BLDC Motor Workshop – MVPB-A Hardware Description

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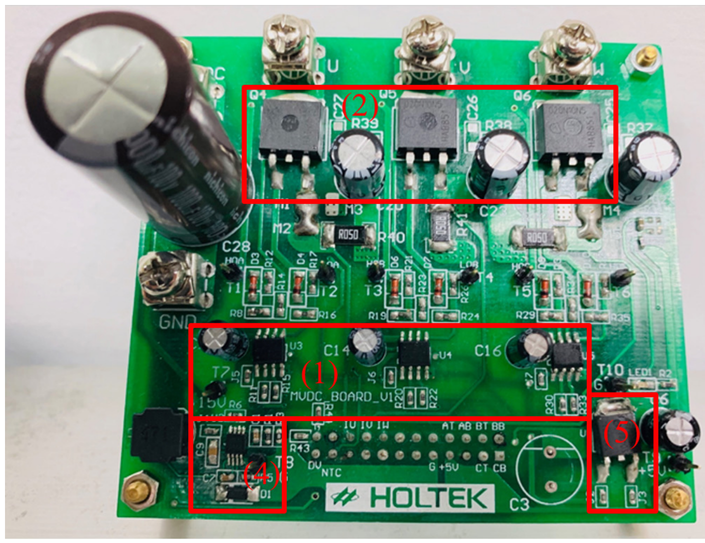
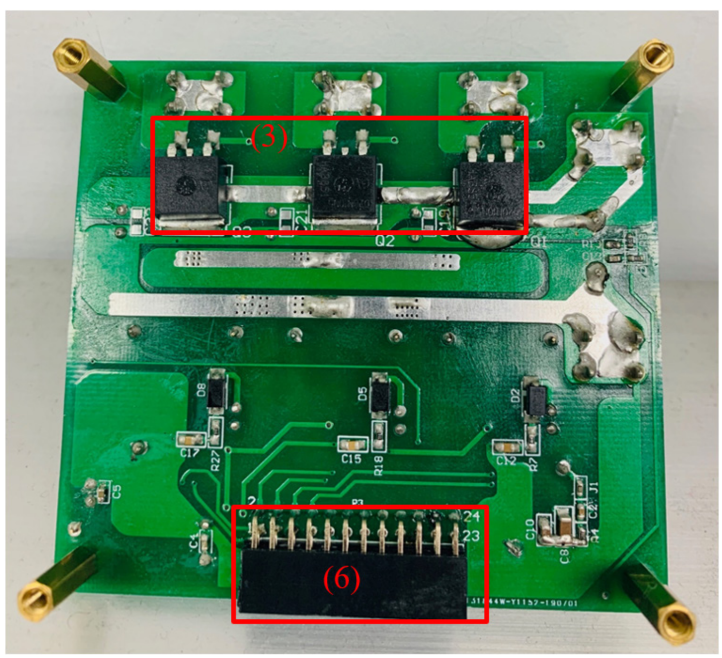
1. Introduction

The BLDC Motor Workshop MVPB-A is shown in Figure 1-1. The framed part (1) in Figure 1-1(a) is the gate driver circuit. The framed part (2) in Figure 1-1(a) is the low side MOSFET switching components while the framed part (3) in Figure 1-1(b) is the high side MOSFET switching components. The framed part (4) in Figure 1-1(a) is the DC-DC power converter circuit and the framed part (5) in Figure 1-1(a) is the 5V LDO circuit. The connector between MVPB-A and FOC-EVB is shown in the framed part (6) in Figure 1-1(b). In addition, the MVPB-A includes the VDC voltage feedback circuit and MOSFET temperature feedback circuit, users can use the MCU peripheral ADC pins, ADC1-IN3 and ADC1-IN6, to read the signals.



(a)



(b)

Figure 1-1 BLDC Motor Workshop MVPB-A

The MVPB-A development environment is shown in Figure 1-2. Users should connect the MVPB-A with FOC-EVB, and connect the EV board to PC through a USB cable simultaneously, allowing the target MCU to communicate with the BLDC motor workshop. The input voltage range is DC 10V~60V.

