Inverter for Cordless Power Tool

Reference Guide

RD252-RGUIDE-01

Toshiba Electronic Devices & Storage Corporation

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1. Introduction

This reference guide (hereinafter referred to as "this guide") describes the specifications and operation procedures of this reference design (hereinafter referred to as "this design") of the Inverter for Cordless Power Tool.

In recent years, the power tool market has grown significantly beyond the sales of hand tools. This growth is driven by expanding infrastructure in developing countries and the growing number of do-it-yourself (DIY) enthusiasts. In addition, in recent years, advances in battery technology have led to the cordless power tools with lighter weight, higher efficiency, and longer operating times on a single charge, leading to a shift from corded to cordless power supply, improving usability, portability, and safety. In addition, the number of motors used is increasing shifting from brushed motors to high-output-power and high-efficiency brushless DC motors (hereinafter referred to as BLDC motors). For these cordless power tools, it is important to design a motor drive circuit that efficiently converts the electrical energy of the battery into mechanical energy.

We have developed the reference design of the motor drive circuit for the cordless power tools that need to have small size and high efficiency with a limited battery capacity. In this design, two types of circuits are available: Type 1 for 18V Li-ion batteries and Type 2 for 36V Li-ion batteries. Therefore, this design also supports the models that increase the motor applied voltage (battery voltage) to achieve higher output.

Three-phase gate driver IC TB67Z833SFTG with various built-in protection functions and adjustable gate drive capability via SPI (Serial Peripheral Interface) communication drives six SOP Advance package (5mm × 6mm) power MOSFETs on a small 55mm x 55mm board. Type 1 circuit uses the 40V TPH1R204PB power MOSFETs, and Type 2 circuit uses the 80V TPH2R408QM power MOSFETs. These latest-generation power MOSFETs have low on-resistance and contributes to compactness and high efficiency. Current sensing is done using TB67Z833SFTG internal op-amp, and overcurrent detection is realized using the TC75W58FU comparators.

This design is configured to assume control by an external MCU. The motor current sensing is done by the 3-shunt method, which can also be used for sensorless control. In addition, it is possible to switch the solder jumper on the board to create the 1-shunt configuration. Please use this design with a control method and a current detection method suitable for actual application.

2. Specifications and Appearance

2.1. Specifications

The main specifications of this design are shown in Table 2.1.

Table 2.1 Specifications of This design

Board	Type1 For 18V Battery	Type2 For 36V Battery	
Item	Value		Unit
Output Power	200	400	W
Input Voltage	12 to 24	24 to 48	V
Average Current	±20	±20	A
Maximum Peak Current	±40	±40	A
Switching Frequency	20	20	kHz
Current Sensing Method	3-Shunt Method / 1-Shunt Method		
Board Size	55mm x 55mm		
Board Layer Composition	FR-4 2.0mm Thick, 2 Layer Configuration 105μm Copper Thickness		

2.2. Block Diagram

The block diagram of this design is shown in Fig. 2.1.

