

## Getting started with the X-NUCLEO-IHM16M1 three-phase brushless motor driver board based on STSPIN830 for STM32 Nucleo

### Introduction

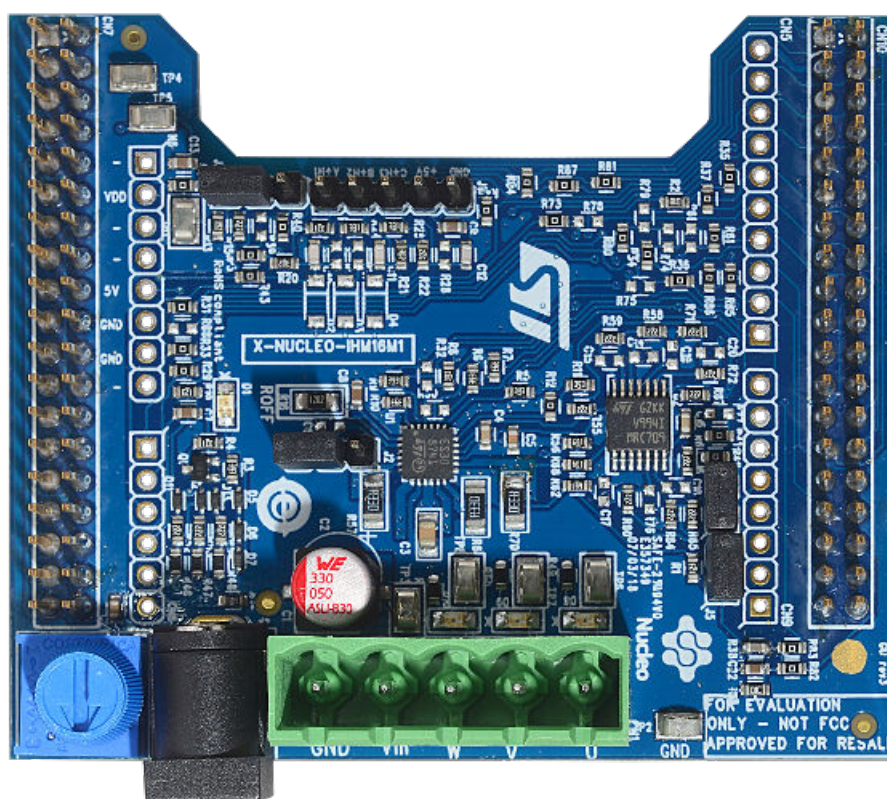
The **X-NUCLEO-IHM16M1** motor driver expansion board is based on the **STSPIN830** monolithic driver for three-phase brushless motors.

It represents an affordable, easy-to-use solution for driving brushless motors in your STM32 Nucleo project, implementing single and three-shunt current sensing.

The **STSPIN830** embeds a PWM current limiter with adjustable threshold together with a full set of protections.

The **X-NUCLEO-IHM16M1** expansion board is compatible with the Arduino and ST morpho connectors, so it can be plugged to an STM32 Nucleo development board and stacked with additional STM32 Nucleo expansion boards.

Figure 1. X-NUCLEO-IHM16M1 expansion board



## 1 Hardware and software requirements

To use the [STM32 Nucleo](#) development boards with the [X-NUCLEO-IHM16M1](#) expansion board, the following software and hardware are required:

- a Windows PC (7, 8 or 10)
- an [X-NUCLEO-IHM16M1](#) expansion board
- an [STM32 Nucleo](#) development board
- a type A USB to mini-B USB cable to connect the [STM32 Nucleo](#) board to the PC
- the STM32 Motor Control SDK ([X-CUBE-MCSDK](#))
- an IDE chosen among IAR Embedded Workbench for ARM ([IAR-EWARM](#)), Keil microcontroller development kit ([MDK-ARM-STR](#)) and integrated development environment for STM32 ([STM32CubeIDE](#))
- a power supply with output voltage between 7 and 45 V
- a three-phase brushless motor with compatible voltage and current for the power supply and the [STSPIN830](#) driver

## 2 Safety precautions

**Danger:**



*Some of the components mounted on the board could reach hazardous temperature during operation.*

While using the board:

- Do not touch the components
- Do not cover the board
- Do not put the board in contact with flammable materials or with materials releasing smoke when heated
- After operation, allow the board to cool down before touching it

## 3 Getting started

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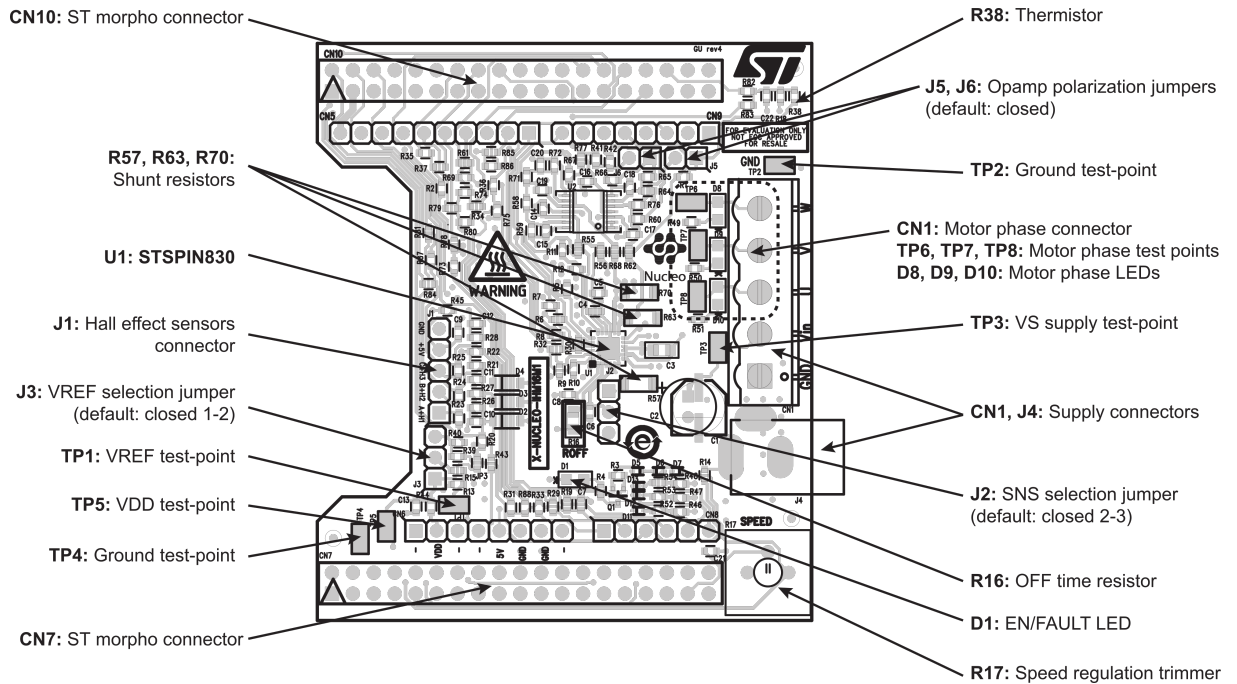
To start your project with the board:

- Step 1.** Check the jumper positions and the mounting options according to the desired operation mode (see [Section 4.1: Operation mode and sensing topology selection](#)) and STM32 Nucleo development board (see STM32 Nucleo development board compatibility)
- Step 2.** Connect the X-NUCLEO-IHM16M1 with the STM32 Nucleo development board through ST morpho connectors (CN7, CN10)
- Step 3.** Connect the brushless motor to 3-4-5 outputs of CN1 using the provided screw terminal
- Step 4.** Connect the STM32 Nucleo development board to the PC using a USB cable and download the corresponding pre-compiled code
- Step 5.** Supply the board through one of the supply connectors:
  - inputs 2 (VIN) and 1 (ground) of CN1 using the provided screw terminal
  - J4 jack input (2.1 mm or 2.5 mm, tip positive)
- Step 6.** Develop your application using the STM32 Motor Control SDK ([X-CUBE-MCSDK](#))

## 4 Hardware description and configuration

The figure below shows the X-NUCLEO-IHM16M1 main component positions.

**Figure 2. X-NUCLEO-IHM16M1 component positions**



The table below lists the signals mapped on the ST morpho connectors.

**Table 1. X-NUCLEO-IHM16M1 ST morpho connector pinouts**

| Connector | Pin | Signal                           | Remarks   |
|-----------|-----|----------------------------------|---|
| CN7       | 12  | VDD (pull-up voltage)            | 3.3 V in STM32 Nucleo dev. boards.<br>Through R44 |
|           | 17  | Hall-effect sensor 1             | R43   |
|           | 18  | 5 V                              |   |
|           | 20  | Ground                           |   |
|           | 22  | Ground                           |   |
|           | 28  | Motor supply voltage sensing     | R33   |
|           | 30  | Current feedback phase U         | R29   |
|           | 32  | Current reference (DAC)          | R39 (NP by default)                               |
|           | 34  | Current feedback phase W         | R36   |
|           |     | STM32F303RE embedded PGA input U | R75 (NP by default)                               |
|           | 35  | Speed reference signal           |   |
|           | 36  | BEMF feedback phase W            |   |
|           | 37  | BEMF feedback phase V            |   |
|           | 38  | BEMF feedback phase V            |   |
| CN10      | 1   | BEMF divider GPIO                |   |
|           | 2   | Hall-effect sensor 3             | R87   |

| Connector | Pin | Signal                           | Remarks             |
|-----------|-----|----------------------------------|---------------------|
| CN10      | 4   | Hall-effect sensor 1             | R81                 |
|           | 6   | Motor supply voltage sensing     | R31                 |
|           | 11  | ENU driving signal               | R79 (NP by default) |
|           | 13  | ENV driving signal               | R78 (NP by default) |
|           | 14  | EN/FAULT signal                  | R35                 |
|           | 15  | Current feedback phase W         | R34                 |
|           |     | ENU driving signal               | R69 (NP by default) |
|           |     | ENW driving signal               | R74 (NP by default) |
|           | 16  | EN/FAULT signal                  | R37                 |
|           | 18  | Current feedback phase V         | R41                 |
|           |     | STM32F303RE embedded PGA input W | R77 (NP by default) |
|           |     | PCB temperature sensing (NTC)    | R83 (NP by default) |
|           | 19  | Hall-effect sensor 2             | R85                 |
|           | 21  | INV driving signal               |                     |
|           | 23  | INU driving signal               |                     |
|           | 24  | Current feedback phase V         | R42                 |
|           | 25  | Hall-effect sensor 3             | R84                 |
|           | 26  | ENW driving signal               | R61                 |
|           | 27  | Current reference (PWM)          | R40                 |
|           | 28  | ENV driving signal               | R73                 |
|           |     | Motor supply voltage sensing     | R88 (NP by default) |
|           | 29  | Active low standby               |                     |
|           | 30  | STM32F303RE embedded PGA input V | R76 (NP by default) |
|           |     | ENU driving signal               | R80                 |
|           | 31  | Hall-effect sensor 2             | R86                 |
|           | 33  | INW driving signal               |                     |
|           | 34  | PCB temperature sensing (NTC)    | R82                 |

## 4.1 Operation mode and sensing topology selection

The X-NUCLEO-IHM16M1 expansion board supports 6-step and field oriented control (FOC) algorithms. According to the algorithm, the board hardware configuration must be changed as follows:

**Table 2. X-NUCLEO-IHM16M1 expansion board configuration based on the algorithm used**

| 6-step <sup>(1)</sup>                          |                        |  |   | FOC (3-shunt) <sup>(2)</sup>                  |                         |                           |                                 | FOC (single shunt)                             |                         |  |   |
|--|------------------------|--|---|---|-------------------------|---------------------------|---------------------------------|--|-------------------------|--|---|
| Single shunt                                   | Current sensing        | Current limiter enabled <sup>(3)</sup> | Adjustable current limiter threshold <sup>(3)</sup> | Three-shunt                                   | Current sensing         | Current limiter disabled  | Fixed current limiter threshold | Single shunt                                   | Current sensing         | Current limiter enabled <sup>(3)</sup> | Adjustable current limiter threshold <sup>(3)</sup> |
| Close JP4 and JP7, solder bridge at the bottom | Open J5 and J6 jumpers | J2 closed to 1-2 position              | J3 closed to 2-3 position                           | Open JP4 and JP7, solder bridge at the bottom | Close J5 and J6 jumpers | J2 closed to 2-3 position | J3 closed to 1-2 position       | Close JP4 and JP7, solder bridge at the bottom | Close J5 and J6 jumpers | J2 closed to 1-2 position              | J3 closed to 2-3 position                           |

1. Voltage or current mode.
2. Default configuration
3. Optional.

## 4.2 Current sensing

The X-NUCLEO-IHM16M1 expansion board mounts three shunt resistors to sense the current in each motor phase.

For each shunt resistor, the TSV994 operational amplifier performs signal conditioning before sending the sensed value to the ADC inputs of the STM32.

