Getting started with the STEVAL-CTM011V1 evaluation board for 250 W mainstream compressors

Introduction

The STEVAL-CTM011V1 is a three-phase inverter based on the STSPIN32F0601Q controller, which embeds a 3-phase 600 V gate driver and an Arm® Cortex®-M0 STM32 MCU. The power stage features STGD5H60DF IGBTs.

The board supports one-shunt and two- plus one-shunt sensing topology. You can properly set the shunt topology by populating the related shunt resistors (RS1, RS2, and RS3).

Moreover, you can implement a sensorless field-oriented control (FOC). This allows driving permanent magnet synchronous motors (PMSMs) and brushless DC (BLDC) motors to cover a wide range of applications, such as refrigerator compressors, pumps, fans, and industrial appliances.

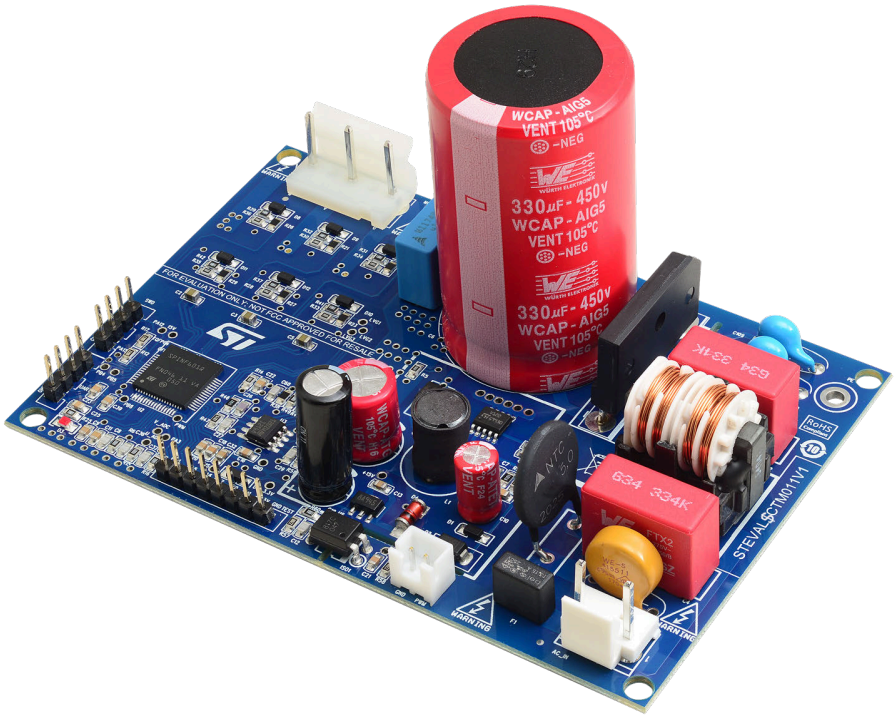
The STEVAL-CTM011V1 evaluation board is compatible with a wide range of input voltages. It includes a power supply stage with the VIPER122 in buck configuration that generates +15 V and +3.3 V supply voltages required by the application.

The companion firmware is X-CUBE-MCSDK, available for download on www.st.com, to be used with the STSW-CTM011 firmware example for compressor motors.

You can compile, debug, and configure the firmware through the STM32CubeIDE and B-STLINK-ISOL plus STLINK-V3SET.

SWD and UART TX-RX connectors are also available.

Figure 1. STEVAL-CTM011V1 evaluation board



1 Getting started

1.1 Safety and operating instructions

1.1.1 General terms

Warning: *During assembly, testing, and normal operation, the evaluation board poses several inherent hazards, including bare wires, moving or rotating parts, and hot surfaces. There is danger of serious personal injury and damage to property if you improperly use or incorrectly install the board or its components. The board is not electrically isolated from the AC-DC input. The evaluation board is directly linked to the mains voltage. No insulation is ensured between the accessible parts and the high voltage. All measuring equipment must be isolated from the mains before powering the board. When using an oscilloscope with the demo, it must be isolated from the AC line. This prevents shock that derives from touching any single point in the circuit, but does not prevent shock when touching two or more points in the circuit.*

All operations involving transportation, installation, and use, as well as maintenance, have to be carried out by skilled technical personnel (national accident prevention rules must be observed). For the purpose of these basic safety instructions, “skilled technical personnel” are considered as suitably qualified people who are familiar with the installation, use, and maintenance of power electronic systems.

1.1.2 Intended use of the board

The STEVAL-CTM011V1 evaluation board is designed for evaluation purposes only and must not be used for electrical installations or machinery.

The documentation details technical data and information about the power supply conditions that have to be strictly observed.

1.1.3 Evaluation board installation

- The installation and cooling of the evaluation board must be in accordance with the specifications and target applications.
- The motor drive converters must be protected against excessive strain. In particular, components should not be bent, or isolating distances altered during transportation or handling.
- No contact must be made with other electronic components and contacts.
- The board contains electrostatically sensitive components that are prone to damage if used incorrectly. Do not mechanically damage or destroy the electrical components (potential health risks).

1.1.4 Evaluation board operation

Note: Do not touch the evaluation board after it has been disconnected from the voltage supply as several parts and power terminals containing potentially energized capacitors need time to discharge.

A system architecture that supplies power to the STEVAL-CTM011V1 evaluation board must be equipped with additional control and protective devices in accordance with the applicable safety requirements (that is, compliance with technical equipment and accident prevention rules).

Caution: Follow the safety recommendations to operate the board. Use proper PPE, such as protective shields and glasses to avoid injuries due to malfunctions.