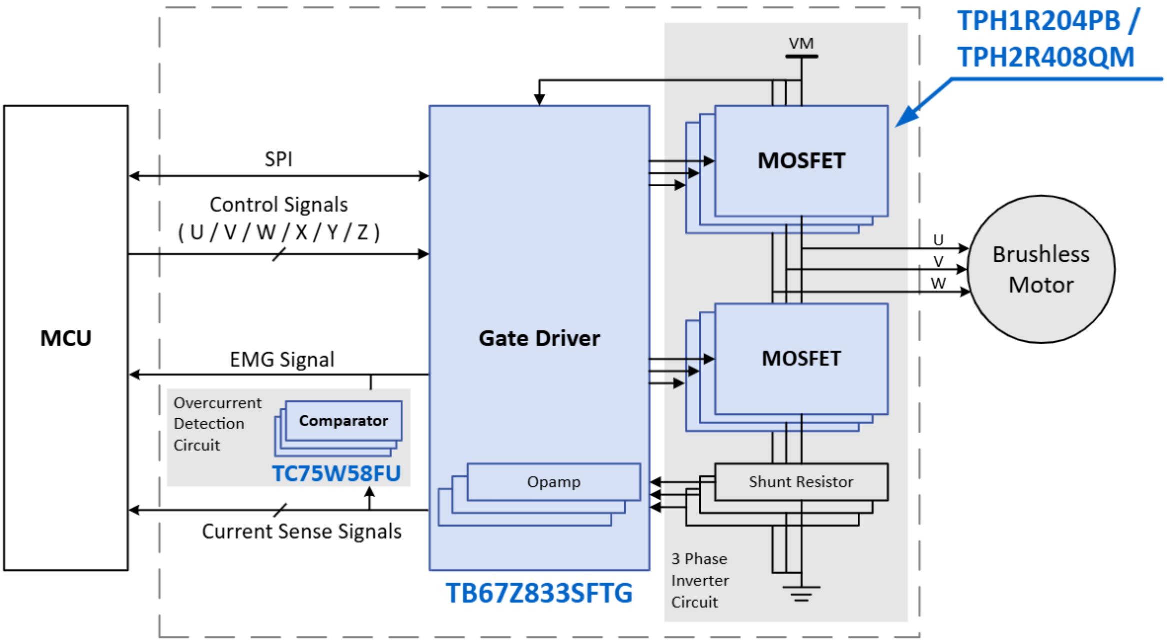


Fig. 2.1 Block Diagram of This Design

TB67Z833FTG receives control signals from an external MCU and drives a total of six MOSFETs arranged in the U, V, and W phases to control the brushless motor. When an error is detected, an EMG (Emergency) signal is sent to the external MCU.

2.3. Appearance and Component Layout

Fig. 2.2 to 2.4 show the board appearance of this design. Fig. 2.5 and Fig. 2.6 show the layout of the main components.

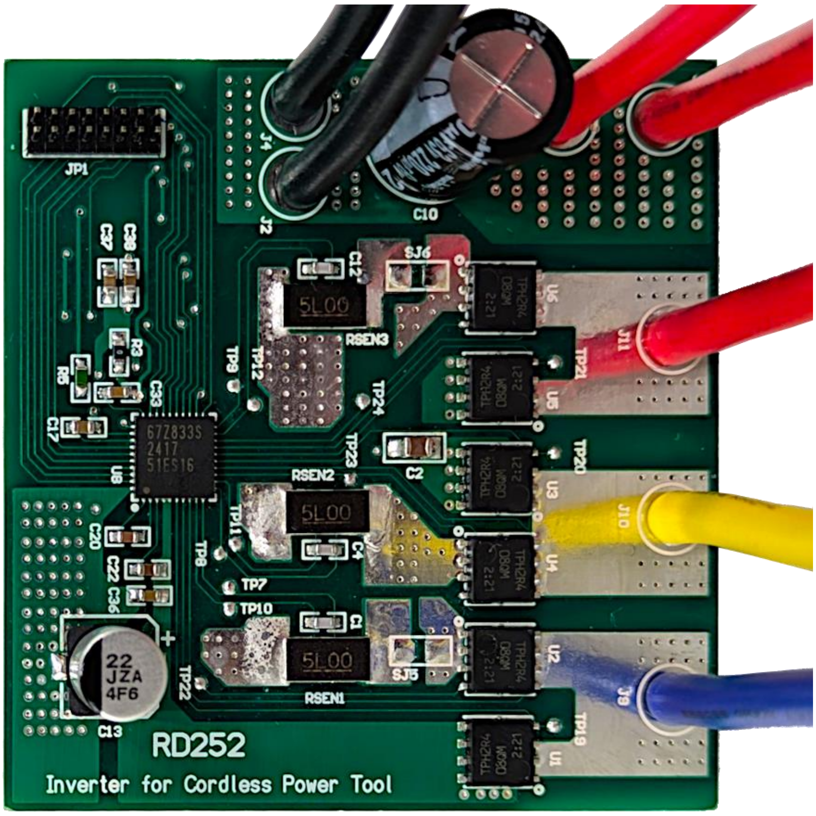


Fig. 2.2 Board of This Design (Top View)