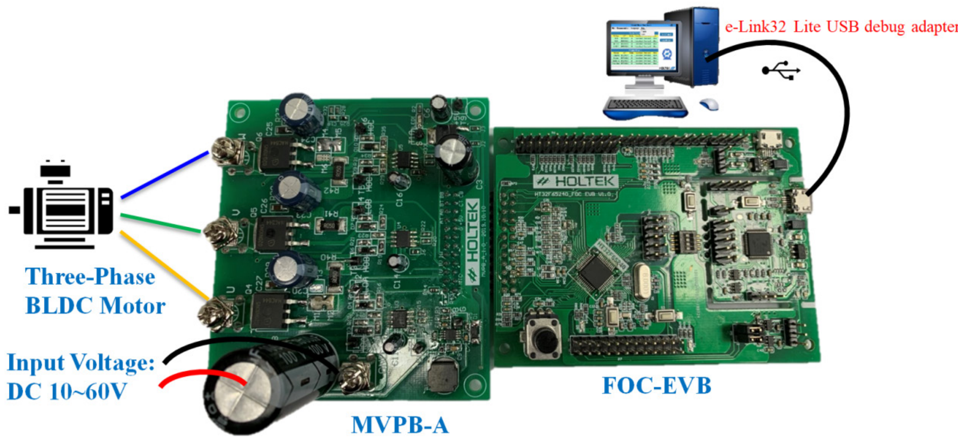


Figure 1-2 MVPB-A Development Environment

Feature

- Input voltage: DC10V~60V
- Max. DC Bus current: 20A
- Max. motor phase current: 20.0A
- R_Shunt(Phase): 0.05Ω/2512/1%
- DC Bus Voltage Divider Ratio: 1/16.00
- Gate-Driver Polarity:
  - ♦ Low side active low
  - ♦ High side active high

As the above feature shows, the MVPB-A maximum motor phase current is 20A. However, the default hardware parameters are shown as follows:

(1) The MVPB-A R40, R41 and R42 R_shunt specifications are all 0.05Ω/2512/1%.

(2) The FOC-EVB R11 and R12 specifications are both 7.5kΩ/0603/1%.

(3) The FOC-EVB R26, R27, R29 and R30 specifications are all 15kΩ/0603/1%.

Under these hardware parameters, the maximum motor operating current is:

$$I(\text{motor max current}) = 2.3/(R\_shunt \times OPA\ Gain) = 2.3/(0.05 \times 7.5) = 6.1A.$$

If users want to adjust the maximum motor operating current to 20A, the following actions are required:

(1) Change the MVPB-A R40, R41 and R42 specifications to 0.005Ω/2512/1%.

(2) Change the FOC-EVB R15, R16, R19 and R22 specifications from 820Ω/0603/1% to 150Ω/0603/1%.

With these configurations, the MVPB-A maximum motor operating current will be changed from 6.1A to 20A.

2. Schematics

This section will present the schematics and explain the MVPB-A hardware circuit as shown in chapters from 2-1 to 2-7.

2-1 Gate Driver Circuit

Figure 2-1 shows the gate driver circuit, which utilises the half-bridge bootstrap driver IR2103. For polarity, the high side active level is high while the low side active level is low. Taking the Phase-A gate driver, U3, as an example, the R3 together with D3, R16 together with D4 components are used to accelerate the turn-off action of the switching components. In addition, the jumper resistors, J5, J6 and J7, are used to connect to the gate driver VCC pin, which can supply power to gate driver separately during the hardware function testing. Users can use an oscilloscope to observed the input and output signals and verify if the function operates normally.