1.2 Features

- Complete system solution made by ready-to-use hardware and firmware
- Fitting wide range of applications supplied from the mains, rated up to 250 W:
  - refrigerator compressors
  - pumps and fans
  - industrial appliances

- High efficiency value:
  - Inverter efficiency > 96.5% at 3000 rpm
- Very low stand-by power consumption and overcurrent/undervoltage protections
- Based on STSPIN32F0601Q intelligent 3-phase motor controller with embedded STM32
- Power supply based on VIPER122 in buck configuration to generate on-board DC voltages
- Inverter power stage based on STGD5H60DF IGBT rated 600 V and 5 A
- Compact size: 7.5 x 11.2 cm
- Equipped with proven sensorless field-oriented control (FOC) firmware in one-shunt or 2+1 shunt topology
- RoHS compliant

1.3 Target applications

- Three-phase motor drivers
- Fans
- Pumps
- Refrigerator compressors
- Industrial appliances
- Inverters

2 Hardware and software requirements

To use the STEVAL-CTM011V1 evaluation board, you need the following software and hardware:

- a Windows PC (XP, Vista, Win 7, Win 8, or Win 10) to install the software package;
- B-STLINK-ISOL plus STLINK-V3SET;
- an isolated USB-to-UART wire to connect the board to the PC (optional);
- X-CUBE-MCSDK (v5.3 or later);
- STM32CubeMX (v4.24.0 or later);
- a three-phase brushless PMSM DC motor with compatible voltage and current ratings;
- AC mains power supply or external DC power supply
- any of the supported IDEs:
  - IAR Embedded Workbench® for Arm® (v7.80.4)
  - Keil® MDK tools (v5.24.2 or later)
  - Ac6 System Workbench (v2.3.0 or later)
  - STM32CubeIDE

3 Hardware description and configuration

3.1 Board components

The figures below show the position of the main circuitry blocks of the board.

Figure 2. STEVAL-CTM011V1 main components (top view)

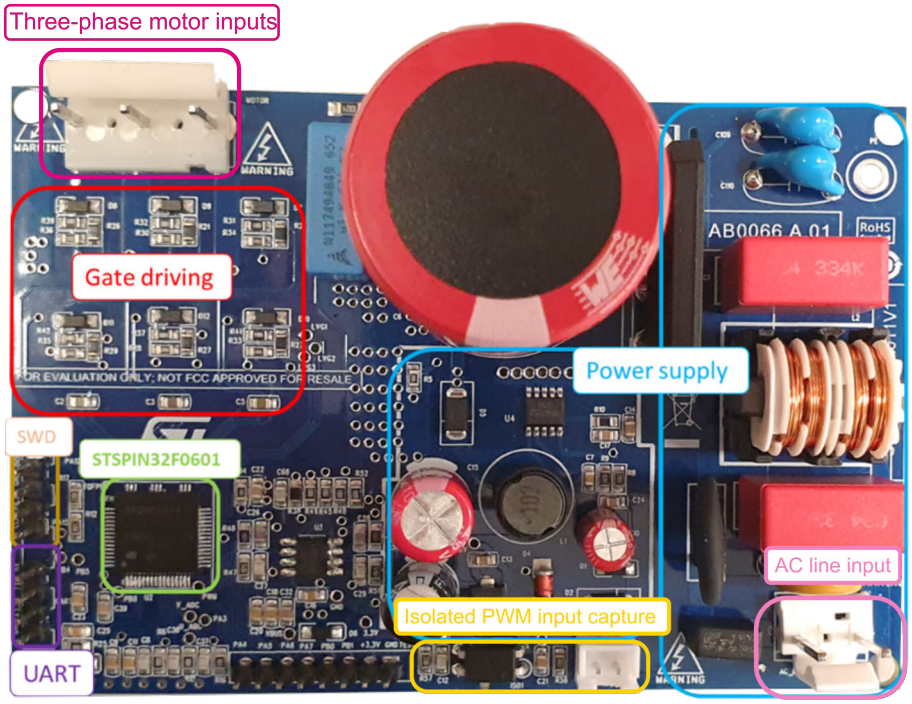
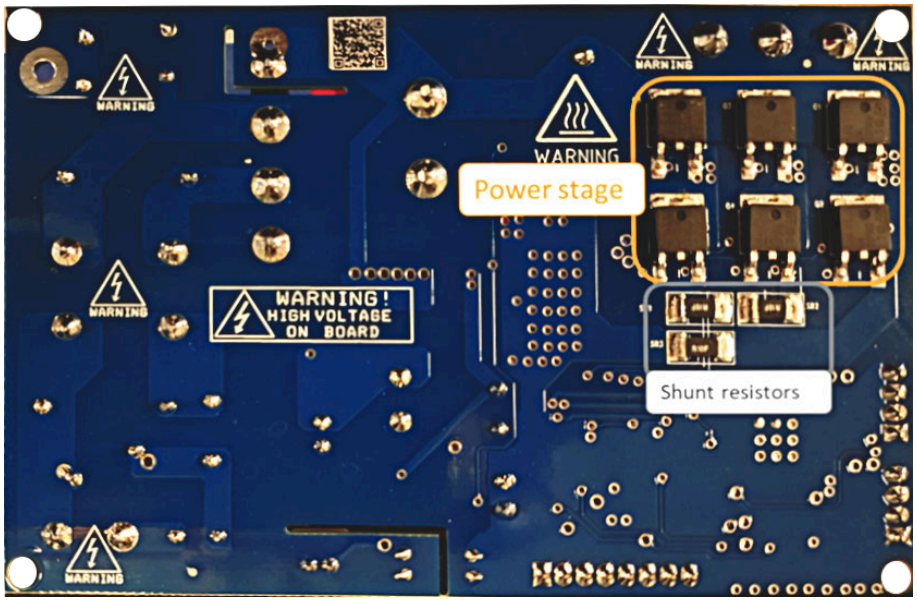


Figure 3. STEVAL-CTM011V1 main components (bottom view)

