STM32 motor-control pack using the FOC algorithm for three-phase, low-voltage, and low-current motor evaluation

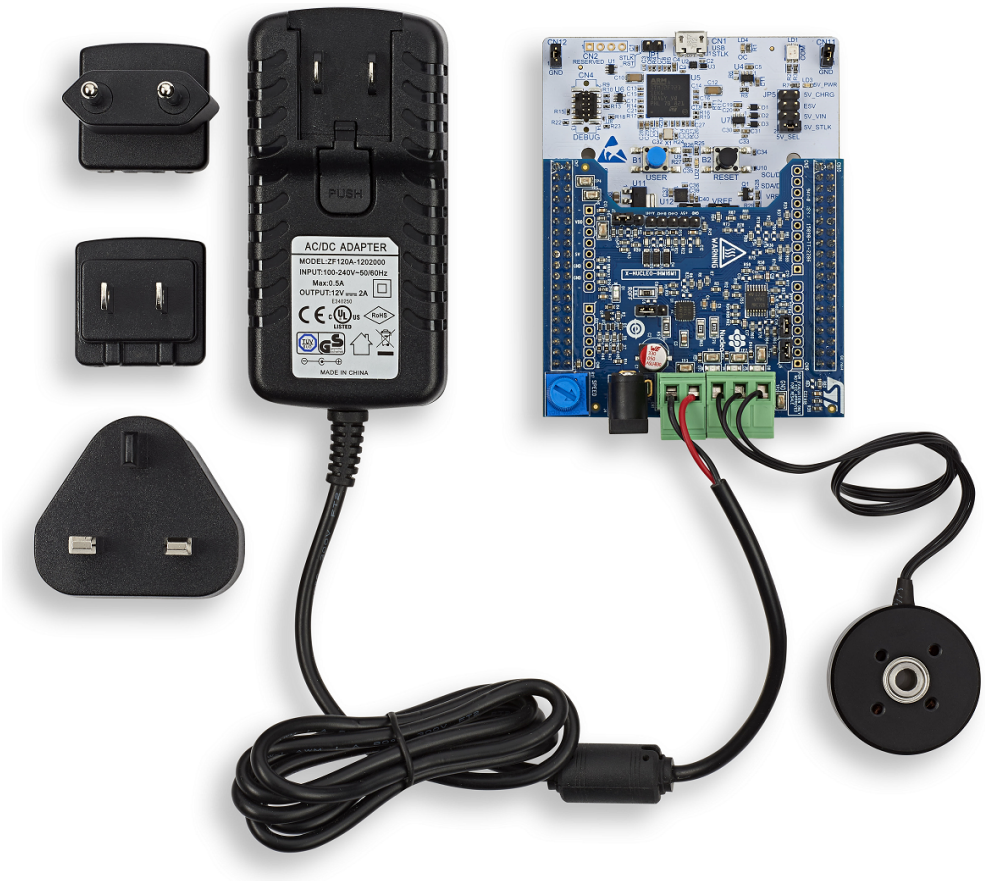
Introduction

The P-NUCLEO-IHM03 pack is the motor-control kit based on the X-NUCLEO-IHM16M1 and NUCLEO-G431RB boards. The power board with the STSPIN830 driver in the STPIN family provides a motor-control solution for three-phase, low-voltage, PMSM motors with the addition of the STM32 Nucleo board through the ST morpho connector as illustrated in Figure 1. P-NUCLEO-IHM03 is provided with a power supply unit also shown in Figure 1.

The device used on the power board is the STSPIN830. It is a compact and versatile FOC-ready driver for a three-phase motor. It supports both single- and three-shunt architectures and embeds a PWM current controller based on user-settable values of reference voltage and OFF time. Thanks to a dedicated MODE input pin, the device offers the freedom to decide whether to drive it through 6 inputs (one for each power switch) or a more common 3 PWM direct-driving inputs. In addition, it integrates both the control logic and a fully protected low-RDSon triple-half-bridge power stage. The NUCLEO-G431RB board provides an affordable and flexible way for users to try out new concepts and build prototypes with the STM32G4 microcontroller. It does not require any separate probe as it integrates the STLINK-V3E debugger and programmer.

This motor-control evaluation kit is fully configurable to support the closed-loop control (FOC only). It can be used with either a speed sensor mode (Hall or Encoder), or speed sensorless mode. It is compatible with both 1-shunt and 3-shunt current-sense topologies.

Figure 1. P-NUCLEO-IHM03 pack



Picture is not contractual.

1 Features

- X-NUCLEO-IHM16M1
  - Three-phase driver board for BLDC/PMSM motors based on STSPIN830
  - Nominal operating voltage range from 7 V dc to 45 V dc
  - Output current up to 1.5 A rms
  - Over-current, short-circuit, and interlocking protections
  - Thermal shutdown and under-voltage lockout
  - BEMF sensing circuitry
  - Support of 3-shunt or 1-shunt motor current sensing
  - Hall-effect-based sensors or encoder input connector
  - Potentiometer available for speed regulation
  - Equipped with ST morpho connectors
- NUCLEO-G431RB
  - STM32G431RB 32-bit microcontroller based on the Arm® Cortex®-M4 core at 170 MHz in LQFP64 package with 128 Kbytes of Flash memory and 32 Kbytes of SRAM
  - Two types of extension resources:
    - Arduino™ Uno V3 expansion connector
    - ST morpho extension pin headers for full access to all STM32 I/Os
  - On-board STLINK-V3E debugger/programmer with USB re-enumeration capability: mass storage, Virtual COM port, and debug port
  - 1 user and 1 reset push-buttons
- Three-phase motor:
  - Gimbal motor: GBM2804H-100T
  - Maximum DC voltage: 14.8 V
  - Maximum rotational speed: 2180 rpm
  - Maximum torque: 0.981 N·m
  - Maximum DC current: 5 A
  - Number of pole pairs: 7
- DC power supply:
  - Nominal output voltage: 12 V dc
  - Maximum output current: 2 A
  - Input voltage range: from 100 V ac to 240 V ac
  - Frequency range: from 50 Hz to 60 Hz

The STM32 32-bit microcontrollers are based on the Arm® Cortex®-M processor.

Note: Arm is a registered trademark of Arm Limited (or its subsidiaries) in the US and/or elsewhere.

2 Ordering information

To order the P-NUCLEO-IHM03, refer to Table 1. Additional information is available from the datasheet and reference manual of the target STM32.

Table 1. List of available products

Order code	Boards	Target STM32	Additional content
P-NUCLEO-IHM03	• X-NUCLEO-IHM16M1 • NUCLEO-G431RB	STM32G431RBT6U	• Power supply (12 V dc, 2 A) • Gimbal motor (GBM2804H-100T)

2.1 Product marking

Evaluation tools marked as “ES” or “E” are not yet qualified and therefore not ready to be used as reference design or in production. Any consequences deriving from such usage will not be at ST charge. In no event, ST will be liable for any customer usage of these engineering sample tools as reference design or in production.

“E” or “ES” marking examples of location:

- On the targeted STM32 that is soldered on the board (for illustration of STM32 marking, refer to the STM32 datasheet “Package information” paragraph at the *www.st.com* website).
- Next to the evaluation tool ordering part number that is stuck or silk-screen printed on the board.

This board features a specific STM32 device version, which allows the operation of any bundled commercial stack/library available. This STM32 device shows a "U" marking option at the end of the standard part number and is not available for sales.

In order to use the same commercial stack in his application, a developer may need to purchase a part number specific to this stack/library. The price of those part numbers includes the stack/library royalties.

2.2 Codification

The meaning of the codification of the Nucleo board is explained in Table 2.

Table 2. Nucleo-board codification explanation

NUCLEO-XXYYZT	Description	Example: NUCLEO-G431RB
XX	MCU series in STM32 32-bit Arm Cortex MCUs	STM32G4 Series
YY	MCU product line in the series	STM32G431
Z	STM32 package pin count: • R for 64 pins	64 pins
T	STM32 Flash memory size: • B for 128 Kbytes	128 Kbytes

The order code is mentioned on a sticker placed on the top side of the board.