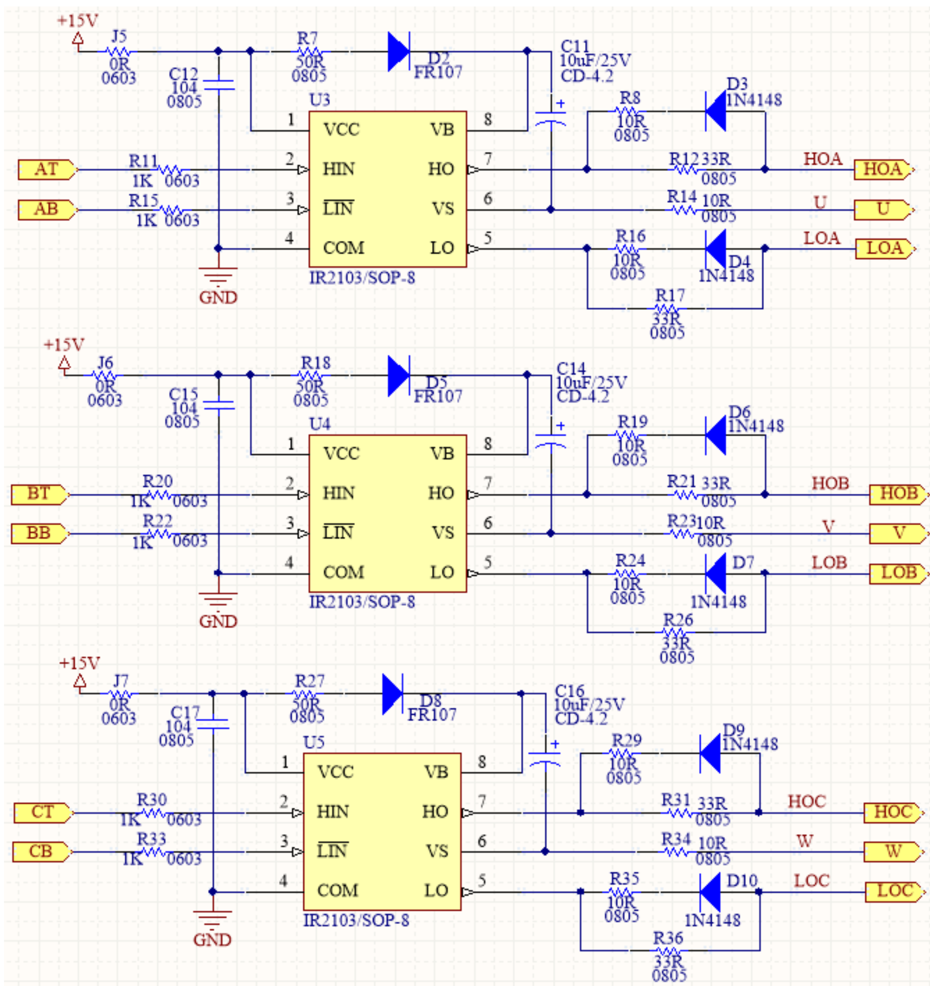


Figure 2-1 Gate Driver Circuit

2-2 Inverter Circuit

Figure 2-2 shows the inverter circuit, in which the switching component model is IPB020N10N5, the component specifications of which are shown in Table 2-1. For jumper pads, to select three R_Shunts feedback motor current, the source electrode of the low side MOSFETs should be connected to the shunt resistors, that is, M1 should be shorted to M2 and M4 should be shorted to M5. The Shunt resistors are used to feedback motor phase current signals to MCU for FOC closed-loop control, and also feedback to MCU internal comparators for three phase over current protection. The hardware default value of these resistors are 0.05Ω/2512. Users should pay attention that the component rated power is 2W if they want to change the resistance.