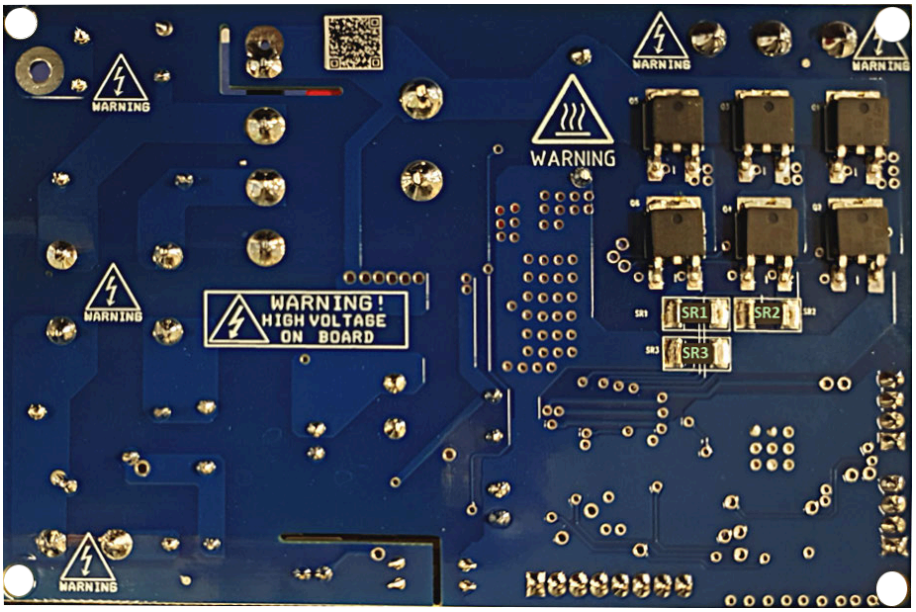


3.2 Shunt resistor configuration

You can configure the shunt resistors according to the desired operation:

- SR1 = 0 Ω and SR2 = 0 Ω to operate in single shunt mode set by SR3 value = 0.1 ohm (default configuration);
- two-shunt plus one-shunt mode by setting:
  - SR1 and SR2 to the desired value (that is SR1=0.1 Ω and SR2= 0.1 Ω);
  - SR1: shunt for U phase current sensing;
  - SR2: shunt for V phase current sensing;
  - SR3: shunt for overcurrent protection.

Figure 4. STEVAL-CTM011V1 - shunt configuration



3.3 Overcurrent detection and current-sensing measurement

The STEVAL-CTM011V1 evaluation board implements overcurrent protection based on the STSPIN32F0601Q integrated comparator.

The SR3 shunt resistor measures the load current that brings the voltage signal to the CIN pin. When the phase peak current exceeds the selected threshold, the integrated comparator is triggered and all the power switches are disabled. Power switches are enabled again when the current falls below the threshold and the `output disable time` expires, thus implementing a current limitation control.

By default, the evaluation board has an overcurrent threshold set to I_{OC_typ}= 4.6 A and a restart time after fault detection of ~28 µs. You can change these values by changing SR3, C18, and R14.

3.4 Bus voltage circuit

The STEVAL-CTM011V1 evaluation board features bus voltage sensing.

You can set this signal through a voltage divider from the motor supply voltage (V_{BUS} - R65, R66, and R5) and send it to the PA0 GPIO (ADC channel 0) of the embedded MCU. The input voltage is then downsized of a 200x factor.

4 Firmware debug

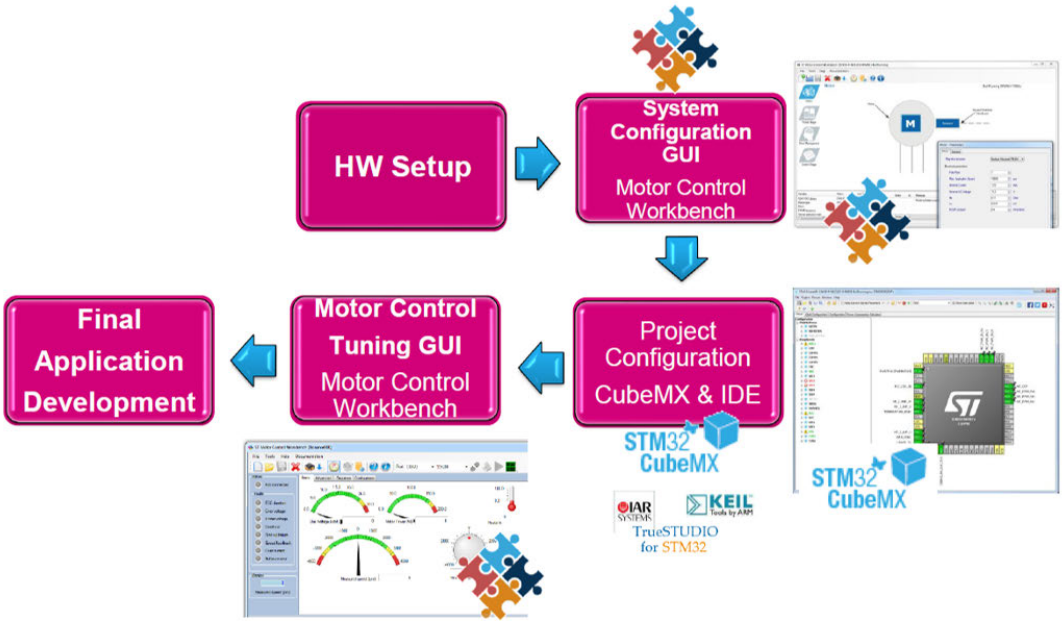
The “STEVAL-CTM01xV1 1shunt_FOC” folder contains a reference firmware generated for IAR v8.5. It works on the evaluation board with one shunt resistor (default configuration).

You can download the firmware through the SWD port as described in 5.

You can also generate the firmware and download it on the MCU through the SWD port.

The diagram below shows the workflow of the firmware generation and application debug process.

Figure 5. STEVAL-CTM011V1 - X-CUBE-MCSDK workflow



To generate the firmware by using X-CUBE-MCSDK, follow the procedure below.