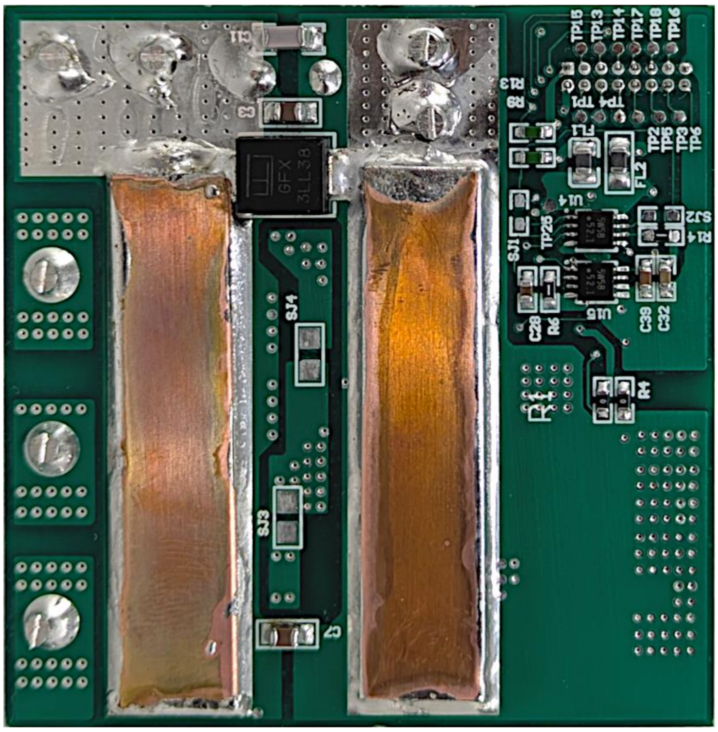


Fig. 2.3 Board of This Design (Bottom View)