3 Development environment

3.1 System requirements

- Windows® OS (7, 8 and 10), Linux® 64-bit, or macOS®
- USB Type-A to Micro-B cable

Note: macOS® is a trademark of Apple Inc. registered in the U.S. and other countries.

3.2 Development toolchains

- Keil® MDK-ARM (see note)
- IAR™ EWARM (see note)
- GCC-based IDEs

Note: On Windows® only.

3.3 Demonstration software

The demonstration software, included in the X-CUBE-MCSDK STM32Cube Expansion Package, is preloaded in the STM32 Flash memory for easy demonstration of the device peripherals in standalone mode. The latest versions of the demonstration source code and associated documentation can be downloaded from *www.st.com*.

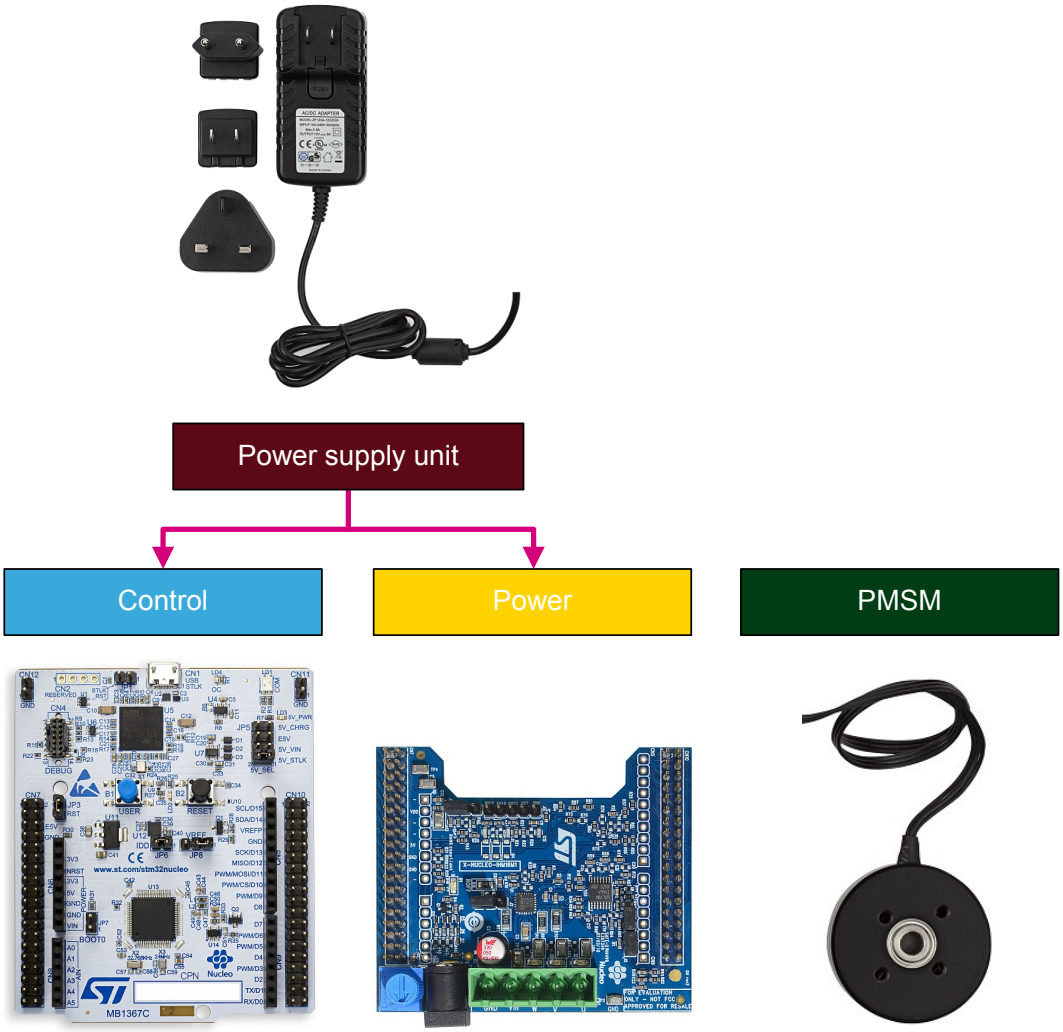
4 Getting started (basic user)

4.1 System architecture

The P-NUCLEO-IHM03 kit is based on the usual four-block architecture for a motor-control system :

- **Control block:** it interfaces user commands and configuration parameters to drive a motor. The P-NUCLEO-IHM03 kit is based on the NUCLEO-G431RB board that provides all needed signals to perform the proper motor-driving control algorithm (for instance FOC).
- **Power block:** the X-NUCLEO-IHM16M1 is based on a 3-phase inverter topology. The core of the power block embedded on board is the STSPIN830 driver, which embeds all the necessary active power and analog components to perform a low-voltage PMSM motor control.
- **PMSM motor:** low-voltage, 3-phase, brushless motor.
- **DC Power supply unit:** it provides the power for the other blocks (12 V, 2 A).

Figure 2. Four-block architecture of the P-NUCLEO-IHM03 pack



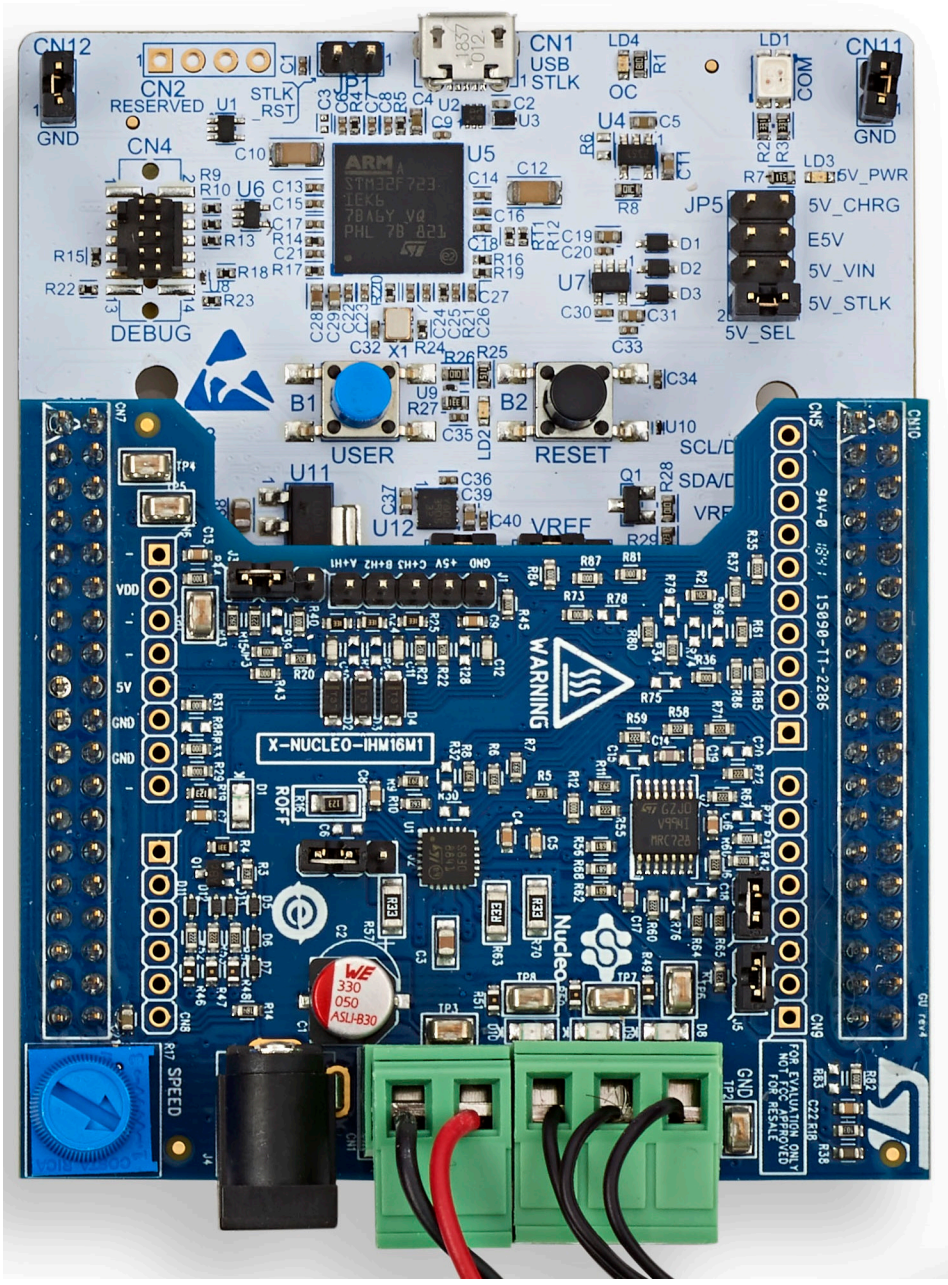
4.2 Configure and run the motor control from the STM32 Nucleo motor-control pack