Note: In this example, we use X-CUBE-MCSDK version 5.4.4, but you can use later versions, too.

Step 1. Launch X-CUBE-MCSDK.

Step 2. To start with an environment already set for the evaluation board, load the configuration file provided with the firmware package, named “STEVAL-CTM01xV1 1shunt_FOC.stmcx”.

- **Step 2a.** Choose [**Load Project**] and select the file.
- **Step 2b.** Alternatively, create a new project by selecting [**New Project**]>[**Inverter**]>[**Custom board**] and follow the next steps.

Step 3. Configure the motor parameters, start-up sequence, and all the relevant parameters according to the target application, as per the user manual in [**Documentation**]>[’**Getting started with STM32 motor control SDK v5.x**’].

Figure 6. X-CUBE-MCSDK configuration options

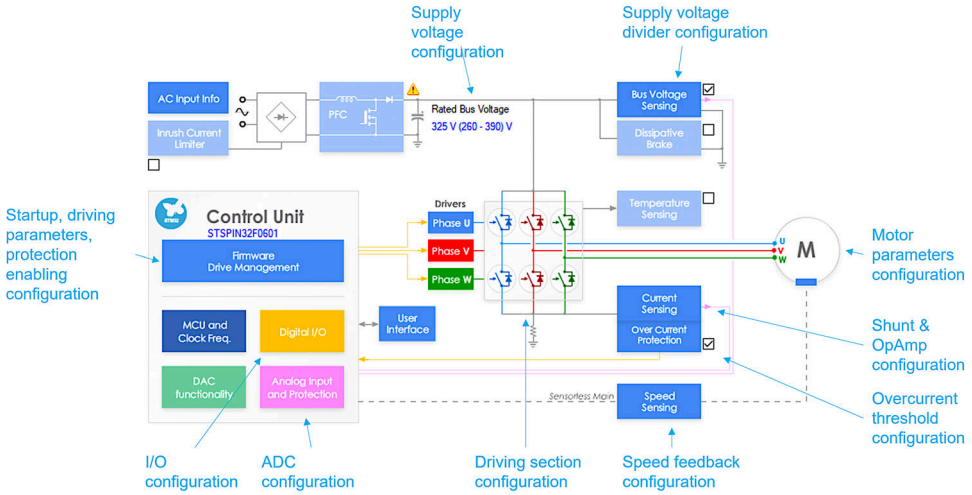


Figure 7. X-CUBE-MCSDK configuration example (1 of 2)

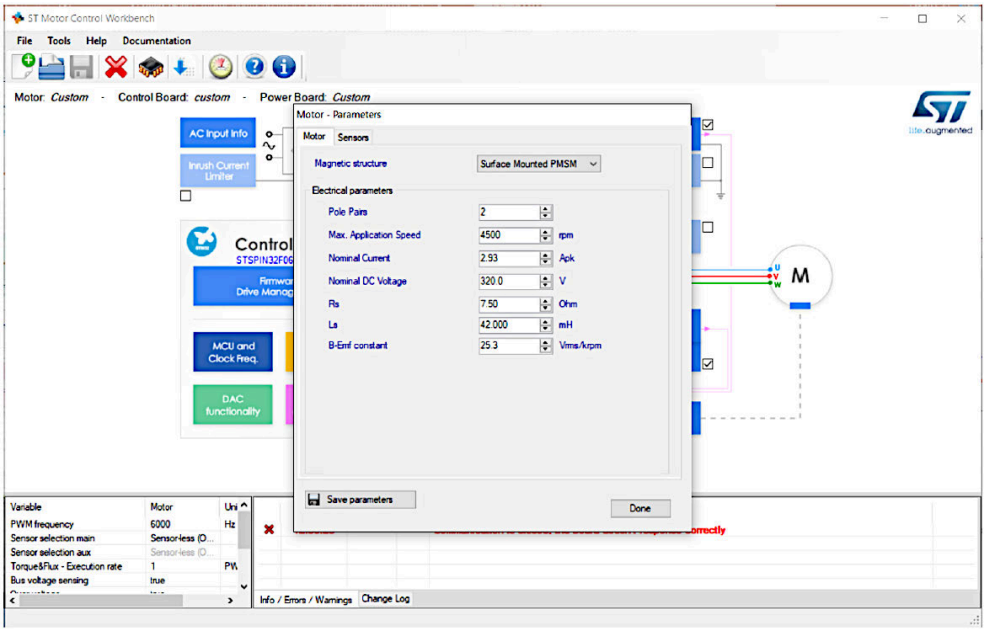
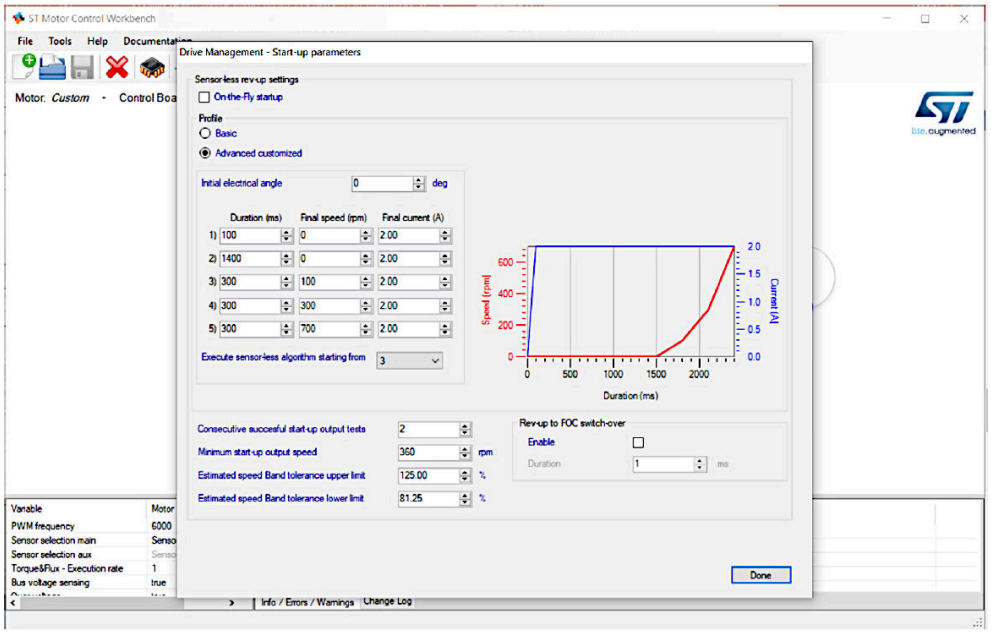


Figure 8. **X-CUBE-MCSDK configuration example (2 of 2)**



Step 4. Click on the generate icon.