Item	Value
Vds	100V
Rds(on).max	2.0mΩ
Id	176A
Qg	168nC

Table 2-1 IPB020N10N5 Specifications

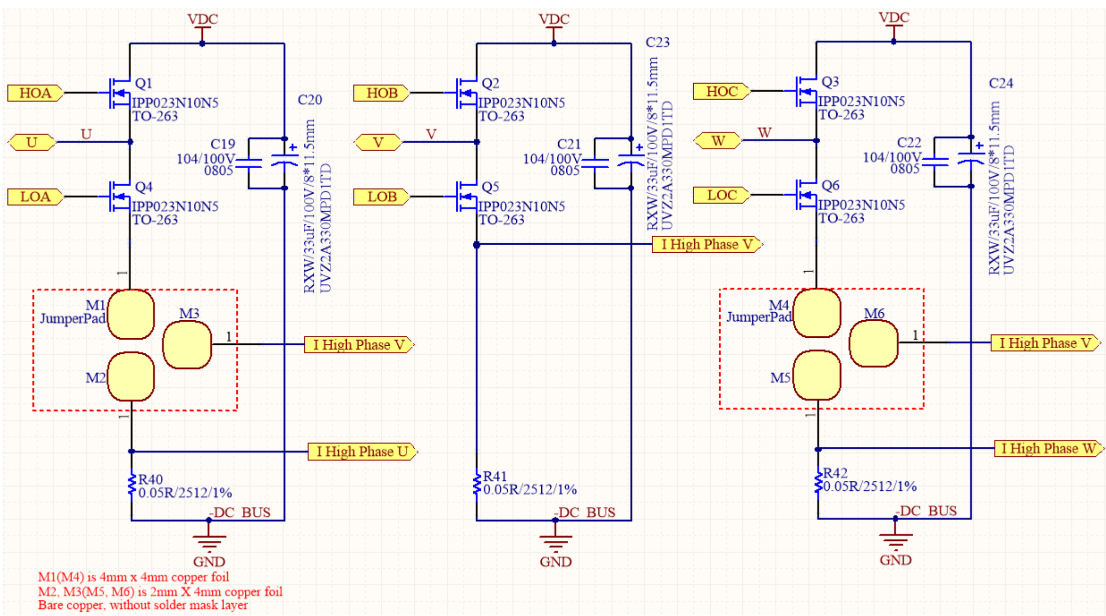


Figure 2-2 Inverter Circuit

2-3 DC-DC Power Converter Circuit

Figure 2-3 shows the DC-DC power converter circuit, in which the adopted component is the buck switching regulator LM5008. The circuit output is mainly used for gate driver power supply, the specifications of which are shown in Table 2-2. The hardware default value of the DC-DC power converter output voltage is 15V. When Vo=15V, the maximum output current is 0.3A. If the input voltage is lower than 10V, the power converter components can not operate normally.

Item	Value
Vo default value	15V
Io.max | (Vo=15V)	0.3A
Range of Vi	10~72V

Table 2-2 DC-DC Power Converter Specifications

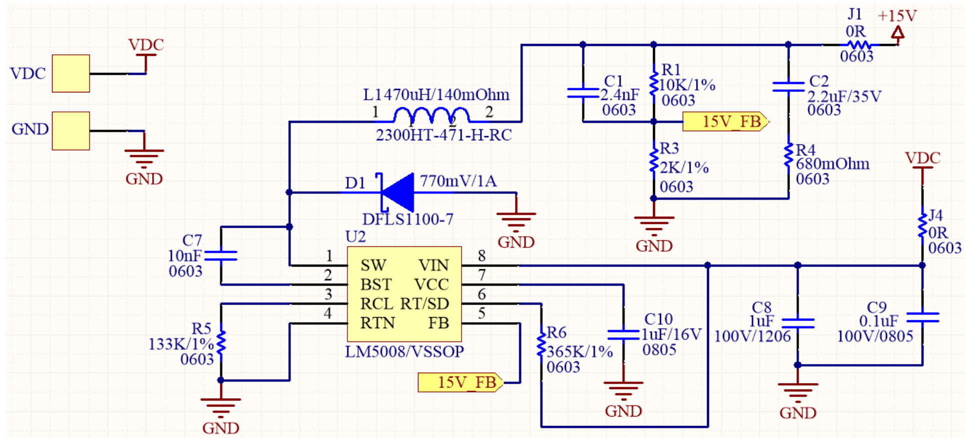


Figure 2-3 DC-DC Power Converter Circuit

2-4 LDO Circuit

Figure 2-4 shows the 5V LDO circuit, in which the LDO model is 7805. The circuit output is used for MCU component power supply by being connected to the FOC-EVB through the connector P3. Users can check the LED1 to determine if the MVPB-A circuit supplies power to the EV board successfully.

