BLDC Motor Workshop
HT32F65532G BLDC-EVB_V1.0
Hardware Description

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Table of Contents

1. Introduction

The HT32F65532G_BLDC_EVB_V1.0 is shown in Figure 1-1. The framed part (1) in Figure 1-1 is the MOSFET inverter. The framed part (2) in Figure 1-1 is the 12V and 5V LDO output circuit. The framed part (3) in Figure 1-1 is the differential amplifier current sampling circuit. The framed part (4) in Figure 1-1 is the Hall sensor interface. The framed part (5) in Figure 1-1 is the VR variable resistor. The framed part (6) in Figure 1-1 is the Reset button. The framed part (7) in Figure 1-1 is the SWD programming interface. The framed part (8) in Figure 1-1 is the Motor Workshop communication interface. The framed part (9) in Figure 1-1 is the HT32F65532G device. The framed part (10) in Figure 1-1 is the MOSFET temperature feedback circuit.

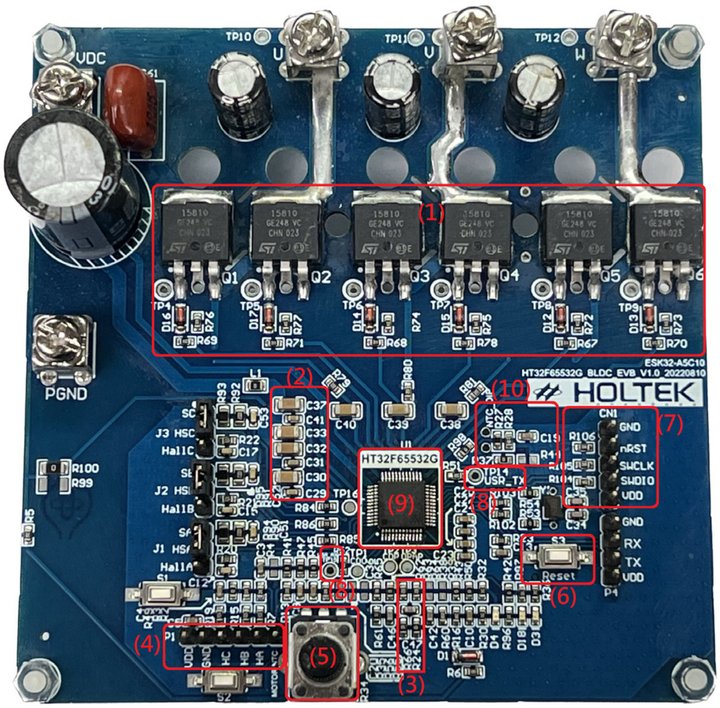


Figure 1-1 BLDC Motor Workshop HT32F65532G_BLDC_EVB Front View

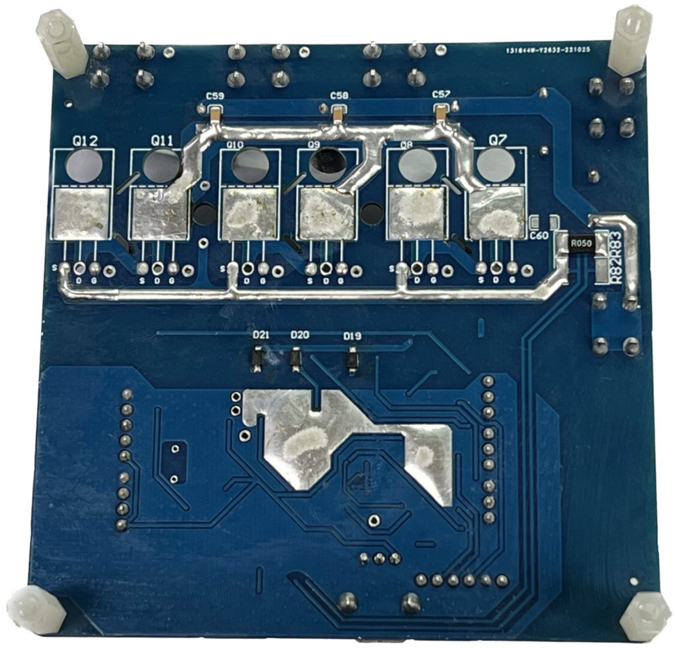


Figure 1-2 BLDC Motor Workshop HT32F65532G_BLDC_EVB Back View

The HT32F65532G_BLDC_EVB development environment is shown in Figure 1-3. The PC should be connected to the e-Link32 Pro via the USB port using a Mini USB cable. Then connect it to the HT32F65532G device using the e-Link32 Pro to allow the HT32F65532G device to communicate with the BLDC motor workshop. The input voltage range is DC 10V~32V.