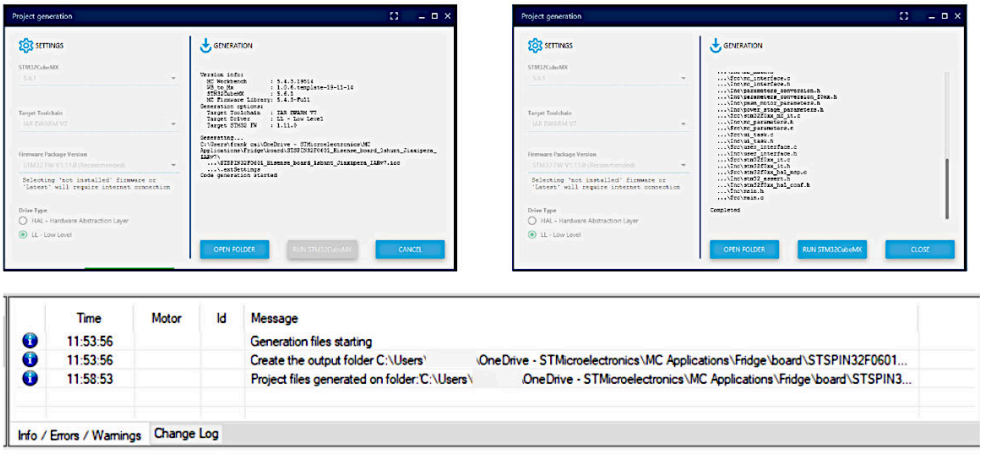
You can then generate the project according to your selected IDE environment.

The X-CUBE-MCSDK motor control workbench calls the STM32CubeMX in background to generate the project frame in the selected IDE.

When the firmware generation starts, a progress window shows that the script is running.

When finished, the tip window appears. The user information table is updated accordingly.

Figure 9. **X-CUBE-MCSDK firmware generation**



Step 5. After project generation, open the project file, compile, and download it onto the STSPIN32F0601Q device.

Figure 10. Project opened in the selected IDE

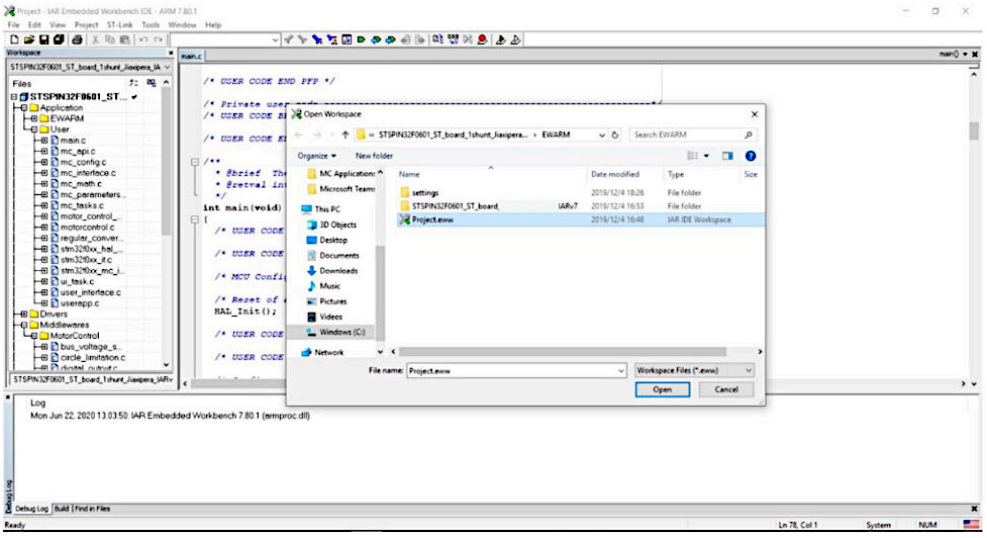
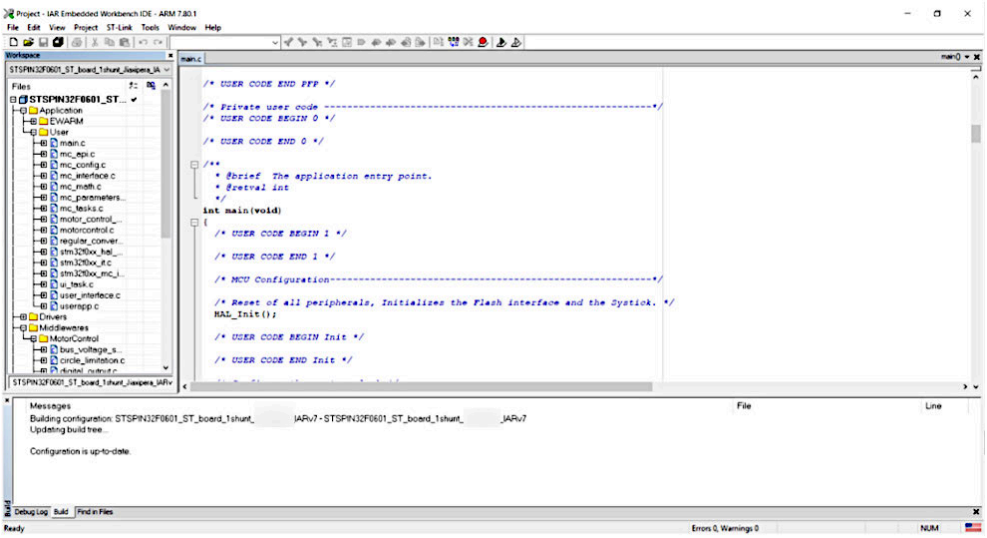


Figure 11. Project compiled



5 How to use the board

To start your project with the STEVAL-CTM011V1 evaluation board:

Step 1. Connect the motor to the CON_UVW connector.