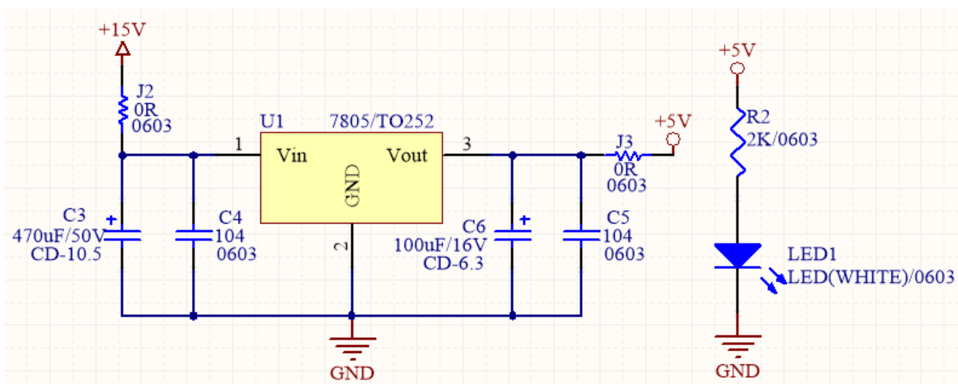


Figure 2-4 LDO Circuit

2-5 MOSFET Temperature Feedback Circuit

Figure 2-5 shows the MOSFET temperature feedback circuit. The NTC placement should be close to the MOSFET in hardware circuit design. In this circuit, the NTC component model is B57343V5103F360, which is a negative temperature coefficient resistor with a B value of 3624K. Users can read the signals by the MCU ADC1-IN6 pin to calculate the current NTC resistance, and then use the B value to calculate the current MOSFET temperature.

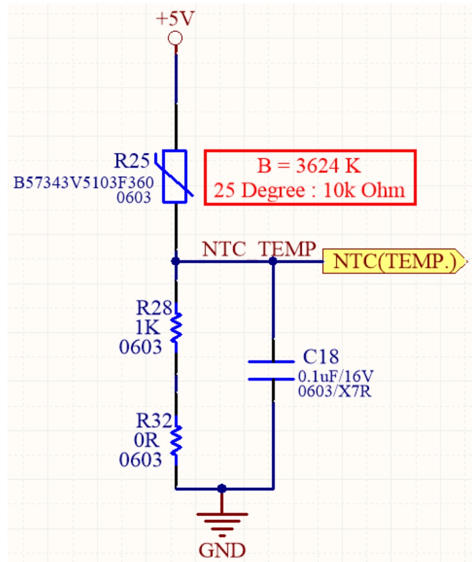


Table 2-5 MOSFET Temperature Feedback Circuit

2-6 VDC Voltage Feedback Circuit

Figure 2-6 shows the VDC voltage feedback circuit. In hardware design, the ratio of the Det_VDC feedback signal and the actual VDC voltage is 1/16 by default. The current VDC voltage can be calculated by the voltage read from MCU ADC1-IN3 together with the hardware default reduction ratio.

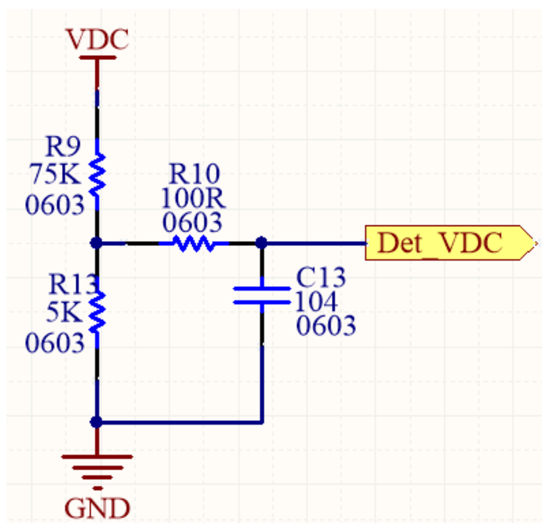


Table 2-6 VDC Voltage Feedback Circuit

2-7 Signal and Power Test Points

Figure 2-7 shows the signal and power test points including the gate driver output signals of HOA, LOA, HOB, LOB, HOC and LOC, the DC-DC power converter output voltage as well as the 5V LDO output voltage.