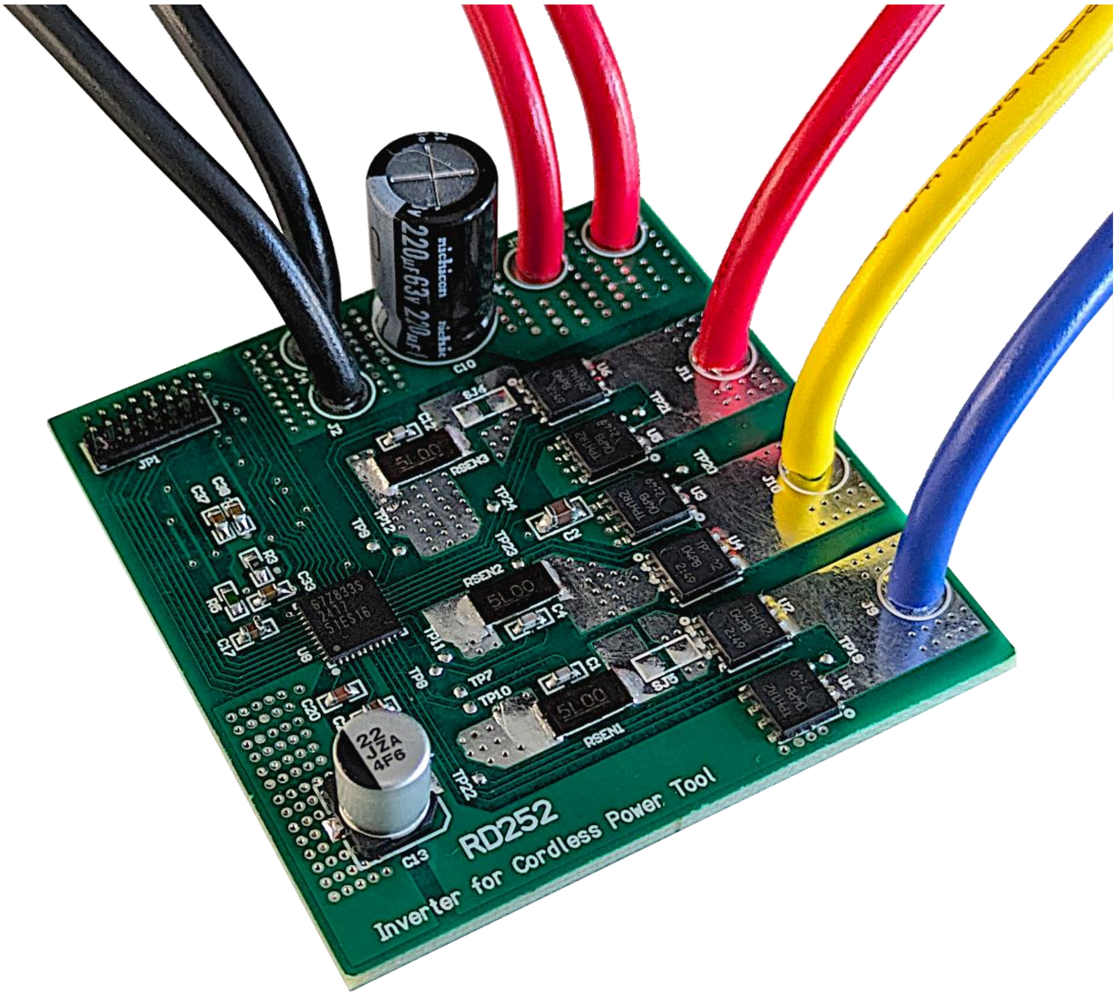


Fig. 2.4 Board of This Design (Side View)

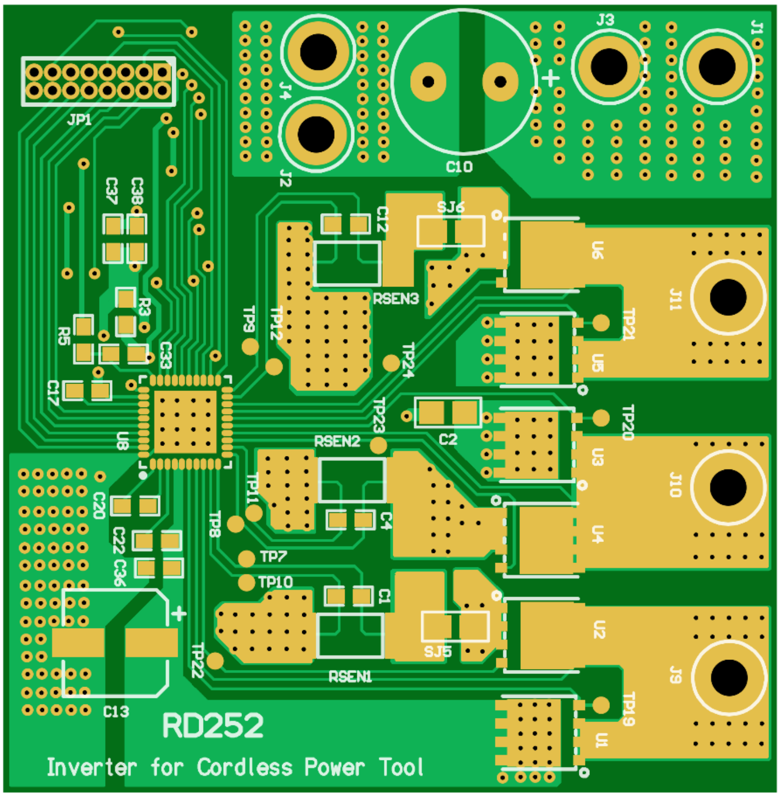


Fig. 2.5 Layout of Main Components (Top View)