The P-NUCLEO-IHM03 Nucleo pack is a complete hardware development platform for the STM32 Nucleo ecosystem to evaluate a motor-control solution with a single motor.

For operating the standard pack, follow these hardware configuration steps:

1. The X-NUCLEO-IHM16M1 must be stacked on the NUCLEO-G431RB board through the CN7 and CN10 ST morpho connectors. There is only one position allowed for this connection, in particular the two buttons on the NUCLEO-G431RB board (blue button B1 and black button B2) must be kept out, as shown in Figure 3.

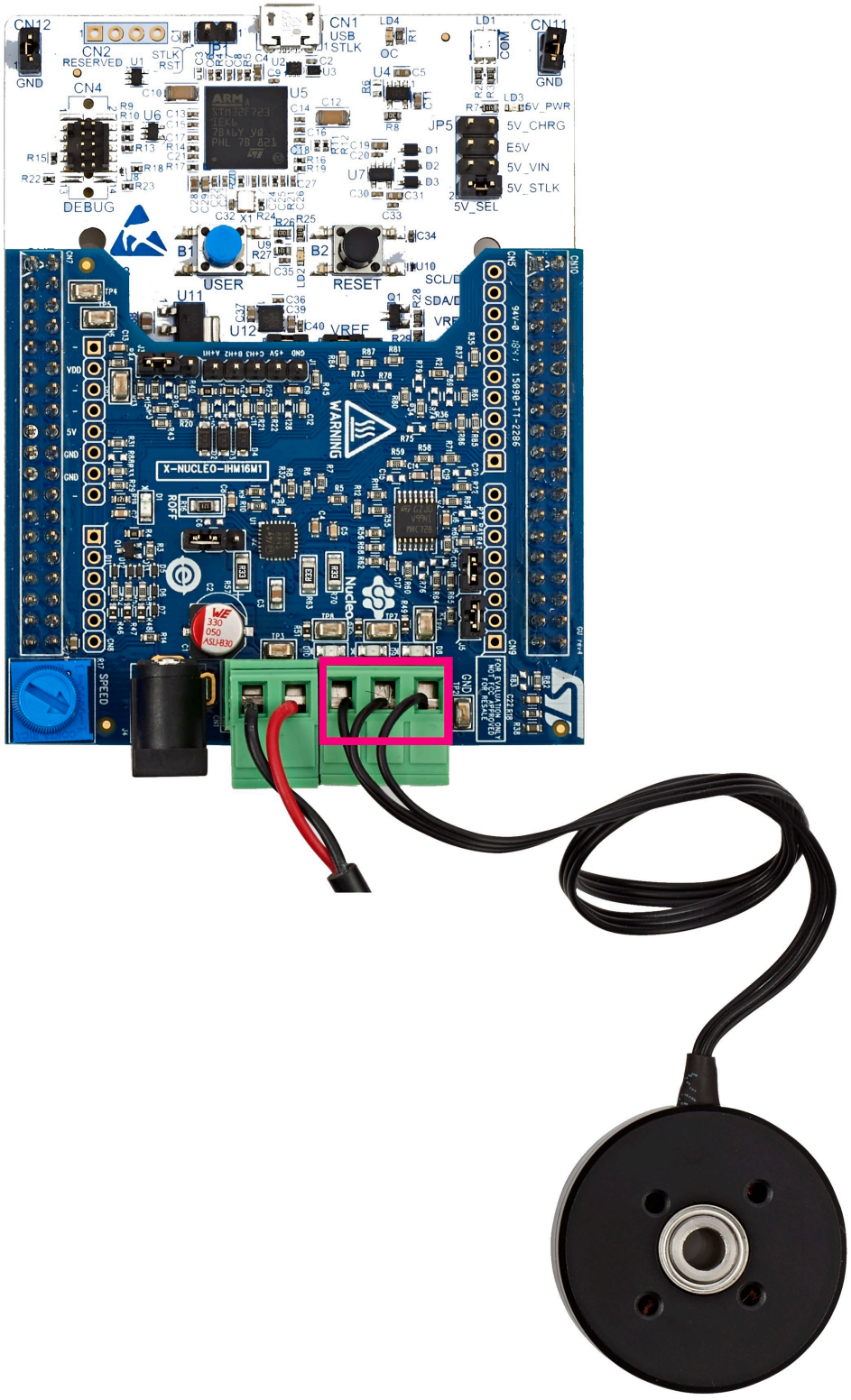
Figure 3. X-NUCLEO-IHM16M1 and NUCLEO-G431RB assembled



The interconnection between the X-NUCLEO-IHM16M1 and the NUCLEO-G431RB board is designed for full compatibility with many control boards. No modification of solder bridges is required for the use of the FOC algorithm.

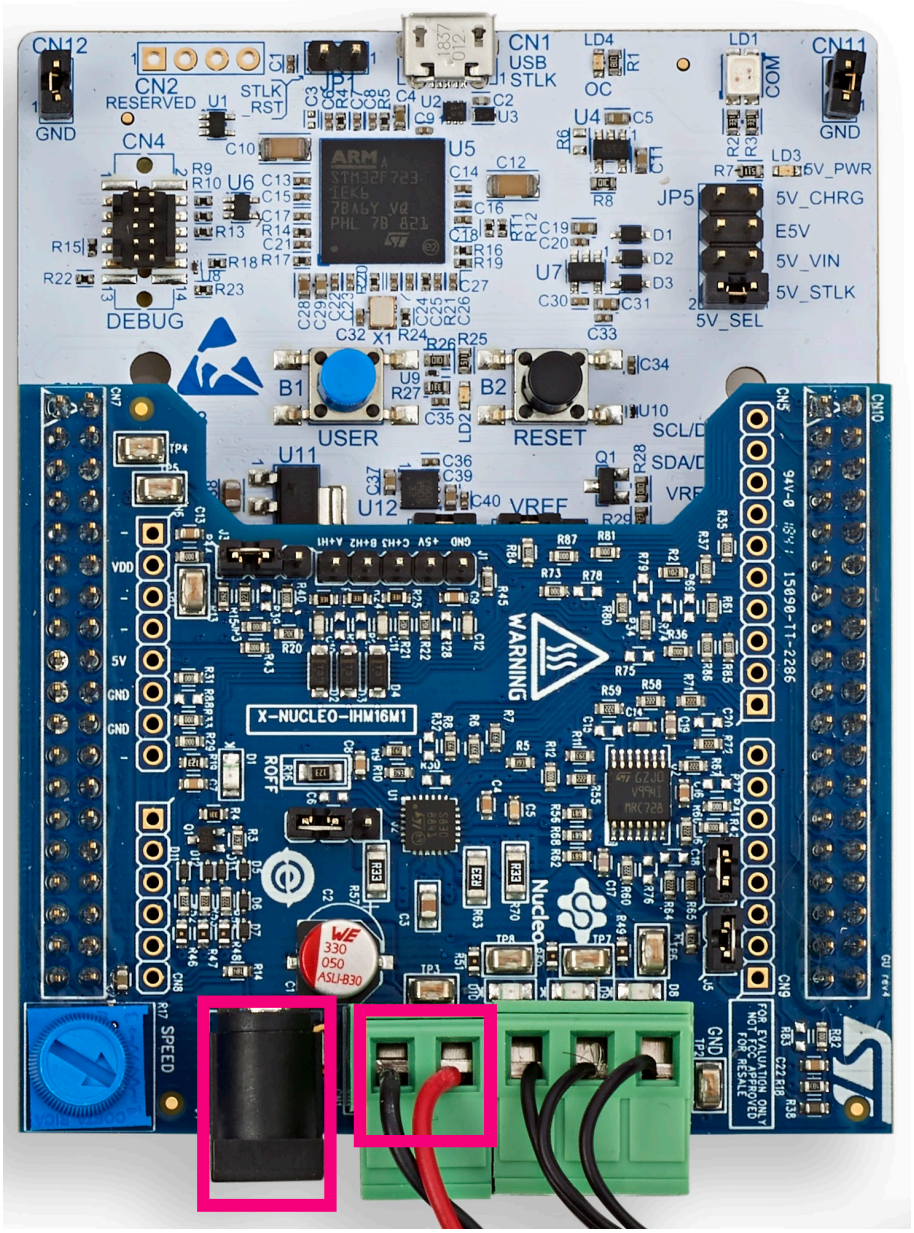
2. Connect the three motor wires U,V,W on the CN1 connector as shown in Figure 4.