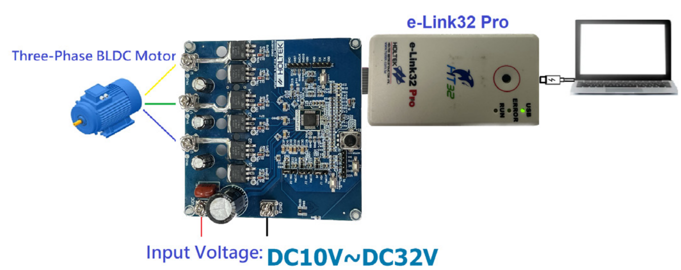


Figure 1-3 HT32F65532G_BLDC_EVB Development Environment

Features

- Input voltage: DC 10V~32V
- Maximum DC Bus current: 20A
- Maximum motor phase current: 22A
- R_Shunt (Phase): 0.05Ω/2512/1%/2W
- DC Bus voltage divider ratio: 1/16.00
- Gate-driver polarity:
  - Low side active low
  - High side active high

As the above features shows, the BLDC_EVB maximum motor phase current is 22A. For the phase current sampling OPA amplification setting as shown in Figure 1-4, the default hardware parameters are shown as follows:

(1) The BLDC_EVB R83 specification is 0.05Ω/2512/1%.

(2) The BLDC_EVB R24 and R66 specifications are 180Ω.

The BLDC_EVB R63 and R64 specifications are 820Ω.

The BLDC_EVB R60 specification is 7.5kΩ.

The BLDC_EVB R61 and R65 specifications are 15kΩ.

Under these hardware parameters, the maximum phase current under which the motor can operate is:

$$I_{MAX}=2.5V/(R\_Shunt \times OPA\ Gain)=2.5V/(0.05\Omega \times 7.5)=6.667A$$

If it is required to adjust the maximum motor operating phase current to 22A, the following actions are required:

(1) Change the BLDC_EVB R83 specification to 0.005Ω/2512/1%.

(2) Change the BLDC_EVB R63 and R64 specifications from 820Ω to 150Ω.

With these configurations, the BLDC_EVB maximum motor operating phase current can be changed from 6.667A to 22A. In addition, when the amplifier gain and R_Shunt are being determined, it should be noted that the motor operating phase current range must not be larger than the maximum sampling value of the motor phase current. If the motor operating phase current range is set too large, the resolution of the sampling current will be affected.

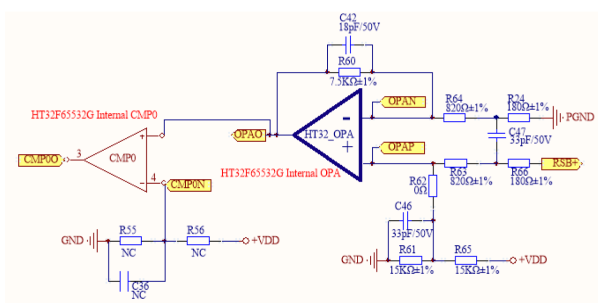


Figure 1-4 Phase Current Sampling OPA Amplification Setting

2. Schematics

This chapter will present the schematics and explain the HT32F65532G_BLDC_EVB_V1.0 hardware circuit as shown in sections from 2-1 to 2-12.

2-1 Gate-driver Circuit

Figure 2-1 shows the Gate-driver circuit, which uses the N-N half-bridge bootstrap driver. It has an integrated bootstrap diode and three external 2.2µF bootstrap capacitors to drive the MOSFETs. It also contains an internal 12V LDO for the Gate-driver circuit power supply as well as an internal 5V LDO for the MCU circuit power supply. The current drive capacity is 700mA for the source and 1000mA for the base. The Gate-driver circuit provides various protection functions, such as over temperature protection, VCC under voltage protection, VBST under voltage protection, 12V LDO under voltage protection and 5V LDO under voltage protection.

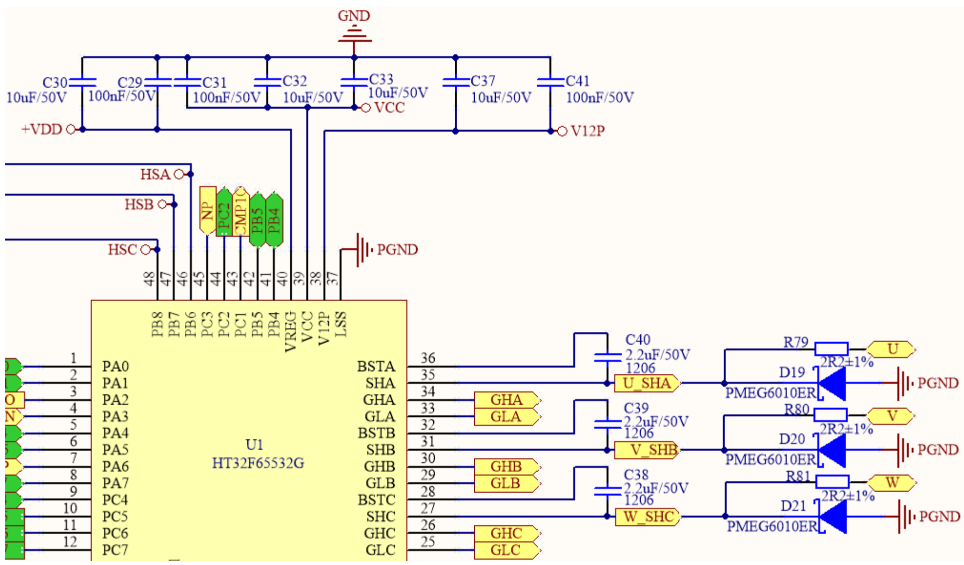


Figure 2-1 Gate-driver Circuit

2-2 Inverter Circuit

Figure 2-2 shows the inverter circuit, in which the switching component model is the STB15810, the component specifications of which, are shown in Table 2-1. The MOSFET drive capability can be adjusted by the rising and falling time, which is implemented using the gate resistor and the diode. The R_Shunt resistors are used to feedback the value of the amplified motor phase current signals using the OPA and to the MCU for FOC closed-loop control. The hardware default values of these resistors are 0.05Ω/2512. Users should pay attention to the component rated power to ensure that they are above 2W if they wish to change the resistance value.

