UM3374

User manual

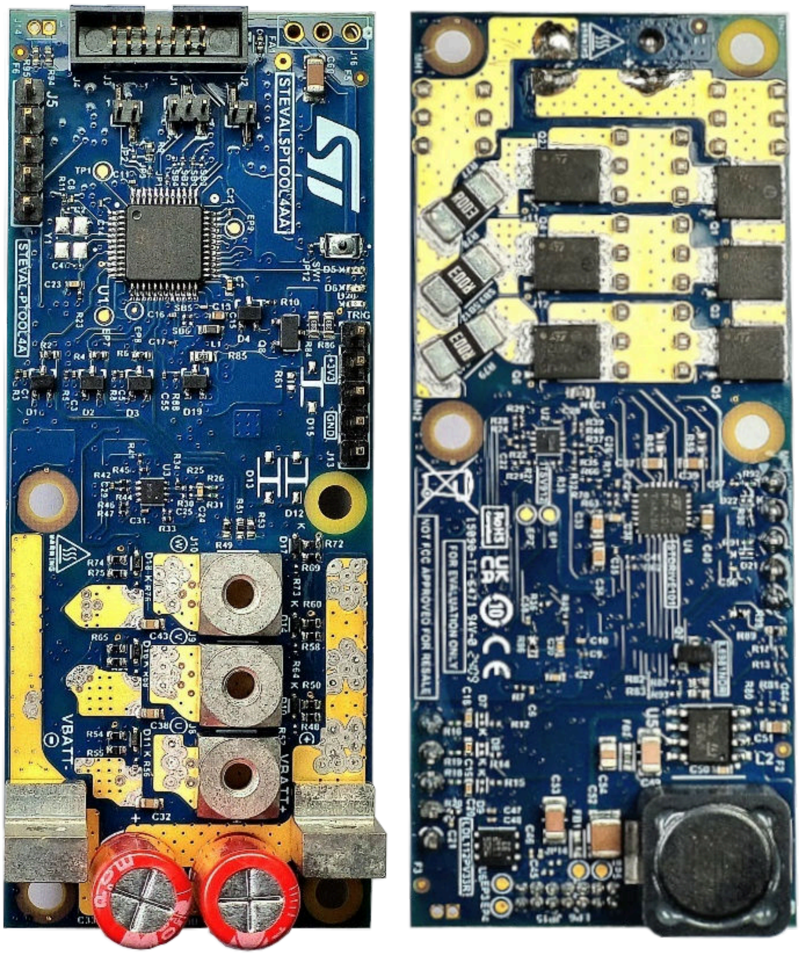
Getting started with the STEVAL-PTOOL4A reference evaluation board

Introduction

The STEVAL-PTOOL4A reference evaluation board is a compact system designed to control BLDC/PMSM motors in a battery-operated systems. The board is powered by the STM32G473CET6 MCU along with the STDRIVE101 3-phase gate drive control IC to drive six STL220N6F7 power MOSFETs. The board is empowered with the STM32 motor control ecosystem for PMSM/BLDC motors. The board supports CAN, USART, SPI, and I²C interfaces to support a wide range of data logging and communication interfacing options.

This reference design is ideal for high-performance motor control applications in power tools such as drill machines, grinders, disc cutters, circular saws, leaf blowers, handheld mowers, etc. The small form factor and ample computing power make it suitable even for applications such as drones, wheelchairs, home appliances, and robotic platforms.

Figure 1. STEVAL-PTOOL4A board



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1 Main features (key features)

- Suitable for applications up to 250 W
- 12-28 V operation (nominally 21 V)
- 20 A maximum output RMS current
- SPI, USART, I²C communication interfaces and provision for CAN bus signals
- Sensorless (position and speed) operation (thanks to high speed observer in MCSDK)
- Provision for Hall sensor
- Configuration examples are also provided for MCSDK for FOC and 6-step operation
- Independent ADCs for 3-phase current sensing through shunts
- Connector for mounting daughterboard with MEMS sensor
- 3 ADC channels for back EMF sensing
- Customizable for sensor-enabled operation
- Option for manual user operations
- Temperature protection
- Overcurrent protection
- Connector for user inputs
- On-board push button input
- Connectivity and test points for signal monitoring
- Connectivity for data logging and automation
- Desinged to have comptiblity with both MCSDK library or powerful ZeST algorithm
- Connector for increasing input voltage range by replacement of DC-DC converter
- Option for mounting heat sink

1.1 STMicroelectronics components featured

- STM32G473CET6: A high-performance Arm®-based Cortex®-M4 32-bit MCU+FPU in LQFP48 (7x7 mm) package
- STDRIVE101: Triple half-bridge, high-voltage gate driver in VFQFPN (4x4 mm) with inbuilt regulator
- STL220N6F7: Six N-channel 60 V, 0.0012 Ω typ., 120 A, STripFET F7 power MOSFETs in a PowerFLAT 5x6 package
- L6981NDR: 38 V, 1.5 A synchronous step-down converter in a PowerSO-8 package
- LDL112: 1.2 A low quiescent current LDO with reverse current protection in an SO8-batwing package
- TSV912IQ2T: dual rail-to-rail input/output 8 MHz op amp
- BAT54KFILM: 40 V, 300 mA small signal Schottky diode (single)
- BAT54SWFILM: 40 V, 300 mA small signal Schottky diode (series)
- 2STR2160: Low-voltage, fast switching PNP power transistor
- 2STR1160: Low-voltage, fast switching NPN power transistor
- 2STR21STPS0560Z: 60 V, 0.25 A power Schottky rectifier
- ESDALC6V1-1U2: Single line, low capacitance TransilTM for ESD protection is a precision 500 mA regulator

2 About the document

2.1 Scope and purpose

The user manual presents a detailed description of the STEVAL-PTOOL4A evaluation board for motor control. The system block description, including the hardware description, software description including control and firmware, and system startup, has been detailed in this document. The schematic, PCB layout, and bill of materials are detailed in the document.

Note that the board has provision for numerous communication interfaces and user inputs. The default firmware only provides a very basic functionality of driving a low-power motor. Users can enable and update the firmware as per the application requirements. The motor and drive parameters are also to be customized as per requirement. This document is intended to provide all the information needed for such customizations and updates.

2.2 Intended audience

The document is intended for users who are familiar with 3-phase motor drive controls and looking for a flexible motor control drive to implement a wide range of motor control applications.

2.3 Important notice

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2.4 Safety precautions

Always keep in mind the following safety precautions:

- The high current from battery packs can cause wire meltdown and fire hazards in case of malfunction. Ensure that a suitably rated fuse or circuit breaker is used close to the battery pack to avoid this situation.
- Allow enough time to cool the board after powering off and before touching it.
- Use appropriate torque-limited tools for tightening the connecting wire leads to the input and output power connectors.

3 Development tools

3.1 Hardware requirements

- STLINK-V3SET debugger and programmer for STM32/STM8.
- USB 2.0 Type B micro USB cable.
- Throttle/potentiometer (optional).

3.2 Software tool requirements

- STM32 motor control software for development kit (X-CUBE-MCSDK-6)
-
- STMicroelectronics - STM32CubeIDE [(1)]
  or
  – IAR Systems - IAR Embedded Workbench
  or
  – Keil® - MDK-ARM

1. *EMAX-1500 BLDC motor can be driven just by connecting a 30 kΩ potentiometer at throttle terminal J13 utilizing preloaded FW (refer to schematics for connection).*

4 Quick start

Follow the sequence below to configure the STEVAL-PTOOL4A board. The board is preprogrammed for sensorless speed control operation of the EMAX-1500 BLDC drone motor. To use the EMAX-1500 BLDC motor, it can be driven just by connecting a 30 kΩ potentiometer at throttle terminal J13 (refer to the schematics and Appendix A for details).

To work with another motor, follow the steps below:

Step 1. Select STEVALPTOOL4A from the list of boards of supported in X-CUBE-MCSDK-6 (MCSDK 6.3.1 onwards)
or
(Refer Appendix B for method using an older version of MCSDK-6 or a custom board based on this design).

Step 2. Open a New project and fill in the *project name*, *Num. Motors*, *driving algorithms* (FOC preferred), select Inverter in *Hardware mode*.

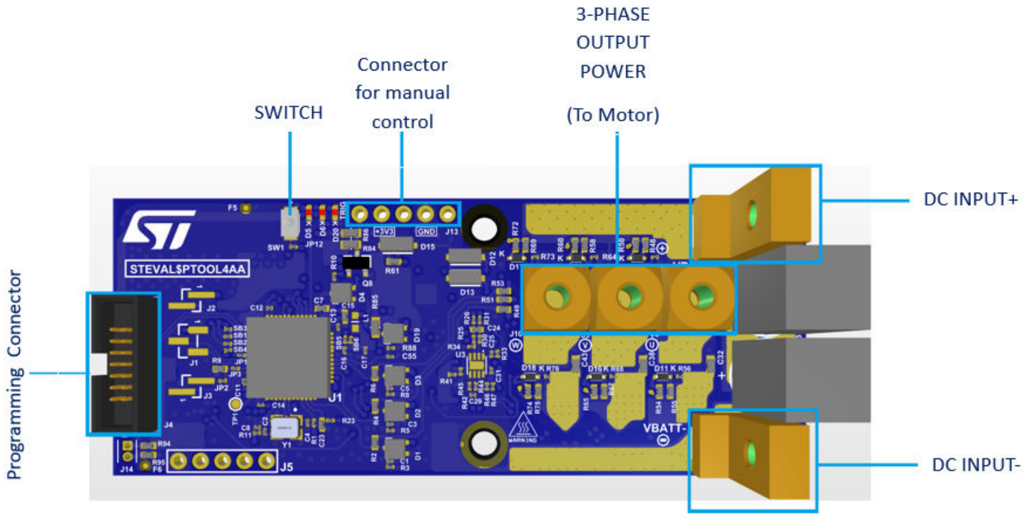
Step 3. Select the motor in the *Motors* section (motor parameters can be varied and saved for a custom motor separately by selecting *create the clone of the motor*).

Step 4. In the *Inverter* section, select the STEVAL-PTOOL4A board. The motor control workbench GUI appears where the motor control related parameters can be changed, and source code can be generated. For more information, refer to the software description section in this document.

Step 5. Connect the DC input supply (18 V-23 V) at VBATT+ and VBATT- terminals.

Step 6. Connect the motor terminals at 3-phase output connectors U, V, and W.

Figure 2. STEVAL-PTOOL4A top view (power connections)



5 Hardware description

The system block diagram illustrates MCU connections with peripheral components. Figure 2, Figure 3, and Figure 4 help to locate these features on the STEVAL-PTOOL4 board.

Figure 3. System block diagram (functional block diagram)

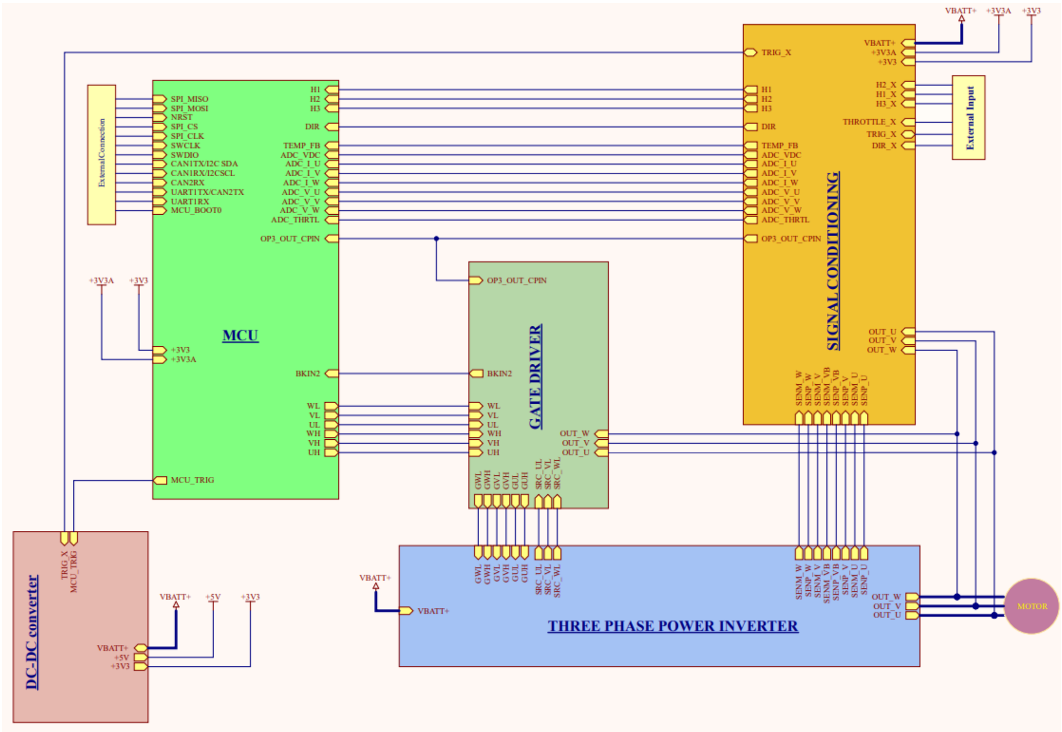
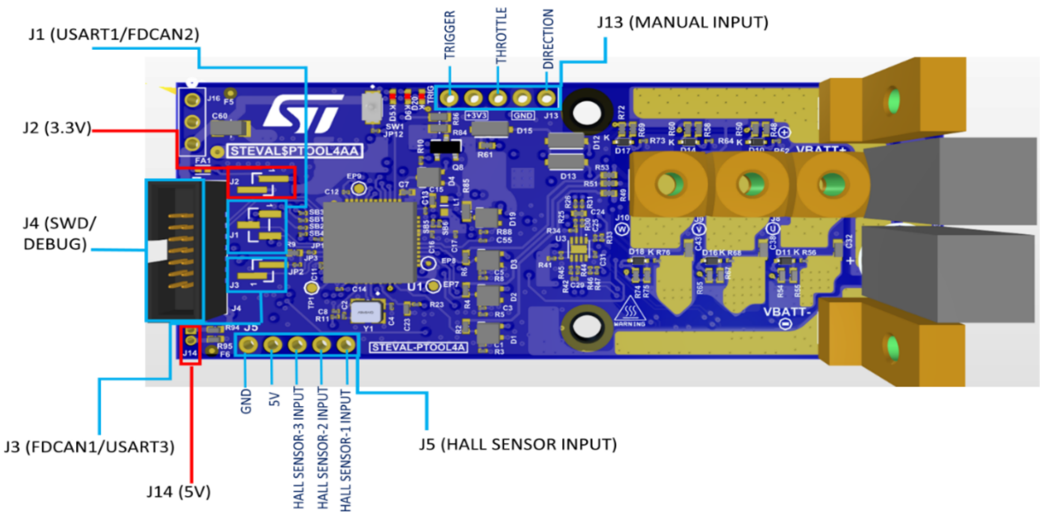