Figure 4. Motor connection with X-NUCLEO-IHM16M1



3. Select the jumper configuration on the power board to choose the desired control algorithm (FOC) as described below:
   a. On the NUCLEO-G431RB board, check the jumper settings: JP5 on position [1-2] for 5V_STLK source, JP8 (VREF) on position [1-2], JP6 (IDD) closed.(1)
   b. On the X-NUCLEO-IHM16M1 board(2):
      - Check jumper settings: J5 closed, J6 closed
      - For FOC control, set jumper settings as: JP4 and JP7 solder bridge left open, J2 closed on position [2-3], J3 closed on position [1-2]
4. Connect the DC power supply (use the power supply provided with the pack or an equivalent one) on CN1 or J4 connector and power-on (up to 12 V DC for the Gimbal motor included in the P-NUCLEO-IHM03 pack, as shown in Figure 5.

Figure 5. Power-supply connection for X-NUCLEO-IHM16M1



5. Press the blue button on NUCLEO-G431RB (B1) to start spinning the motor.

6. Rotate the potentiometer on X-NUCLEO-IHM16M1 to regulate the motor speed.

1. *To supply the NUCLEO-G431RB from the USB, the jumper JP5 must be connected between Pin 1 and Pin 2. For further details on Nucleo settings refer to [3].*
2. *Supply voltage must be off before changing the control mode.*

4.3 Hardware settings

Table 3 shows the jumper configuration on the X-NUCLEO-IHM16M1 board as shown in Figure 6. According to the jumper selection, it is possible to choose the 1-shunt or 3-shunt current-sensing mode, the Hall encoder with pull-up, or the external supply for the NUCLEO-G431RB board.

Table 3. Jumper settings

Jumper	Permitted configuration	Default condition
J5	Selection of the FOC control algorithm.	CLOSED
J6	Selection of the FOC control algorithm.	CLOSED
J2	Selection of the HW current limiter threshold (disabled in 3-shunt configuration by default).	[2-3] CLOSED
J3	Selection of fixed or adjustable current limiter threshold (fixed by default).	[1-2] CLOSED
JP4 and JP7(1)	Selection of 1-shunt or 3-shunt configuration (3-shunt by default).	OPEN

1. *JP4 and JP7 must have both the same configuration: both left open for 3-shunt configuration, both closed for 1- shunt configuration. On the silkscreen, the correct position for 3- or 1-shunt is indicated together with the default position.*

Table 4 shows the main connectors on the X-NUCLEO-IHM16M1 board.

Table 4. Screw terminal table

Screw terminal	Function
J4	Motor power supply input (7 to 45 Vdc)
CN1	3-phase motor connector (U,V,W) and Motor Power Supply input (when J4 is not used)

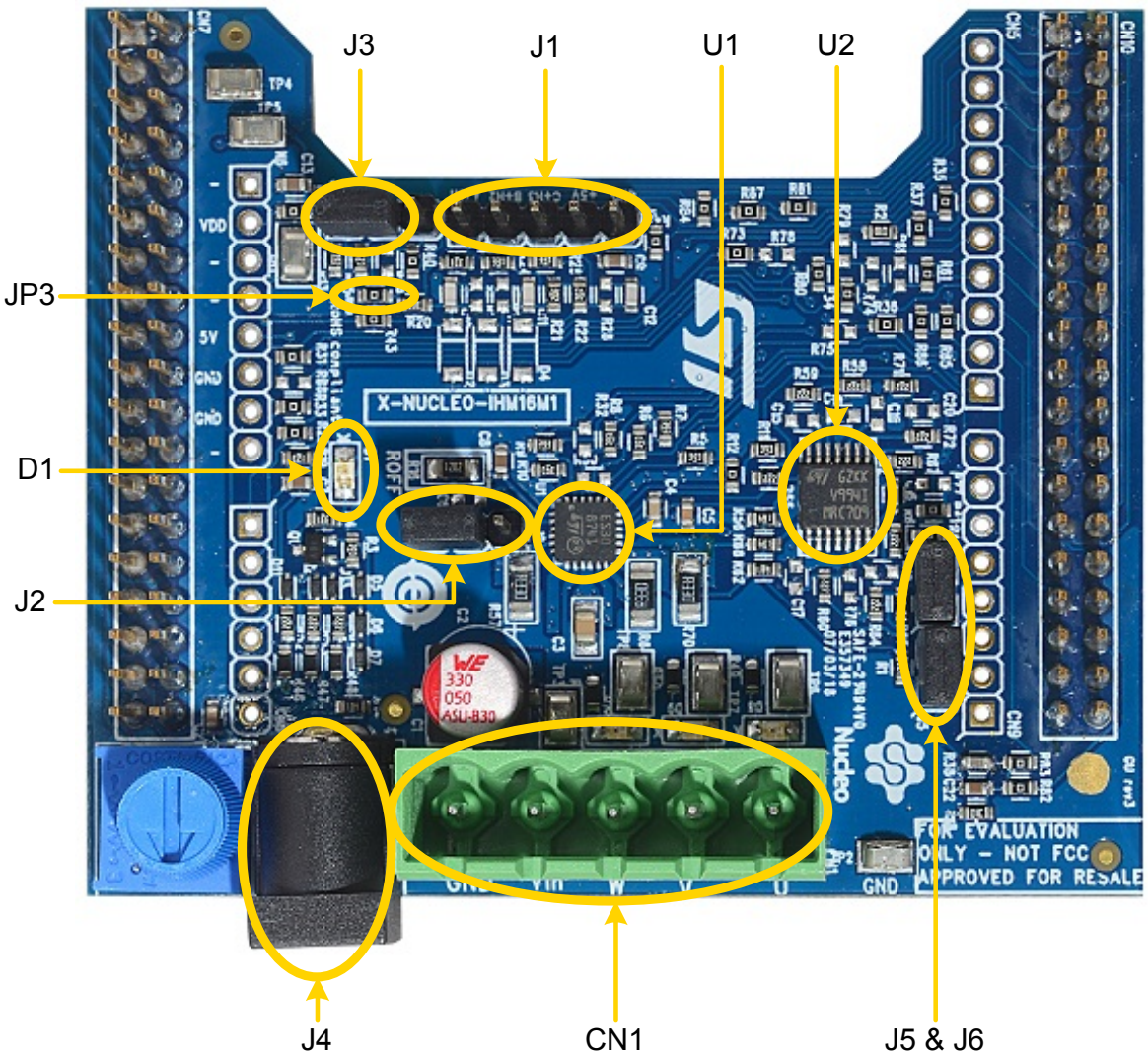
The X-NUCLEO-IHM16M1 is stacked on ST morpho connectors, male pin headers (CN7 and CN10) accessible on both sides of the board. They can be used to connect this power board to the NUCLEO-G431RB board. All signals and power pins for the MCU are available on the ST morpho connectors. For further details refer to the *"ST morpho connectors"* section in [3].

