

Getting started with the industrial drive system kit based on ACEPACK™ 2 power module

Introduction

The **STEVAL-HKI001V1** is an industrial drive evaluation system designed to demonstrate the capabilities of the **A2C35S12M3-F** IGBT power module for motor control applications.

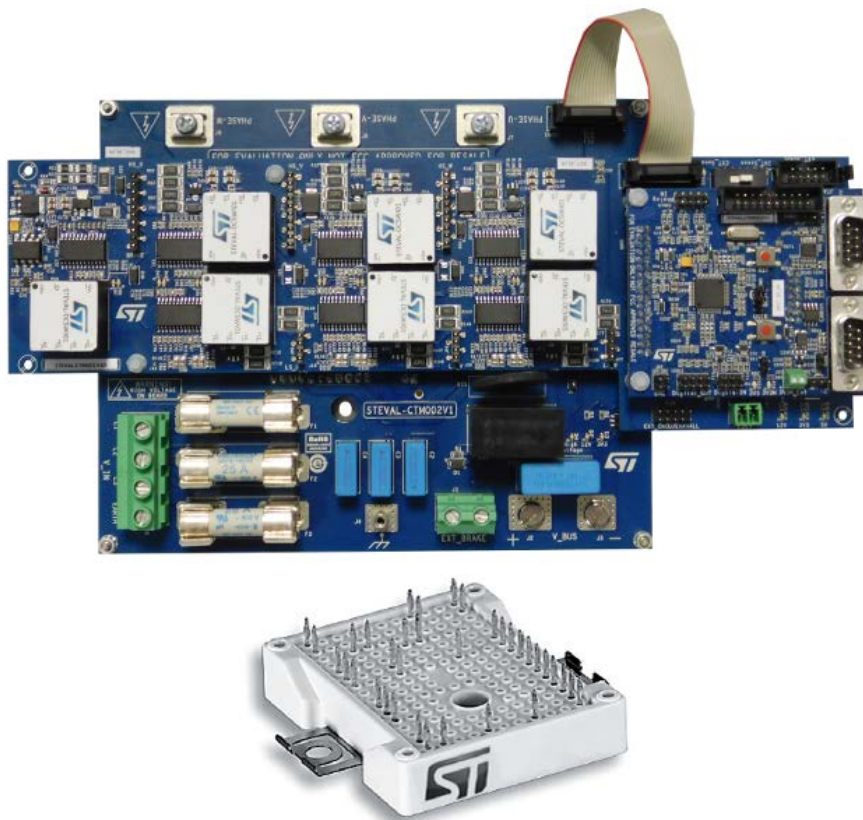
It offers a solution for single- or three-phase main input with a converter inverter brake (CIB) topology able to handle a motor current up to 35 A (power module maximum current rating).

The hardware platform is a stackable solution which consists of the power stage (**STEVAL-CTM002V1**), which contains the power module and current sensing circuitry, and the driving kit (**STEVAL-CTM001V1**) connected via external connectors.

The **STEVAL-CTM001V1** driving kit consists of a **STEVAL-CTM001V1C** control board based on the **STM32F303RBT7** microcontroller able to execute the field oriented control (FOC) algorithm to obtain the best performance in all motor control applications, and the **STEVAL-CTM001V1D** driving board based on the new galvanically isolated **STGAP1AS** gapDRIVE™, with suitable circuitry to drive the embedded IGBTs in the power module.

The control board has RS232 and CAN external interfaces to let you monitor and control your application on the evaluation system via PC.

Figure 1. ACEPACK™ industrial drive evaluation system



1 **Getting started**

1.1 ACEPACK™ evaluation system features

1.1.1 Electrical and functional characteristics

The evaluation system kit features:

- [A2C35S12M3-F](#) ACEPACK™ 2 power module in converter inverter brake (CIB) topology
- Control stage based on [STM32F303](#) ARM® Cortex®-M3 MCU and compatible with ST MC library with ST-FOC algorithm (sensored and sensorless mode)
- In-rush current, thermal and overcurrent protection
- Brake function with external resistor
- On-board isolated current sensing of 2.1 kV_{RMS}
- Galvanically isolated driving stage with [STGAP1AS](#)
- Additional gate driving for dissipative brake section (external power resistor)
- Protections and sensing (overvoltage, overcurrent, overtemperature, current reading input)
- Input/output interface (analog/digital)

1.1.2 Target applications

Motor drives with input from single or three-phase grid for:

- Industrial motor drives
- Motion/Servo Control
- Pumps

1.2 Safety and operating instructions

1.2.1 General terms

All operations involving transportation, installation and use, as well as maintenance, are 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.