Figure 4. STEVAL-PTOOL4A top view (signal connections)



5.1 Microcontroller unit (STM32G473CET6)

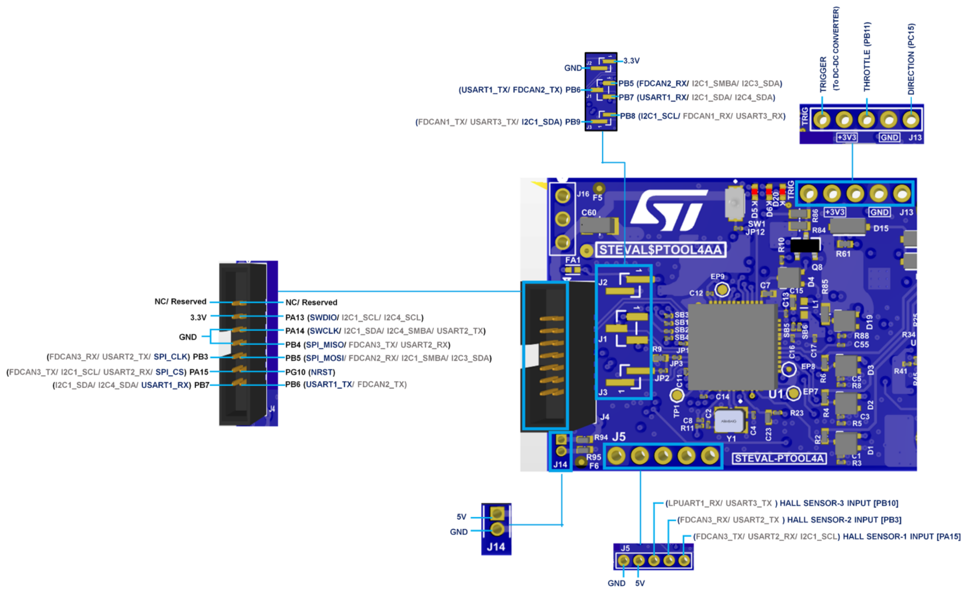
Based on the high-performance Arm® Cortex®-M4 32-bit RISC core, the STM32G473CET6 operates at a frequency of up to 170 MHz. The Cortex®-M4 core features a single-precision floating-point unit (FPU), which supports all the Arm single-precision data-processing instructions and all the data types. It also implements a full set of DSP (digital signal processing) instructions and a memory protection unit (MPU) which enhances the application's security.

It features a QUADSPI flash memory interface, and an extensive range of enhanced I/Os and peripherals connected to two APB buses, two AHB buses, and a 32-bit multi-AHB bus matrix. The devices embed peripherals allowing mathematical/arithmetic function acceleration (CORDIC for trigonometric functions and FMAC unit for filter functions).

5.2 MCU programming and interface

The 7x2-pin header, 1.27 mm pitch connector (J4) used for debugging, is provided on the board and programmed using the STLINK-V3SET debugger. To program the board, the DC supply is connected at DC input connectors.

Figure 5. Communication interface connections



5.3 Serial communication interface

Table 1 describes the configuration of various communication interfaces.

Table 1. Communication interface connections

Communication interface	Setting	Comment
USART	JP15 should be connected (default)	USART1 can be configured is Motor control workbench MCSDK GUI (configured in JSON file is older versions). CAN2 and USART1 can’t be configured simultaneously.
CAN2 (1)	Remove JP1	SPI1 cannot be configured with CAN2
SPI1	SB1 opened, JP1 closed	SPI1 cannot be configured with CAN2
CAN1 (1)	Remove JP2, Remove JP3	CAN1 and I2C1 cannot be configured together
I2C1	Remove JP2, Remove JP3	CAN1 and I2C1 cannot be configured together

1. *An onboard CAN transceiver is not provided. It can be added externally.*

5.4 LED

LEDs are provided to check the status of the working of the board, namely LED_ERROR (D5-Red LED) and LED_INFO (D6-Green LED).

5.5 Signal conditioning and sensing

Various signal conditioning and sensing circuits are used to determine the values of various parameters of the board.

5.5.1 V_{DC} sense

The input DC voltage (V_{DC}) is a key parameter of the STEVAL-PTOOL4A, which requires constant monitoring as its value is crucial in determining the various conditions of the control mechanism involved in the development board. This function is realized by a voltage divider circuit connected to the VDC and whose output is maintained across the capacitance C55 along with a diode protection circuit. The Potential divider is selected to operate up to 23 V DC input. If the voltage is more than this value (max. up to 28 V). The divider network must be modified. This output is provided to one of the ADCs of the MCU to assess the input DC voltage for normal operation as well as, for over and under voltage protection.

5.5.2 Temperature measurement

The constant monitoring of temperature across the board is critical to evaluate the environment in which the board functions. This parameter is evaluated by negative temperature coefficient (NTC) resistors whose resistance value decreases upon increasing temperature and the corresponding voltage in a voltage-divider circuit involving an NTC is proportional to the temperature in the board and is given to one of the ADCs of the MCU.

5.5.3 Overcurrent protection

In agreement with the circuit design associated with current sensing, the overcurrent detection is realized. The op amp output is given as a comparator input to the MCU and once it exceeds a predetermined limit, the presence of overcurrent is detected by the MCU.

TSV912 Opamp (U3A) based overcurrent circuit conditions and amplifies signal due to current flowing in one of the shunt resistors and provides signal (OP3_OUT_CPIN) to a comparator inside the MCU. Users can utilize this signal to realize overcurrent protection. Appropriate reference to the internal comparator can be refined through the MCSDK motor pilot to set the desired protection level. In case of an overcurrent event the comparator output can be used to deactivate PWM timer output.

5.5.4 Current sense (via shunts)

Three shunt resistors placed in series with the bottom devices of the full-bridge inverter are used to sense the motor currents. The drop across the shunt resistors is fed to a TSV912 op amp-based amplifier via a level-shifting circuit. The TSV912 provides wide bandwidth with the capability of rail-to-rail input/output. The RC circuits at the input and output suppress high-frequency noise in the input signal of the three ADCs. The gain of the amplifier circuit ensures good resolution in measured motor currents.

5.5.5 BEMF sense

Back-EMF (BEMF) is a pivotal parameter in deciding the position and speed of the rotor of a BLDC motor. BEMF is measured by means of a voltage divider circuit aided with an RC filter and diode protection from the output voltages across each phase of the motor control drive.

5.5.6 Hall sensor (optional)

The board is designed to operate in sensorless mode. However, provision for interfacing Hall effect-based rotor position sensors is provided at J5 (refer to board schematic for connection). Table 2. Hall sensor connections describes the configuration of Hall sensors.

Table 2. Hall sensor connections

Signal	Setting	Comment
HALL signal H1	Remove SB1, Connect SB3	SPI_CS and H1 need to be separated.
HALL signal H2	Remove SB2, Connect SB4	SPI_CLK and H2 need to be separated.
HALL signal H3	Remove SB5, Connect SB6	LED_INFO cannot be used while using Hall signal H3

5.5.7 External control input (throttle or potentiometer)

For power tool related applications wherein the operator manually triggers the required operational condition, the PTOOL4A can be fitted with the trigger option to achieve the best possible operation of the motor for the given condition.

5.5.8 DC-DC converter

For the control and operation of various functionalities, the evaluation board requires a 5 V and 3.3 V DC supply obtained from the DC input voltage. The required constant 5 V is obtained from the L6981NDR synchronous step-down converter. This 5 V is in turn provided as supply to the LDL112 LDO to obtain the required 3.3 V supply.

5.5.9 Latch enable circuit (optional)

STEVAL-PTOOL4A comes with an ON-OFF latch circuit for the DC-DC converter to keep the board powered only for a short duration as per need. But this circuit is bypassed and not the default configuration. To enable this feature, R82 must be removed. Now the DC-DC converter is enabled by pressing push-button SW1 (or similar eternal trigger input in parallel) on the board. MCU can also be programmed to keep the DC-DC converter even after release of the trigger inout through MCU_TRIG signal shown in schematic this feature reduces standby power taken from the battery when the board is not driving the motor. To program the board in this case, connect a jumper between TRIG_X (J13-1) and GND (J13-4). Latch enable circuit can be controlled by MCU by setting MCU_TRIG high.

5.5.10 Provision for external supply

An external 5 V supply can be given to the board at J16. This feature provides the board to be operated at higher voltages. To utilize this feature, remove R81, R82, C44, and FB1. More details can be found in Appenidix C of this document.

Note: The latch enable circuit does not work in this case.

5.5.11 GATE driver

Triple half-bridge gate driver STDRIVE101 provides MOSFET gate drive source , and sink current with appropriate protections. For the activation of the MOSFETs present in the inverter, the gate STDRIVE101 provides the required gate signals to the six STL220N6F7 power MOSFETs based on the logic command of the MCU.

5.5.12 3-phase power inverter

Triple half-bridge gate driver STDRIVE101 provides MOSFET gate drive source and sink current with appropriate protections. For the activation of the MOSFETs present in the inverter, the STDRIVE101 provides the required gate signals to the six STL220N6F7 power MOSFETs based on the logic command of the MCU.

6 System operation

To operate the STEVAL-PTOOL4A board with the PMSM/BLDC motor, the 18 V-24 V DC input is connected at the DC input connectors and the three phase terminals of the motor is connected at three phase connectors of the board.

Establishing serial connection with PC:

Hardware connection can be made through STLink debugger, which is connected via flat cable to STEVAL-PTOOL4A's 14-Pin connector J4.

To verify the connection "STMicroelectronics STLink Virtual COM Port (COMx)" can be checked in the PC environment. On a Windows machine this can be done by checking ports in the device manger (go to Windows Start-> Device Manager->Ports). Note Com port No. (COMx). Next ST Motor Pilot can be launched. Upon opening if there is a "Discover Board" option this can be used to find the board. Otherwise the UART dropdown menu can be used to do COM port selection option. And this must match the previously noted COM port from the PC settings. UART baud rate is set to the pre-set (in MC workbench) baud rate (or the value set through generated code generated through a IOC file).

From the ST motor pilot GUI (included in MCSDK), the user can change the reference inputs, control modes (Speed, torque, etc.) and see the status of the faults and other related parameters.

6.1 System startup

To start the motor, the user should first give the output frequency (speed) or torque references (depending on control mode). And then click on the enable icon in the motor pilot GUI.

6.2 Software and control description

The STEVAL-PTOOL4A board works with the motor control workbench (MCSDK). This tool provides the Field oriented control (FOC), 6-step firmware generation facility for Single or Dual Permanent magnet synchronous motor (PMSM), brushless DC motor (BLDC) with its graphical user interface (GUI). To learn more about the motor control workbench (MCSDK), the related documentation can be followed.

MCSDK includes support of quie a few reference Motor drive boards.

At the time of writing this Manual the latest released version MCSDK is 6.3.0 which does not support STEVAL-PTOOL4A.It is Expected that this board will also be available in version released in near future. However, to include STEVAL-PTOOL4A as a custom board please follow instructions in Appendix B. Also, this process can be used to include any modified board based on this reference design.