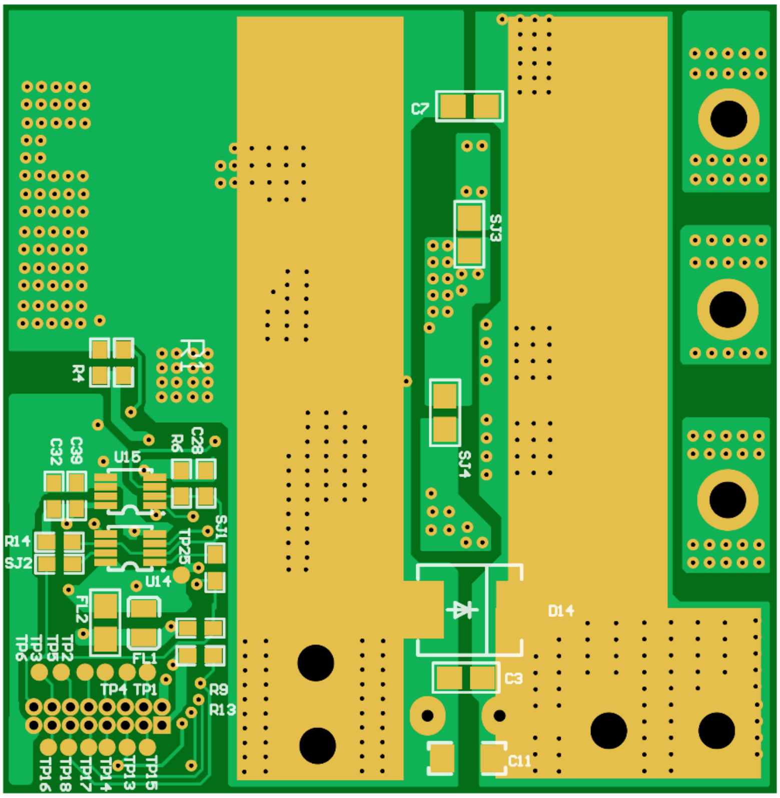


Fig. 2.6 Layout of Main Components (Bottom View)

3. Schematic, Bill of Materials, and PCB Pattern Diagram

3.1. Schematic

Refer to the following files.

Type1: RD252-SCHEMATIC1-xx.pdf

Type2: RD252-SCHEMATIC1-xx.pdf

(xx is the revision number.)

3.2. Bill of Materials

Refer to the following files.

Type1: RD252-BOM1-xx.pdf

Type2: RD252-BOM2-xx.pdf

(xx is the revision number.)

3.3. PCB Pattern Diagram

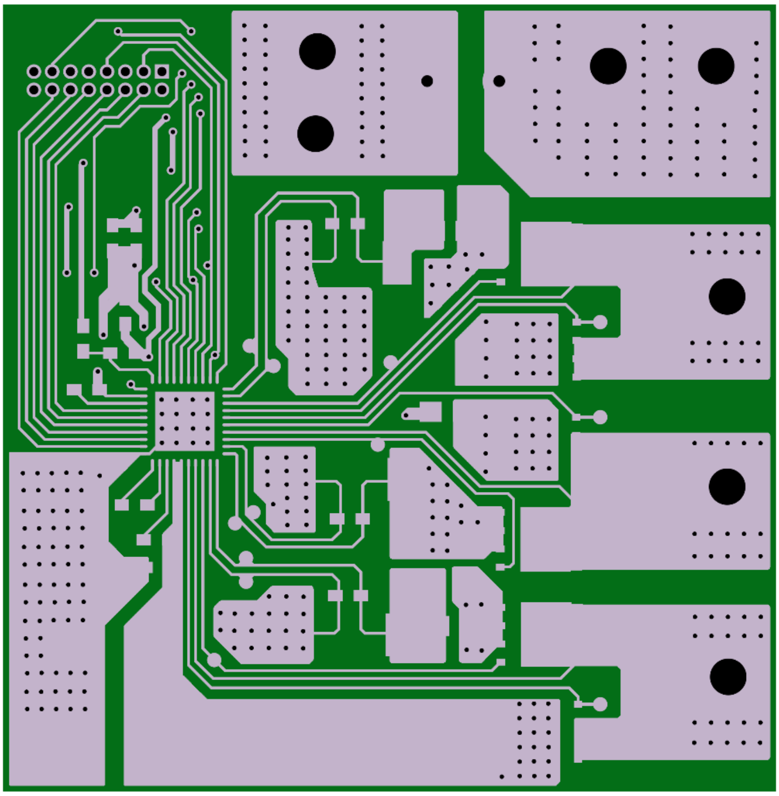
PCB pattern diagram of this design is shown in Fig. 3.1.

Refer to the following files.