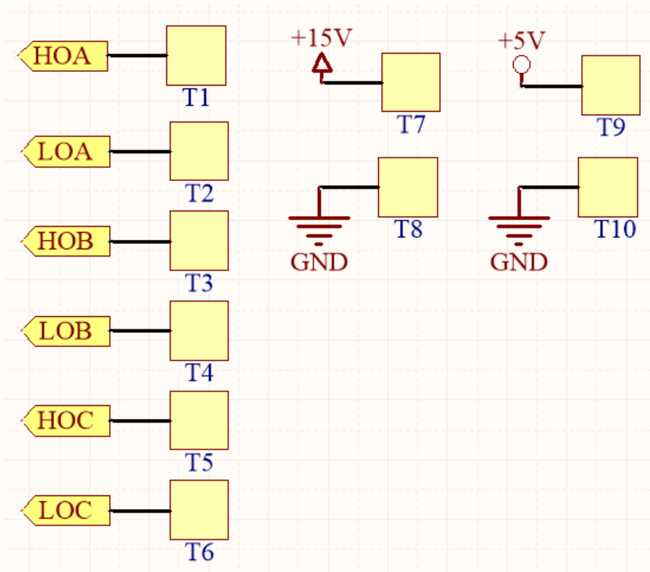


Figure 2-7 Signal and Power Test Points

2-8 Connector Between MVPB-A and FOC-EVB

Figure 2-8 shows the connector between MVPB-A and FOC-EVB, the pins of which contains the gate driver input signals of AT, AB, BT, BB, CT and CB, the VDC voltage feedback signal Det_VDC, the MOSFET temperature feedback signal NTC_MOSFET, the three phase current feedback signal of I High Phase U, I High Phase V and I High Phase W as well as the 5V LDO output voltage. The pin definitions are shown in Table 2-3.

Pin No.	Definition	Pin No.	Definition
1	CB	2	BB
3	CT	4	BT
5	NC	6	AB
7	5V	8	AT
9	GND	10	NC
11	NC	12	NC
13	NC	14	NC
15	NC	16	I High Phase W
17	NC	18	I High Phase V
19	NC	20	I High Phase U
21	NTC_MOSFET	22	NC
23	Det_VDC	24	GND