The generation of motor control source code is done in the *New Project* section by putting the user *project name, number of motors, algorithm, type of motor*, and *selection of board*.

On the motor control workbench GUI, the user can see all the parameters related to the hardware and they can select the control algorithm and modes.

The ST motor control workbench works with the different speed sensor interface (Hall sensor, encoder) and sensorless algorithms, for example, Observer+PLL, Observer+Cordic, high sensitivity observer (HSO). At very low speeds HSO works very well compared to other methods of speed sensing.

One of the important parameters is the selection of switching frequency which is selected in to match motor inductance and desired loss and performance. MCSDK allows selection in the rang eof 2 kHz to 50 kHz. This also has a role in harmonic frequency and power quality. Other important parameters to consider are Max Rated Speed, Nominal Current and Nominal DC Voltage parameters.

The source code can be generated by clicking on generate the project. The user can select its IDE of interest (IAR EWARM, Keil® MDK-ARM, or ST STM32CubeIDE).

At the time of writing this Manual the latest released version MCSDK is 6.3.0. MCSDK includes the board description of few reference platforms. It is expected that this board will also be available in version released in near future. However, to include STEVAL-PTOOL4A as a custom board please follow instructions in Appendix B. Also, this process can be used to include any modified board based on this reference design. In any case once the board description is from included board or generated through a JSON file (Appendix B), a project has to be created before proceeding with the steps below.

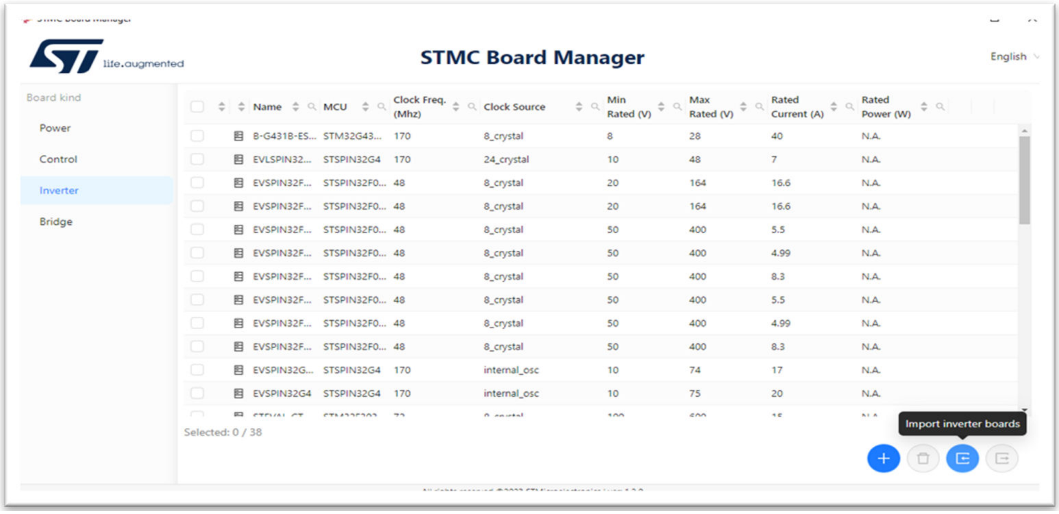


Figure 6. List of inverter boards

Generation of code for the board starts with the creation of a new project. This project is created by clicking on "New Project". Here, the name of the project, type of algorithm, and hardware mode-Inverter.

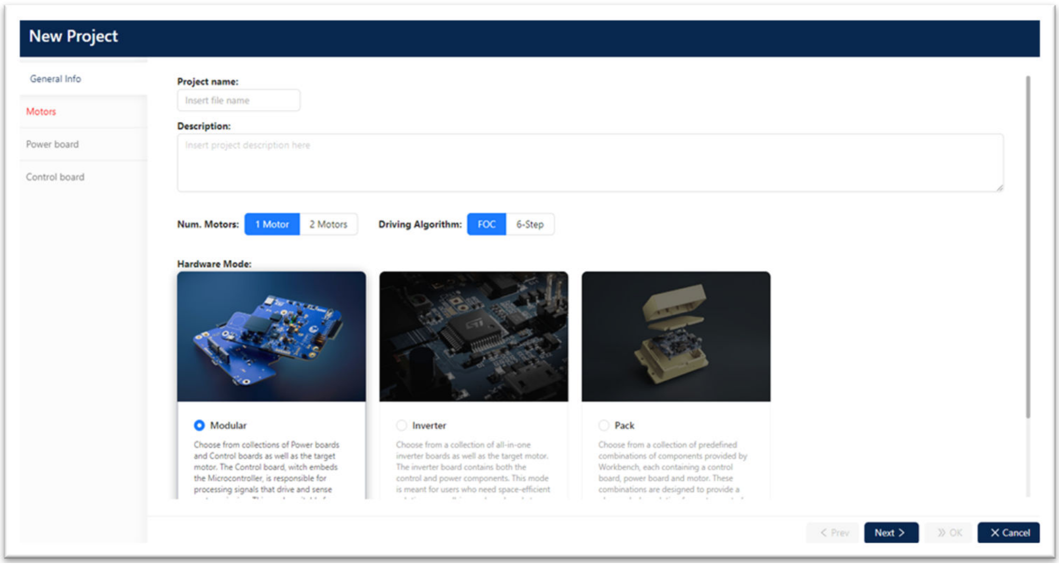
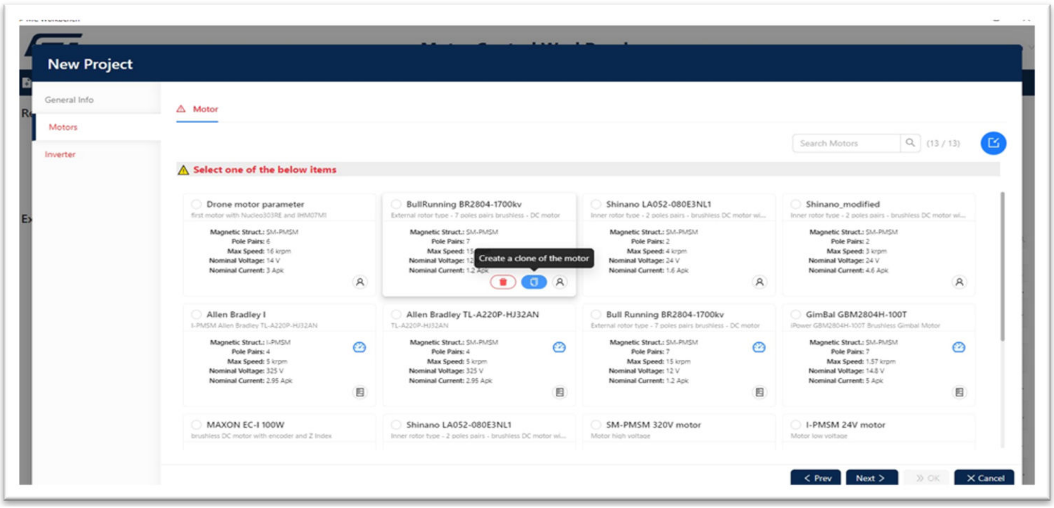


Figure 7. Initiation of project

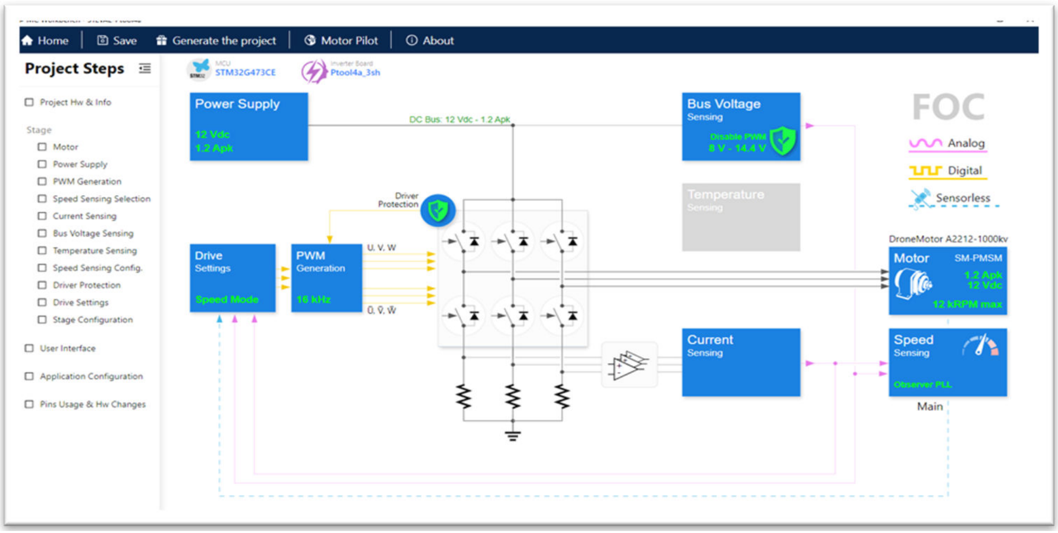
In the motor section, the user can select the default motor if the motor parameters are the same. If they are not, then the clone of the example motor can be made, and the parameters are filled in as per the datasheet of the motor under test. In the Inverter section, the user-imported board can be selected for STEVAL-PTOOl4A.

Figure 8. **List of motors**



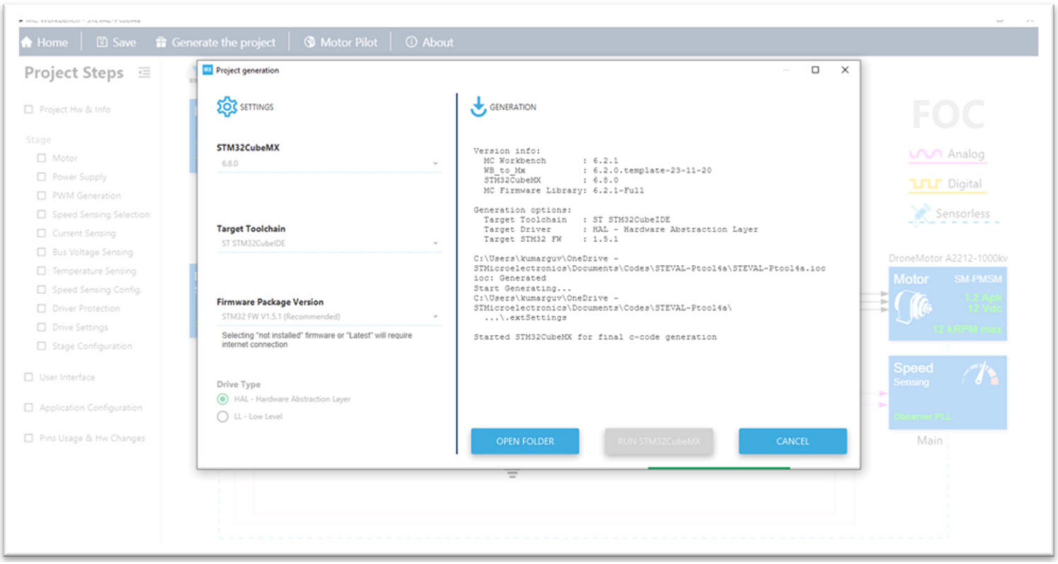
A GUI appears which shows the motor control circuit and motor section. Here, the user can change the switching frequency, speed sensing method, etc.

Figure 9. **Interface to generate the source code**



The source code can be generated by clicking on Generate the Project. The user can find the path of the generated code from the OPEN FOLDER tab.

Figure 10. Selection of IDE and software versions



Motor pilot and Uart connection

The STM32 MC Motor Pilot monitoring tool can be used over UART provide inthe 14pin programming connetor J4.To verify the Connection “STMicroelectronics STLink Virtual COM Port (COMx)” can be checked in the PC environment. On a Windows machine this can be done by checking Ports in device manger (go to Windows Start-> Device Manager->Ports). Note Com poert No. (COMx). Next ST Motor Pilot can be launched. Upon opening if there is a "Discover Board" option this can be used to find the board. Otherwise UART dropdown menu can be used to do COM port selection option. And this must match the previously noted COM port from the PC settings. UART Baud Rate is set to the Pre-set (in MC Workbench) baud rate (or the value set through generated code generated through a IOC file).

6.3 STEVAL-PTOOL4A JSON file

The JSON file can be edited by STMC Board Designer.