**Table 3. TSV994 operational amplifier configuration**

| Opamp | Sensed current         | Gain | Out offset | J5     | J6     | Remarks |
|-------|------------------------|------|------------|--------|--------|---------|
| 1     | None (grounded)        | 1    | 0 V        |        |        | Unused  |
| 2     | Phase V <sup>(1)</sup> | 1.53 | 1.56 V     | Closed | Closed | FOC     |
|       |                        | 3    | 0 V        | Open   | Open   | 6STEP   |
| 3     | Phase W <sup>(1)</sup> | 1.53 | 1.56 V     |        |        | FOC     |
| 4     | Phase U <sup>(1)</sup> | 1.53 | 1.56 V     |        |        | FOC     |

1. In single shunt topology, all the operational amplifiers sense the same current.

### 4.2.1 Sense resistor value and maximum current range in FOC mode

The sensed current range in FOC mode could be limited by the value of the shunt resistor.

The mounted resistor of 330 mΩ allows an up to 1 A reading without distortion.

For better performance at 1.5 A, you should reduce the shunt resistor value to 100 mΩ. The op-amp gain has to be tuned accordingly.

#### Related links

For further details, refer to the AN5386, STSPIN830: measuring negative voltages on sense resistors.

## 4.3 STSPIN830 current limiter

The STSPIN830 implements a PWM current limiter.

In single shunt topology, the device monitors the motor current through the SNS pin connected to the sensing resistor.

When the SNS pin ( $V_{SNS}$ ) voltage exceeds the reference voltage threshold ( $V_{REF}$ ) the current limiter is triggered, the OFF time is started and all the power outputs are disabled (high impedance) until the OFF time expires.

J2 jumper selects the SNS input connection: when closed in 2-3 position (default), it shorts the pin to ground disabling the current limiter feature; when closed in 1-2 position, it connects the pin to the shunts.

It is possible to set the  $V_{REF}$  value in two ways:

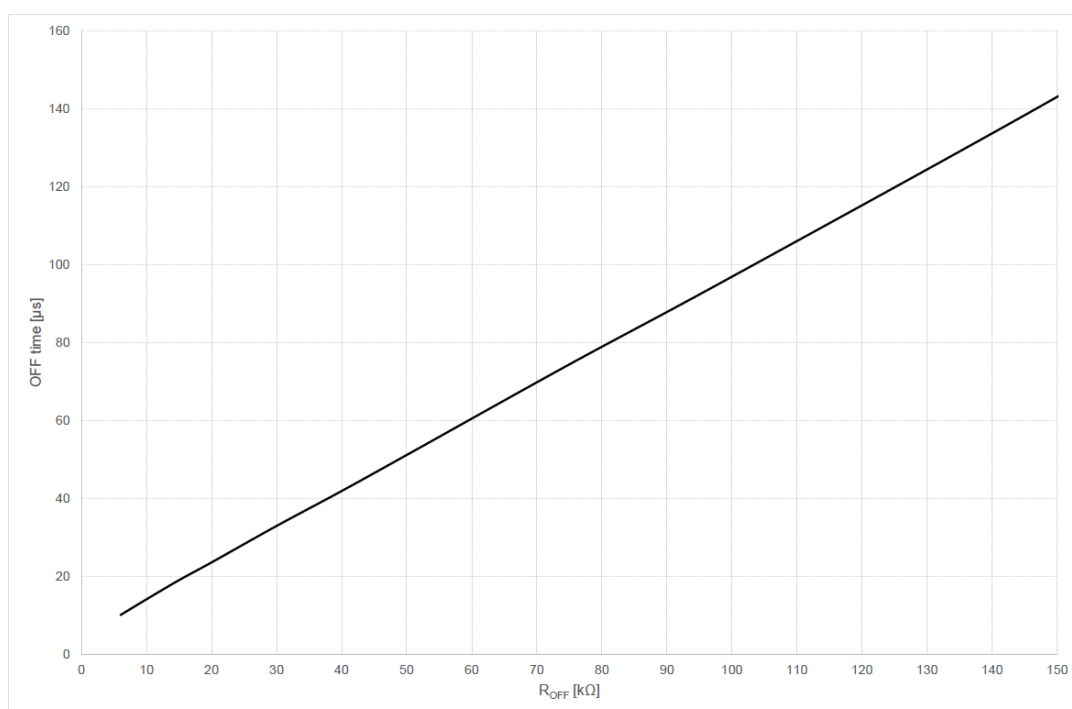
- **J3 closed in 1-2 position:** fixed to 0.497 V corresponding to about 4.5 A in single shunt topology (equivalent resistance 0.11  $\Omega$ )
- **J3 closed in 2-3 position:** adjustable through MCU up to 0.497 V corresponding to about 4.5 A in single shunt topology (equivalent resistance 0.11  $\Omega$ ).

The MCU can set the reference voltage through:

1. PWM signal (default)
2. DAC output, if available (not connected by default)

R16 resistor sets the OFF time duration according to the graph shown below (default value is about 18  $\mu$ s).

**Figure 3. OFF time vs.  $R_{OFF}$  value**



## 4.4 STSPIN830 logic inputs and fault signaling

The STSPIN830 offers two methods for driving the power stage selectable through the MODE pin.

When the MODE pin is low, the ENx and INx inputs control the power outputs according to [Table 4. ENx and INx inputs truth table \(MODE = L\)](#) (the board default configuration).

When MODE pin is high, the INxH and INxL inputs control the power outputs according to [Table 5. INxL and INxH inputs truth table \(MODE = H\)](#). This configuration is set by removing R12 resistor; it is also recommended to replace R11 with a 0  $\Omega$  resistor.

When the ENFAULT input is forced low, the power stage is immediately disabled (all MOSFETs are turned off) in both modes and the D1 LED turns red.

**Table 4. ENx and INx inputs truth table (MODE = L)**

X: Don't care; High Z: High impedance

| EN\FAULT | ENx | INx | OUTx   | 'x' half-bridge condition |
|----------|-----|-----|--------|---------------------------|
| 0        | X   | X   | High Z | Disabled                  |



| EN\FAULT | ENx | INx | OUTx   | 'x' half-bridge condition |
|----------|-----|-----|--------|---------------------------|
| 1        | 0   | X   | High Z | Disabled                  |
| 1        | 1   | 0   | GND    | LS on                     |
| 1        | 1   | 1   | VS     | HS on                     |

**Table 5. INxL and INxH inputs truth table (MODE = H)**

X: Don't care; High Z: High impedance

| EN\FAULT | INxH | INxL | OUTx   | 'x' half-bridge condition |
|----------|------|------|--------|---------------------------|
| 0        | X    | X    | High Z | Disabled                  |
| 1        | 0    | 0    | High Z | Disabled                  |
| 1        | 0    | 1    | GND    | LS on                     |
| 1        | 1    | 0    | VS     | HS on                     |
| 1        | 1    | 1    | High Z | Disabled (interlocking)   |

The EN/FAULT signal is forwarded to the TIM1 BKIN input to implement failure protection.

## 4.5 Hall effect sensors and encoder connector

The **X-NUCLEO-IHM16M1** expansion board provides an interface between the digital Hall effect sensors or encoder mounted on the motor and the **STM32 Nucleo** development board through J1 connector.