Item	Value
V_{ds}	100V
$R_{ds(on).max}$ @ V_{GS}=10V	3.9mΩ
I_d	110A
Q_g	117nC

Table 2-1 STB15810 Specifications

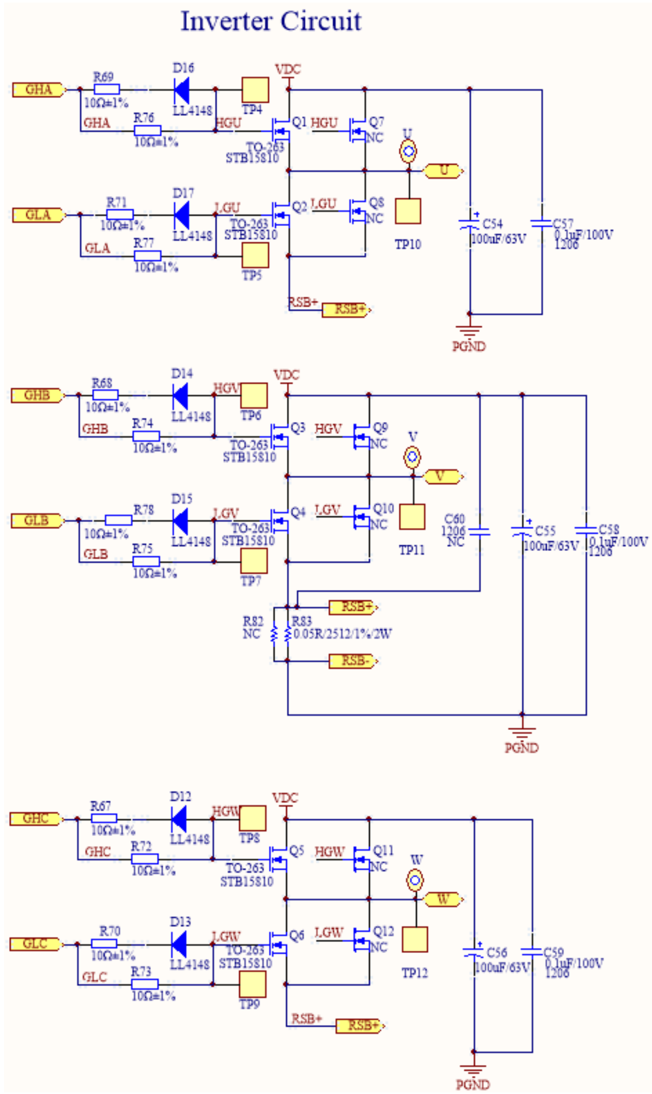


Figure 2-2 Inverter Circuit

2-3 Over Current Circuit and External Setting Over Current Resistor

Figure 2-3 shows the over current circuit and the external over current setting resistor. The voltage on the R_Shunt is input to the internal OPA through a low-pass filter, to set the over current threshold. The hardware external over current setting can also be implemented using the external components R55, R56 and C36.

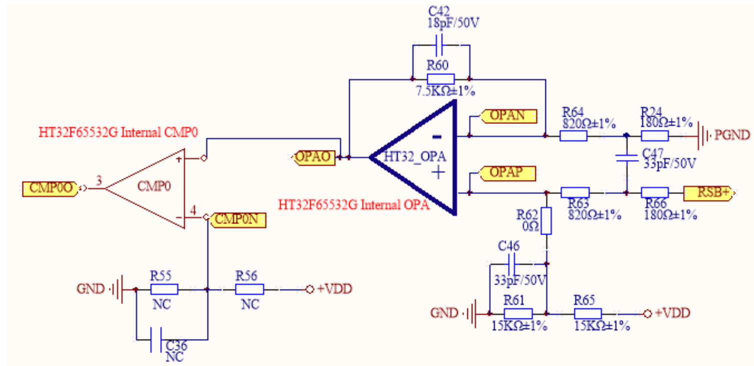


Figure 2-3 Over Current Circuit and External Setting Over Current Resistor

2-4 MOSFET Temperature Feedback Circuit

Figure 2-4 shows the MOSFET temperature feedback circuit. Its NTC type is the NTCG163JF103FT1, which has a negative temperature coefficient resistor with a B value of 3380K±1%. The signals can be read by the MCU ADC to calculate the current NTC resistance. Then the B value can be used to calculate the current MOSFET temperature. R27 is supplied in an SMD 0603 package. If the temperature function is required, the NTC placement should be located close to the MOSFET, the R27 SMD can be removed and replaced with a plug-in NTC resistor. The NTC can be located closer to the heat source using the pin of NTC itself, and the pin of NTC can be soldered to the NTC_DIP through-hole, as shown in Figure 2-5.

