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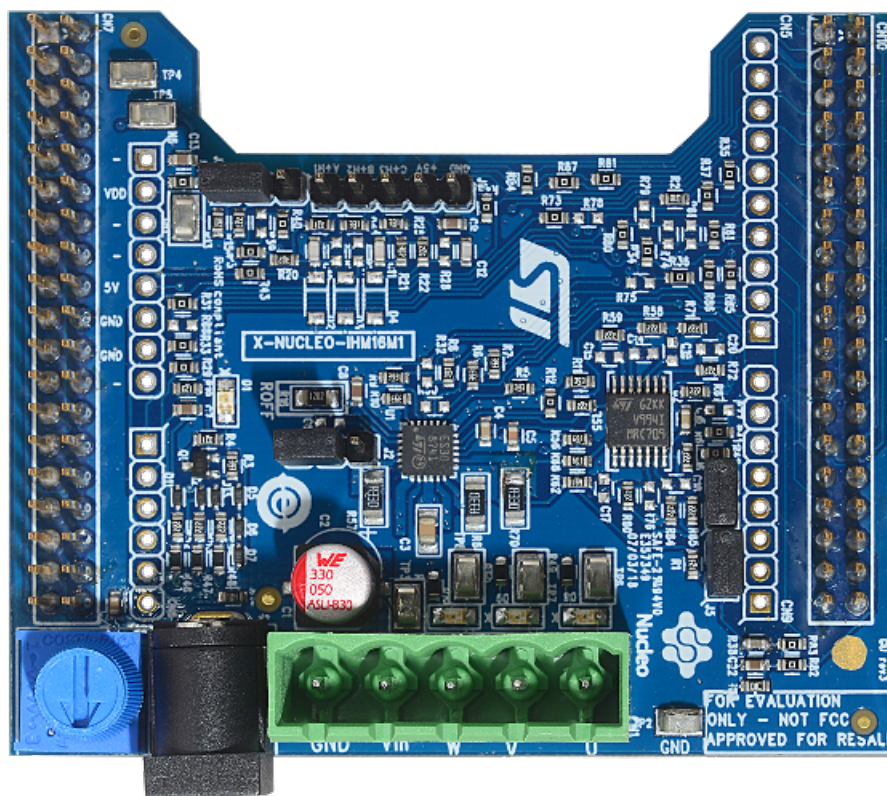
Introduction

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

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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 (NUCLEO-F401RE, NUCLEO-F303RE, NUCLEO-F302R8 or NUCLEO-F030R8)
- 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-Y)
- 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

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 Section 4.7 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-Y)

4   Hardware description and configuration

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

Figure 2. X-NUCLEOIHM16M1 component positions
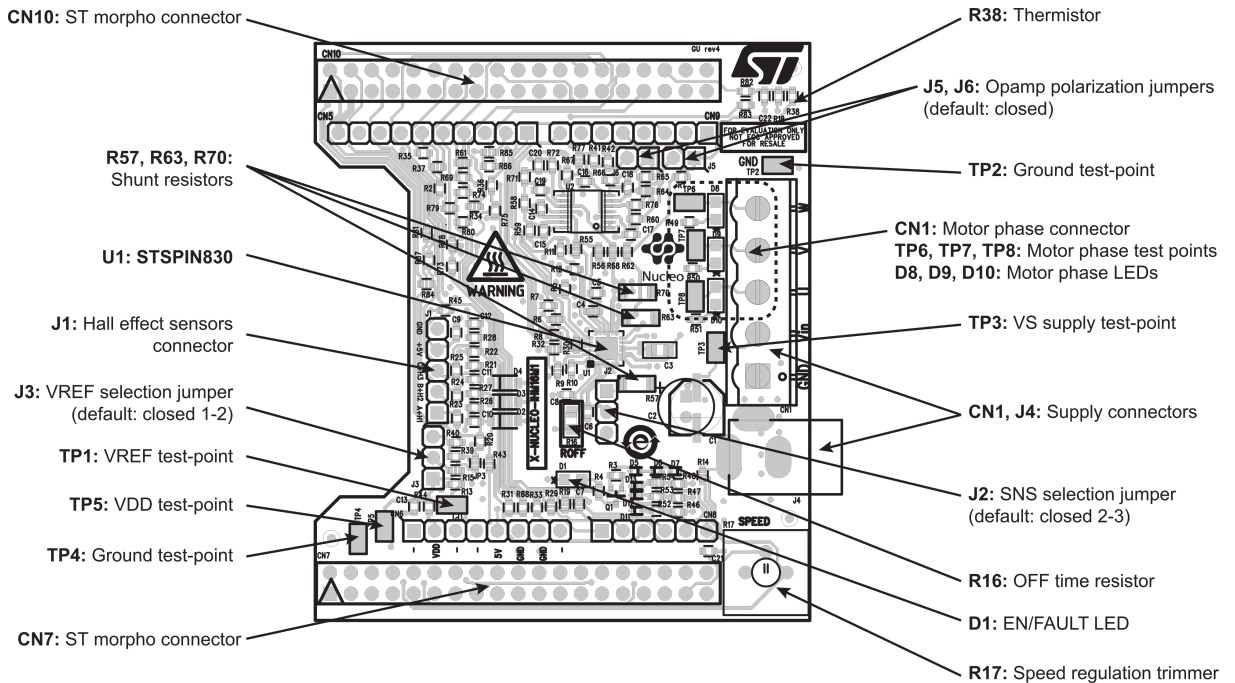
The table below lists the signals mapped on the ST morpho connectors.

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. 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	

Connector	Pin	Signal	Remarks
CN10	2	Hall-effect sensor 3	R87
	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[1]				FOC (3-shunt)[2]				FOC (single shunt)			
Single shunt	Current sensing	Current limiter enabled [3]	Adjustable current limiter threshold [3]	Three-shunt	Current sensing	Current limiter disabled	Fixed current limiter threshold	Single shunt	Current sensing	Current limiter enabled [3]	Adjustable current limiter threshold [3]
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[1]	1.53	1.56 V	Closed	Closed	FOC
		3	0 V	Open	Open	6STEP
3	Phase W[1]	1.53	1.56 V			FOC
4	Phase U[1]	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.