The connector provides:

- Pull-up resistors (R20, R21, R22) for open-drain and open-collector interfacing.

*Note:* It is recommended to remove the pull-up resistors in case of push-pull outputs.

- Protection from overvoltage on the MCU input pin through the D2, D3 and D4 Zener diodes.

Table 5.

**Table 6. J1 connector pinout**

| Pin | Encoder                                     | Hall effect sensor                          |
|-----|---|---|
| 1   | A+  | Hall 1                                      |
| 2   | B+  | Hall 2                                      |
| 3   | Z   | Hall 3                                      |
| 4   | 5 V supply from<br>Nucleo development board | 5 V supply from<br>Nucleo development board |
| 5   | Ground                                      | Ground                                      |

## 4.6 Speed trimmer

The R17 trimmer provides an analog signal to the MCU that can be used by the firmware to set the speed control loop.

The voltage range is from 0 to 3.3 V (VDD) and increases rotating the knob in clockwise direction.

## 5

## X-NUCLEO-IHM16M1 schematic diagrams

Figure 4. X-NUCLEO-IHM16M1 circuit schematic (1 of 5)

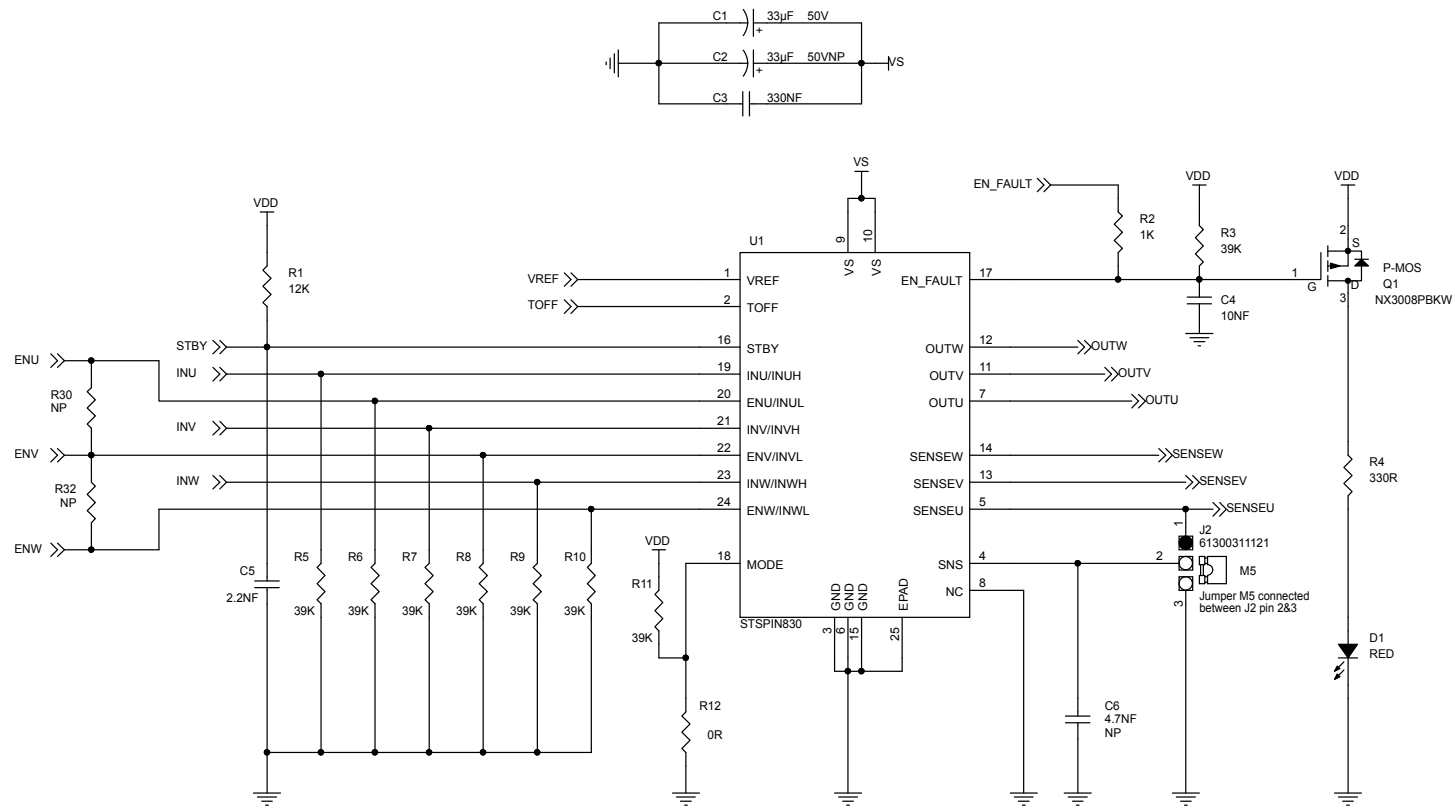
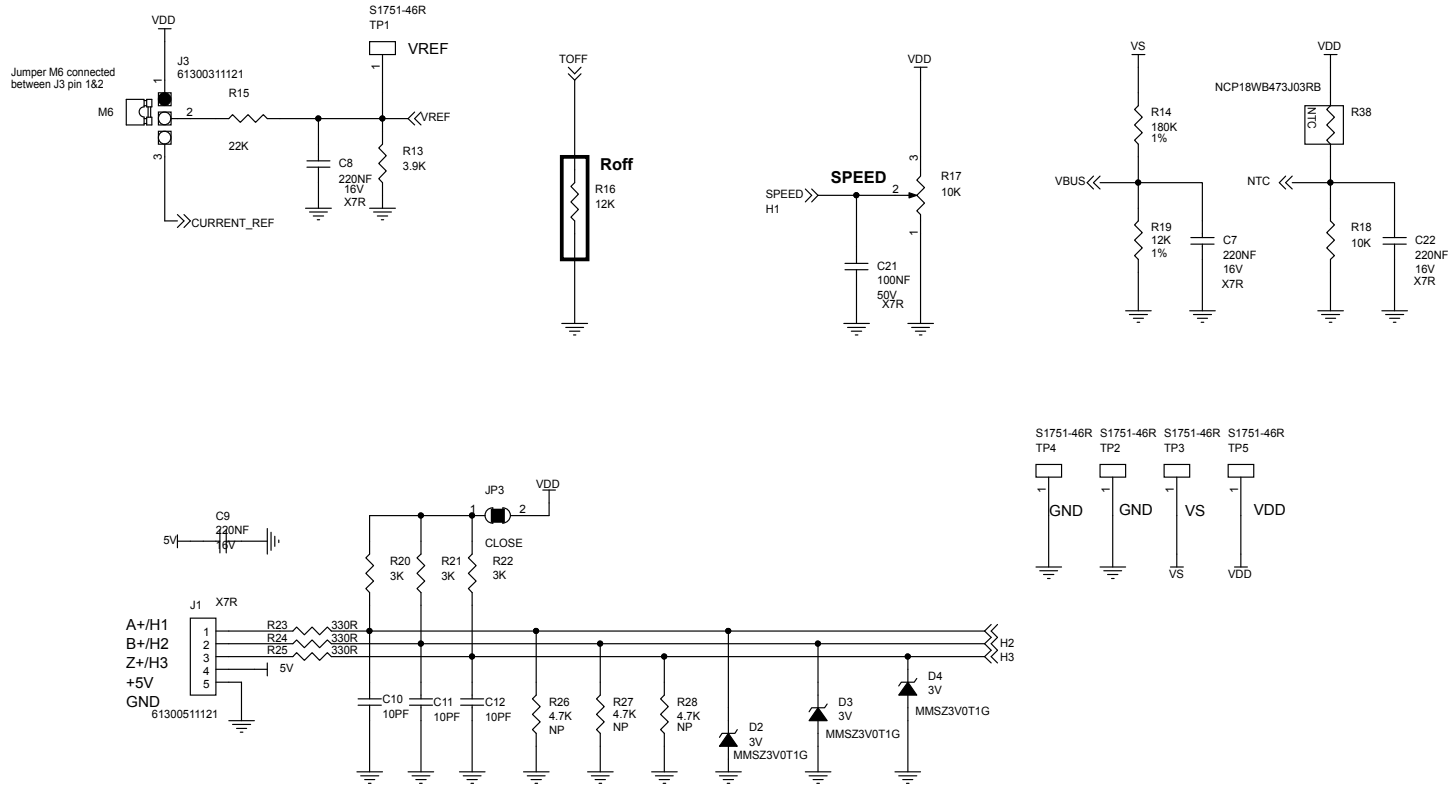