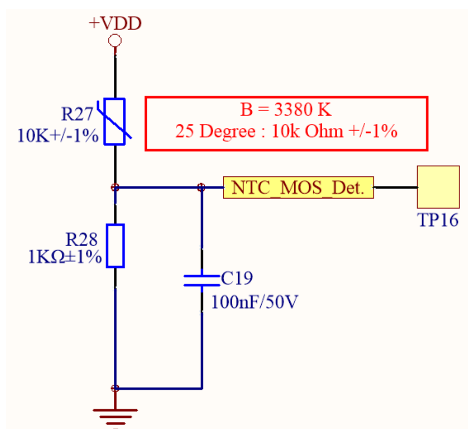


Figure 2-4 MOSFET Temperature Feedback Circuit

Figure 2-5 Actual Component Layout and NTC_DIP Position

2-5 VDC Voltage Feedback Circuit

Figure 2-6 shows the VDC voltage feedback circuit. In the hardware design, the ratio of the V_{DC_DET}. feedback signal and the actual VDC voltage is 1/16 by default. The current VDC voltage can be calculated by the voltage, which is read from the MCU together with the hardware default reduction ratio.

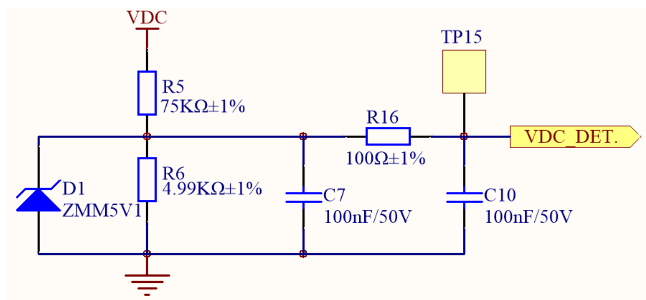


Figure 2-6 DC Voltage Feedback Circuit

2-6 Hall Sensor Feedback Circuit and Motor NTC Temperature Circuit

Figure 2-7 shows the Hall sensor feedback circuit and the motor NTC temperature circuit. If the motor has a Hall sensor, three Hall signals can be connected to Pin3~Pin5 in the P1 header. The signals will be pulled high to $+V_{DD}$ using the pull-up resistor and then be input to the MCU for commutation signal processing through a low-pass filter. If the motor contains a fully integrated NTC resistor, the NTC resistance value will decrease as the ambient temperature increases. Determining whether the current motor internal temperature is normal, can be obtained by the voltage division relationship between R2 and the NTC resistance values. The motor over temperature protection threshold can be configured to turn off the PWM output to stop the motor. Refer to the temperature and impedance curve in the NTC specification.

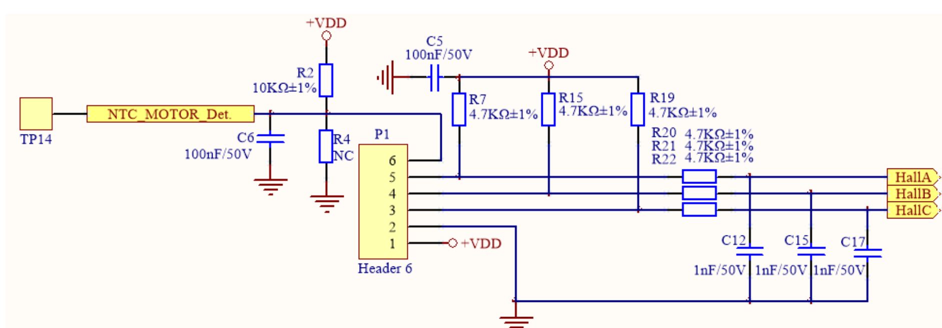


Figure 2-7 Hall Sensor Feedback Circuit

2-7 VR Variable Resistor Circuit

Figure 2-8 shows the VR variable resistor circuit, which transmits the VR divider voltage to the MCU ADC through a low-pass filter. In practical applications, it can be used for motor speed control to implement the human-machine interface function.

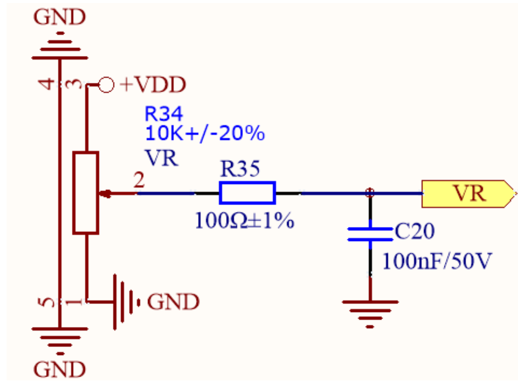


Figure 2-8 VR Variable Resistor Circuit

2-8 Sensorless and Hall Sensor Jumper Settings

Figure 2-9 shows the Sensorless and Hall sensor jumper settings. When the Hall signals, HallA, HallB and HallC, are selected, Pin2 and Pin3 can be short-circuited using the external J1, J2, J3 jumpers. If the sensorless signals, SA, SB, or SC, are selected, Pin1 and Pin2 can be short-circuited using the external J1, J2, and J3 jumpers. The hardware defaults are Sensorless, as shown in Figure 2-10.