4.2.2 Using the STM32F303RE embedded PGA

The STM32F303RE (in the NUCLEO-F303RE) embeds PGAs suitable for sensing the phase currents in field oriented control applications.

To use these feature, the X-NUCLEO-IHM16M1 expansion board configuration must be modified as follows (see also Figure 6. X-NUCLEO-IHM16M1 expansion board mounting options for NUCLEO-F303RE (PGA):

• Three-shunt topology: open JP4 and JP7 solder bridge at the bottom

- Connections between TSV944 operational amplifiers and MCU to be removed: R29, R34, R36, R41, R42 = NP
- Shunt resistors to be connected to PGA 3 and 4 inputs: R75, R76, R77 = 0R
- ENU driving GPIO to be changed from PB13 to PA7: R80 = NP, R74 = 0R

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 Ω)
- **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 Ω).

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 µs).

Figure 3. OFF time vs. R_OFF value
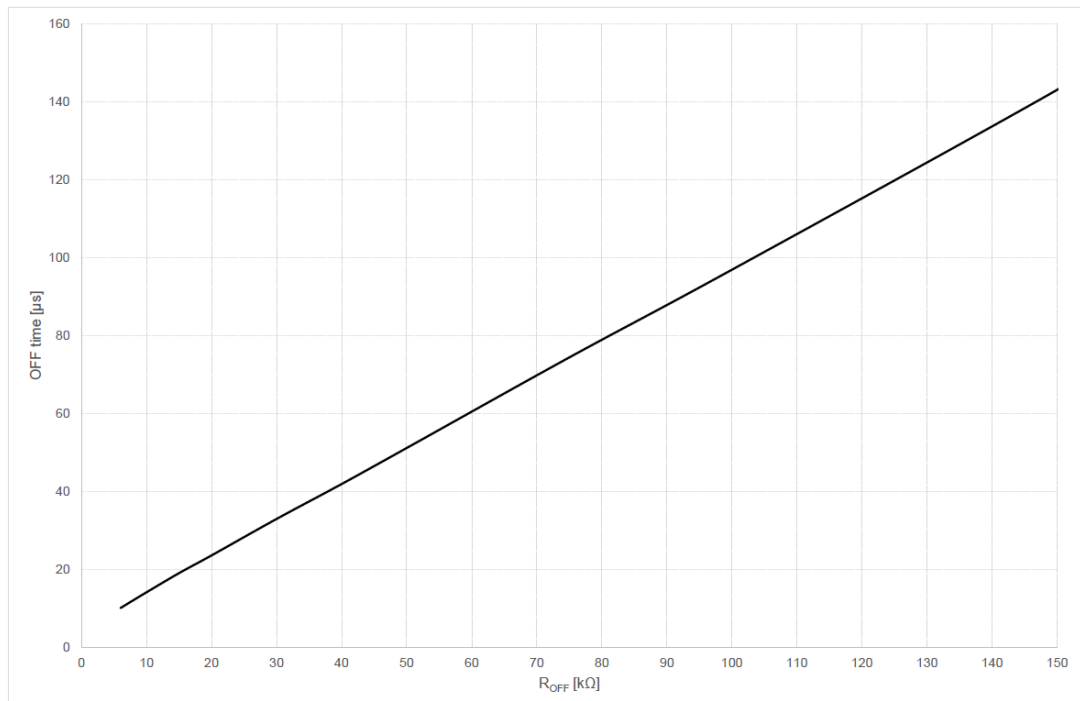
4.4 STSPIN830 logic inputs and fault signaling

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 R resistor.

When the EN\FAULT 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
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 Nucleo development board	5 V supply from 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.

4.7 STM32 Nucleo development board compatibility

The X-NUCLEO-IHM16M1 expansion board supports the following STM32 Nucleo development boards:

- NUCLEO-F401RE (by default)
- NUCLEO-F303RE (by default)
- NUCLEO-F302R8 (modifications needed)
- NUCLEO-F030R8 (by default)

Considering the pinout differences and the peripheral mapping, the compatibility with the different boards is possible only through the mounting options shown below.