Danger:

During assembly, testing, and normal operation, the Evaluation Kit poses several inherent hazards, including bare wires, moving or rotating parts and hot surfaces. There is a danger of serious personal injury if the kit or components are improperly used or incorrectly installed. The kit is not electrically isolated from the AC/DC input. The demonstration board is directly linked to the mains voltage. No insulation is ensured between accessible parts and high voltage. All measuring equipment must be isolated from the mains before powering the board. When using an oscilloscope with the Evaluation Kit, it must be isolated from the AC line. This prevents shock as a result of touching any single point in the circuit, but does not prevent shock when touching two or more points in the circuit. Do not touch the Evaluation Kit after disconnection from the voltage supply: several parts and power terminals, which contain energized capacitors, must be allowed to discharge.

1.2.2 Intended use

This evaluation kit is designed for demonstration purpose only and shall not be used for any commercial purpose. The technical data, as well as information concerning power supply conditions, must be taken from the relevant documentation and strictly observed.

1.2.3 Installation

The evaluation kit installation must be in accordance with the specifications and the target application:

- The kit contains electro-statically sensitive components that are prone to damage through improper use. Electrical components must not be mechanically damaged or destroyed.
- Avoid any contacts with other electronic components.
- During the motor drive, converters must be protected against excessive strain. In particular, no components are to be bent or isolating distances altered during the course of transportation or handling.

1.2.4 Electronic connections

Applicable national accident prevention rules must be followed when working on the main power supply with a motor drive.

The electrical installation must be completed in accordance with the appropriate requirements.

A system architecture which supplies power to the evaluation kit must be equipped with additional control and protective devices in accordance with the applicable safety requirements (e.g. compliance with technical equipment and accident prevention rules).

1.3 System description

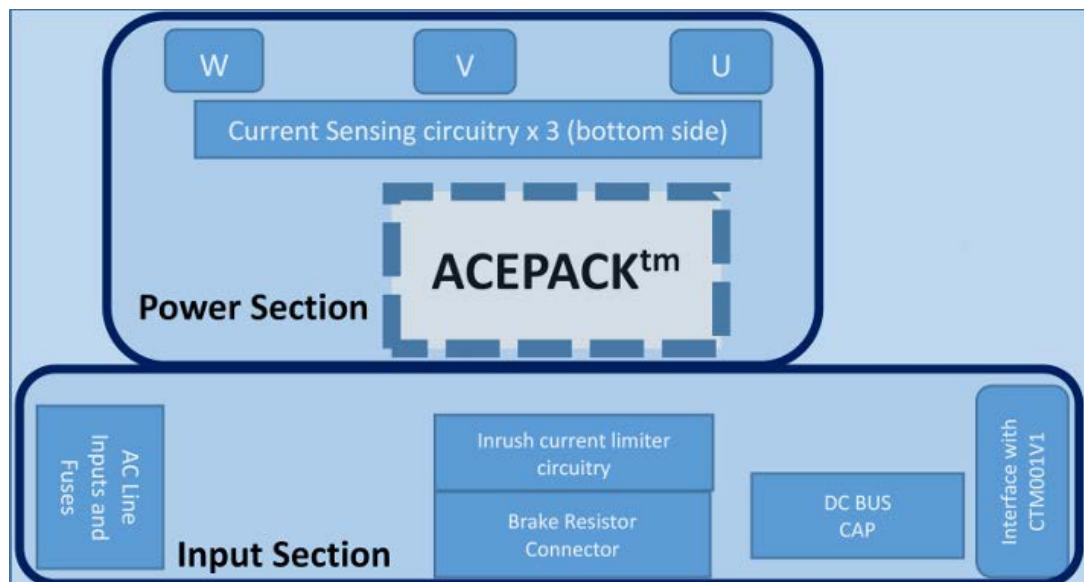
1.3.1 System overview

The STEVAL-CTM002V1 evaluation board is aimed at evaluating the power module for motor control applications.

The board can be schematized in two main blocks:

- Power section: this block hosts the connectors to plug the board itself and the STEVAL-CTM001V1 evaluation board; it also includes 3 isolated current sensors, the [A2C35S12M3-F](#) power module and 3 power connectors for the motor phases.
- Input section: this block is for the single phase and three-phase input with AC line with fuses, inrush current limiter circuitry, connectors for external brake resistor and for connecting the compatible driver board (STEVAL-CTM001V1).