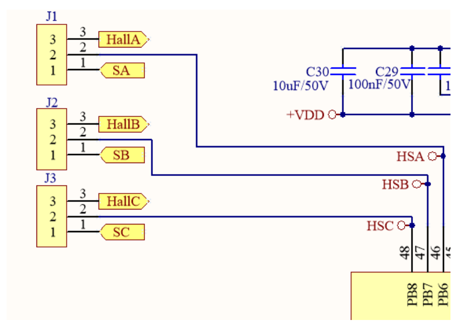


Figure 2-9 Sensorless and Hall Sensor Jumper Settings

Figure 2-10 Actual Component Layout and J1, J2, and J3 Jumper Hardware Default

2-9 Programming Interface and Motor Workshop Communication Connection

Check whether the HT32F65532G_BLDC_EVB hardware connection is setup properly. As shown in Figure 2-11, there are three points to check. The first is the e-Link32 Pro connection, the second is the motor connection and the third is the input power connection.

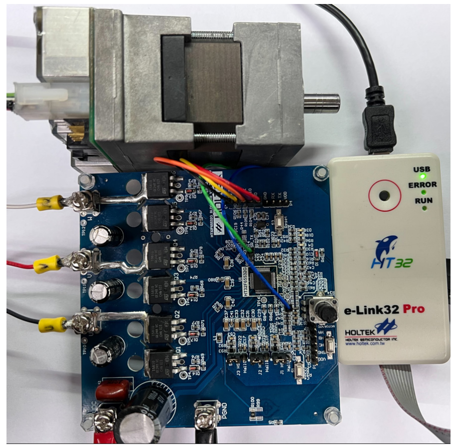
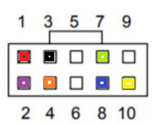


Figure 2-11 Check HT32F65532G_BLDC_EVB Hardware Connection Setup

As shown in Figure 2-11, the HT32F65532G_BLDC_EVB connects the square motor three-phase lines, black, red and white to the U, V and W terminals respectively, and then connects the Mini USB cable to the PC USB port. Connect the e-Link32 Pro output port to the HT32F65532G_BLDC_EVB CN1 header by connecting the header to the Dupont Line, as shown in Figure 2-12, Figure 2-13 and Figure 2-14. The connections for the CN1 header are 5V in red, SWDIO in purple, SWCLK in orange, nRST in yellow and GND in black from bottom to top. The e-Link32 Pro output port Pin8 TXD is connected to the on-board TP15_USR_RX using the blue line. The e-Link32 Pro output port Pin7 RXD is connected to the on-board TP14_USR_TX using the green line. The 24V power supply is connected to the VDC and PGND screw terminals. After this has been implemented, the hardware connection setup is complete, as shown in Figure 2-11.



Pin#	Description	Pin#	Description
1	5V	2	SWDIO
3	GND	4	SWCLK
5	GND	6	Reserved
7	NC (VCOM_RXD(Note))	8	NC (VCOM_TXD(Note))
9	GND	10	Reset

Figure 2-12 e-Link32 Pro Pin Definition

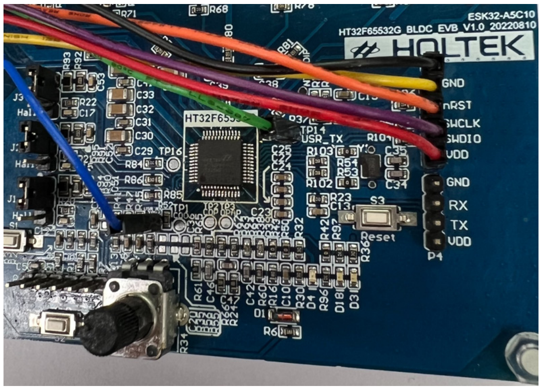


Figure 2-13 Connection Colour Reference from HT32F65532G_BLDC_EVB Header to Dupont Line

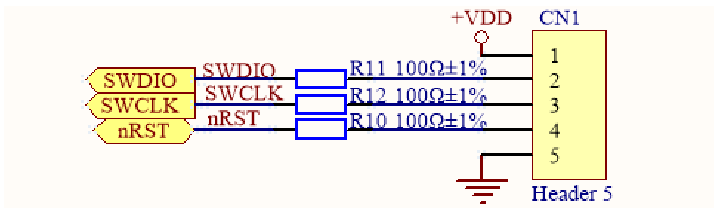


Figure 2-14 CN1 Pin Definition

2-10 LDO Dropping Resistors

As shown in Figure 2-15, the hardware defaults R99 as NC and R100 as 0Ω. If the input voltage exceeds 30V, it is recommended to adjust appropriate resistance values for R99 and R100 to reduce the 12V LDO input voltage and allow the MCU temperature to operate within a reasonable range.

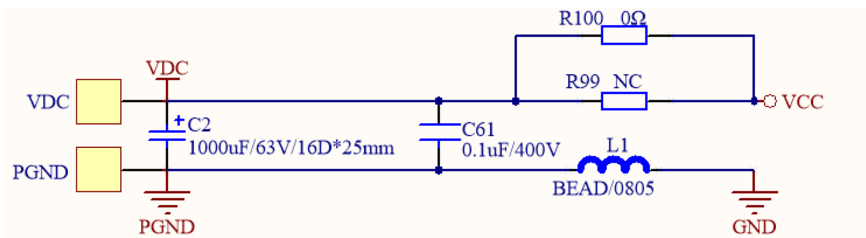


Figure 2-15 R99 and R100 Dropping Resistors

2-11 Back EMF Detection Circuit

Figure 2-16 shows the Back EMF detection circuit which is used to detect the motor phase voltage. It is recommended that the voltage after division should not exceed 4V. The resistance values of the divided voltage points to ground of R90, R91 and R92 are fixed at 10kΩ. Assuming that the highest input voltage is 32V, the resistance of the divided voltage point to the phase voltage will be 75kΩ. The divided voltage can be calculated as follows:

$$32V\times[10k\Omega/(10k\Omega+75k\Omega)]=3.76V$$

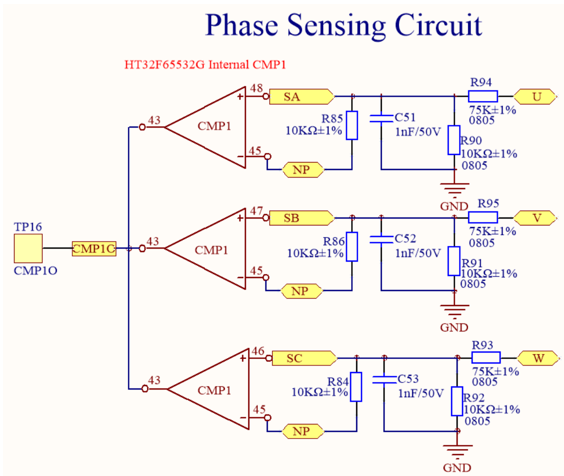


Figure 2-16 Back EMF Detection Circuit

2-12 Other Peripheral Functions

As shown in Figure 2-17, PB13 and PB14 can be used to connect to an external 8MHz crystal oscillator. PA5 and PC6 can be used to drive LEDs. PB4 and PB5 can be defined as button functions. PB10 and PB11 can be used for communication transmission.