Figure 4. X-NUCLEO-IHM16M1 expansion board mounting options for NUCLEO-F401RE
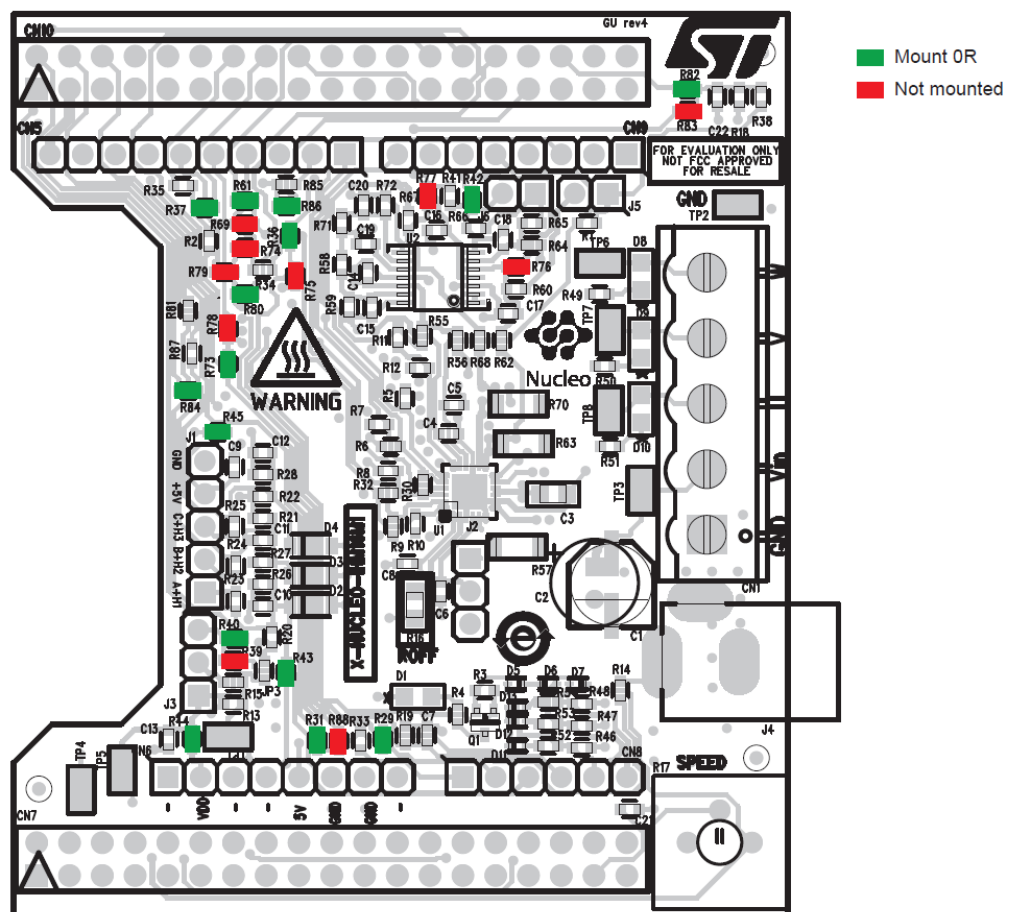
Figure 5. X-NUCLEO-IHM16M1 expansion board mounting options for NUCLEO-F303RE (no PGA)