Table 5. Connector description

Part reference	Description
CN7, CN10	ST morpho connector
CN5, CN6, CN9, CN8	Arduino Uno connector
U1	STSPIN830 driver
U2	TSV994IPT op. amp.
J4	Power-supply jack connector
J5, J6	Jumpers for FOC use
SPEED	Potentiometer
CN1	Motor- and power-supply connector

Part reference	Description
J1	Hall-encoder sensor connector
J2, J3	Current limiter use and configuration
JP3	External pull-up for sensors
JP4, JP7	Current measure mode (1 shunt / 3 shunt)
D1	LED status indicator

Figure 6. X-NUCLEO-IHM16M1 connectors



4.4 Upload the firmware example

The example for the motor-control application example is pre-loaded in the NUCLEO-G431RB board. This example is using the FOC (field-oriented control) algorithm. This chapter describes the procedure to reload the firmware demonstration inside the NUCLEO-G431RB board and restart by the default condition. There are two ways to do it:

- Drag-and-drop procedure (suggested), as detailed in Section 4.4.1

- Through the STM32CubeProgrammer (STM32CubeProg) tool (free download available from STMicroelectronics web site: *www.st.com*), as shown in Section 4.4.2

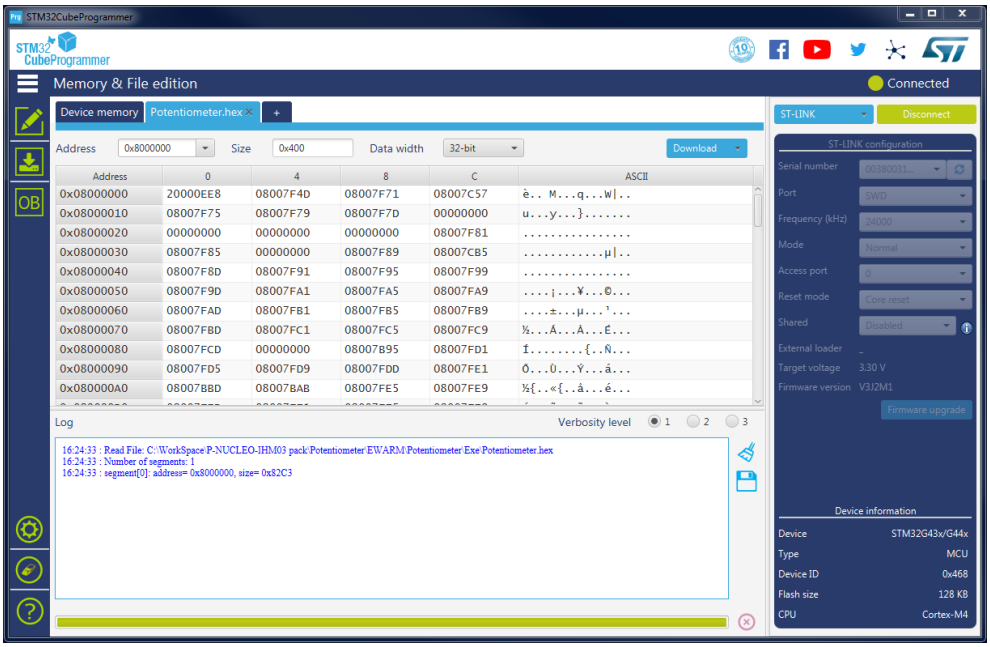
4.4.1 Drag-and-drop procedure

1. Install the ST-LINK drivers from the *www.st.com* website.
2. On the NUCLEO-G431RB board, set the JP5 jumper in position U5V.
3. Plug the NUCLEO-G431RB board to the host PC using a Type-A to Micro-B USB cable. If the ST-LINK driver is correctly installed, it is recognized as an external memory device called *"NUCLEO"* or any similar name.
4. Drag and drop the binary file of the firmware demonstration (*P-NUCLEO-IHM003.out*) into the *"NUCLEO"* device, listed inside the list of the disk drives (click on the *Start* button of Windows®), contained into the X-CUBE-SPN7 firmware pack.
5. Wait until the programming is complete.

4.4.2 STM32CubeProgrammer tool

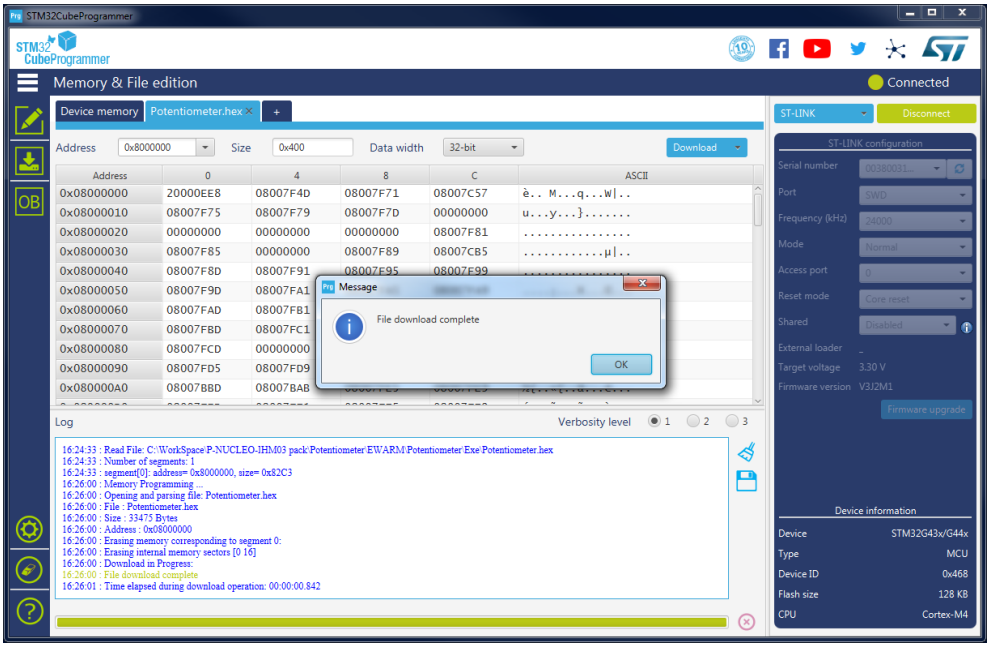
1. Open the STM32CubeProgrammer tool (STM32CubeProg).
2. Connect the NUCLEO-G431RB board to the PC with a USB Type-A to Micro-B cable through the USB connector (CN1) on the NUCLEO-G431RB board.
3. Open either the *Potentiometer.out* or *Potentiometer.hex* file as the code to be downloaded. The corresponding window appears as shown in Figure 7.