Figure 5. X-NUCLEO-IHM16M1 circuit schematic (2 of 5)



**Figure 6. X-NUCLEO-IHM16M1 circuit schematic (3 of 5)**

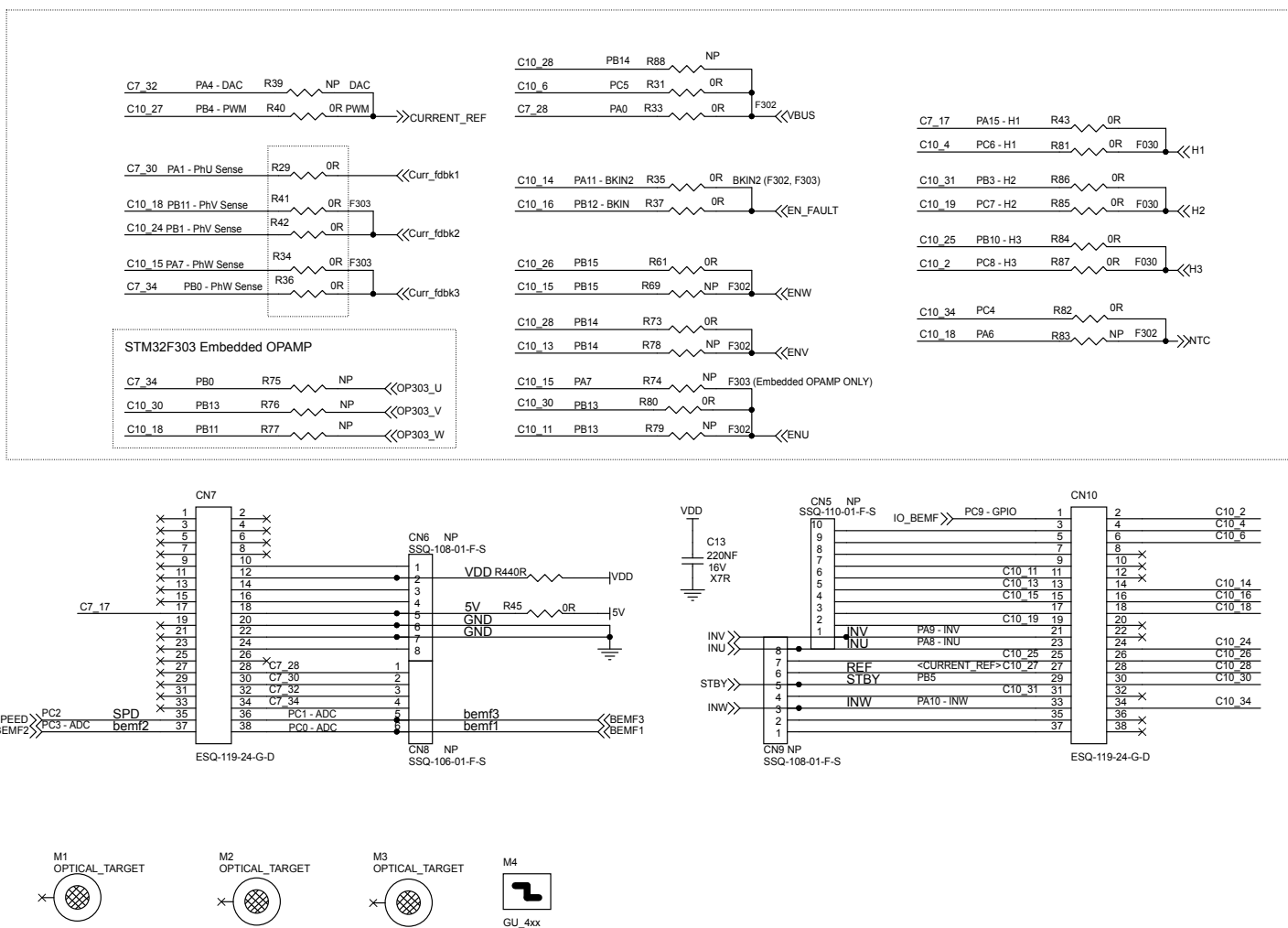


Figure 7. X-NUCLEO-IHM16M1 circuit schematic (4 of 5)