Table 2-3 Pin Definitions for the Connector Between MVPB-A and FOC-EVB

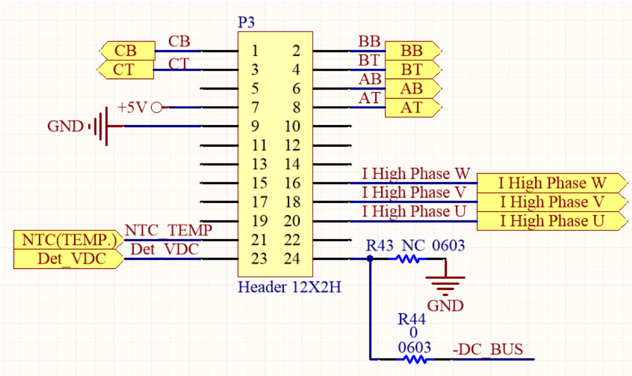


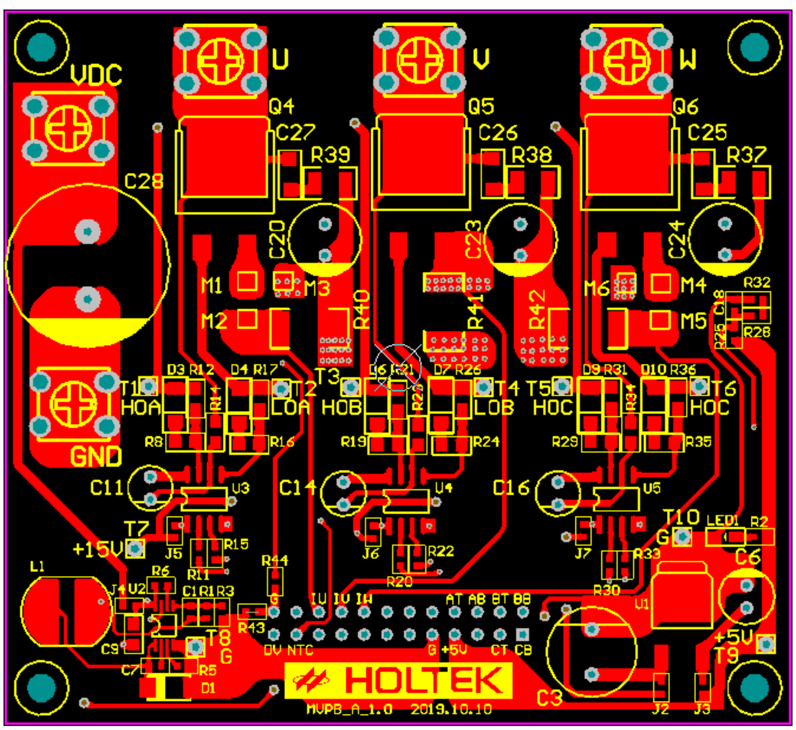
Table 2-8 Connector Between MVPB-A and FOC-EVB

3. PCB Layout

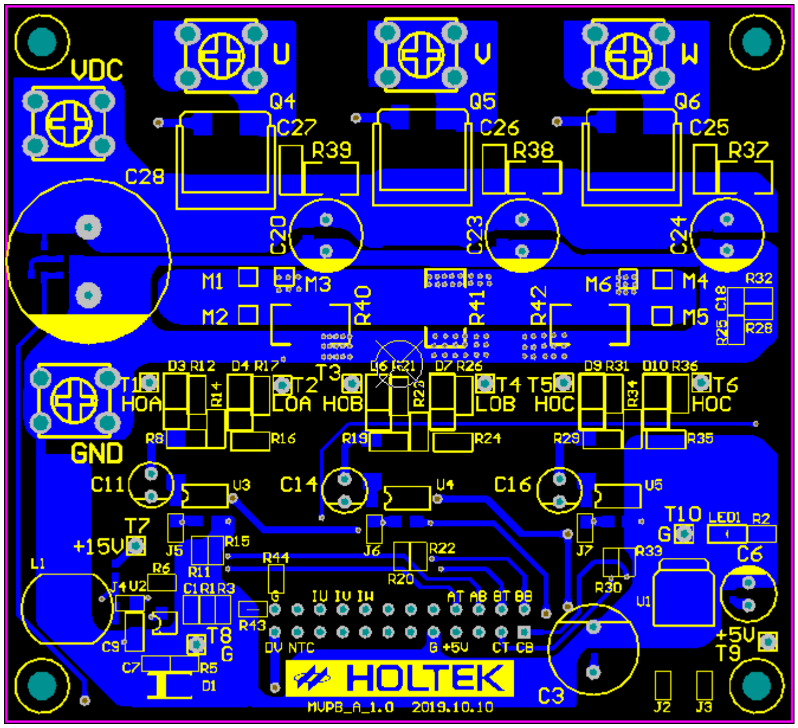
Fig 3-1 shows the MVPB-A PCB layout, the detailed specifications of which are shown in Table 3-1.

Length × Width	80 × 88 (mm)
Thickness	1.6 (mm)
Number of Layers	2 (Layer)
Copper Foil Thickness	2 (Oz)
Material	FR-4
Solder Mask Layer Colour	Green

Table 3-1 MVPB-A Circuit Board Specifications



(a)



(b)

Figure 3-1 BLDC Motor Workshop MVPB-A PCB Layout: (a) Upper Layer; (b) Lower Layer

4. BOM List

Table 4-1 shows the MVPB-A BOM list, which lists all the required components for a set of circuit board.