Figure 7. STM32CubeProgrammer tool



4. Click on the *Download* button (refer to Figure 8).

Figure 8. **STM32CubeProgrammer download**



5. Press the Reset button (B2) on the NUCLEO-G431RB board to start using the motor.

4.5 Demonstration usage

This section describes how to use the setup to spin the motor:

1. Press the Reset button (black) (NUCLEO-G431RB board)
2. Press the User button (blue) to start the motor (NUCLEO-G431RB board)
3. Check that the motor starts spinning and LEDs D8, D9, and D10 are turned on (X-NUCLEO-IHM16M1 board)
4. Rotate the User rotary knob (blue) clockwise to the maximum (X-NUCLEO-IHM16M1 board)
5. Check that the motor is stopped and LEDs D8, D9, and D10 are turned off (X-NUCLEO-IHM16M1 board)
6. Rotate the User rotary knob (blue) counterclockwise to the maximum (X-NUCLEO-IHM16M1 board)
7. Check that the motor is spinning at a higher speed compared to step 3 and LEDs D8, D9, and D10 are turned on (X-NUCLEO-IHM16M1 board)
8. Rotate the User rotary knob (blue) to 1/3 of its maximum (X-NUCLEO-IHM16M1 board)
9. Check that the motor is spinning at a lower speed compared to step 7 and LEDs D8, D9, and D10 are turning on (X-NUCLEO-IHM16M1 board)
10. Press the User button (blue) to stop the motor (NUCLEO-G431RB board)
11. Check that the motor is stopped and LEDs D8, D9, and D10 are turning off (X-NUCLEO-IHM16M1 board)

5 FOC control algorithm settings (advanced user)

The P-NUCLEO-IHM03 pack supports the ST FOC library. No hardware modification is needed to run the motor provided in a 3-shunt current-sensing mode. To use the FOC in a 1-shunt configuration, the user must reconfigure the X-NUCLEO-IHM16M1 board to select the 1-shunt current sensing and the current-limiter features according to the jumper settings as given in Table 3. Jumper settings. The MC SDK installation is required to reconfigure the P-NUCLEO-IHM03 project for 1-shunt current sensing, generation, and use.

For further information about the MC SDK, refer to [5].

6 Electrical schematics

This chapter presents some of the X-NUCLEO-IHM16M1 schematics related to the material detailed in the user manual:

- Figure 9. X-NUCLEO-IHM16M1 motor driver connections
- Figure 10. X-NUCLEO-IHM16M1 current-sensing conditioning circuit
- Figure 11. X-NUCLEO-IHM16M1 sensors and shunt resistor circuit
- Figure 12. X-NUCLEO-IHM16M1 L6230 driver and BEMF detection circuit
- Figure 13. X-NUCLEO-IHM16M1 MCU pin assignment

Note: Users are advised to check for the most up-to-date schematics of X-NUCLEO-IHM16M1 and NUCLEO-G431RB on STMicroelectronics www.st.com web site.