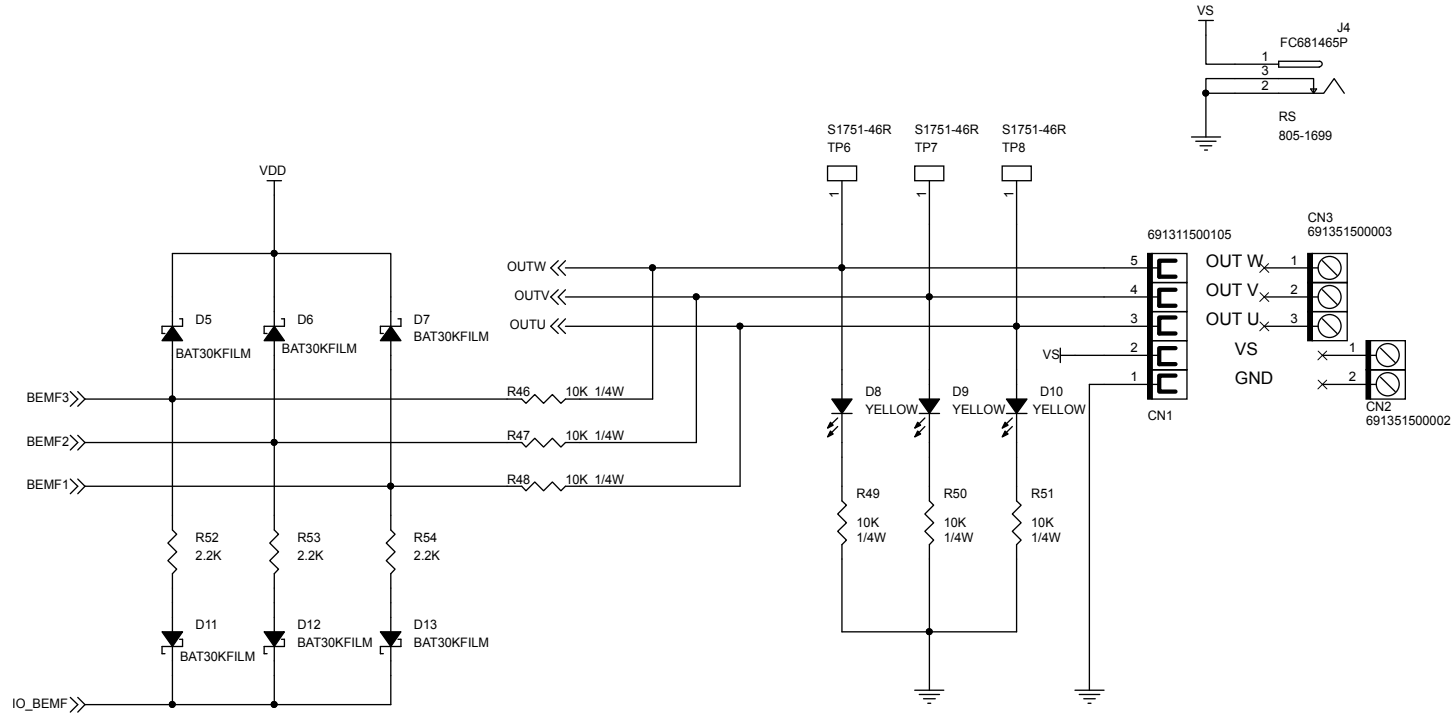
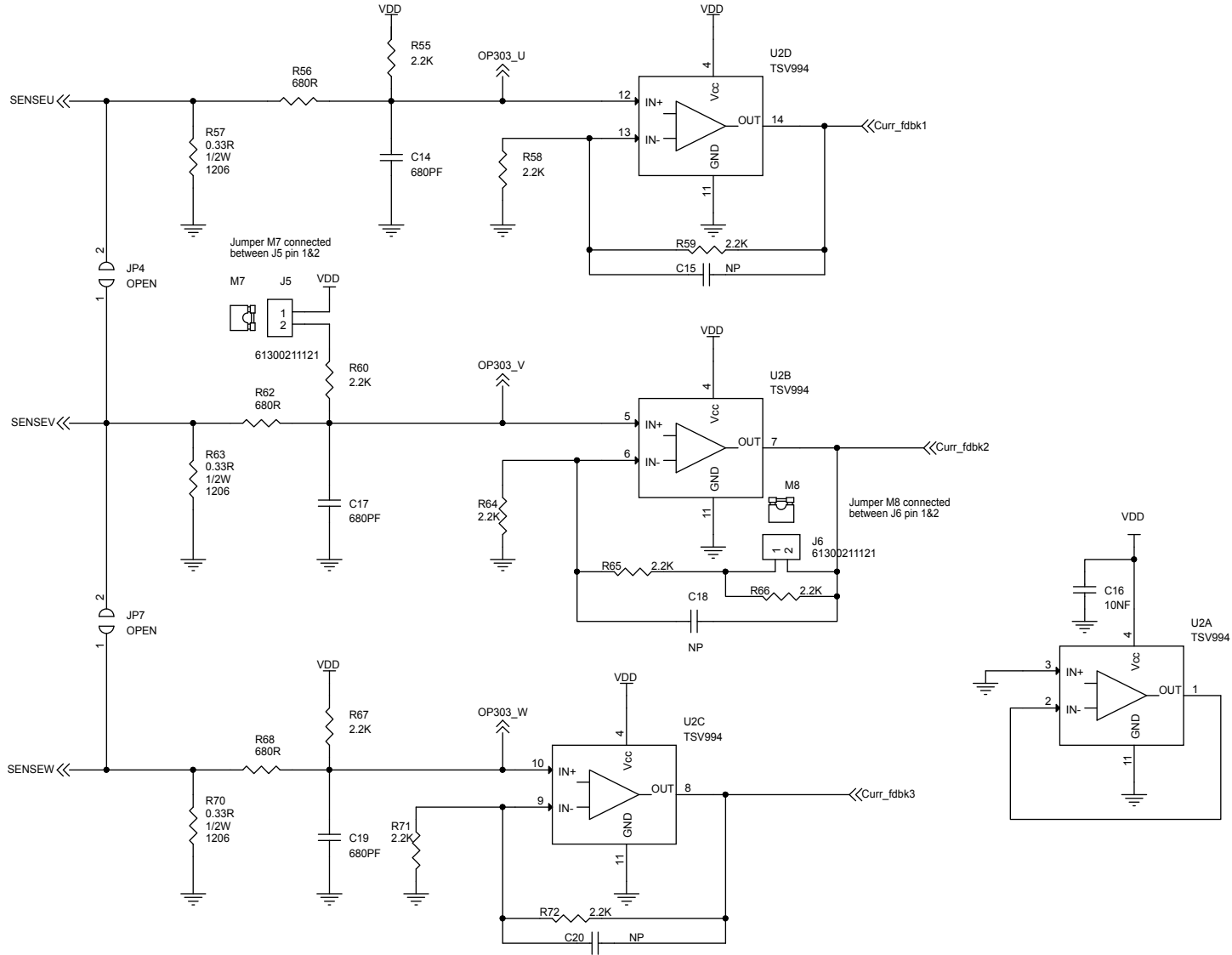


Figure 8. X-NUCLEO-IHM16M1 circuit schematic (5 of 5)