7 Schematic diagrams

Figure 11. **STEVAL-PTOOL4A circuit schematic (1 of 6)**

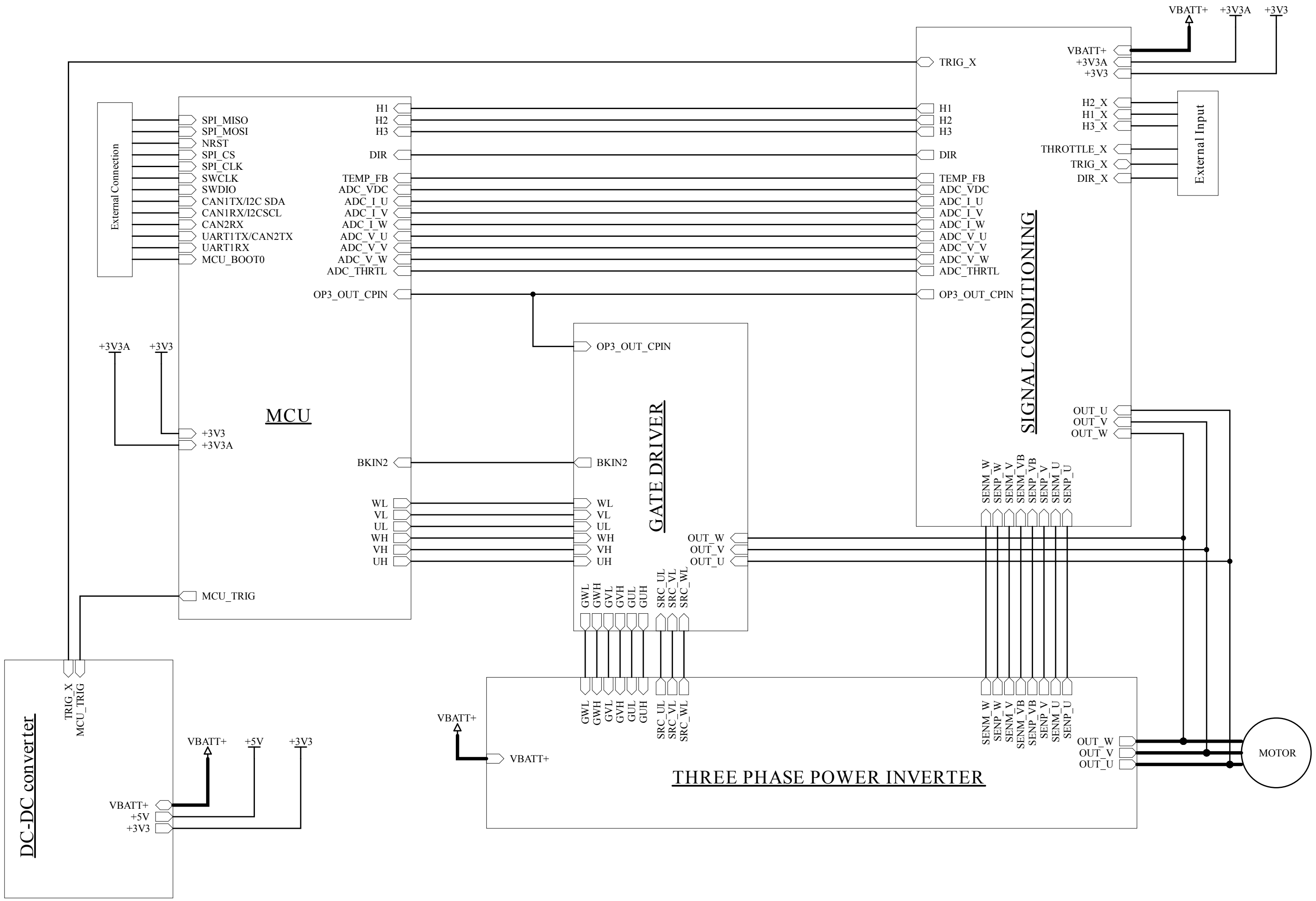


Figure 12. STEVAL-PTOOL4A circuit schematic (2 of 6)

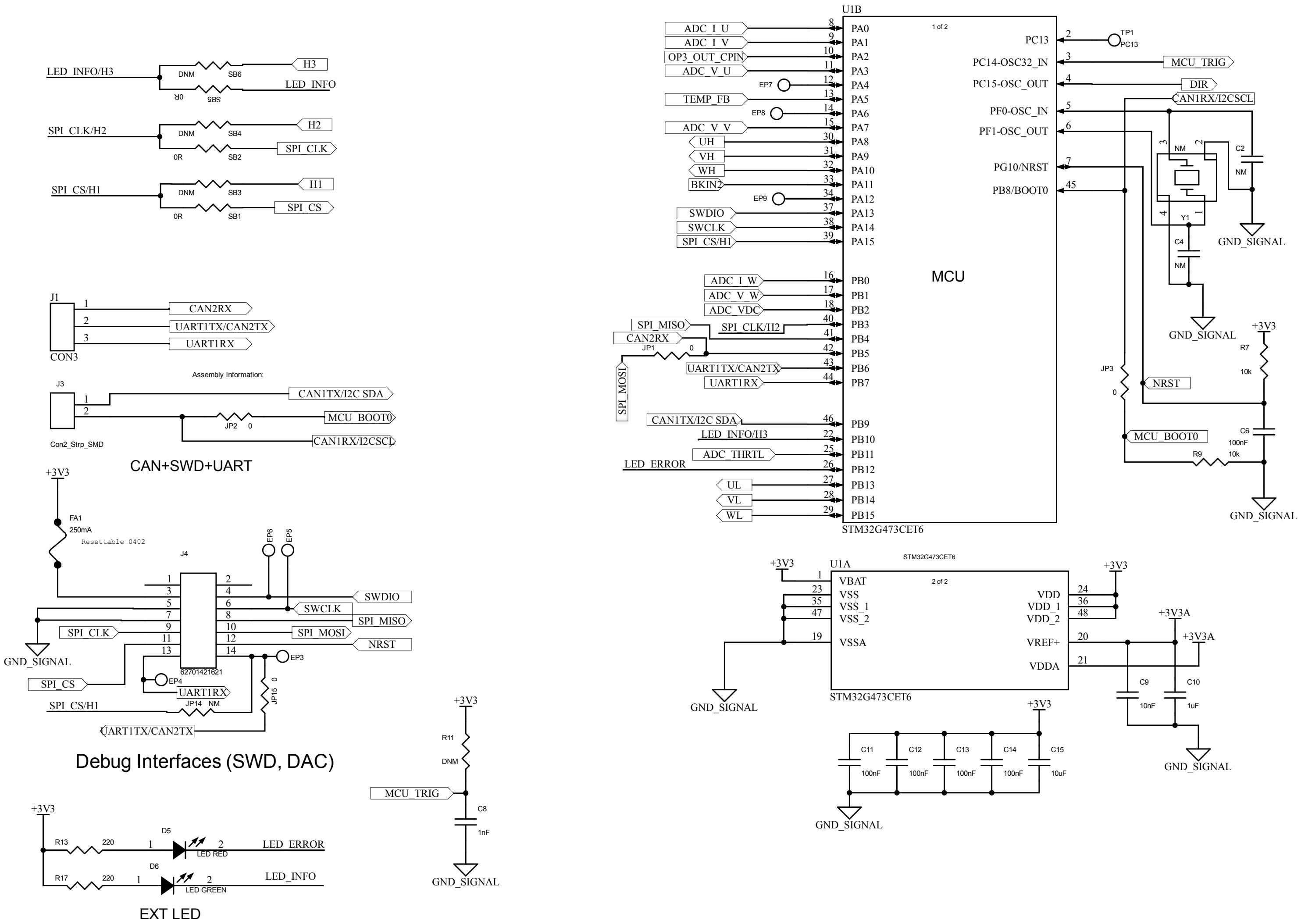


Figure 13. STEVAL-PTOOL4A circuit schematic (3 of 6)

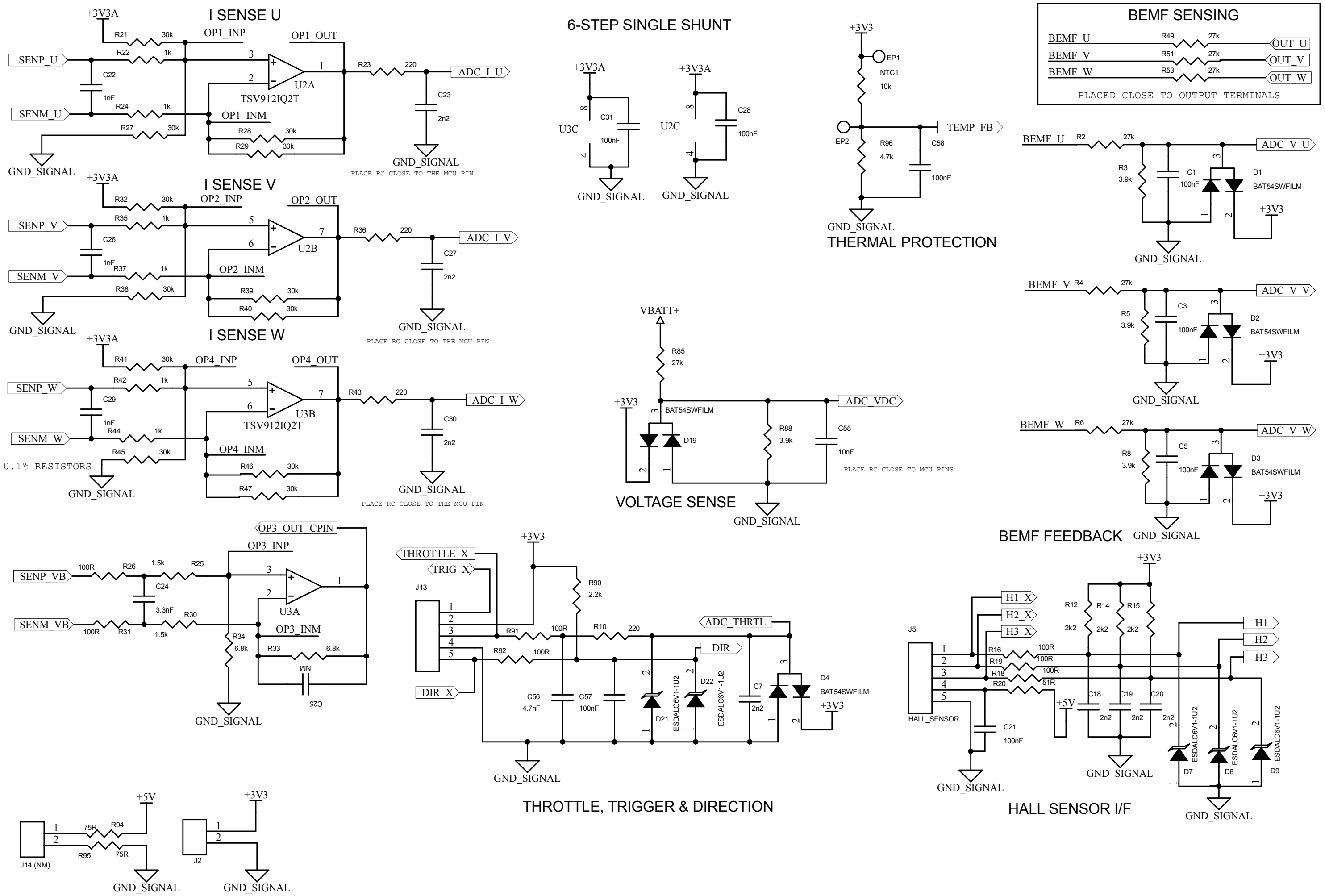


Figure 14. STEVAL-PTOOL4A circuit schematic (4 of 6)