Figure 9. X-NUCLEO-IHM16M1 motor driver connections

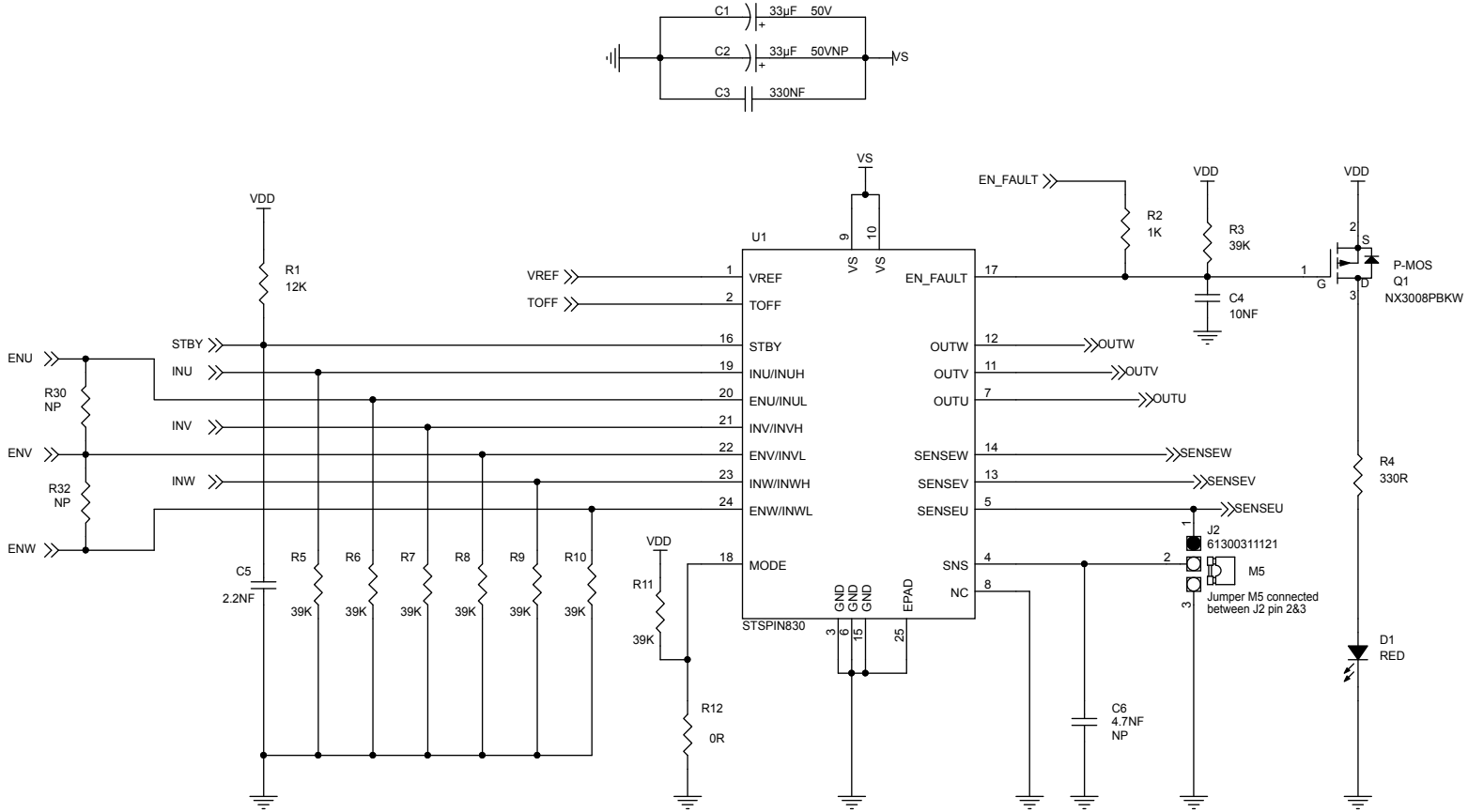


Figure 10. X-NUCLEO-IHM16M1 current-sensing conditioning circuit

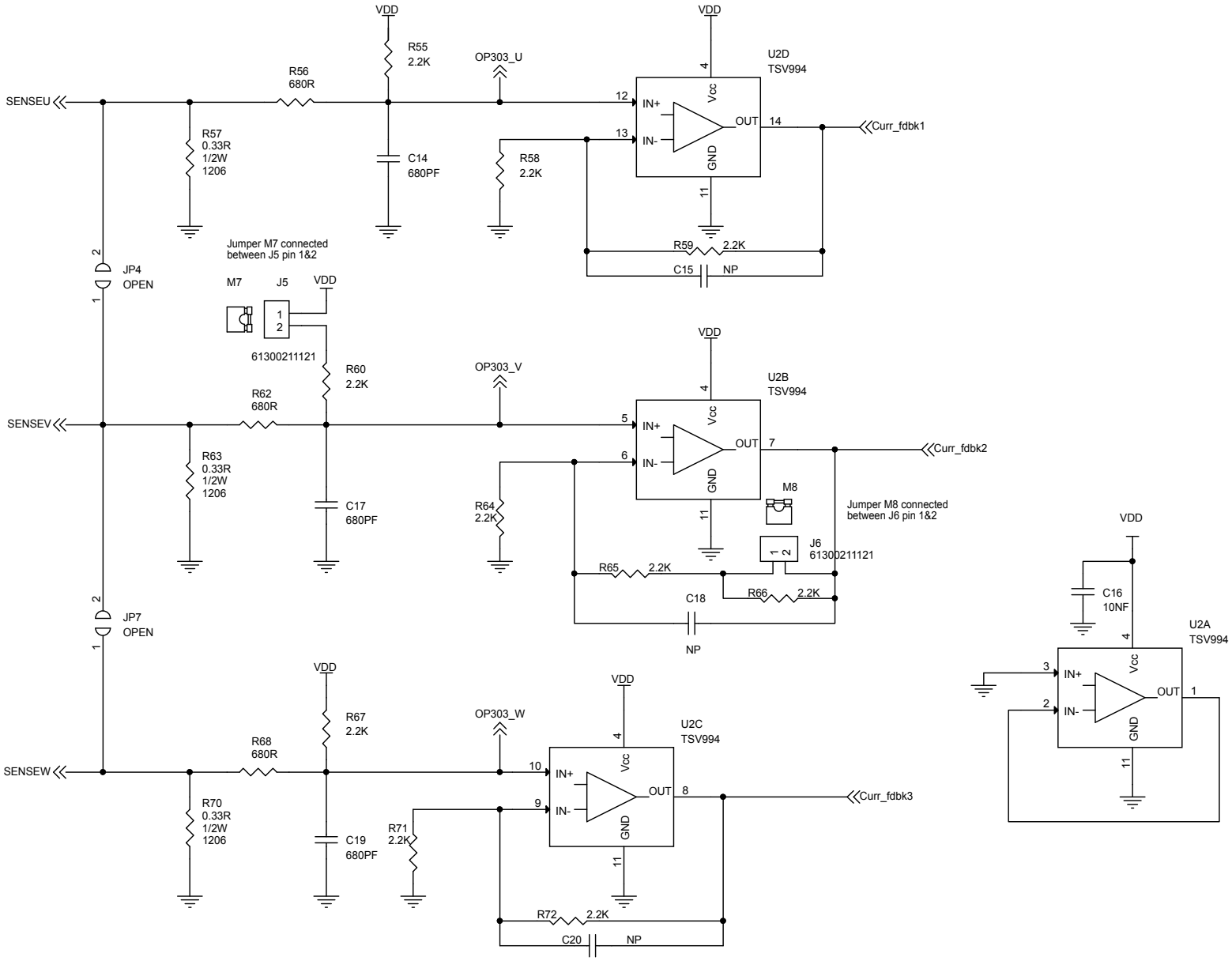


Figure 11. X-NUCLEO-IHM16M1 sensors and shunt resistor circuit

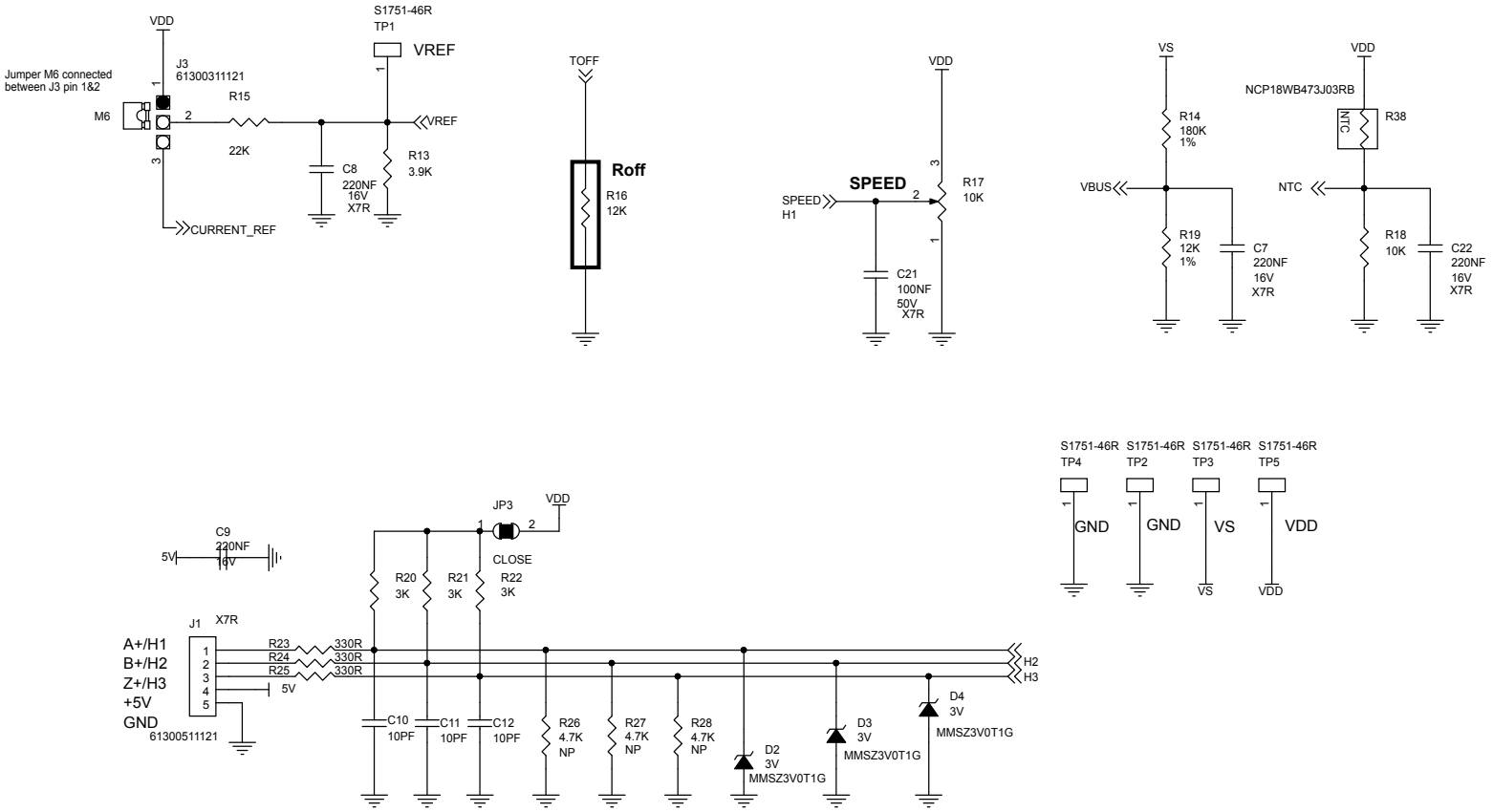


Figure 12. X-NUCLEO-IHM16M1 L6230 driver and BEMF detection circuit

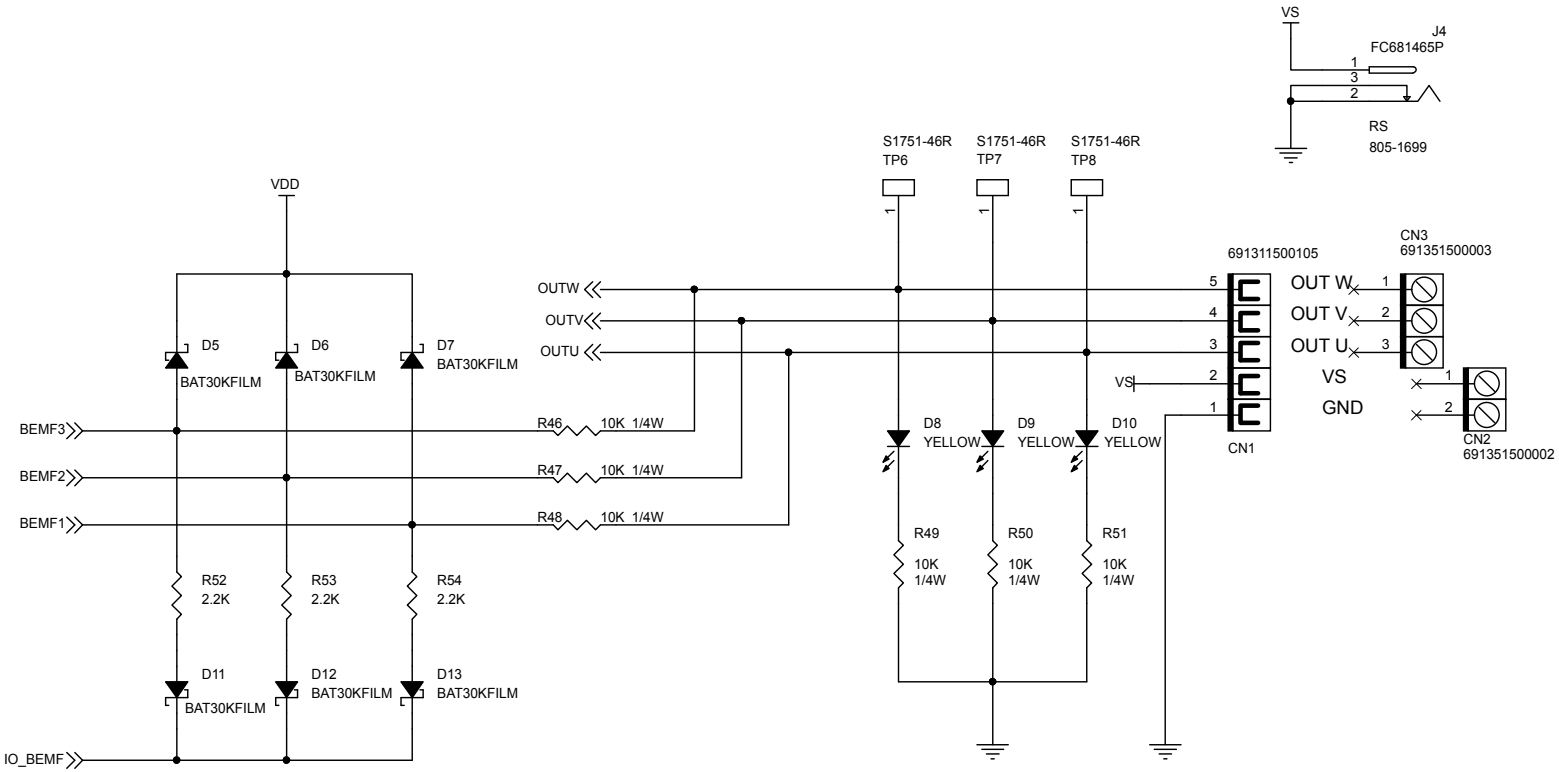
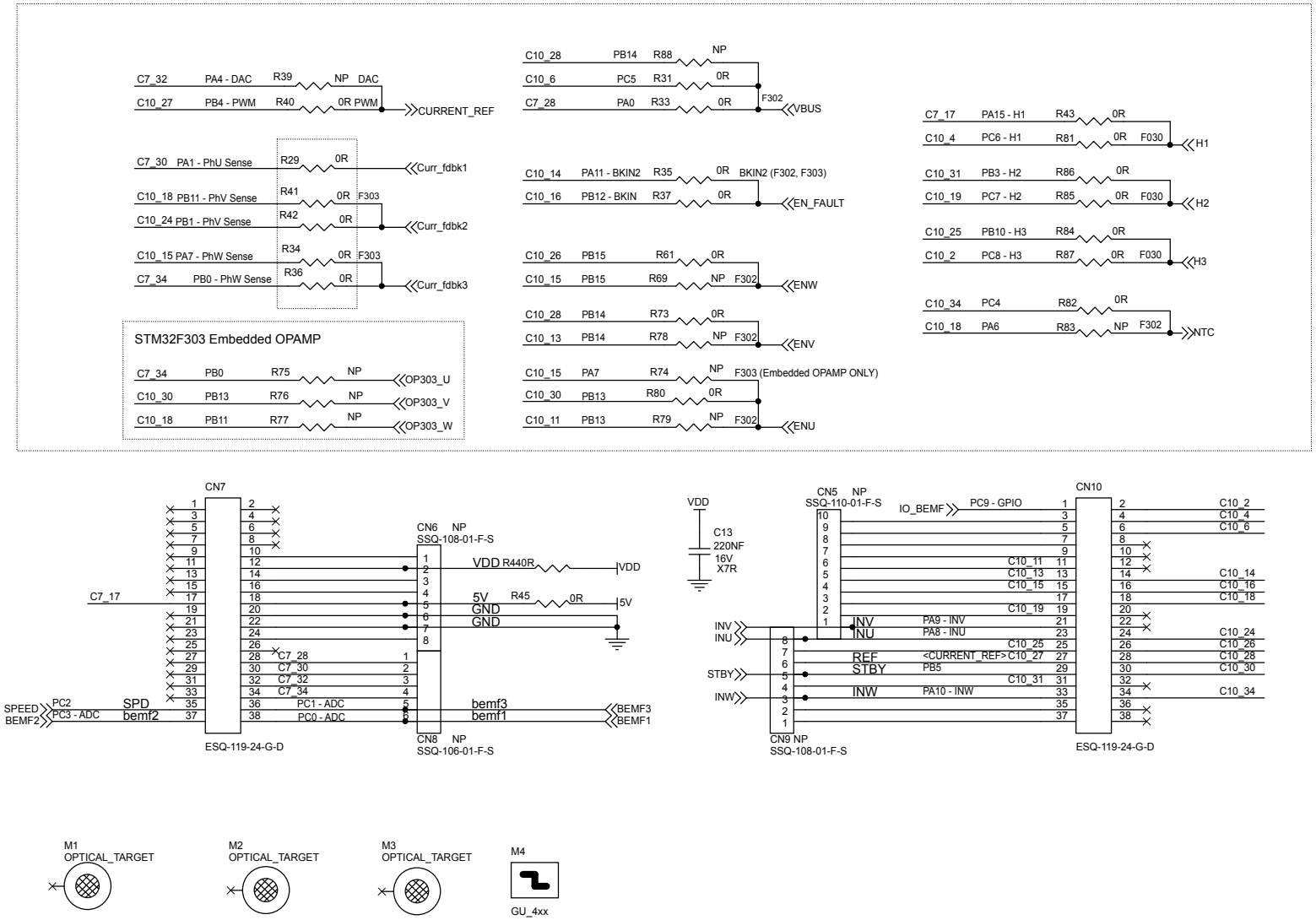


Figure 13. X-NUCLEO-IHM16M1 MCU pin assignment



7 References

Table 6 lists STMicroelectronics related documents available at *www.st.com* for supplementary information.

Table 6. STMicroelectronics reference documents

ID	Reference document
[1]	*Getting started with the X-NUCLEO-IHM16M1 three-phase brushless motor driver board based on STSPIN830 for STM32 Nucleo* user manual (UM2415).
[2]	*Getting started with the X-CUBE-SPN16 three-phase brushless DC motor driver software expansion for STM32Cube* user manual (UM2419).
[3]	*STM32G4 Nucleo-64 boards (MB1367)* user manual (UM2505).
[4]	*Compact and versatile three-phase and three-sense motor driver* datasheet (DS12584).
[5]	*STM32 MC SDK software expansion for STM32Cube* data brief (DB3548).
[6]	*Getting started with STM32 motor control SDK v5.0* user manual (UM2374).

Appendix A Federal Communications Commission (FCC) and Industry Canada (IC) Compliance Statements

A.1 FCC Compliance Statement

Part 15.19

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Part 15.21

Any changes or modifications to this equipment not expressly approved by STMicroelectronics may cause harmful interference and void the user's authority to operate this equipment.

Part 15.105

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception which can be determined by turning the equipment off and on, the user is encouraged to try to correct interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Note: Use only shielded cables.

Responsible party (in the USA)

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750 Canyon Drive | Suite 300 | Coppell, Texas 75019
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A.2 IC Compliance Statement

This device complies with FCC and Industry Canada RF radiation exposure limits set forth for general population for mobile application (uncontrolled exposure). This device must not be collocated or operating in conjunction with any other antenna or transmitter.

Compliance Statement

Notice: This device complies with Industry Canada licence-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Industry Canada ICES-003 Compliance Label: CAN ICES-3 (B) / NMB-3 (B).

Déclaration de conformité

Avis: Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Étiquette de conformité à la NMB-003 d'Industrie Canada : CAN ICES-3 (B) / NMB-3 (B).

Revision history

Table 7. **Document revision history**

Date	Version	Changes
19-Apr-2019	1	Initial release.

Contents

List of tables

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