## 6 Bill of materials

**Table 7. X-NUCLEO-IHM16M1 bill of materials**

| Item | Q.ty | Ref.                      | Part/Value                             | Description                      | Manufacturer     | Order code           |
|------|------|---------------------------|--|----------------------------------|------------------|----------------------|
| 1    | 1    | CN1                       |  | Pluggable terminal block         | Würth Elektronik | 691311500105         |
| 2    | 1    | CN2                       |  | Pluggable terminal block         | Würth Elektronik | 691351500002         |
| 3    | 1    | CN3                       |  | Pluggable terminal block         | Würth Elektronik | 691351500003         |
| 4    | 1    | CN5                       | NP                                     | 10 position receptacle connector | Samtec           | SSQ-110-01-F-S       |
| 5    | 2    | CN6, CN9                  | NP                                     | 8 position receptacle connector  | Samtec           | SSQ-108-01-F-S       |
| 6    | 2    | CN7, CN10                 |  | Board-to-board connectors        | Samtec           | ESQ-119-24-G-D       |
| 7    | 1    | CN8                       | NP                                     | 6 position receptacle connector  | Samtec           | SSQ-106-01-F-S       |
| 8    | 1    | C1                        | 33 $\mu$ F, 50 V, $\pm$ 20%, D6.3_H7.7 | Aluminium electrolytic capacitor | Würth Elektronik | 865080645010         |
| 9    | 1    | C2                        | NP, 50 V, $\pm$ 20%, D6.3_H11_P2.5     | Aluminium electrolytic capacitor | Würth Elektronik | 860080673003         |
| 10   | 1    | C3                        | 330 NF, 50 V, $\pm$ 10%, 805           | Ceramic capacitor                | Any              | 330NF_50V_X7R_0805   |
| 11   | 2    | C4, C16                   | 10 NF, 50 V, $\pm$ 15%, 603            | Ceramic capacitors               | Any              | 10NF_50V_X7R_0603    |
| 12   | 1    | C5                        | 2.2 NF, 50 V, $\pm$ 15%, 603           | Ceramic capacitor                | Any              | 2.2NF_50V_X7R_0603   |
| 13   | 1    | C6                        | NP, 50 V, $\pm$ 15%, 603               | Ceramic capacitor                | Any              | 4.7NF_50V_X7R_0603   |
| 14   | 5    | C7, C8, C9, C13, C22      | 220 NF, 16 V, $\pm$ 10%, 603           | Ceramic capacitors               | Any              | 220NF_16V_X7R_0603   |
| 15   | 3    | C10, C11, C12             | 10 PF, 50 V, $\pm$ 10%, 603            | Ceramic capacitors               | Any              | 10PF_50V_COG_0603    |
| 16   | 3    | C14, C17, C19             | 680 PF, 50 V, $\pm$ 15%, 603           | Ceramic capacitors               | Any              | 680PF_50V_X7R_0603   |
| 17   | 3    | C15, C18, C20             | NP 603                                 | Ceramic capacitors               | Any              | C_NP_0603            |
| 18   | 1    | C21                       | 100 NF, 50 V, $\pm$ 15%, 603           | Ceramic capacitor                | Any              | 100NF_50V_X7R_0603   |
| 19   | 1    | D1                        | RED, 805                               | LED                              | Würth Elektronik | 150080RS75000        |
| 20   | 3    | D2, D3, D4                | 3 V, SOD123                            | Zener diodes                     | OnSemiconductors | MMSZ3V0T1G           |
| 21   | 6    | D5, D6, D7, D11, D12, D13 | SOD523                                 | Small signal Schotky diodes      | ST               | BAT30KFILM           |
| 22   | 3    | D8, D9, D10               | YELLOW, 805                            | LED                              | Würth Elektronik | 150080YS75000        |
| 23   | 1    | JP3                       | CLOSE, 603                             | Resistors                        | Any              | SMALL TIN-DROP CLOSE |

| Item | Q.ty | Ref.  | Part/Value                               | Description                 | Manufacturer     | Order code            |
|------|------|---|--|-----------------------------|------------------|-----------------------|
| 24   | 2    | JP4, JP7  | OPEN                                     | Resistor                    | Any              | SOLDER_BRIDGE         |
| 25   | 1    | J1  |  | 5 position connector header | Würth Elektronik | 61300511121           |
| 26   | 2    | J2, J3  | CON_HEADER_1X3_L7.62_W2.54_P2.54         | 3 position connector header | Würth Elektronik | 61300311121           |
| 27   | 1    | J4  | FC681465P                                | Jack connector              | RS               | FC681465P             |
| 28   | 2    | J5, J6  | CON_HEADER_1X2_L5.08_W2.54_P2.54         | 2 pin THT header            | Würth Elektronik | 61300211121           |
| 29   | 3    | M1, M2, M3  | OPTICAL_TARGET                           | OPTICAL_TARGET              | Any              | OPTICAL_TARGET        |
| 30   | 1    | M4  | GU_4xx                                   | PCB                         | Any              | PCB GU -rev4 2 layers |
| 31   | 4    | M5, M6, M7, M8  | CLOSED JUMPER                            | 2 position shunt connector  | Würth Elektronik | 60900213421           |
| 32   | 1    | Q1  | P-MOS, SOT323                            | P-channel MOSFET            | NXP              | NX3008PBKW            |
| 33   | 1    | R1  | 12 K, 1/10 W, $\pm 5\%$ , 603            | Resistor                    | Any              | 12K_5%_0603           |
| 34   | 1    | R2  | 1 K, 1/10 W, $\pm 5\%$ , 603             | Resistor                    | Any              | 1K_5%_0603            |
| 35   | 8    | R3, R5, R6, R7, R8, R9, R10, R11  | 39 K, 1/10 W, $\pm 5\%$ , 603            | Resistors                   | Any              | 39K_5%_0603           |
| 36   | 4    | R4, R23, R24, R25   | 330 R, 1/10 W, $\pm 5\%$ , 603           | Resistors                   | Any              | 330R_5%_0603          |
| 37   | 23   | R12, R29, R31, R33, R34, R35, R36, R37, R40, R41, R42, R43, R44, R45, R61, R73, R80, R81, R82, R84, R85, R86, R87 | 0 R, 1/10 W, $\pm 5\%$ , 603             | Resistors                   | Any              | 0R_5%_0603            |
| 38   | 1    | R13   | 3.9 K, 1/10 W, $\pm 5\%$ , 603           | Resistor                    | Any              | 3.9K_5%_0603          |
| 39   | 1    | R14   | 180 K, 1/10 W, $\pm 1\%$ , 603           | Resistor                    | Any              | 180K_1%_0603          |
| 40   | 1    | R15   | 22 K, 1/10 W, $\pm 5\%$ , 603            | Resistor                    | Any              | 22K_5%_0603           |
| 41   | 1    | R16   | 12 K, 1/8 W, $\pm 5\%$ , 805             | Resistor                    | Any              | 12K_5%_0805           |
| 42   | 1    | R17   | 10 K, 1/2 W, $\pm 10\%$ , L9.5_W4.9_H9.5 | Resistor                    | Bourns           | 3386P-1-103TLF        |
| 43   | 1    | R18   | 10 K, 1/10 W, $\pm 5\%$ , 603            | Resistor                    | Any              | 10K_5%_0603           |
| 44   | 1    | R19   | 12 K, 1/10 W, $\pm 1\%$ , 603            | Resistor                    | Any              | 12K_1%_0603           |
| 45   | 3    | R20, R21, R22   | 3 K, 1/10 W, $\pm 5\%$ , 603             | Resistors                   | Any              | 3K_5%_0603            |