Important: *Pay attention to the motor phase sequence.*

Step 2. Supply the evaluation board through the AC_IN AC mains connector.

Step 3. Develop your application using the STM32 FOC MC library.

6 Schematic diagrams

Figure 12. **STEVAL-CTM011V1 circuit schematic (1 of 2)**

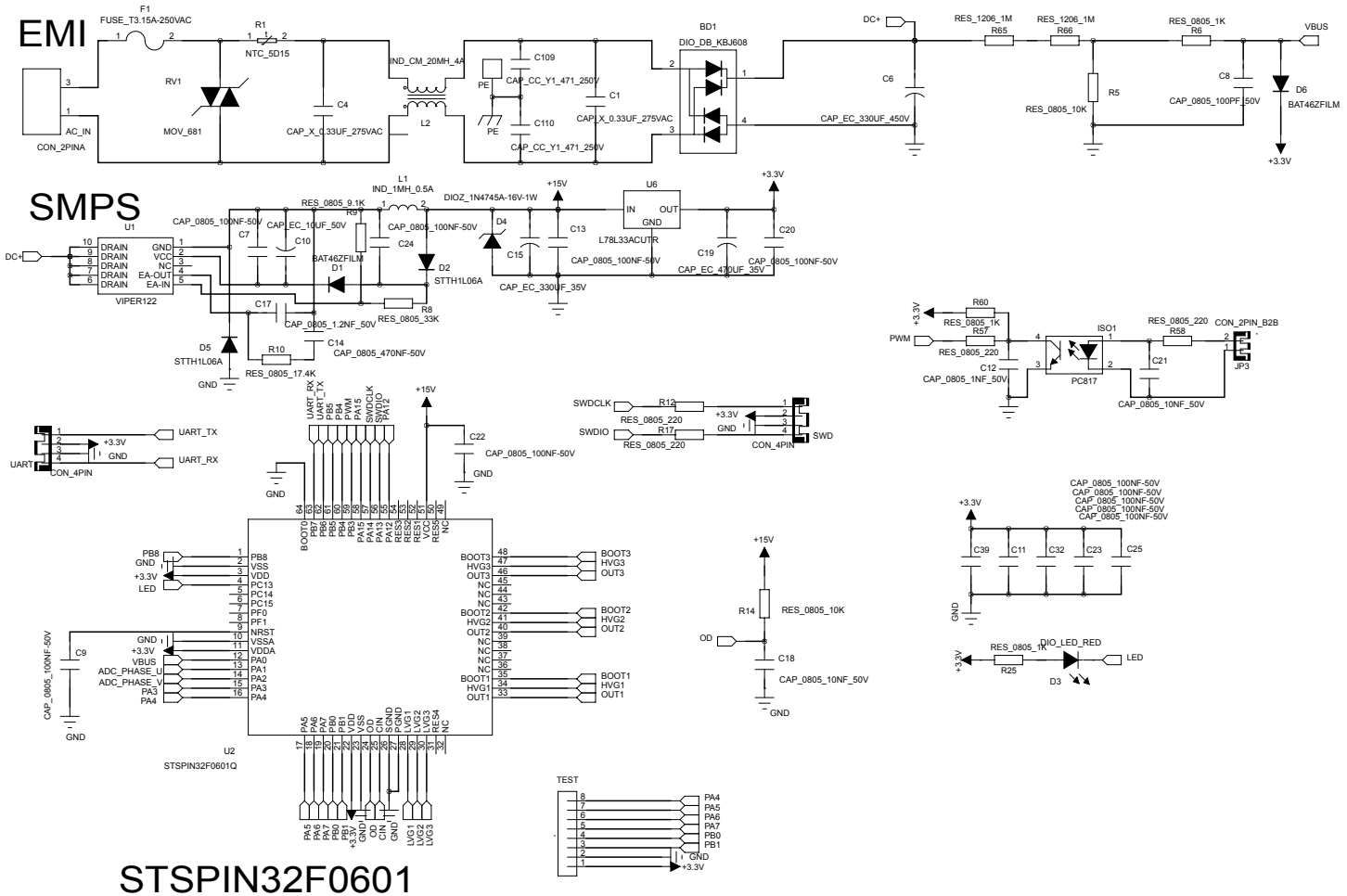
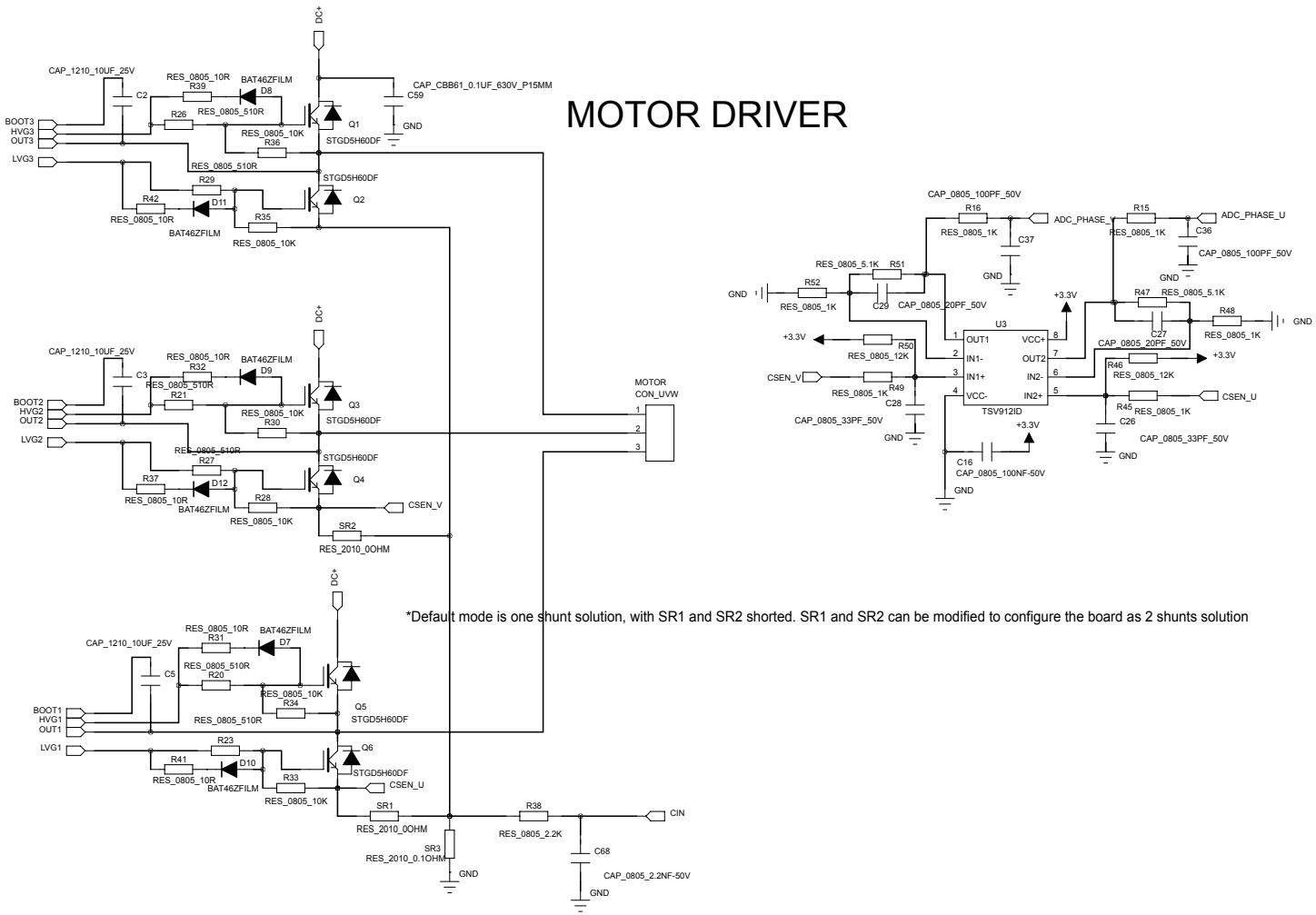