Figure 6. X-NUCLEO-IHM16M1 expansion board mounting options for NUCLEO-F303RE (PGA)
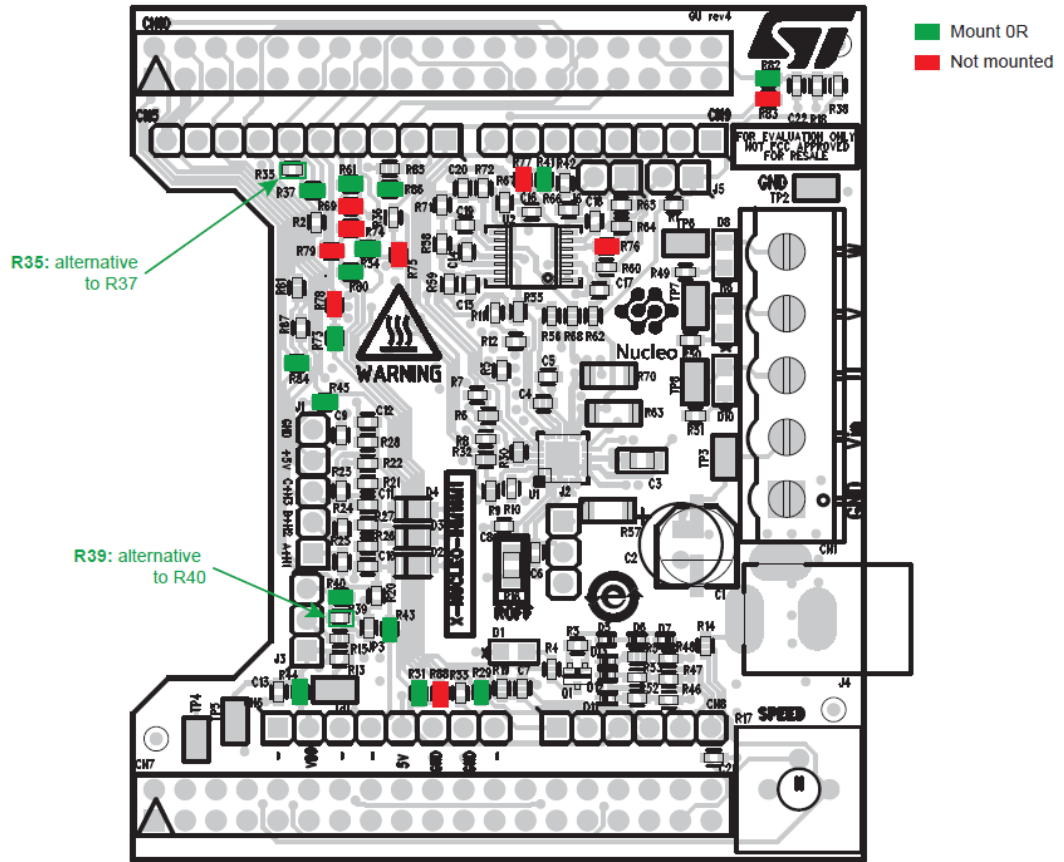
Figure 7. X-NUCLEO-IHM16M1 expansion board mounting options for NUCLEO-F302R8
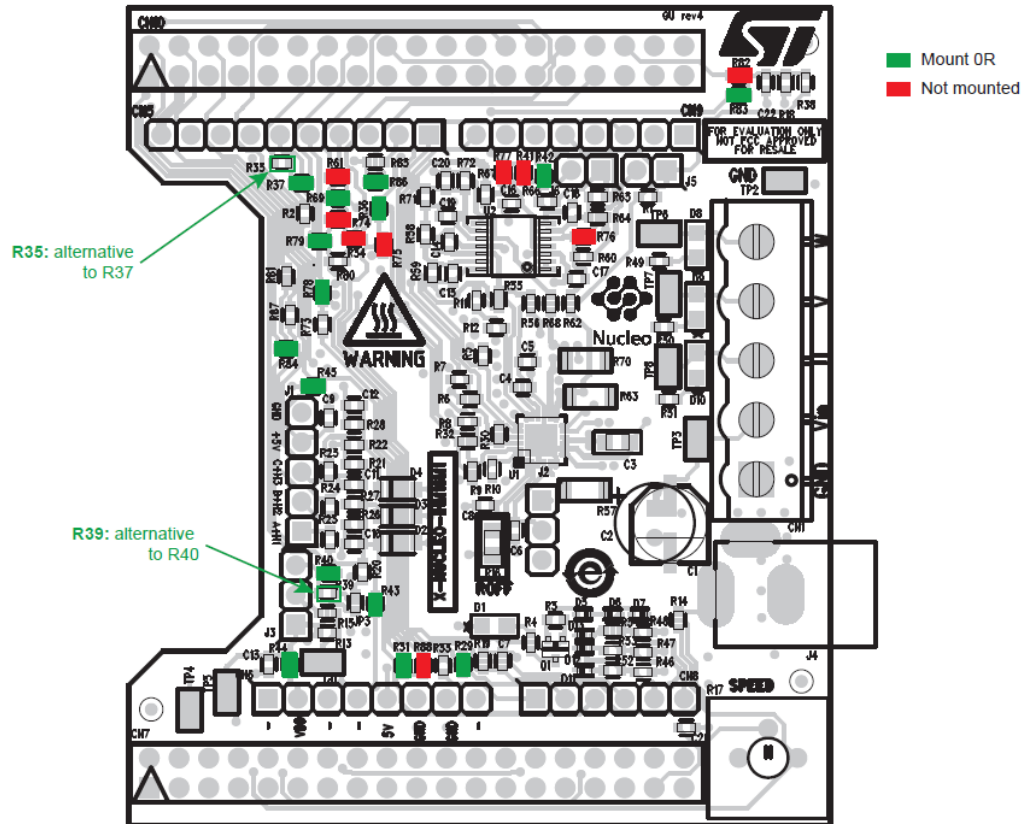