| Item | Q.ty | Ref.  | Part/Value                  | Description  | Manufacturer | Order code                |
|------|------|---|-----------------------------|--|--------------|---------------------------|
| 46   | 3    | R26, R27, R28   | NP, 1/10 W,<br>±1%, 603     | Resistors  | Any          | 4.7K_1%_0603              |
| 47   | 11   | R30, R32, R39,<br>R69, R74, R75,<br>R76, R77, R78,<br>R79, R83              | NP, 603                     | Resistors  | Any          | R_NP_0603                 |
| 48   | 1    | R38   | 47 K, 1/10 W,<br>±5%, 603   | Thermistor   | Murata       | NCP18WB473J03RB           |
| 49   | 6    | R46, R47, R48,<br>R49, R50, R51   | 10 K, 1/4 W,<br>±5%, 603    | Resistors  | Any          | 10K_5%_0603_1/4W          |
| 50   | 13   | R52, R53, R54,<br>R55, R58, R59,<br>R60, R64, R65,<br>R66, R67, R71,<br>R72 | 2.2 K, 1/10 W,<br>±5%, 603  | Resistors  | Any          | 2.2K_5%_0603              |
| 51   | 3    | R56, R62, R68   | 680 R, 1/10 W,<br>±5%, 603  | Resistors  | Any          | 680R_5%_0603              |
| 52   | 3    | R57, R63, R70   | 0.33 R, 1/2 W,<br>±1%, 1206 | Resistors  | Any          | 0R33_1%_1206_0.5W         |
| 53   | 1    | R88   | NP, 1/10 W,<br>±5%, 603     | Resistor   | Any          | 0R_5%_0603                |
| 54   | 8    | TP1, TP2, TP3,<br>TP4, TP5, TP6,<br>TP7, TP8                                | S1751-46R                   | Test terminals   | Harwin       | S1751-46R                 |
| 55   | 1    | U1  | QFN24_L4_W4_<br>P0.5        | Three-phase<br>brushless<br>monolithic motor<br>driver                       | ST           | <a href="#">STSPIN830</a> |
| 56   | 1    | U2  | TSSOP14                     | Wide bandwidth<br>rail-to-rail input/<br>output 5 V<br>CMOS quad Op-<br>Amps | ST           | <a href="#">TSV994IPT</a> |

## Revision history

**Table 8. Document revision history**

| Date        | Revision | Changes   |
|-------------|----------|---|
| 17-May-2018 | 1        | Initial release.  |
| 01-Sep-2020 | 2        | Added Section 4.2.1 Sense resistor value and maximum current range in FOC mode.   |
| 20-Jul-2021 | 3        | Updated Getting started and Hardware and software requirements.<br>Added references to X-CUBE-MCSDK-Y.  |
| 21-Feb-2024 | 4        | Updated <a href="#">Section 1: Hardware and software requirements</a> and <a href="#">Section 3: Getting started</a> . Removed Using the STM32F303RE embedded PGA and STM32 Nucleo development board compatibility. |

## Contents

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>Hardware and software requirements .....</b>                  | <b>2</b>  |
| <b>2</b> | <b>Safety precautions.....</b>                                   | <b>3</b>  |
| <b>3</b> | <b>Getting started .....</b>                                     | <b>4</b>  |
| <b>4</b> | <b>Hardware description and configuration .....</b>              | <b>5</b>  |
| 4.1      | Operation mode and sensing topology selection.....               | 7         |
| 4.2      | Current sensing .....  | 7         |
| 4.2.1    | Sense resistor value and maximum current range in FOC mode ..... | 7         |
| 4.3      | <b>STSPIN830 current limiter.....</b>                            | <b>7</b>  |
| 4.4      | STSPIN830 logic inputs and fault signaling .....                 | 8         |
| 4.5      | Hall effect sensors and encoder connector .....                  | 9         |
| 4.6      | Speed trimmer.....   | 9         |
| <b>5</b> | <b>X-NUCLEO-IHM16M1 schematic diagrams.....</b>                  | <b>10</b> |
| <b>6</b> | <b>Bill of materials.....</b>                                    | <b>15</b> |
|          | <b>Revision history .....</b>                                    | <b>18</b> |

## List of tables

|                 |  |    |
|-----------------|--|----|
| <b>Table 1.</b> | X-NUCLEO-IHM16M1 ST morpho connector pinouts . . . . .                               | 5  |
| <b>Table 2.</b> | X-NUCLEO-IHM16M1 expansion board configuration based on the algorithm used . . . . . | 7  |
| <b>Table 3.</b> | TSV994 operational amplifier configuration . . . . .                                 | 7  |
| <b>Table 4.</b> | ENx and INx inputs truth table (MODE = L) . . . . .                                  | 8  |
| <b>Table 5.</b> | INxL and INxH inputs truth table (MODE = H) . . . . .                                | 9  |
| <b>Table 6.</b> | J1 connector pinout . . . . .  | 9  |
| <b>Table 7.</b> | X-NUCLEO-IHM16M1 bill of materials . . . . .   | 15 |
| <b>Table 8.</b> | Document revision history . . . . .  | 18 |

## List of figures

|           |   |    |
|-----------|---|----|
| Figure 1. | X-NUCLEO-IHM16M1 expansion board . . . . .            | 1  |
| Figure 2. | X-NUCLEOIHM16M1 component positions . . . . .         | 5  |
| Figure 3. | OFF time vs. $R_{OFF}$ value . . . . .                | 8  |
| Figure 4. | X-NUCLEO-IHM16M1 circuit schematic (1 of 5) . . . . . | 10 |
| Figure 5. | X-NUCLEO-IHM16M1 circuit schematic (2 of 5) . . . . . | 11 |
| Figure 6. | X-NUCLEO-IHM16M1 circuit schematic (3 of 5) . . . . . | 12 |
| Figure 7. | X-NUCLEO-IHM16M1 circuit schematic (4 of 5) . . . . . | 13 |
| Figure 8. | X-NUCLEO-IHM16M1 circuit schematic (5 of 5) . . . . . | 14 |

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