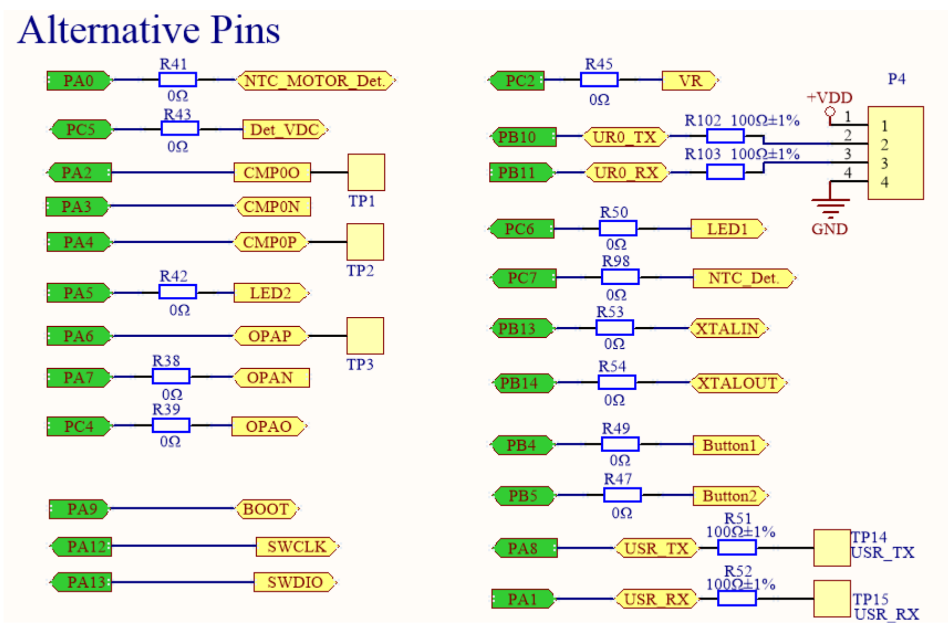


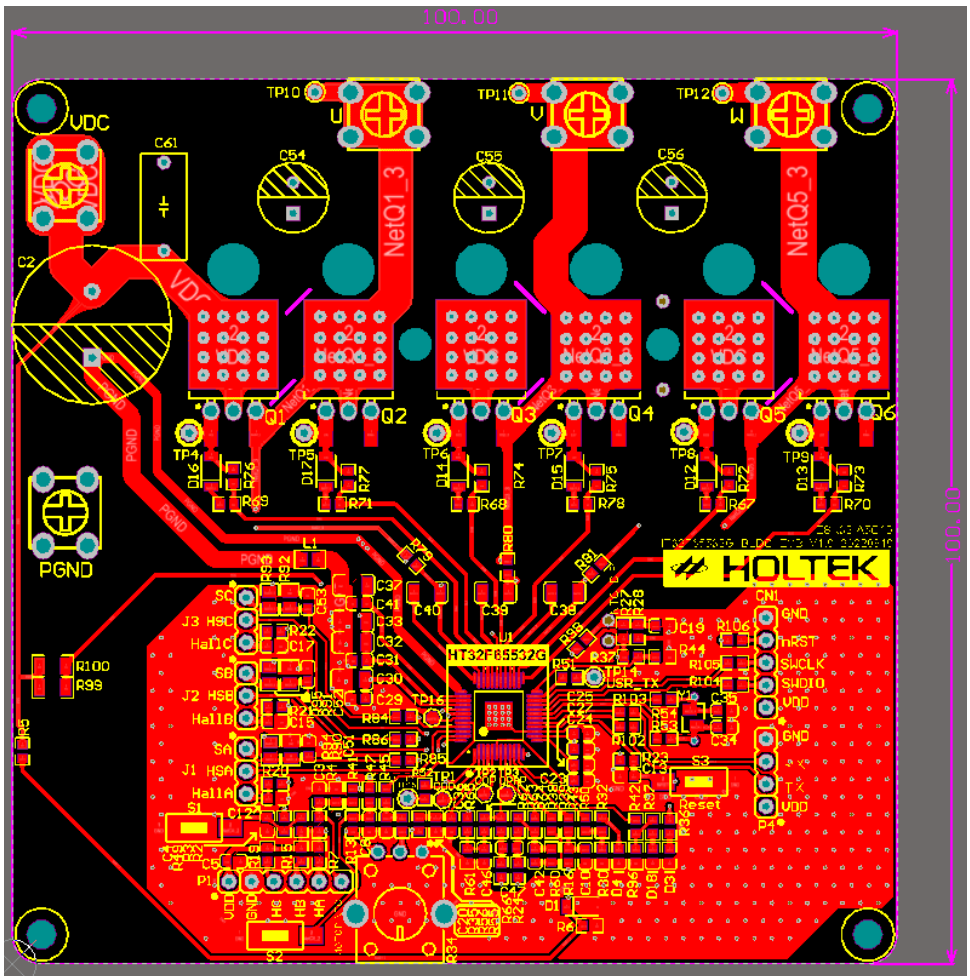
Figure 2-17 Other Peripheral Functions

3. PCB Layout

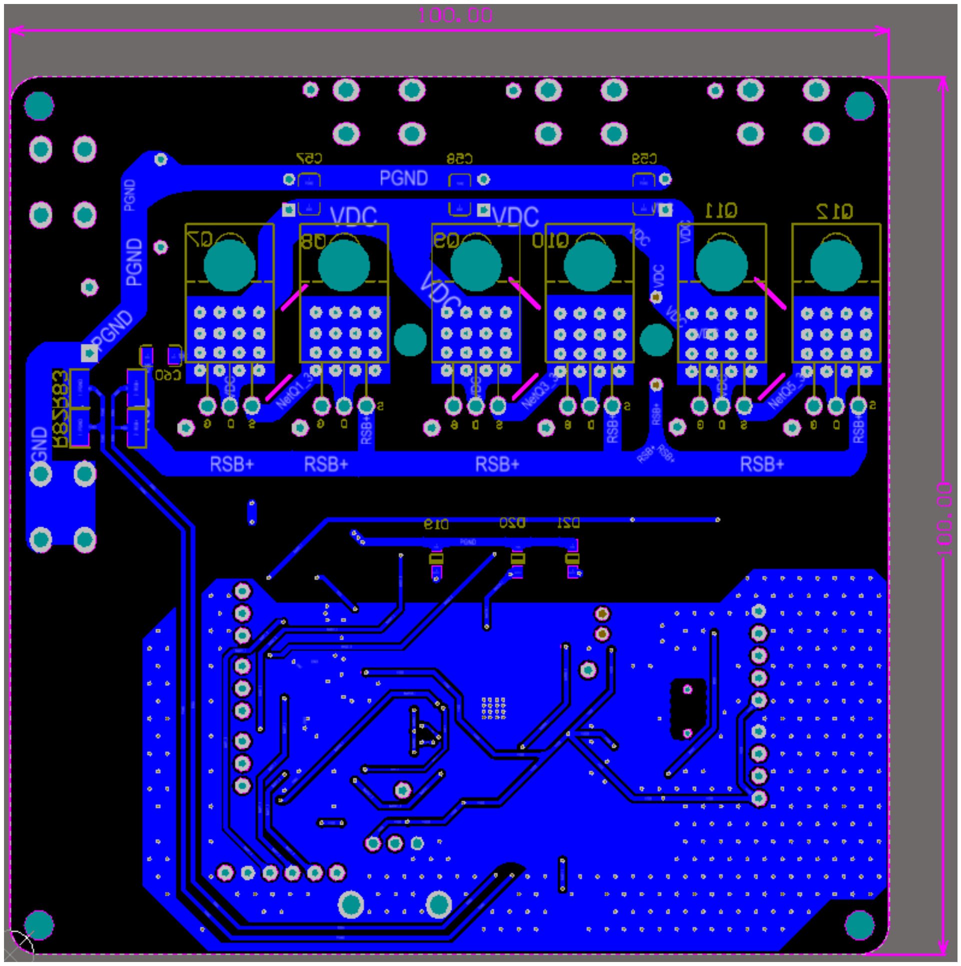
Figure 3-1 shows the HT32F65532G_BLDC_EVB_V1.0 PCB layout, the detailed specifications of which are shown in Table 3-1.

Length×Width	100×100 (mm)
Thickness	1.6 (mm)
Number of Layers	2 (layers)
Copper Foil Thickness	2 (Oz)
Material	FR-4
Solder Mask Layer Colour	Blue

Table 3-1 HT32F65532G_BLDC_EVB Circuit Board Specifications



(a) Top Layer



(b) Bottom Layer

Figure 3-1 BLDC Motor Workshop HT32F65532G_BLDC_EVB PCB Layout

4. BOM List

Table 4-1 shows the HT32F65532G_BLDC_EVB_V1.0 BOM list, which shows all the circuit board required components.