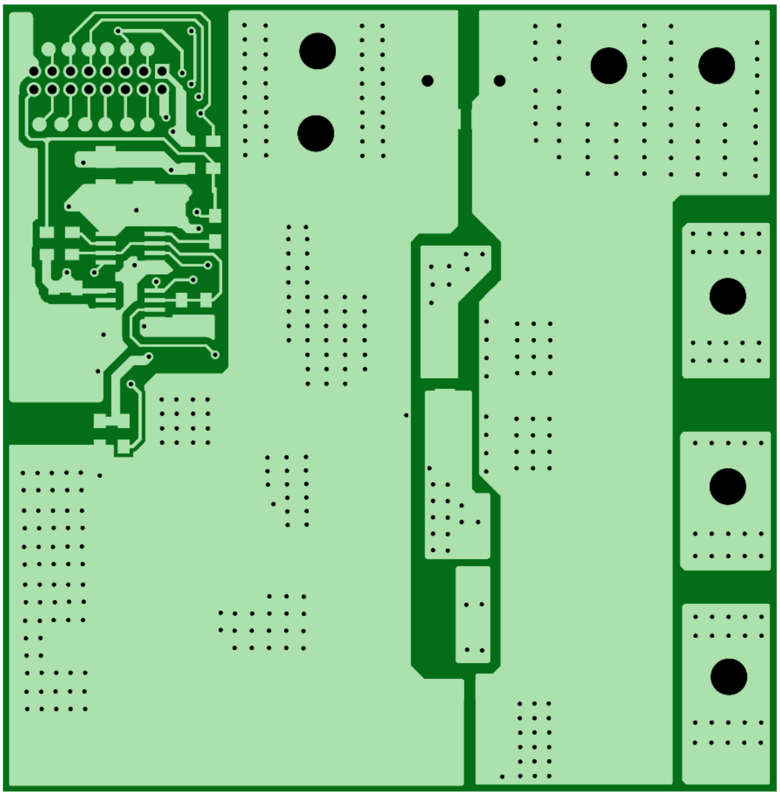
Type1: RD252-LAYER1-xx.pdf

Type2: RD252-LAYER2-xx.pdf

(xx is the revision number.)



<Layer 1>



<Layer 2>

Fig. 3.1 PCB Pattern Diagram (Top View)

4. Names and Functions of Components

4.1. Motor Connection (J9, J10, J11)

This section is used to connect all the three phases of the brushless motor. U phase is connected to J9, V phase is connected to J10, and W phase is connected to J11. Cables with sufficient rating must be used to allow the motor current flow with enough margin.

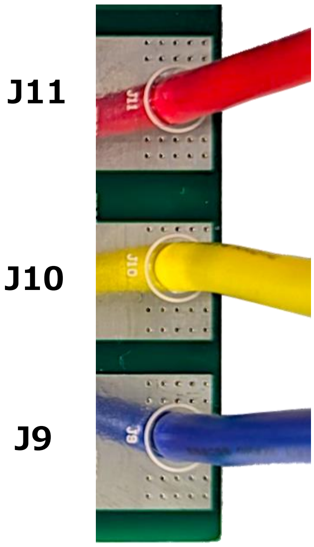


Fig. 4.1 Motor Connection

4.2. Power Connection (J1, J2, J3, J4)

This section is used to connect the DC power supply (VM). The positive of the power supply is connected to J1 and J3, and the negative (GND) of the power supply is connected to J2 and J4. Cables with sufficient rating must be used to allow the required current flow with enough margin.

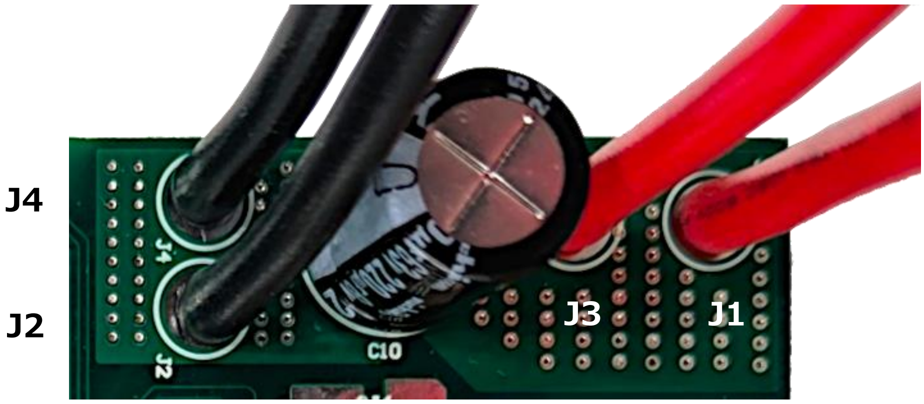


Fig. 4.2 Power Connection

4.3. External MCU Connector (JP1)

This connector is used to connect an external MCU for motor-control. M50-3500842 (Harwin) connector is being used. 5V power used in this design is also supplied through pin 1 of this connector.