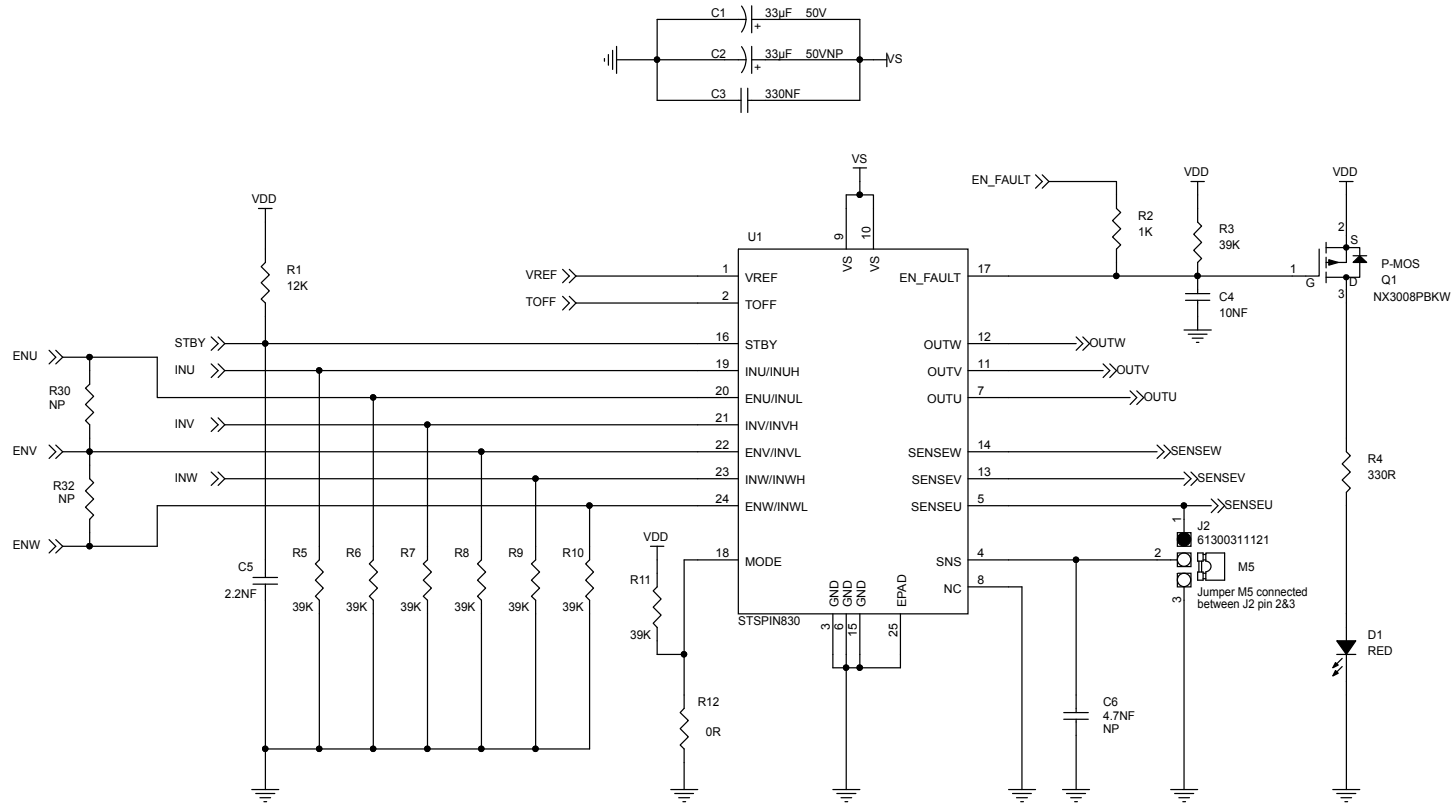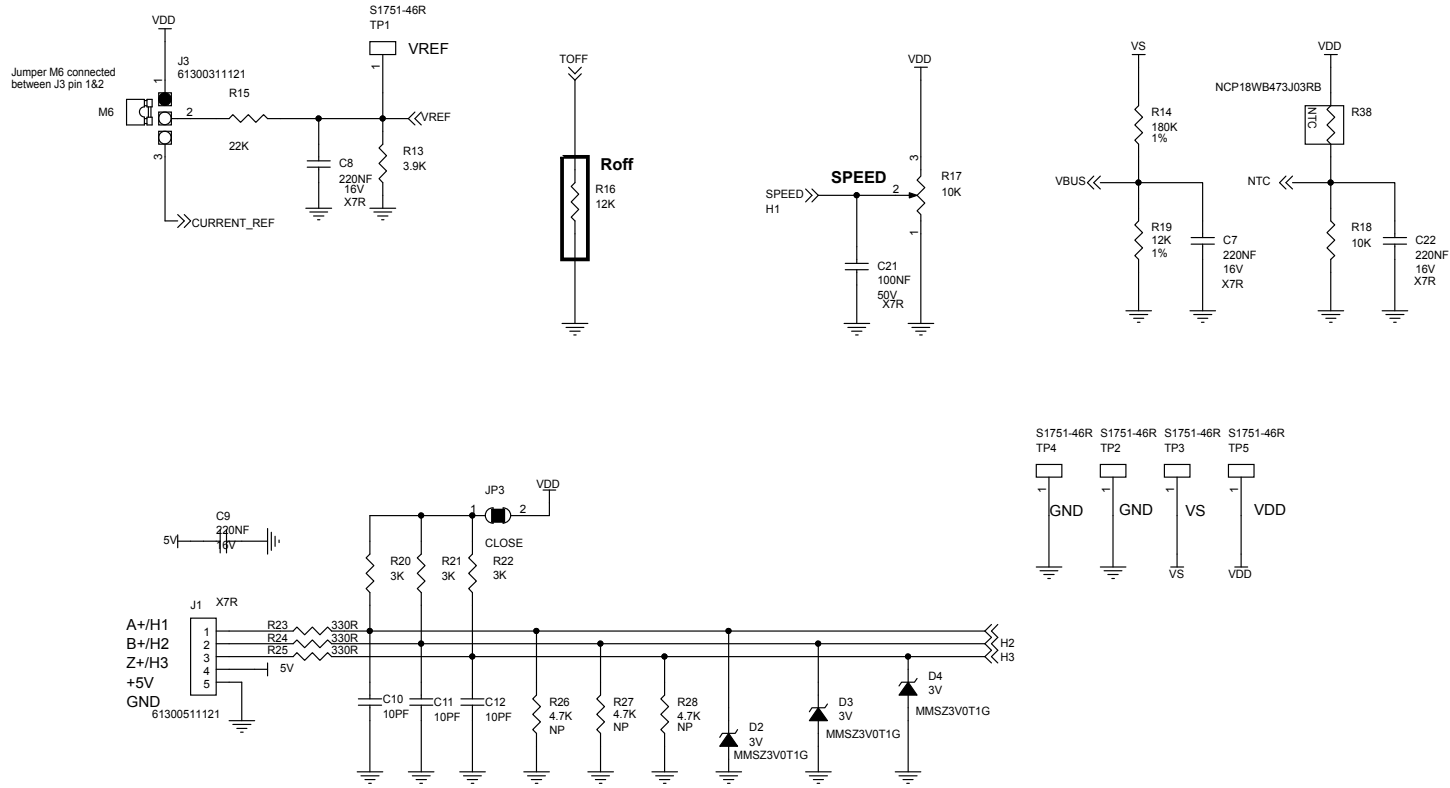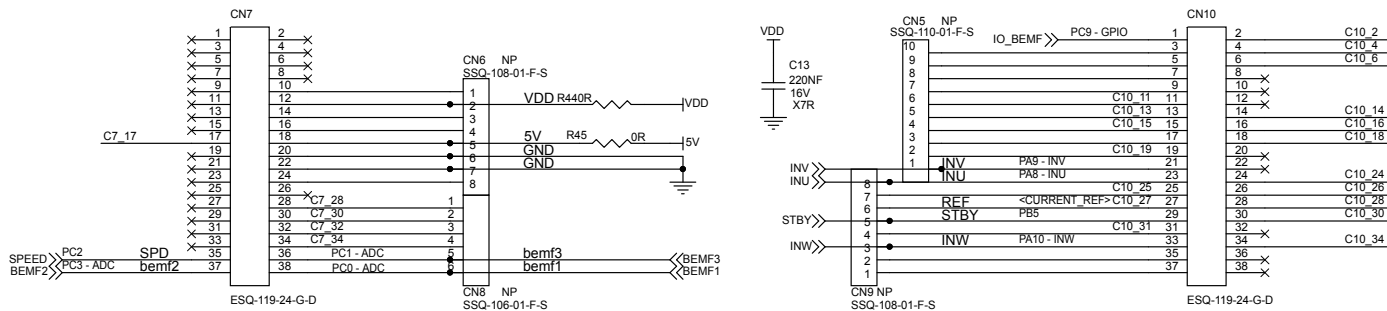**Figure 8. X-NUCLEO-IHM16M1 expansion board mounting options for NUCLEO-F030R8**
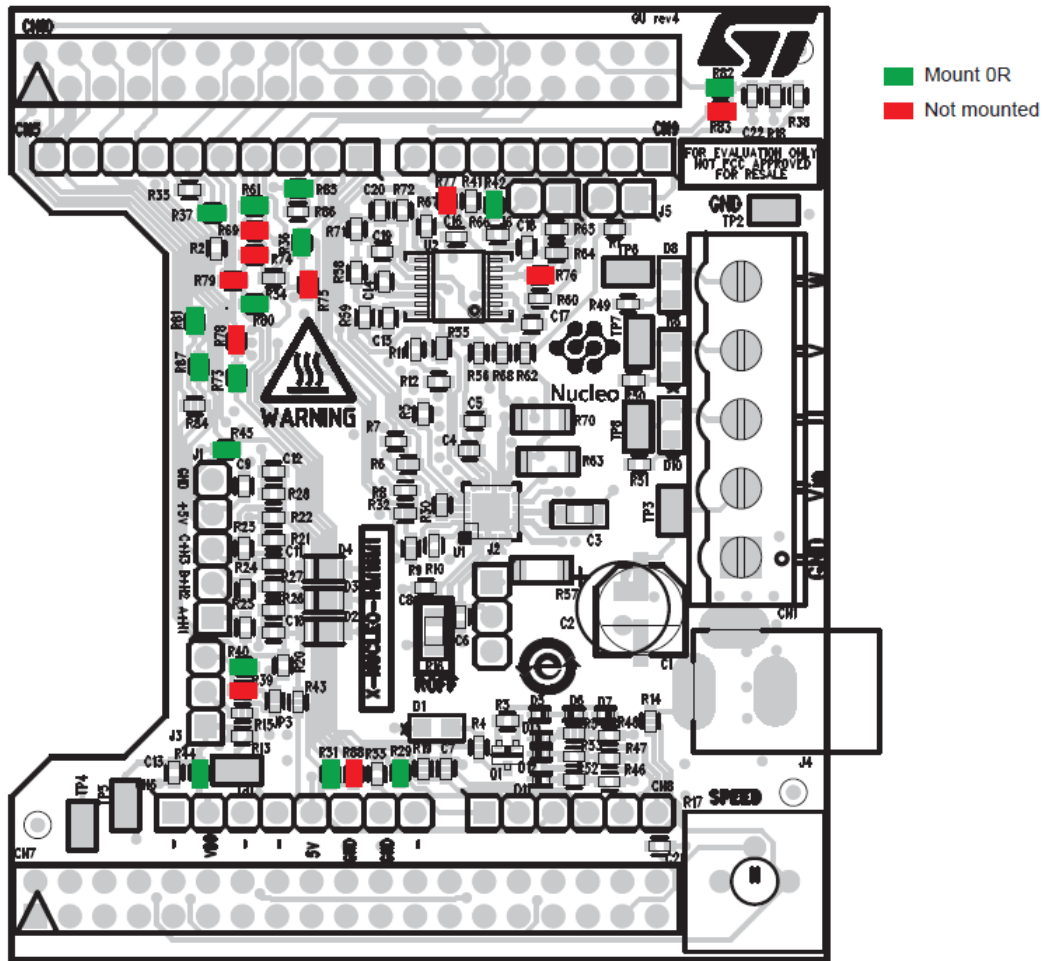
Figure 9. **X-NUCLEO-IHM16M1 circuit schematic (1 of 5)**

