causing the triangular wave to be distorted. R2 should be at least 9 kΩ.

- The above triangular wave oscillator charges and discharges a tiny current via external C4 and R2. Therefore, a board-level noise could cause the triangular wave to be distorted or the TPD4152F to malfunction. To prevent this, it is effective to place external parts as close as possible to the TPD4152F package leads or isolate them from board traces that carry a large current.

- In the application circuits shown in Figure 2.1 and Figure 2.1, C5 helps stabilize the control power supply whereas C6 helps stabilize the V_{REG} power supply. Adjust the values of these capacitors according to the actual usage conditions of the TPD4152F. Place C5 and C6 as close as possible to the TPD4152F package leads to minimize noise.

- The FG pin is an open-drain output. When unused, the FG pin should be connected to GND.

- If noise is detected at input signal pins, add a capacitor between inputs.

- Use indium-antimonide Hall sensors. Set the peak output voltage of Hall sensors above 300 mV.

- At power-up and power-down, ensure that V_S is lower than VV_SOFF (i.e., all IGBT outputs are off). The order of V_{CC} and V_{BB} is insignificant. Note that even when VCC and VBB are powered down as described above, the TPD4152F might be permanently damaged if the V_{BB} line is disconnected by a relay or other means while the motor is running because this blocks a current recirculation path to V_{BB}.

- The TPD4152F has a forward/reverse selection pin (FR). Change the rotation direction while the motor is at a standstill with the V_S voltage being equal to or less than 1.1 V. The following problems might occur if you change the rotation direction while the motor is still rotating:

The motor shaft might be distorted by application of excessive stress.
The output IGBTs might be destroyed by a shoot-through current due to cross conduction.
Both high-side and low-side IGBTs could be on for a brief period while they are switching. Then, excessive current might flow through a path that is not protected by the overcurrent protection circuit and permanently damage the device.

- The PWM generator of the TPD4152F is controlled by switching on and off the high-side IGBTs.

- If a motor is locked when the V_{BB} voltage is low and the PWM duty cycle is 100%, it might become impossible to restart it after the load is released. This is because when the bootstrap voltage decreases due to the long "on" time of the high side immediately prior to the motor lock, the high-side undervoltage protection circuit trips, turning off the high-side output. If this occurs, the motor cannot be restarted since the TPD4152F cannot generate a level-shifting pulse to turn on the high side. The TPD4152F generates a level-shifting pulse from edges of either the Hall sensor output or the internal PWM signal. However, these edges are unavailable after the motor-lock and 100%-duty-cycle commands. In order to restart the locked motor, it is necessary to 1) raise the high-side power supply to a voltage at least 0.5 V higher than the undervoltage protection threshold and 2) apply a high-side input signal. Since the TPD4152F generates a high-side input signal from the level-shifting pulse as described above, a motor can be restarted by setting the PWM duty cycle to less than 100% or externally turning the motor to generate edges on the Hall sensor output. In order to make it possible for a system to restart a locked motor, the rotation of a motor should be constrained by a maximum PWM duty cycle of less than 100% according to the motor specification.

5. Product overview

5.1. Overview

The TPD4152F provides simplified variable-speed control of a BLDC motor based on the inputs from Hall sensors or a Hall IC without the need for a PWM controller. The TPD4152F incorporates IGBTs and features small size.

Overview

- Isolates high-voltage pins and low-voltage control pins on the opposite sides of the package
- A bootstrap circuit eliminates the need for a power supply for the high-side driver
- Incorporates bootstrap diodes
- Incorporates a PWM generator and a three-phase distribution circuit
- Outputs rotation pulse signals
- Incorporates a three-phase bridge composed of IGBTs
- Incorporates fast-recovery diodes (FRDs)
- Provides overcurrent protection, thermal shutdown, and undervoltage protection
- Compatible with Hall amplifier and Hall IC inputs
- Package: HSSOP31 (17.7 mm x 11.96 mm x 2.2 mm (maximum))