No.	Comment	Description	Designator	Quantity
1	3.3nF, 50V, ±5%, 0603	Capacitor MLCC	C1	1
2	2.2µF, 50V, ±5%, 0603	Capacitor MLCC	C2	1
3	10nF, 50V, ±5%, 0603	Capacitor MLCC	C7	1
4	0.1µF, 50V, ±5%, 0603	Capacitor MLCC	C4, C5, C13, C18	4
5	0.1µF, 50V, ±5%, 0805	Capacitor MLCC	C9, C12, C15, C17, C19, C21, C22	7
6	1µF, 50V, ±10%, 0805	Capacitor MLCC	C10	1
7	1µF, 50V, ±10%, 1206	Capacitor MLCC	C8	1
8	10nF, 50V, ±5%, 1206	Capacitor MLCC	C25, C26, C27	3
9	1000µF, 100V, (18×40mm)	Polarized Capacitor (Radial)	C28	1
10	470µF, 50V, (10×22mm)	Polarized Capacitor (Radial)	C3	1
11	100µF, 16V, (6.3×12.5mm)	Polarized Capacitor (Radial)	C6	1
12	10µF, 25V, (5×12.5mm)	Polarized Capacitor (Radial)	C11, C14, C16	3
13	RXW/33µF, 100V, (8×11.5mm)	Polarized Capacitor (Radial)	C20, C23, C24	3
14	DFLS1100-7, PowerDI 123	Schottky Diodes & Rectifiers	D1	1
15	FR107, SMA	FAST RECOVERY RECTIFIER	D2, D5, D8	3
16	1N4148, SOD123	Small Signal Fast Switching Diode	D3, D4, D6, D7, D9, D10	6
17	GD-G14	4-Pin DIP Connector (GD-G14)	VDC, GND, U, V, W	5

No.	Comment	Description	Designator	Quantity
18	Connector, 2×12Pin, Pitch2.54mm, 90degree	Header, 12-Pin, Dual row, Right Angle	P3	1
19	FNR8040S471MT, (COIL2_RC0810)	Inductor	L1	1
20	LED, GREEN, 0603	Typical INFRARED GaAs LED	LED1	1
21	NTC, 0603,10K,1%	NTC	R25	1
22	0Ω, 0603, ±5%	SMD Resistor	J1, J2, J3, J4, J5, J6, J7, R32, R4, R44	10
23	1kΩ, 0603, ±5%	SMD Resistor	R11, R15, R20, R22, R28, R30, R33	7
24	5kΩ, 0603, ±5%	SMD Resistor	R13	1
25	75kΩ, 0603, ±5%	SMD Resistor	R9	1
26	100Ω, 0603, ±5%	SMD Resistor	R10	1
27	130kΩ, 0603, ±5%	SMD Resistor	R5	1
28	360kΩ, 0603, ±5%	SMD Resistor	R6	1
29	51Ω, 0805, ±5%	SMD Resistor	R7, R18, R27	3
30	10Ω, 0805, ±5%	SMD Resistor	R8, R14, R16, R19, R23, R24, R29, R34,R35	9
31	33Ω, 0805, ±5%	SMD Resistor	R12, R17, R21, R26, R31, R36	6
32	4.7Ω, 1210, ±5%	SMD Resistor	R37, R38, R39	3
33	0.05Ω, 2512, ±1%	1% SMD Resistor	R40, R41, R42	3
34	10kΩ, 0603, ±1%	1% SMD Resistor	R1	1
35	2kΩ, 0603, ±1%	1% SMD Resistor	R2,R3	2
36	IR2103STRPBF, SOIC-8	Half-Bridge Gate Driver	U3, U4, U5	3
37	LM5008, VSSOP8	High Voltage (95V) Step Down Switching Regulator	U2	1
38	7805, TO252	Voltage Regulator IC	U1	1
39	NPN MOSFET, SQM70060EL_GE3, TO-263	N-CH MOSFET	Q1, Q2, Q3, Q4, Q5, Q6	6
40	NC	Pad (NC)	R43, M1, M2, M3, M4, M5, M6	7
41	NC	Test Point (NC)	T1, T2, T3, T4, T5, T6, T7, T8, T9, T10	10

Table 4-1 BLDC Motor Workshop MVPB-A BOM List