Figure 2. STEVAL-CTM002V1 evaluation board main blocks

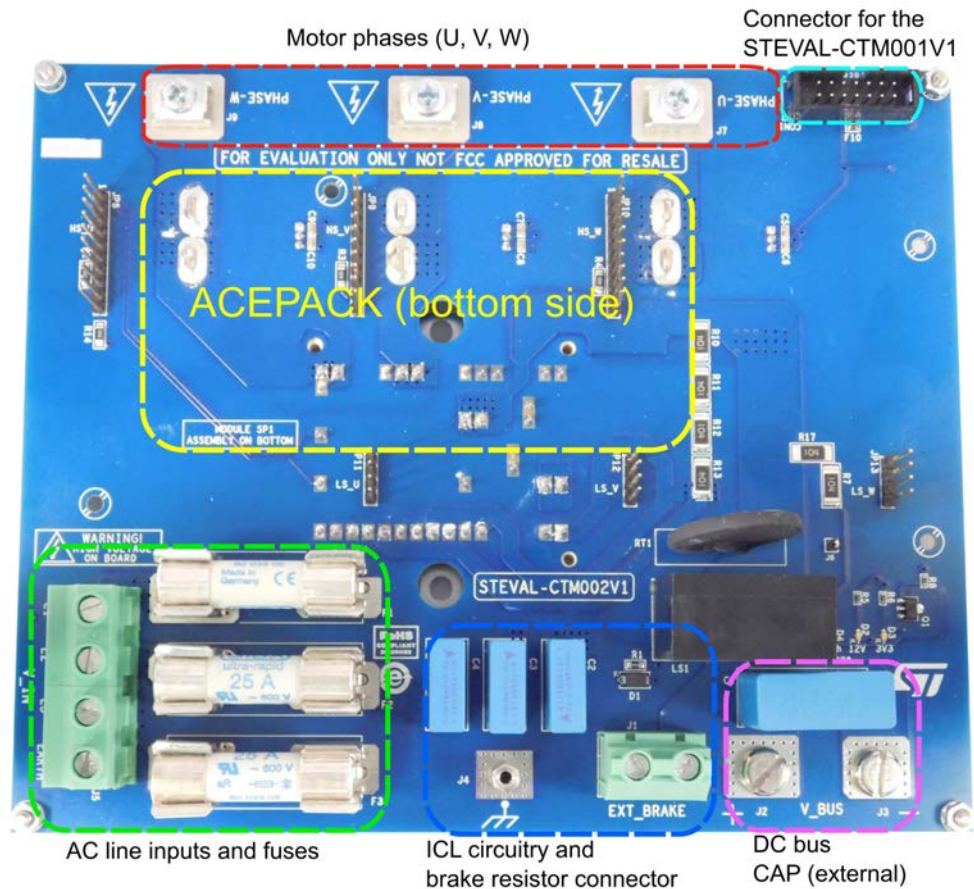


1.3.2 Power section

As shown in [Figure 2. STEVAL-CTM002V1 evaluation board main blocks](#), the STEVAL-CTM002V1 evaluation board power stage is the [A2C35S12M3-F ACEPACK™](#), available in two package options: solderable and press-fit contact pins.

For an exhaustive evaluation, three isolated current sensors have been mounted to implement a FOC algorithm based on the ST motor control software library ([STSW-STM32100](#)).

The power section also hosts the connectors to plug both the driver board (STEVAL-CTM001V1D) via JP8 (HS_U), JP9 (HS_V) and JP10 (HS_W) for the high-side driving (U, V and W motor phases, respectively) and, similarly, for the low-side driving via JP11, JP12 and JP13 (LS_U, LS_V, LS_W).

Figure 3. STEVAL-CTM002V1 evaluation board sections


1.3.2.1 ACEPACK™ power module characteristics

The hardware is designed to test the [A2C35S12M3](#) power module.

It is highly flexible as it is possible to plug, for example, either the solderable version (here soldered) or the [A2C35S12M3-F](#) (press-fit version).

The power module mainly features:

- Converter inverter brake (CIB) topology:
 - 1600 V very low drop rectifiers for converter
 - 1200 V, 35 A IGBTs and diodes
 - $V_{CE(sat)} = 1.85 \text{ V}$ at $I_C = 35 \text{ A}$
 - Soft and fast recovery diode
- Compact dimension plastic case (52.7 x 48 x 12.0 mm)
- Al_2O_3 direct bonded copper (DBC)
- Integrated NTC temperature sensor
- Available as press-fit pin type
- Typical applications: inverters, motor drives, UPS