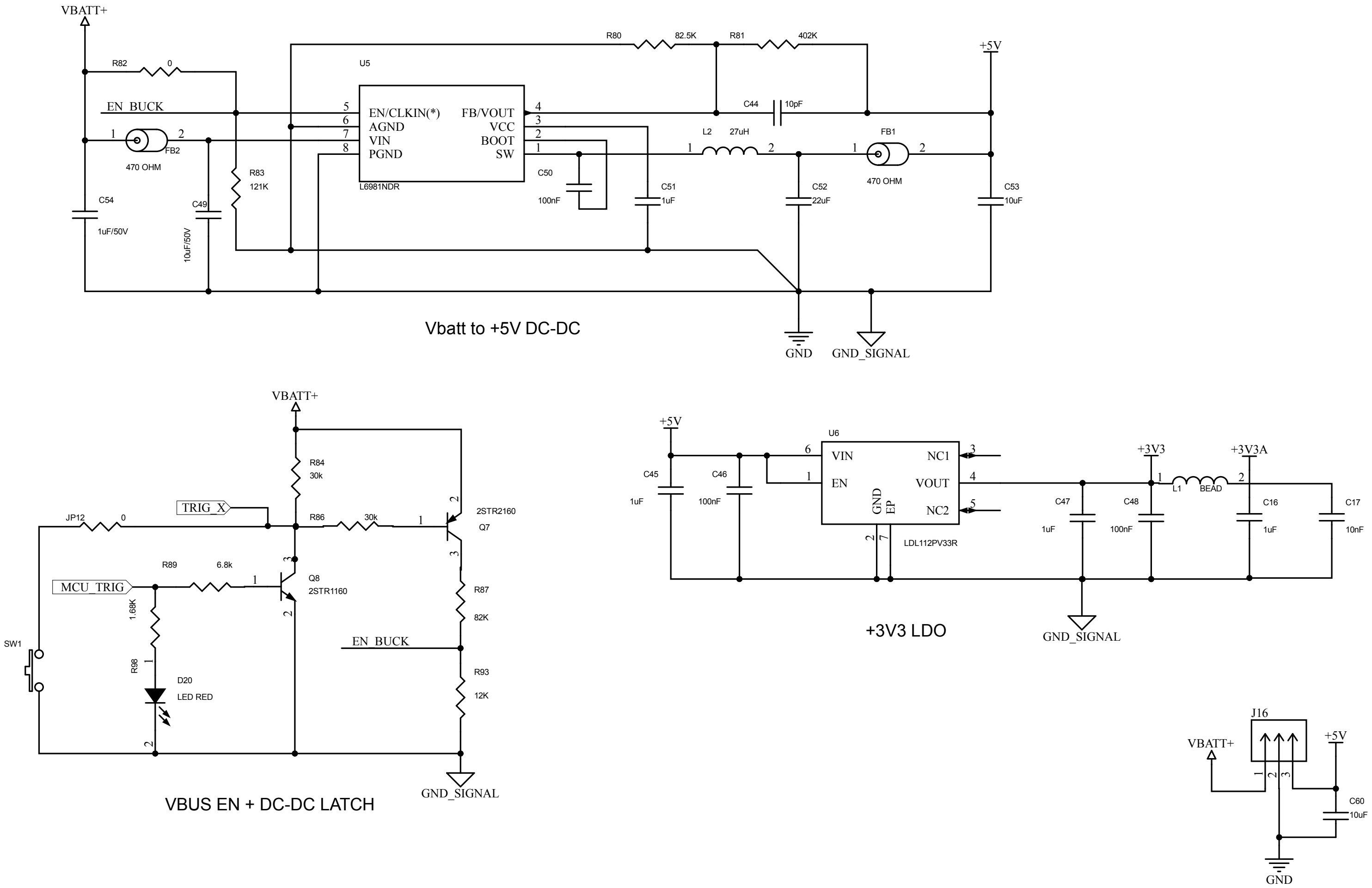


Figure 15. **STEVAL-PTOOL4A circuit schematic (5 of 6)**

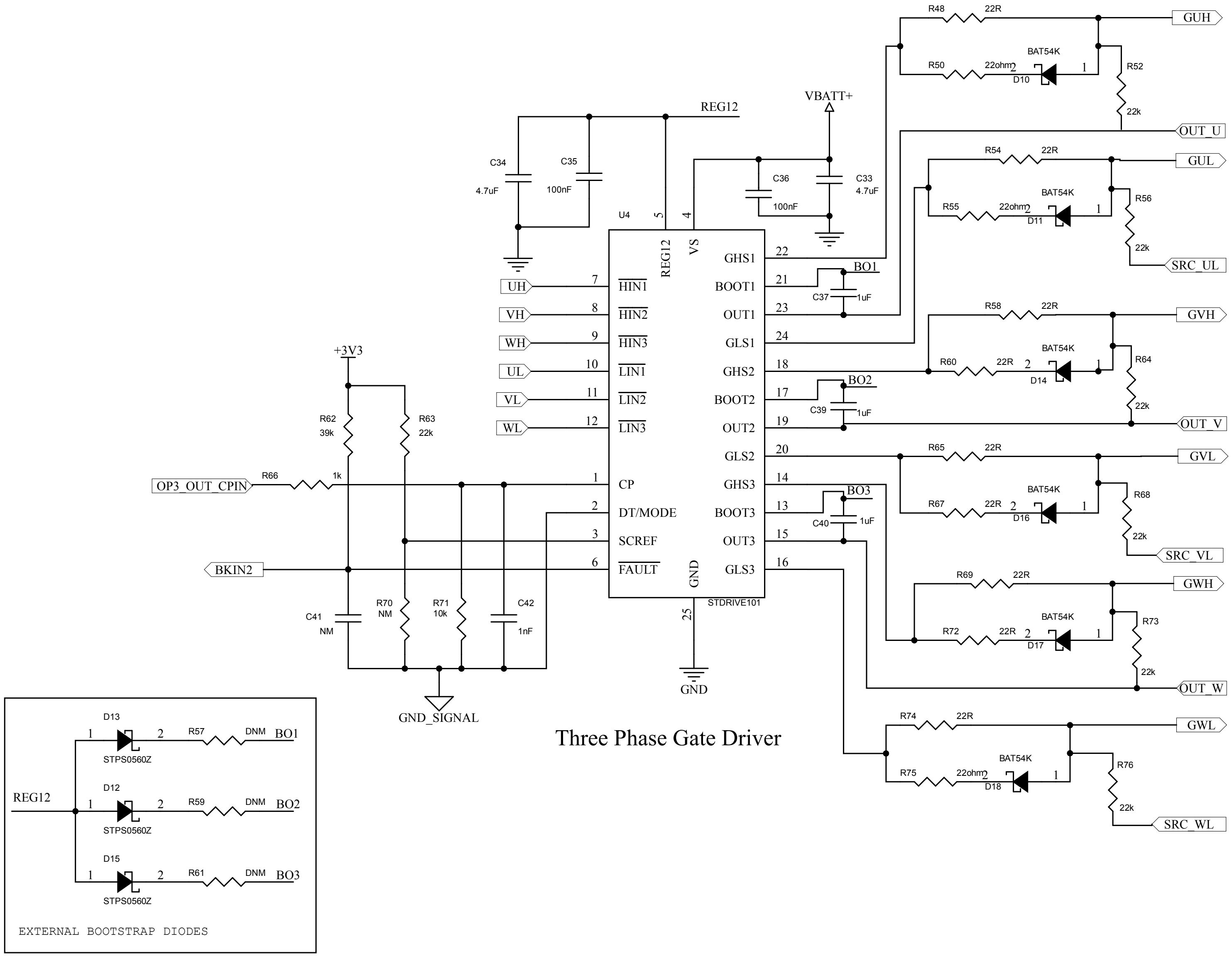
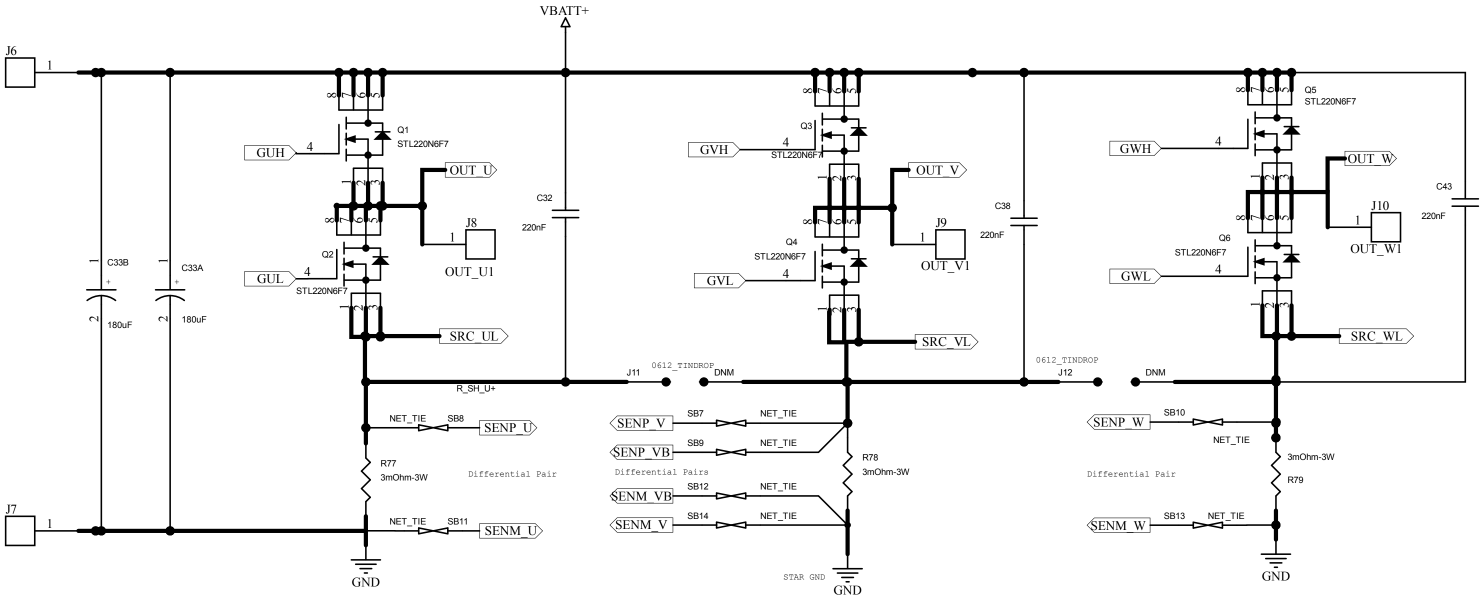


Figure 16. STEVAL-PTOOL4A circuit schematic (6 of 6)



8 Bill of materials

Table 3. STEVAL-PTOOL4A bill of materials

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
1	16	C1 C3 C5 C6 C11 C12 C13 C14 C21 C28 C31 C35 C46 C48 C57 C58	100nF, 0201, 16V, +/-10%	CAPACITOR CERAMIC SMD 0201	Wurth Elektronik	885012104001
2	2	C2 C4	20p, 0201, 25V, +/-5%	CAPACITOR CERAMIC SMD 0201 (not assembled)	Wurth Elektronik	885012004008
3	7	C7 C18 C19 C20 C23 C27 C30	2n2, 0402 (1005 Metric), 16V, +/-10%	CAPACITOR CERAMIC SMD 0402	Wurth Elektronik	885012205027
4	5	C8 C22 C26 C29 C42	1nF, 0201, 25V, +/-10%	CAPACITOR CERAMIC SMD 0201	Wurth Elektronik	885012204006
5	3	C9 C17 C55	10nF, 0201, 25V, +/-10%	CAPACITOR CERAMIC SMD 0201	Wurth Elektronik	885012204004
6	4	C10 C16 C45 C47	1uF, 0201, 16V, +/-20%	CAPACITOR CERAMIC SMD 0201	Wurth Elektronik	885012104007
7	1	C15	10uF, 0402, 10V, +/-20%	CAPACITOR CERAMIC SMD 0402	Wurth Elektronik	885012105022
8	1	C24	3.3nF, 0402, 16V, +/-10%	CAPACITOR CERAMIC SMD 0402	Wurth Elektronik	885012205028
9	2	C25 C41	NM 0201	CAPACITOR CERAMIC SMD 0201 (not assembled)	Any	Any
10	3	C32 C38 C43	220nF, 0603, 50V, +/-10%	CAPACITOR CERAMIC SMD 0603	TDK	CGA3E3X7R1H224K080A E
11	2	C33A C33B	180uF, Radial, 8x9mm, 50V, +/-20%	Cap Pol Radial (Electrolytic); 3.50MM C X 8.00MM Dia X 9.00MM H body	Wurth Elektronik	860080674013
12	2	C33 C34	4.7uF, 0603, 25V, +/-10%	CAPACITOR CERAMIC SMD 0603	TDK	C1608X5R1E475K080AC
13	2	C36 C50	100nF, 0402, 50V, +/-10%	CAPACITOR CERAMIC SMD 0402	Wurth Elektronik	885012205086
14	4	C37 C39 C40 C51	1uF, 0603, 50V, +/-10%	CAPACITOR CERAMIC SMD 0603	Wurth Elektronik	885012206126
15	1	C44	10pF, 0201, 25V, +/-5%	CAPACITOR CERAMIC SMD 0201	Wurth Elektronik	885012004004
16	3	C49 C53 C60	10uF, 1206, 50V, +/-10%	CAPACITOR CERAMIC SMD 1206	Wurth Elektronik	885012108022

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
17	1	C52	22uF, 1210, 25V, +/-10%	CAPACITOR CERAMIC SMD 1210	Wurth Elektronik	885012209074
18	1	C54	1uF, 0805, 50V, +/-10%	CAPACITOR CERAMIC SMD 0805	Wurth Elektronik	885012207103R
19	1	C56	4.7nF, 0201, 25V, +/-10%	CAPACITOR CERAMIC SMD 0201	Wurth Elektronik	885012104008
20	5	D1 D2 D3 D4 D19	BAT54SWFILM , SC-70, SOT-323, 40V, 0.3A	DIODE ARRAY Schottky 40V SOT323	STMicroelectronics	BAT54SWFILM
21	2	D5 D20	LED RED, 0402 (1005 Metric)	Rectangle with Flat Top, 1.00MM x 0.50MM, LED YELLOW-GREEN	Wurth Elektronik	150040RS73220
22	1	D6	LED GREEN, 0402 (1005 Metric)	Rectangle with Flat Top, 1.00MM x 0.50MM, LED YELLOW-GREEN	Wurth Elektronik	150040VS73240
23	5	D7 D8 D9 D21 D22	ESDALC6V1-1U2, 0201 (0603 Metric), 3V, 2A, 20W	TVS DIODE 3VWM ST0201 (not assembled)	STMicroelectronics	ESDALC6V1-1U2
24	6	D10 D11 D14 D16 D17 D18	BAT54K, SC-79, SOD-523, 40V, 0.3A	DIODE Schottky 40V 300MA SOD523	STMicroelectronics	BAT54KFILM
25	3	D12 D13 D15	STPS0560Z, SOD-123, 60V, 0.5A	DIODE Schottky 60V 500MA SOD123 (not assembled)	STMicroelectronics	STPS0560Z
26	1	FA1	250mA, 0.039" L x 0.020" W x 0.013" H (0.99mm x 0.51mm x 0.33mm), 32V, 0.25A	FUSE BOARD MNT 250MA 32VDC 0402	Littelfuse	0435.250KRS
27	2	FB1 FB2	470 OHM, 0402 (1005 Metric), 0.25A, +/-25%	FERRITE BEAD 470OHM 0402 1LN	Wurth Elektronik	7427927141
28	1	J1	Con3_Strip_SMD, 1A	CONN HEADER SMD 3POS 1.27MM	Sullins Connector Solutions	GRPB031VWTC-RC
29	2	J2 J3	Con2_Strp_SMD , 1A	CONN HEADER SMD 2POS 1.27MM	Harwin	M50-3630242R
30	1	J4	62701421621, 50V, 1A	CONN HEADER SMD 14POS 1.27MM	Wurth Elektronik	62701421621