5.1.1. External view and pin assignment

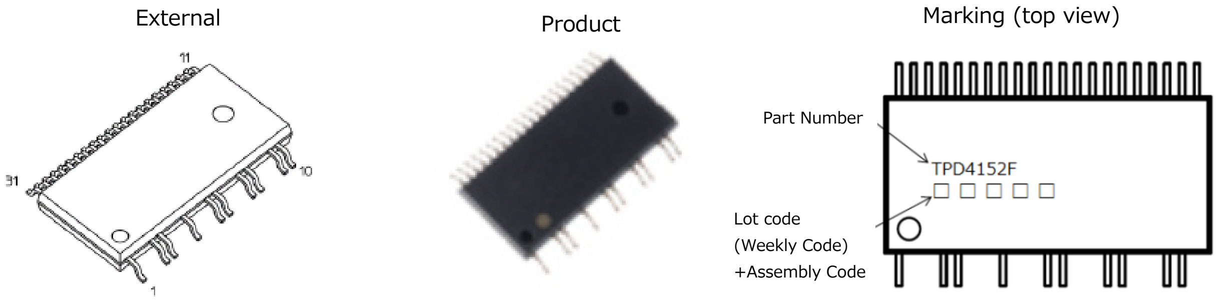


Figure 5.1 External view and marking of the TPD4152F

5.1.2. Internal block diagram

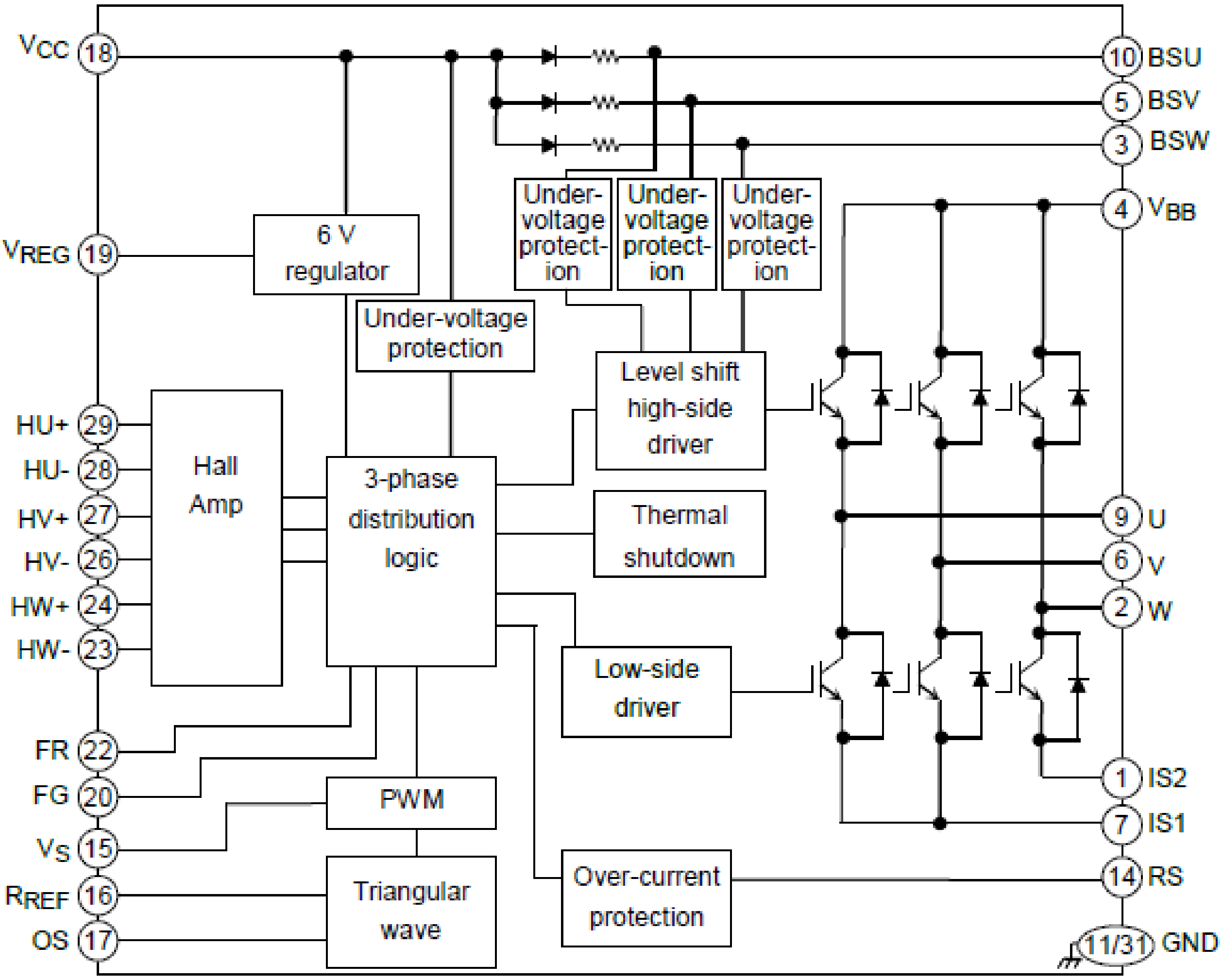


Figure 5.2. Internal block diagram of the TPD4152F

5.1.3. Pin description

Table 5.1. Pins of the TPD4152F

Pin no.	Symbol	Description
1	IS2	IGBT emitter/FRD anode pin
2	W	Phase-W output pin
3	BSW	Phase-W bootstrap capacitor connection pin
4	V_{BB}	High-voltage power supply pin
5	BSV	Phase-V bootstrap capacitor connection pin
6	V	Phase-V output pin
7	IS1	IGBT emitter/FRD anode pin
8	NC	No-connect pin, which is not connected to the internal chip
9	U	Phase-U output pin
10	BSU	Phase-U bootstrap capacitor connection pin
11	GND	Ground pin
12	NC	No-connect pin, which is not connected to the internal chip
13	NC	No-connect pin, which is not connected to the internal chip
14	RS	Overcurrent detection pin
15	V_S	Speed control input pin (PWM reference voltage input)
16	R_{REF}	Pin for setting a PWM triangle wave frequency (Connect a resistor to this pin.)
17	OS	Pin for setting a PWM triangle wave frequency (Connect a capacitor to this pin.)
18	V_{CC}	Control power supply pin
19	V_{REG}	6-V regulator output pin
20	FG	Rotation pulse output pin
21	NC	No-connect pin, which is not connected to the internal chip
22	FR	Forward/reverse selection input pin
23	HW-	Phase-W Hall amplifier input pin (A Hall IC can be used.)
24	HW+	Phase-W Hall amplifier input pin (A Hall IC can be used.)
25	NC	No-connect pin, which is not connected to the internal chip
26	HV-	Phase-V Hall amplifier input pin (A Hall IC can be used.)
27	HV+	Phase-V Hall amplifier input pin (A Hall IC can be used.)
28	HU-	Phase-U Hall amplifier input pin (A Hall IC can be used.)
29	HU+	Phase-U Hall amplifier input pin (A Hall IC can be used.)
30	NC	No-connect pin, which is not connected to the internal chip
31	GND	Ground pin

End of Document

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