Figure 10. X-NUCLEO-IHM16M1 circuit schematic (2 of 5)

Figure 11. X-NUCLEO-IHM16M1 circuit schematic (3 of 5)
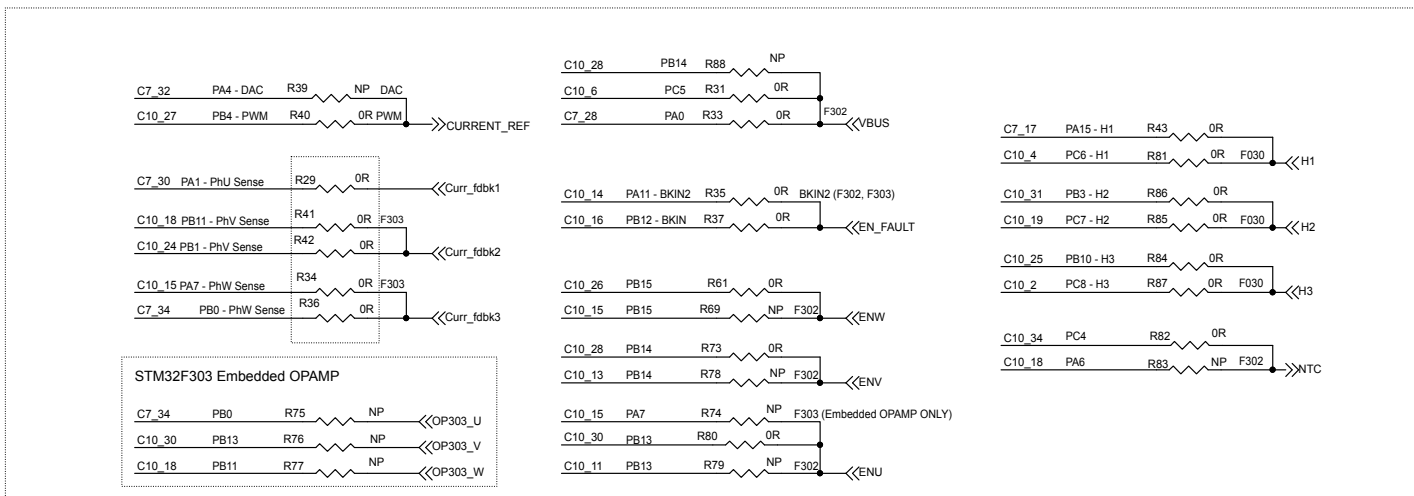
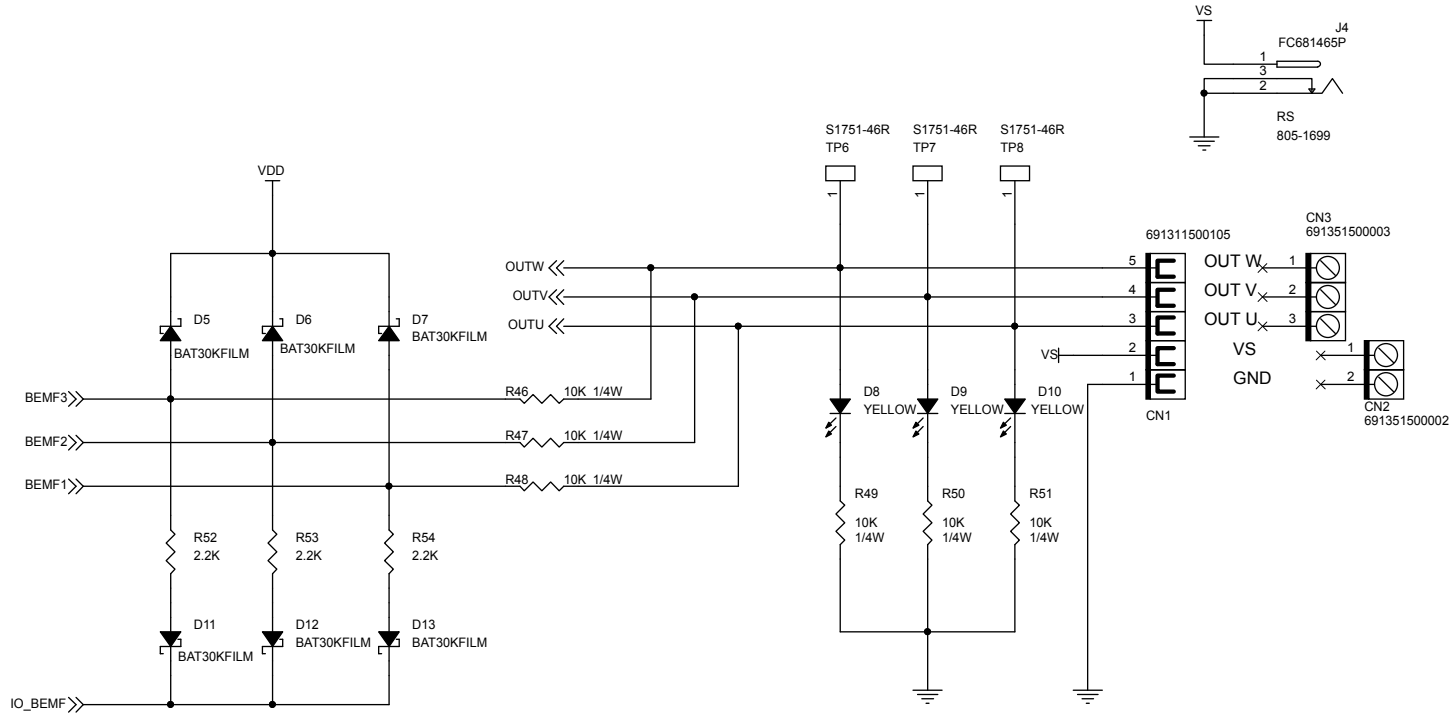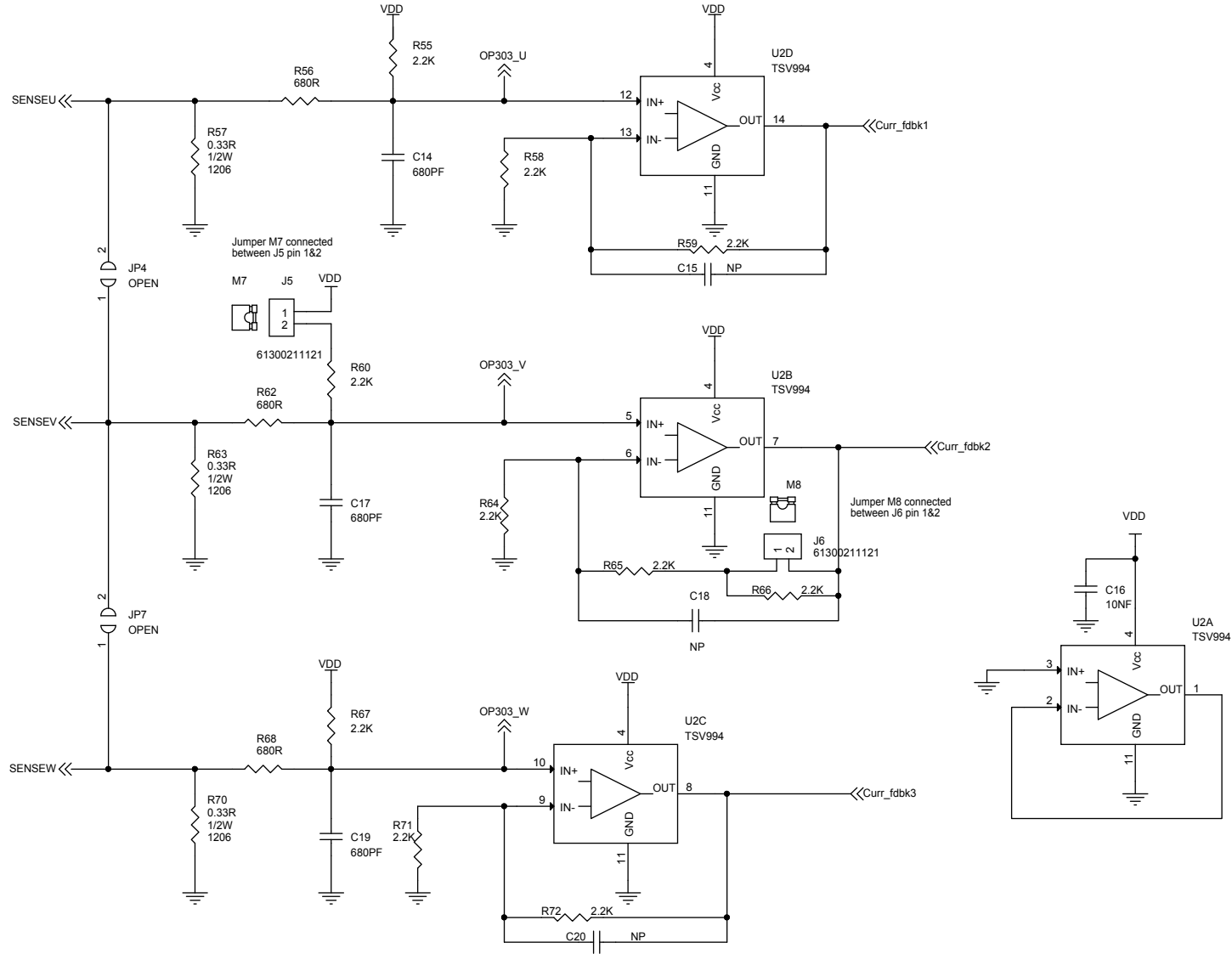**Figure 12. X-NUCLEO-IHM16M1 circuit schematic (4 of 5)**