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
31	2	J5 J13	250V, 3A	CONN HEADER 2.54MM STR 5POS	Wurth Elektronik	61300511121
32	2	J6 J7	Battery+, Battery-, 100A	CONN HEADER R/A 6POS, M3	Wurth Elektronik	7461101
33	3	J8 J9 J10	OUT_U1, OUT_V1, OUT_W1, 100A	CONN HEADER R/A 6POS, M3	Wurth Elektronik	7461057
34	2	J11 J12	DNM 0612	TIN DROP JUMPER 0612 (not assembled)		Dimension provided
35	1	J14	DNM, 1A	CONN HEADER 1.27MM 2POS PCB GOLD (not assembled)	Sullins Connector Solutions	GRPB021VWVN-RC
36	1	J16	3Amp/250V, 2.54mm pitch	3-pin Header (not assembled)	Wurth Elektronik	61300311121
37	6	JP1 JP2 JP3 JP12 JP14 JP15	0 Ohm, 0201, 25V, 50mW, +/-1%	RES SMD 1% 1/20W 0201	Panasonic	ERJ-1GN0R00C
38	1	JP14	0 Ohm, 0201, 25V, 50mW, +/-1%	RES SMD 1% 1/20W 0201 (not assembled)	Panasonic	ERJ-1GN0R00C
39	1	L1	BEAD, 0603, 2A	INDUCTOR SMD 0603	Wurth Elektronik	782631141
40	1	L2	27uH, 12*12mm, 3.7A, +/-20%	FIXED IND 27UH 3.7A 46mOhm SMD	Wurth Elektronik	744770127
41	4	MH1 MH2 MH3 MH4	M2 HOLE NOT PLATED	Mounting Hole M2 not plated		As per the Gerber
42	1	NTC1	10k, 0603 (1608 Metric), 150V, 125mW, +/-1%	CHIP RESISTOR SMD 1% 1/8W 0603	SEI Stackpole	TX06F103F3435ER
43	6	Q1 Q2 Q3 Q4 Q5 Q6	STL220N6F7, PowerFLAT 5x6, 60V, 120A, 187W	N-channel 60V, 1.9mO typ., 120 A STripFET F7	STMicroelectronics	STL220N6F7
44	1	Q7	2STR2160, TO-236-3, SC-59, SOT-23-3, 60V, 2A, 500mW	TRANS PNP 60V 1A SOT23-3	STMicroelectronics	2STR2160
45	1	Q8	2STR1160, TO-236-3, SC-59, SOT-23-3, 60V, 1A, 500mW	TRANS NPN 60V 1A SOT-23	STMicroelectronics	2STR1160

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
46	6	R2 R4 R6 R49 R51 R53	27k, 0402, 50V, 62.5mW, +/-1%	CHIP RESISTOR SMD 1% 1/16W 0402	Bourns	CR0402-FX-2702GLF
47	4	R3 R5 R8 R88	3.9k, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201	Yageo	AF0201FR-073K9L
48	3	R7 R71	10k, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201	Yageo	RC0201FR-0710KL
49	1	R11	10K, 0201, 25V, 50mW, +/- 1%	CHIP RESISTOR SMD 1% 1/20W 0201 (not assembled)	Yageo	RC0201FR-0710KL
50	1	R9	10k, 0402, 50V, 62.5mW, +/-1%	CHIP RESISTOR SMD 1% 1/16W 0402	Yageo	RC0402FR-0710KL
51	6	R10 R13 R17 R23 R36 R43	220, 0201, 25V, 50mW, +/-1%	RES SMD 1% 1/20W 0201	Yageo	RC0201FR-07220RL
52	3	R12 R14 R15	2k2, 0201, 25V, 50mW, +/- 1%	CHIP RESISTOR SMD 1% 1/20W 0201	Yageo	RC0201FR-072K2L
53	7	R16 R18 R19 R26 R31 R91 R92	100R, 0201, 25V, 75mW, +/- 0.1%	CHIP RESISTOR SMD 0.1% 75mW 0201	Vishay/Dale	TNPW0201100RBEED
54	1	R20	51R, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201	Yageo	RC0201FR-0751RL
55	12	R21 R27 R28 R29 R32 R38 R39 R40 R41 R45 R46 R47	30k, 0201, 25V, 50mW, +/-1%	RES SMD 1% 1/20W 0201	Yageo	RC0201FR-0730KL
56	7	R22 R24 R35 R37 R42 R44 R66	1k, 0201, 25V, 50mW, +/-1%	RES SMD 1% 1/20W 0201	Yageo	RC0201FR-071KL
57	8	SB7 SB8 SB9 SB10 SB11 SB12 SB13 SB14			Any	Any
58	2	R33 R34	6.8k, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201	Yageo	RC0201FR-076K8L
59	12	R48 R50 R54 R55 R58 R60 R65 R67 R69 R72 R74 R75	22R, 0402 (1005 Metric), 50V, 62.5mW, +/-1%	CHIP RESISTOR SMD 1% 1/16W 0402	Yageo	RC0402FR-0722RL
60	7	R52 R56 R63 R64 R68 R73 R76	22k, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201	Yageo	AC0201FR-0722KL

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
61	3	R57 R59 R61	DNM, 0402	CHIP RESISTOR SMD 1% 1/8W 0402 (not assembled)		RC0201FR-07220RL
62	1	R62	39k, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201	Yageo	RC0201FR-0739KL
63	1	R70	10K, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201 (not assembled)		ERJ-1GJF1002C
64	3	R77 R78 R79	3mOhm-3W, 2512 (6332 metric), 3W, +/-1%		Bussmann/ Eaton	MSMA2512R0030FGN
65	1	R80	82.5K, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201	Panasonic	ERJ-1GNF8252C
66	1	R81	402K, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201	Panasonic	ERJ-1GNF4023C
67	1	R82	0, 0201, 25V, 50mW, +/-1%	RES SMD 0Ohm JUMPER 1/20W 0201	Panasonic	ERJ-1GN0R00C
68	1	R83	121K, 0201, 25V, 50mW, +/-1%	CHIP RESISTOR SMD 1% 1/20W 0201	Panasonic	ERJ-1GNF1213C
69	2	R84 R86	30K, 0603 (1608 Metric), 75V, 100mW, +/-1%	CHIP RESISTOR SMD 1% 1/10W 0603	Yageo	RC0603FR-0730KL
70	1	R85	27k, 0603 (1608 Metric), 50V, 100mW, +/-1%	CHIP RESISTOR SMD 1% 1/10W 0603	Walsin	WR06X2702FTL
71	1	R87	82K, 0402 (1005 Metric), 50V, 62.5mW, +/-1%	CHIP RESISTOR SMD 1% 1/16W 0402	Bourns	CR0402-FX-8202GLF
72	1	R89	6.8K, 0402 (1005 Metric), 50V, 62.5mW, +/-1%	CHIP RESISTOR SMD 1% 1/16W 0402	Walsin	WR04X6801FTL
73	1	R90	2.2K, 0201, 25V, 50mW, +/-1%	RES SMD 1% 1/20W 0201	Yageo	AC0201FR-132K2L
74	1	R93	12K, 0402 (1005 Metric), 50V, 62.5mW, +/-1%	CHIP RESISTOR SMD 1% 1/16W 0402	Yageo	RC0402FR-1312KL

Item	Q.ty	Ref.	Part/value	Description	Manufacturer	Order code
75	2	R94 R95	75R, 0402 (1005 Metric), 50V, 62.5mW, +/-1%	CHIP RESISTOR SMD 1% 1/16W 0402	Bourns	CR0402-FX-75R0GLF
76	1	R96	4.7K, 0402 (1005 Metric), 50V, 62.5mW, +/-1%	CHIP RESISTOR SMD 1% 1/16W 0402	Bourns	CR0402-FX-4701GLF
77	1	R98	1.43K, 0402, 50V, 100mW, +/-1%	CHIP RESISTOR SMD 1% 1/10W 0402	Panasonic	ERJ-2RKF1431X
78	3	SB1 SB2 SB5	0R, 0201, 25V, 50mW, +/-1%	RES SMD 1% 1/20W 0201	Panasonic	ERJ-1GN0R00C
79	3	SB3 SB4 SB6	DNM, 0201	RES SMD 1% 1/20W 0201 (not assembled)		RC0201FR-07220RL
80	1	SW1	miniswitch, 3.00mm x 2.00mm, 15V, 0.02A	SWITCH TACTILE SPST-NO 0.02A 15V	E-Switch	TL3780AF240QG
81	1	TP1	PC13	TEST POINT 1MM SMD PADSTASCK	As per the Gerber	
82	1	U1	STM32G473CET6, 48-LQFP, 3.6V	IC MCU 32BIT 512KB FLASH 48LQFP	STMicroelectronics	STM32G473CET6
83	2	U2 U3	TSV912IQ2T, 8-UFDFN Exposed Pad, 5.5V, 0.035A	IC OP AMP GP 2 CIRCUIT 8DFN	STMicroelectronics	TSV912IQ2T
84	1	U4	STDRIVE101, 24-VFQFN Exposed Pad (4mmX4mm, pitch 0.5mm), 75V, 0.6A	STDRIVE101 - 3-phase gate driver	STMicroelectronics	STDRIVE101
85	1	U5	L6981NDR, 8-SOIC (0.154", 3.90mm width), 24V, 1.5A	38 V, 1.5 A SYNCHRONOUS STEP-DOWN	STMicroelectronics	L6981NDR
86	1	U6	LDL112PV33R, 6-VDFN Exposed Pad, 5.5V, 1.2A, +/-2%	IC REG LINEAR 3.3V 1A 6DFN	STMicroelectronics	LDL112PV33R
87	1	Y1	24MHz, 4-SMD, No Lead, 10uW	CRYSTAL 8MHZ 18PF SMD (not assembled)	ABRACON	ABM8AIG-8.000MHZ-1Z-T

9 Board versions

Table 4. STEVAL-PTOOL4A versions

PCB version	Schematic diagrams	Bill of materials
STEVAL$PTOOL4AA (1)	STEVAL$PTOOL4AA schematic diagrams	STEVAL$PTOOL4AA bill of materials

1. *This code identifies the STEVAL-PTOOL4A evaluation board first version. The STEVAL$PTOOL4AA code is printed on the board.*

10 Regulatory compliance information

Notice for US Federal Communication Commission (FCC)

For evaluation only; not FCC approved for resale

FCC NOTICE - This kit is designed to allow:

(1) Product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and

(2) Software developers to write software applications for use with the end product.

This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18, or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter 3.1.2.

Notice for Innovation, Science and Economic Development Canada (ISED)

For evaluation purposes only. This kit generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to Industry Canada (IC) rules.

À des fins d'évaluation uniquement. Ce kit génère, utilise et peut émettre de l'énergie radiofréquence et n'a pas été testé pour sa conformité aux limites des appareils informatiques conformément aux règles d'Industrie Canada (IC).