Figure 13. STEVAL-CTM011V1 circuit schematic (2 of 2)



*Default mode is one shunt solution, with SR1 and SR2 shorted. SR1 and SR2 can be modified to configure the board as 2 shunts solution

7 Bill of materials

Table 1. **STEVAL-CTM011V1 bill of materials**

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	8	D1, D6, D7-12	BAT46ZFILM, SOD-123	100 V, 150 mA SMD general-purpose signal Schottky diode	ST	BAT46ZFILM
2	1	C17	0805, 1.2 nF, 50 V, ±10%	Capacitor	Kyocera AVX	08055C122K4T2A
3	12	C7, C9, C11, C13, C16, C20, C22-25, C32, C39	0805, 50 V, ±10%	Capacitors	Wurth Elektronik	885012207098
4	3	C8, C36-37	150 pF, 0805, 50 V, ±10%, C0G/NP0	Ceramic capacitors	Wurth Elektronik	885012007058
5	2	C18, C21	0805, 10 nF, 50 V, ±10%	Capacitors	Wurth Elektronik	885012207092
6	1	C12	1500 pF, 0805, 50 V, C0G/NP0	Ceramic capacitor	Wurth Elektronik	885012007064
7	1	C68	0805, 2.2 nF, 50 V, ±10%	Capacitor	Wurth Elektronik	885012007065
8	2	C27, C29	0805, 20 pF, 50 V, ±5%	Capacitors	KEMET	C0805X200J5GACTU
9	2	C26, C28	0805, 33 pF, 50 V, ±5%	Capacitors	Kyocera AVX	08055C330JAT2A
10	1	C14	0805, 470 nF, 50 V, ±10%	Capacitor	Taiyo Yuden	UMK212C7474KGHTE
11	3	C2-C3, C5	10 µF, 0805, 25 V	Ceramic capacitors	Taiyo Yuden	TMK212BBJ106KG-T
12	1	C59	CBB61, 0.1 µF, 630 V, through-hole, P = 15 mm 630 V, ±10%	Capacitor	Panasonic	ECQ-E6104KFA
13	2	C109-110	CC, Y1, 471, 250 V, through-hole, P = 7.5 mm, 250 V_{AC}, ±10%	Capacitors	Panasonic	ECW-F2474JAB
14	1	C10	10 µF, Ø5*L11, 50 V, ± 20%	Capacitor	Wurth Elektronik	860130673001
15	1	C15	EC, 330 µF, 35 V Ø10*L12.5	Capacitor	Wurth Elektronik	860020575013
16	1	C6	EC, 330 µF, 450 V Ø30*L51	Capacitor	Wurth Elektronik	861021485026
17	1	C19	470 µF, Ø8*L122, 35 V, ±20%	Aluminum capacitor	Panasonic	EEU-FR1V471L
18	2	C1, C4	0.33 µF, 275 V_{AC}, pitch 15 mm	Film capacitors	Wurth Elektronik	890324025034CS
19	1	AC_IN	CON_2PINA, P = 7.92 mm	Connector header	Molex	0359790210
20	1	JP3	CON_2PIN_B2B, Through hole,P=2.5mm	Connector header	Samtec	TSW-101-07-F-D