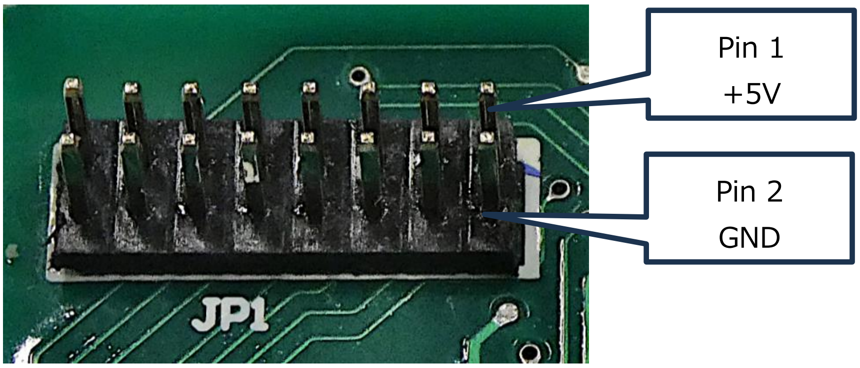


Fig. 4.3 External MCU Connector

Table 4.1 External MCU Connector Pins

No.	Name	I/O	Description
1	+5V	In	External 5V power (+)
2	GND	-	GND (External 5V Power (-))
3	AINB10	Out	Amplifier output (U-phase) (built-in TB67Z833SFTG)
4	U0	In	High-side gate control signal (U-phase)
5	AINB12	Out	Amplifier output (V-phase) (built-in TB67Z833SFTG)
6	X0	In	Low-side gate control signal (U-phase)
7	AINB11	Out	Amplifier output (W-phase) (built-in TB67Z833SFTG)
8	V0	In	High-side gate control signal (V-phase)
9	SDI	In	Serial communication data input
10	Y0	In	Low-side gate control signal (V-phase)
11	SDO	Out	Serial communication data output
12	W0	In	High-side gate control signal (W phase)
13	SCLK	In	Serial communication clock input
14	Z0	In	Low-side gate control signal (W phase)
15	AGND	-	Analog GND
16	EMG*	Out/In	Error detection signal / Serial communication chip select

*:Pin 16 (EMG) is shared between the ORed output of the overcurrent detection comparators and the fault signal of TB67Z833SFTG and the serial communication chip select input of TB67Z833SFTG. When the status of this pin is read from the external MCU, the status of the EMG signal can be checked. In addition, when Low is input to this pin from the external MCU, the SPI communication is enabled. Do not input High to this pin from the external MCU. If High is input to this pin, the power supply and GND may get short-circuited depending on the status of the EMG signal.

5. Operation

5.1. Start Procedure

The standard procedure for starting the motor in this design is described below.

- Connect brushless motor to J9, J10, J11.
- Connect VM power supply to J1 to J4.
- Connect external MCU and 5V power to JP1.
- Turn on the VM and 5V power supply.
- Perform SPI communication with TB67Z833SFTG and sets various registers.
- Drive the motor using the external MCU.

5.2. Stop procedure

The standard procedure for stopping the motor in this design is described below.

- Stop the motor using the external MCU.
- Turn off the VM and 5V power supply.

6. Precautions (To Prevent Electric Shocks, Burns, etc.)

Special attention must be paid to the following points when using this design.

- Make sure that the polarities of all connections are correct before supplying electricity.
- Make sure that the capacitor is sufficiently discharged before touching the BOARD.
- When checking the operation, cover the BOARD and motor with an acrylic case for safety.
- MOSFET and other components may generate heat during operation. Be careful not to get burned while handling them.

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