Notice for the European Union

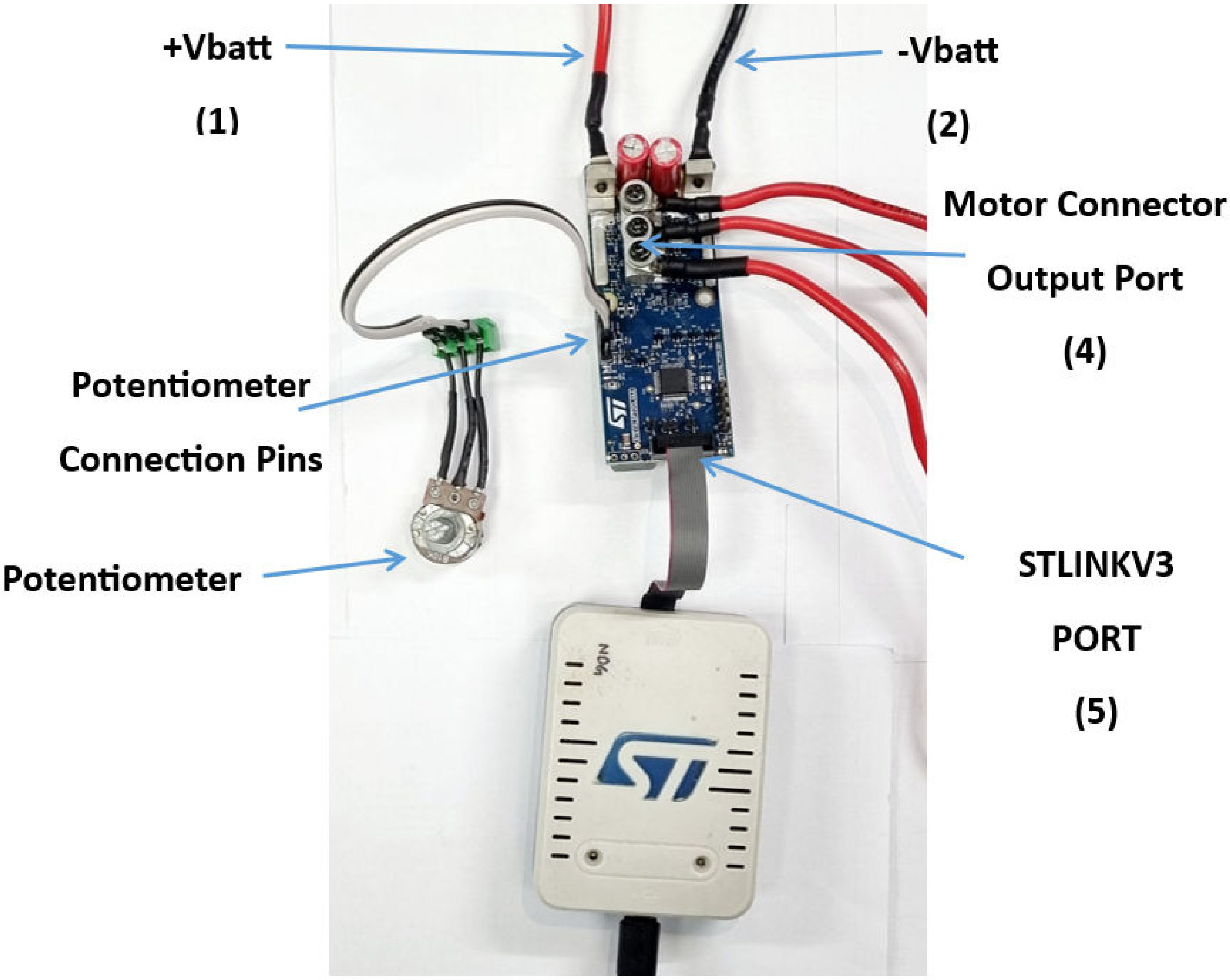
This device is in conformity with the essential requirements of the Directive 2014/30/EU (EMC) and of the Directive 2015/863/EU (RoHS).

Notice for the United Kingdom

This device is in compliance with the UK Electromagnetic Compatibility Regulations 2016 (UK S.I. 2016 No. 1091) and with the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2012 (UK S.I. 2012 No. 3032).

Appendix A Running preprogrammed firmware

Figure 17. Connection points of the PTOOL4A board



1. *Connection Point 1: +Vbatt*
2. *Connection Point 2: -Vbatt*
3. *Connection Point 3: Potentiometer connection pins*
4. *Connection Point 4: 3-phase motor connector output port*
5. *Connection Point 5: stlinkv3 port*

A.1 Test description - connection and wiring

1. Set the input DC voltage range in the power supply within 19 V - 23 V.
2. Set the current range in the power supply within 1.5 Amp - 5 Amp.
3. Connect the power supply +VE and -VE with the STEVAL-PTOOL4A board's +Vbatt and -Vbatt respectively, as shown in figure 2.
4. Connect the STLINKV3 debugger with the STEVAL-PTOOL4A board via the STLINKV3 connector.
5. Connect STLINKV3 with the PC via USB.

6. Connect the 3-phase EMAX motor with the board (as shown in figure below).
7. Connect the potentiometer's respective pins with STEVAL-PTOOL4A j13 pinouts 3.3.v, GND, and the Throttle pin respectively (as shown in figure below).

Figure 18. Connection of the PTOOL4A board with EMAX motor and potentiometer

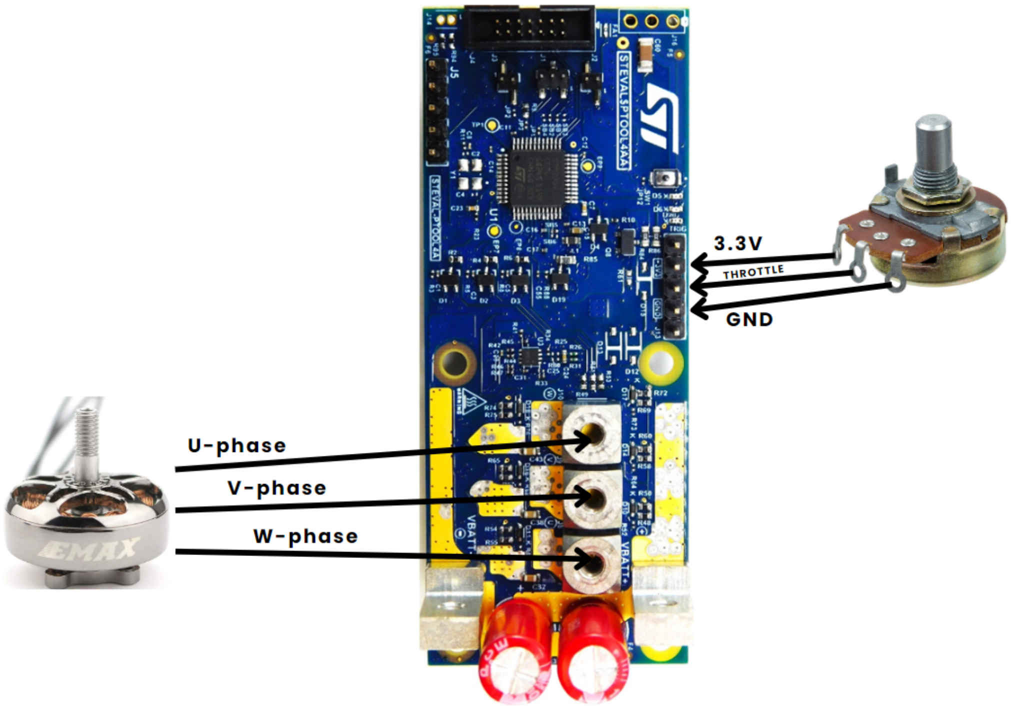
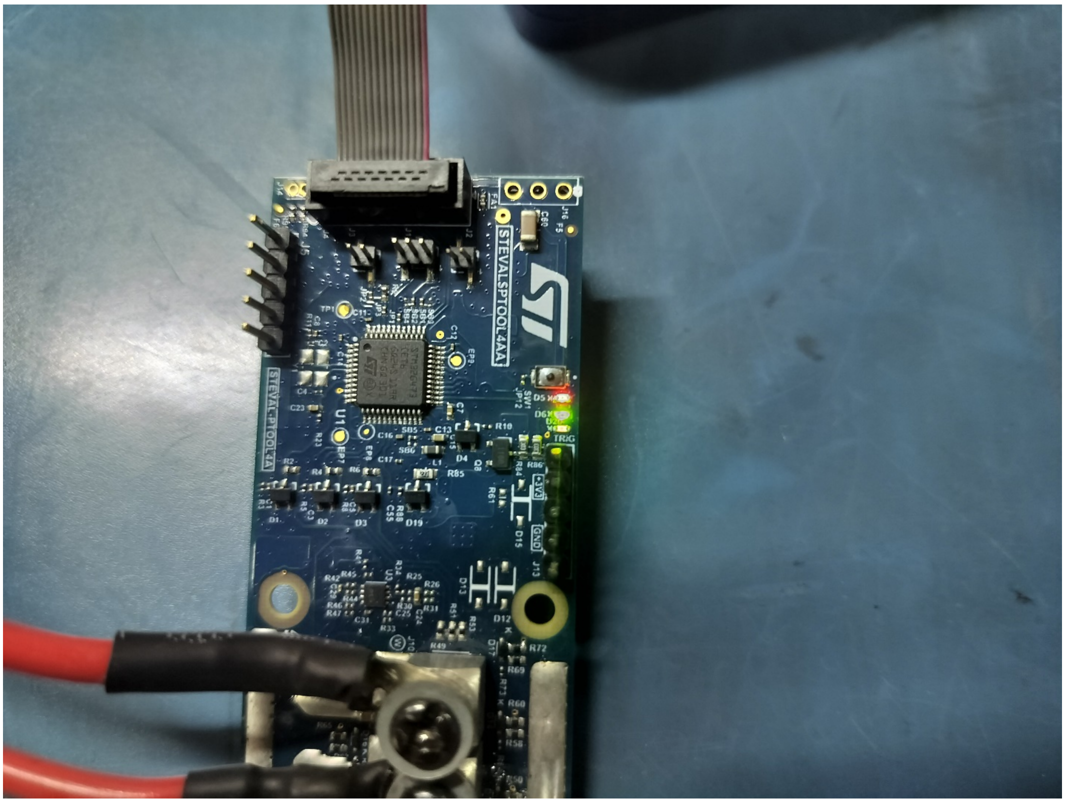


Figure 19. Both LEDs on during basic checks before running the motor



When the board is initially powered, both the LEDs are switched on for 2-3 s. After this, if the red LED blinks it implies some error. Ideally, the green LED should blink to show readiness upon rotating the potentiometer, the motor is actuated and starts to rotate at a speed proportional to potentiometer input.

Appendix B Generation of Code with MCSDK V6.3.0

To generate Firmware for STEVAL-PTOOL4A in older version of MCSDK environment , a board descriptor JSON file of the STEVAL-PTOOL4A board for MCSDK version such as Ver6.3.0 (or Ver6.2.1). This file contains the control circuit-related information viz Pin mapping of PWM/ADC/Hall sensor/GPIOs, type of current sensing and OP-AMP gains etc. The JSON file is prepared from a software tool,-ST Motor Control Board Designer (STMCBD). For All the details related to preparation of JSON file, STMC Board Designer documentation can be followed.

After generation of the JSON file for STEVAL-PTOOL4A board, this will be imported in motor control workbench (MCSDK) in Tools → Board Manager → Inverter.

The generation of motor control source code is done in the *New Project* section by putting user *project name, number of motors, algorithm, type of motor* and *board selection*.

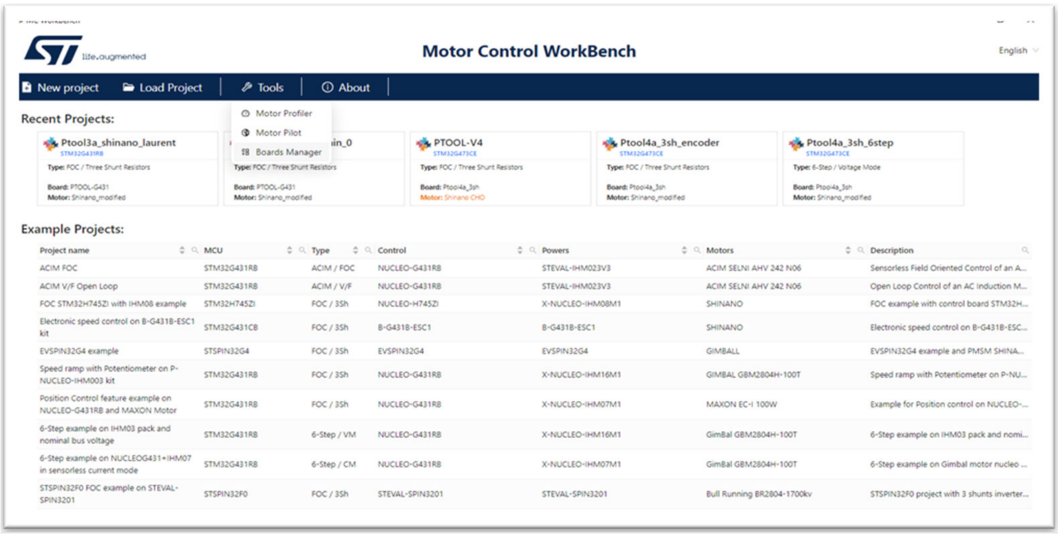
On the motor control workbench GUI, User can see all the parameters related to the hardware and user can select the control algorithm and modes.

ST motor control workbench works with the different speed sensor interface (hall sensor, encoder) and sensor less algorithms e.g. Observer+PLL, Observer+Cordic, high sensitivity observer (HSO). At very low speeds HSO works very well compared to other methods of speed sensing.

The source code can be generated by clicking on generate the project. User can select its IDE of interest (IAR EWARM, KEIL MDK-ARM or ST STM32CubeIDE).