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
21	2	SWD UART	CON_4PIN, through hole,P=2.54mm	Header spacer connector	Amphenol	75970-3BB-04LF
22	1	TEST	CON_8PIN, through hole,P=2.54mm	Connector header	Amphenol	78511-408HLF
23	1	MOTOR	CON_UVW, through hole	Connector header	Molex	0010634037
24	1	D4	DIOZ_1N4745A, 16V, 1W, LL-41	Zener diode	Vishay Semiconductor Diodes Division	ZM4745A-GS08
25	1	BD1	DIO_DB_KBJ608, KBJ	Bridge rectifier	Diodes Incorporated	KBJ608G
26	1	D3	DIO_LED, 0805	Red LED	Visual Communications Company - VCC	CMD17-21VRD/TR8
27	1	F1	FUSE_T3.15A-250 VAC through hole,P=5.08mm 250V	Fuse	Bel Fuse Inc.	RST 3.15-BULK
28	1	L1	1 mH 800 mA 1.15 ohm, pitch 5 mm	Fixed inductor	Wurth Elektronik	7447480102
29	1	L2	CMC 3.9 mH 1 A 2LN TH	Common mode choke	Wurth Elektronik	7448640412
30	1	U6	L78L33ACUTR	Positive voltage regulator	ST	L78L33ACUTR
31	1	RV1	MOV_681	High surge varistor	Wurth Elektronik	820415511B
32	1	R1	NTC_5D15, through-hole, P = 7.5 mm, 5 Ω ±20%	Thermistor	EPCOS - TDK Electronics	B57234S0509M051
33	1	ISO1	PC817, DIP-4	Optoisolator transistor	Taiwan Semiconductor Corporation	TPC817C C9G
34	6	R31-32, R37, R39, R41-42	RES_0805_10R, 0805, 10.0 Ω ±1%	Resistors	Rohm	SFR10EZPF10R0
35	4	R12, R17, R57-58	RES_0805_220R, 0805, 220.0 Ω ±1%	Resistors	Rohm	KTR10EZPF2200
36	6	R20-21, R23, R26-27, R29	RES_0805_510R, 0805, 510 Ω ±1%	Resistors	Rohm	KTR10EZPF5100
37	8	R5, R14, R28, R30, R33-36	RES_0805_10K, 0805, 10 kΩ ±1%	Resistors	Rohm	SFR10EZPF1002
38	2	R46, R50	RES_0805_12K, 0805, 12 kΩ ±1%	Resistors	Rohm	KTR10EZPF1202
39	1	R10	RES_0805_17.4K, 0805, 17.4 kΩ ±1%	Resistor	Rohm	KTR10EZPF1742
40	9	R6, R15-16, R25, R45, R48-49, R52, R60	RES_0805_1K, 0805, 1 kΩ ±1%	Resistors	Rohm	KTR10EZPF1001
41	1	R38	RES_0805_2.2K, 0805, 2.2 kΩ ±1%	Resistor	Rohm	SFR10EZPF2201
42	1	R8	RES_0805_33K, 0805, 33 kΩ ±1%	Resistor	Rohm	KTR10EZPF3302

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
43	2	R47, R51	RES_0805_5.1K, 0805, 5.1 kΩ ±1%	Resistors	Rohm	SFR10EZPF5101
44	1	R9	RES_0805_9.1K, 0805, 9.1 kΩ ±1%	Resistor	Rohm	SFR10EZPF9101
45	2	R65-66	RES_1206_1M, 1206, 1 mΩ ±1%	Resistors	Rohm	KTR18EZPF1004
46	2	SR3	RES_2010_0.1 ohm 2010 0.1 Ω ±1%	Resistor	Vishay	WFMB2010R1000FEA
46	1	SR1-SR2	RES_2010_0OHM, 2010, 0 Ω	Resistors	Vishay	CRCW20100000Z0EFHP
47	6	Q1-6	STGD5H60DF, DPAK	600 V, 5 A high-speed trench gate field-stop IGBT, H series	ST	STGD5H60DF
48	1	U2	STSPIN32F0601Q, TQFP 10x10 64PIN/ QFN10x10 72PIN	600 V three-phase controller with MCU	ST	STSPIN32F0601Q
49	2	D2 D5	STTH1L06A, SOD-123F	600 V, 1 A low drop ultrafast diode	ST	STTH1L06A
50	1	U3	TSV912ID, SO8	Wide bandwidth (8MHz) rail-to-rail input/ output 5 V CMOS op-amp	ST	TSV912ID
51	1	U4	VIPER122, SSOP10	High-voltage converter	ST	VIPER122
52	1	PCB	113x76x1.6mm	FR4 TG 140, CU thickness 35 microns	Any	Any

8 Board versions

Table 2. **STEVAL-CTM011V1 versions**

Finished good	Schematic diagrams	Bill of materials
STEVAL$CTM011V1A (1)	STEVAL$CTM011V1A schematic diagrams	STEVAL$CTM011V1A bill of materials

1. *This code identifies the STEVAL-CTM011V1 evaluation board first version.*

9 References

- STSPIN32F0601Q datasheet
- UM2380: "STM32 motor control SDK v5.x tools"
- UM1718: "STM32CubeMX for STM32 configuration and initialization C code generation"
- UM0892: "STM32 ST-LINK utility software description"

Revision history

Table 3. **Document revision history**

Date	Revision	Changes
12-Jan-2022	1	Initial release.
07-Feb-2022	2	Updated Section 1.1.4 Evaluation board operation.
04-May-2022	3	Updated introduction and Section 1.2 Features.
14-Oct-2022	4	Updated Section 1.2 Features.

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