Figure 13. 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	Wurth Elektronik	691311500105
2	1	CN2		Pluggable terminal block	Wurth Elektronik	691351500002
3	1	CN3		Pluggable terminal block	Wurth 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 µF, 50 V, ±20%, D6.3_H7.7	Aluminium electrolytic capacitor	Wurth Elektronik	865080645010
9	1	C2	NP, 50 V, ±20%, D6.3_H11_P2.5	Aluminium electrolytic capacitor	Wurth Elektronik	860080673003
10	1	C3	330 NF, 50 V, ±10%, 805	Ceramic capacitor	Any	330NF_50V_X7R_0805
11	2	C4, C16	10 NF, 50 V, ±15%, 603	Ceramic capacitors	Any	10NF_50V_X7R_0603
12	1	C5	2.2 NF, 50 V, ±15%, 603	Ceramic capacitor	Any	2.2NF_50V_X7R_0603
13	1	C6	NP, 50 V, ±15%, 603	Ceramic capacitor	Any	4.7NF_50V_X7R_0603
14	5	C7, C8, C9, C13, C22	220 NF, 16 V, ±10%, 603	Ceramic capacitors	Any	220NF_16V_X7R_0603
15	3	C10, C11, C12	10 PF, 50 V, ±10%, 603	Ceramic capacitors	Any	10PF_50V_COG_0603
16	3	C14, C17, C19	680 PF, 50 V, ±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, ±15%, 603	Ceramic capacitor	Any	100NF_50V_X7R_0603
19	1	D1	RED, 805	LED	Wurth 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	Wurth Elektronik	150080YS75000