Comment	Description	Designator	Quantity	Footprint
1000μF/63V	Polarized Capacitor (Radial)	C2	1	CAP_16DX25H_P7.5
100nF/50V	Capacitor MLCC	C3, C4, C5, C8, C10, C13, C19, C20, C23, C27, C29, C31, C41	13	0603_C
1nF/50V	Capacitor MLCC	C12, C15, C17, C51, C52, C53	6	0603_C
2.2μF/16V	Capacitor MLCC	C24, C25	2	0603_C
10μF/50V	Capacitor MLCC	C30, C32, C33, C37	4	1206_C
12pF/50V	Capacitor MLCC	C34, C35	2	0603_C
NC	Capacitor MLCC	C36	1	0603_C
2.2μF/50V	Capacitor MLCC	C38, C39, C40	3	1206_C
18pF/50V	Capacitor MLCC	C42	1	0603_C
33pF/50V	Capacitor MLCC	C46, C47	2	0603_C
100μF/63V	Polarized Capacitor (Radial)	C54, C55, C56	3	CAP_8D*16H_P3.5
0.1μF/100V	Capacitor MLCC	C57, C58, C59	3	1206_C
NC	Capacitor MLCC	C60	1	1206_C
0.1μF/400V	CBB Capacitor	C61	1	CAP_12X5.2_V_P10
Single-row Header (1×5-pin, Pitch2.54mm, 180 degree)	Header, 5-pin, Pitch=2.54mm	CN1	1	Header_1X5P
ZMM5V1	Zener Diode	D1	1	LL-34
0603 Green LED	SMD Green LED	D3, D18	2	0603_LED
0603 Red LED	SMD Red LED	D4	1	0603_LED
LL4148	Diode	D12, D13, D14, D15, D16, D17	6	LL-34
Single-row Header (1×3-pin, Pitch2.54mm, 180 degree)	Header, 3-pin, Pitch=2.54mm	J1, J2, J3	3	HEADER_1X3P
BEAD/0805	SMD Bead	L1	1	0805_L
Single-row Header (1×6-pin, Pitch2.54mm, 180 degree)	Header, 6-pin, Pitch=2.54mm	P1	1	HEADER_1X6P
Single-row Header (1×4-pin, Pitch2.54mm, 180 degree)	Header, 4-pin, Pitch=2.54mm	P4	1	HEADER_1X4P
STB15810	N-Channel MOSFET	Q1, Q2, Q3, Q4, Q5, Q6	6	D2PAK
NC	N-Channel MOSFET	Q7, Q8, Q9, Q10, Q11, Q12	6	TO-220_H
PMEG6010ER	Schottky Diode	D19, D20, D21	3	SOD-123W
2R2±1%	SMD Resistor	R79, R80, R81	3	0603_R
10kΩ±1%	SMD Resistor	R2, R30, R32, R36, R84, R85, R86, R96, R97	9	0603_R
100kΩ±1%	SMD Resistor	R3, R13, R23	3	0603_R
NC	SMD Resistor	R4, R38, R39, R44, R55, R56	6	0603_R
75kΩ±1%	SMD Resistor	R5	1	0603_R
4.99kΩ±1%	SMD Resistor	R6	1	0603_R
4.7kΩ±1%	SMD Resistor	R7, R15, R19, R20, R21, R22	6	0603_R
100Ω±1%	SMD Resistor	R16, R35, R51, R52, R102, R103, R104, R105, R106	9	0603_R

Comment	Description	Designator	Quantity	Footprint
180Ω±1%	SMD Resistor	R24, R66	2	0603_R
10kΩ±1%, NTC	SMD NTC Resistor	R27	1	0603_R
1kΩ±1%	SMD Resistor	R28	1	0603_R
Plug-in Variable Resistor, 10 kΩ, (RK09K1130A5R)	Plug-in Variable Resistor, VR	R34	1	DIP Plug-in
0Ω±1%	SMD Resistor	R37, R38, R39, R41, R42, R43, R45, R47, R49, R50, R53, R54, R62, R98	14	0603_R
7.5kΩ±1%	SMD Resistor	R60	1	0603_R
15kΩ±1%	SMD Resistor	R61, R65	2	0603_R
820Ω±1%	SMD Resistor	R63, R64	2	0603_R
10Ω±1%	SMD Resistor	R67, R68, R69, R70, R71, R72, R73, R74, R75, R76, R77, R78	12	0603_R
NC	SMD Resistor	R82	1	2512_R
0.05R/2512/1%/2W	SMD Resistor	R83	1	2512_R
75kΩ±1%	SMD Resistor	R93, R94, R95	3	0805_R
10kΩ±1%	SMD Resistor	R90, R91, R92	3	0805_R
NC	SMD Resistor	R99	1	1206_R
0Ω±1%	SMD Resistor	R100	1	1206_R
UK-B0240G25-SP25Y	SMD Button	S1, S2, S3	3	SMD Button
Header (1-pin, 180 degree)	HEADER_1X1P	TP14, TP15	2	TP_1mm_via hole
Screw Locked GD-G14 Terminal (including screws), (4-pin/DIP)	Screw Seat	U, V, W, VDC, PGND	5	Screw Seat
HT32F65532G	32-bit MCU	U1	1	LQFP48_EP
SMD Crystal, 8MHz, 1ZCM08000EK0A	SMD Oscillator	Y1	1	SMD-5032_2P

Table 4-1 BLDC Motor Workshop HT32F65532G_BLDC_EVB BOM List