B.1 Source code generation from ST motor control workbench (MCSDK)

Figure 20. Motor control ecosystem (MCSDK)



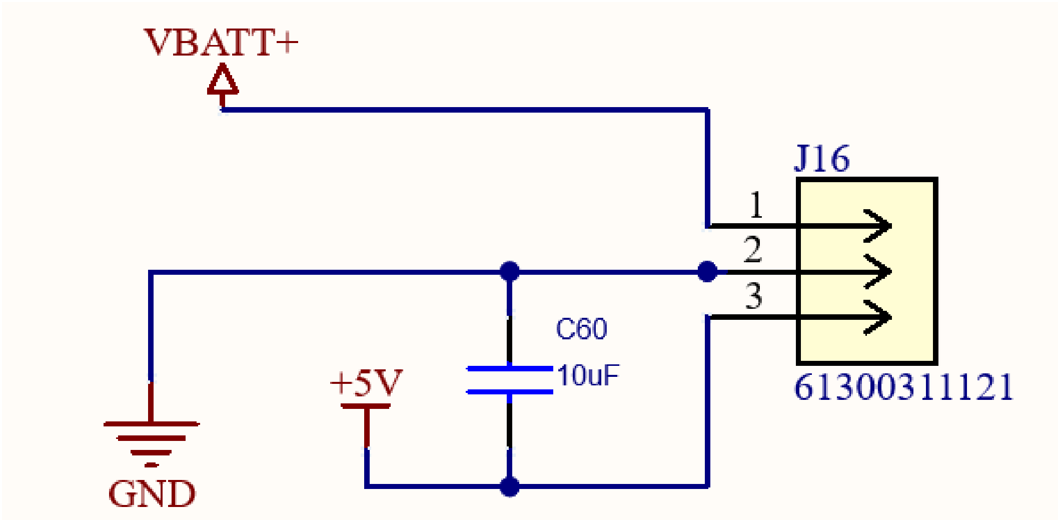
Appendix C Possible customisations

Following Customization are possible. However appropriate precautions must be taken.

C.1 Increase Input supply voltage

The board is designed for nominal input of 21V. However, if required the board can be utilized with higher Voltage say upto 32V. In this case, the on-board DC-DC converter has to be deactivated and removed. An external 5V supply can be given J16 as shown below. The potential divider R85, R88 for VDC sense must be modified. R85 value can be increased in proportion and MCSDK FW library has to be modified according to the change.

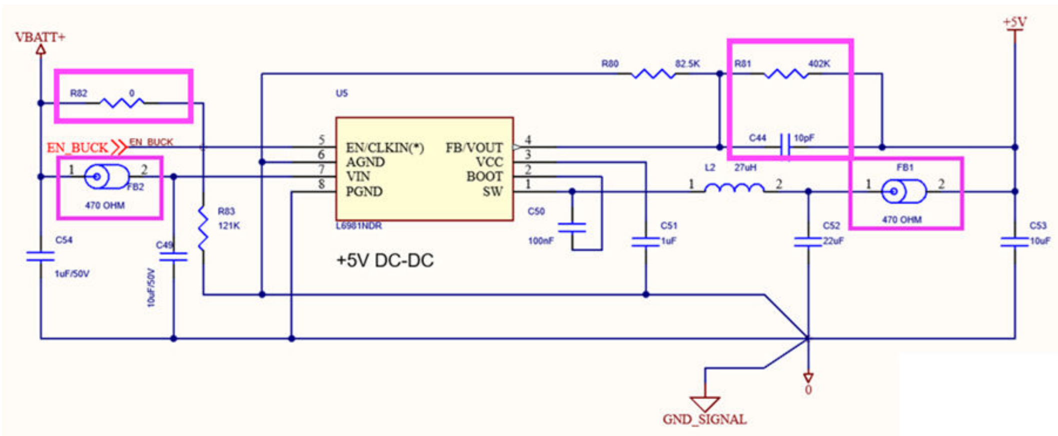
Figure 21. External 5V supply connection via J16, to enable increased Input DC (battery) supply level



- Deactivating the onboard Aux Power supply to connect the external STEVAL-ISA198V1.

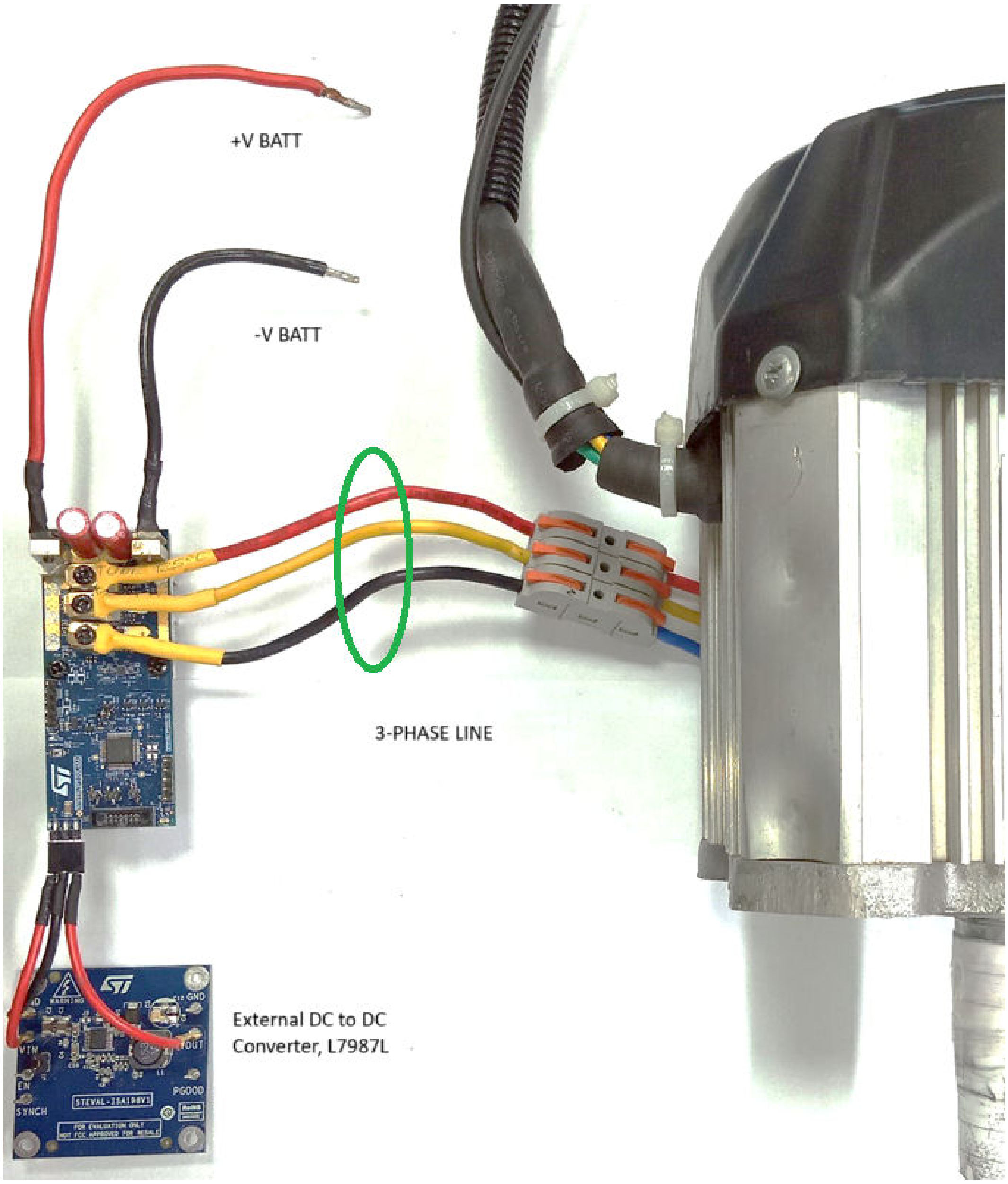
Removal of R82 will deactivate the on-board DC-DC converter. However, it is advisable to remove the FB2 and FB1 and feedback circuit as shown below.

Figure 22. Deactivation of on-board DC-DC converter for connecting external primary DC supply.



An example is shown below:

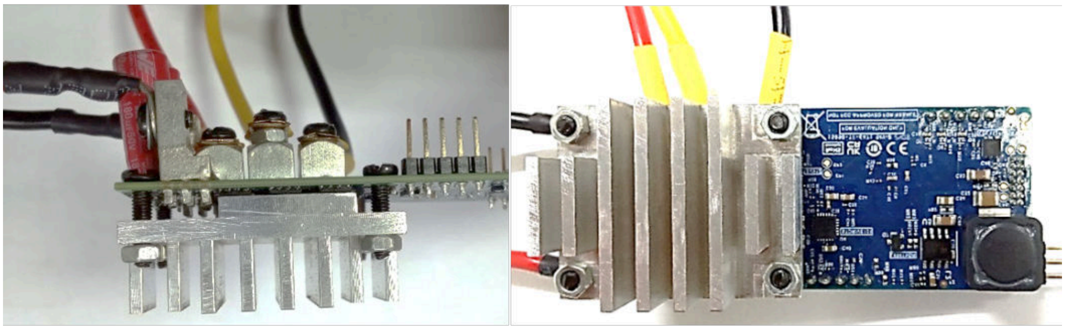
Figure 23. **Connection of an external DC-DC converter board**



C.2 Increase effective power ratings

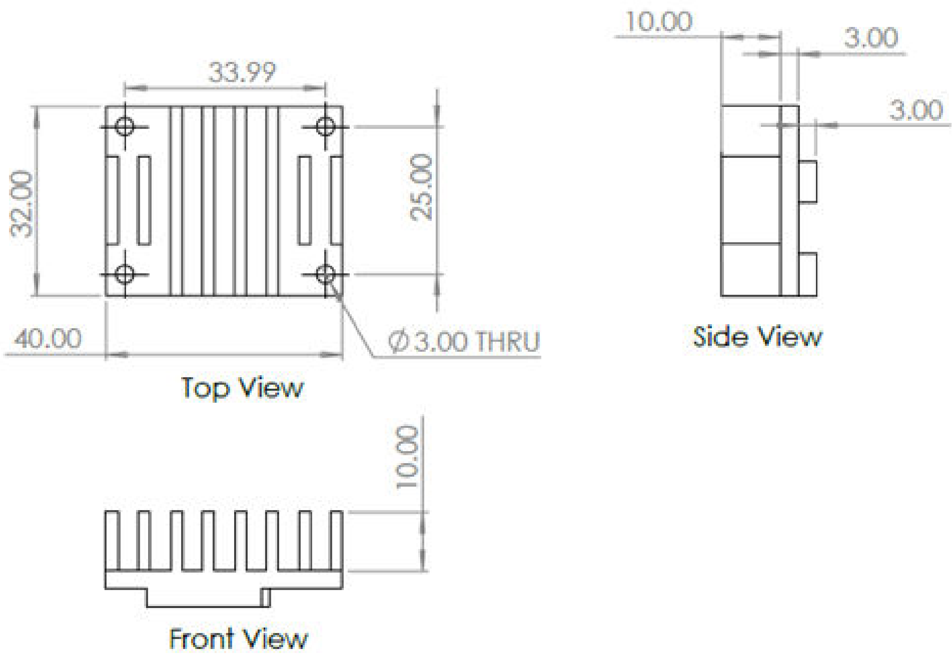
The effective Power rating of board can be improved by providing thermal relief through a heat sink. Possible Sample is shown below for reference users are advised to crosscheck all the dimensions. Actual design can also consider the heat sink thermal capability depending on application and duty cycle etc. Also, reinforcement of PCB tracks with addition solder and especially forced air cooling can help a great deal.

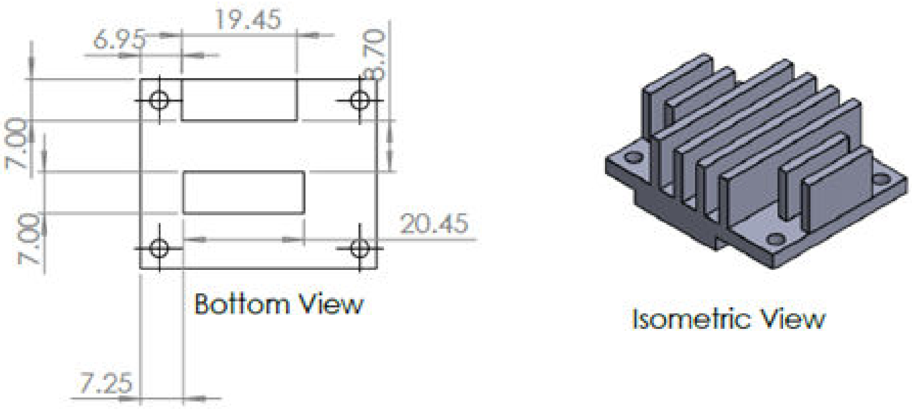
Figure 24. Mounting of a heat sink



Users can choose heat sink dimensions and shape as per the requirement. The dimensions of heat sink user in figure above is given as reference below:

Figure 25. Dimensions of the sample heat sink (see above figure)





Revision history

Table 5. Document revision history

Date	Revision	Changes
10-Oct-2024	1	Initial release.

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