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
23	1	JP3	CLOSE, 603	Resistors	Any	SMALL TIN-DROP CLOSE
24	2	JP4, JP7	OPEN	Resistor	Any	SOLDER_BRIDGE
25	1	J1		5 position connector header	Wurth Elektronik	61300511121
26	2	J2, J3	CON_HEADER_1X3_L7.62_W2.54_P2.54	3 position connector header	Wurth 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	Wurth 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	Wurth Elektronik	60900213421
32	1	Q1	P-MOS, SOT323	P-channel MOSFET	NXP	NX3008PBKW
33	1	R1	12 K, 1/10 W, ±5%, 603	Resistor	Any	12K_5%_0603
34	1	R2	1 K, 1/10 W, ±5%, 603	Resistor	Any	1K_5%_0603
35	8	R3, R5, R6, R7, R8, R9, R10, R11	39 K, 1/10 W, ±5%, 603	Resistors	Any	39K_5%_0603
36	4	R4, R23, R24, R25	330 R, 1/10 W, ±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, ±5%, 603	Resistors	Any	0R_5%_0603
38	1	R13	3.9 K, 1/10 W, ±5%, 603	Resistor	Any	3.9K_5%_0603
39	1	R14	180 K, 1/10 W, ±1%, 603	Resistor	Any	180K_1%_0603
40	1	R15	22 K, 1/10 W, ±5%, 603	Resistor	Any	22K_5%_0603
41	1	R16	12 K, 1/8 W, ±5%, 805	Resistor	Any	12K_5%_0805
42	1	R17	10 K, 1/2 W, ±10%, L9.5_W4.9_H9.5	Resistor	Bourns	3386P-1-103TLF
43	1	R18	10 K, 1/10 W, ±5%, 603	Resistor	Any	10K_5%_0603
44	1	R19	12 K, 1/10 W, ±1%, 603	Resistor	Any	12K_1%_0603
45	3	R20, R21, R22	3 K, 1/10 W, ±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, ±1%, 603	Resistors	Any	4.7K_1%_0603
47	11	R30, R32, R39, R69, R74, R75, R76, R77, R78, R79, R83	NP, 603	Resistors	Any	R_NP_0603
48	1	R38	47 K, 1/10 W, ±5%, 603	Thermistor	Murata	NCP18WB473J03RB
49	6	R46, R47, R48, R49, R50, R51	10 K, 1/4 W, ±5%, 603	Resistors	Any	10K_5%_0603_1/4W
50	13	R52, R53, R54, R55, R58, R59, R60, R64, R65, R66, R67, R71, R72	2.2 K, 1/10 W, ±5%, 603	Resistors	Any	2.2K_5%_0603
51	3	R56, R62, R68	680 R, 1/10 W, ±5%, 603	Resistors	Any	680R_5%_0603
52	3	R57, R63, R70	0.33 R, 1/2 W, ±1%, 1206	Resistors	Any	0R33_1%_1206_0.5W
53	1	R88	NP, 1/10 W, ±5%, 603	Resistor	Any	0R_5%_0603
54	8	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8	S1751-46R	Test terminals	Harwin	S1751-46R
55	1	U1	QFN24_L4_W4_P0.5	Three-phase brushless monolithic motor driver	ST	STSPIN830
56	1	U2	TSSOP14	Wide bandwidth rail-to-rail input/output 5 V CMOS quad Op-Amps	ST	TSV994IPT

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 Section 3 Getting started and Section 1 Hardware and software requirements. Added references to X-CUBE-MCSDK-Y.

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