Figure 4. A2C35S12M3 power module topology

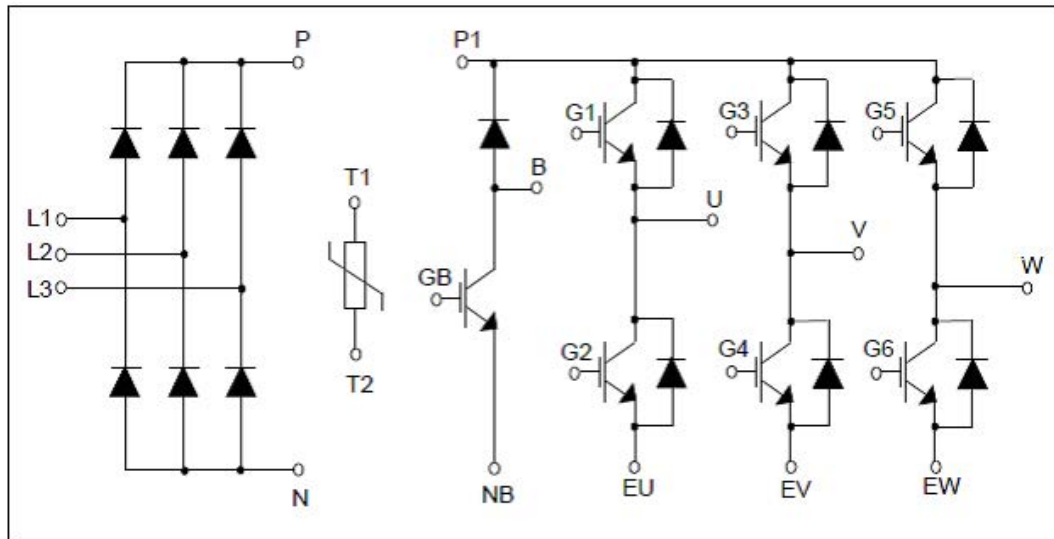
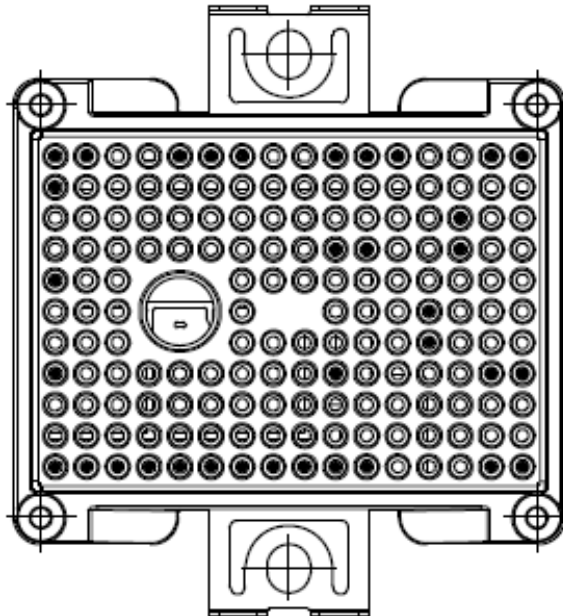


Figure 5. A2C35S12M3 power module drawing



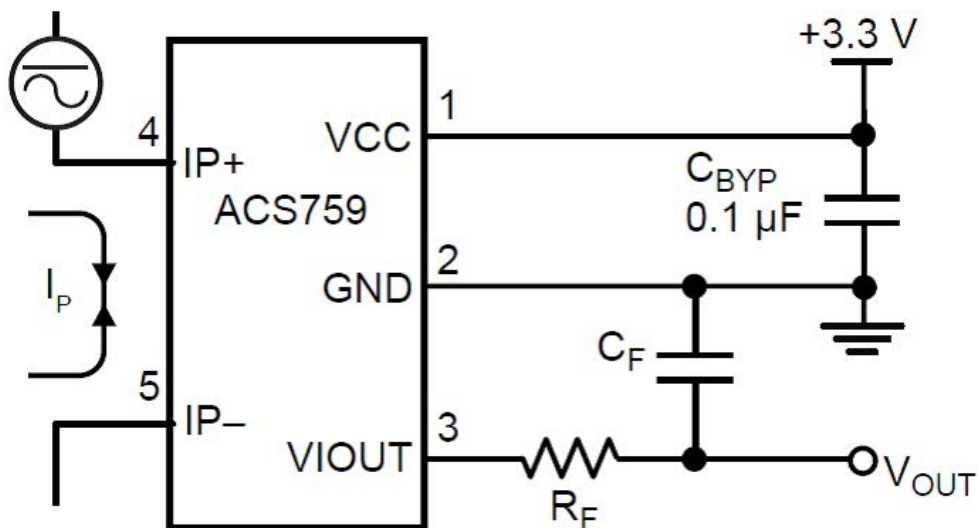
Figure 6. A2C35S12M3 package pin arrangements


1.3.2.2 Phase current sensing

The power stage contains a current sensing circuitry for motor phase implemented via three Hall effect-based current sensors assembled on the bottom side and able to detect the three-phase motor currents.

This sensing feature is necessary to implement a digital control based on FOC algorithm.

These sensors are highly accurate as they have 26.4 mV/A with an operative temperature from -40 to 140°C.

Figure 7. A2C35S12M3 current sensor schematic


Two motor phase currents (I_u and I_v) are used by the algorithm and the third one (not used by ST motor control software library) is estimated by the following equation:

$$I_u + I_v + I_w = 0 \quad (1)$$

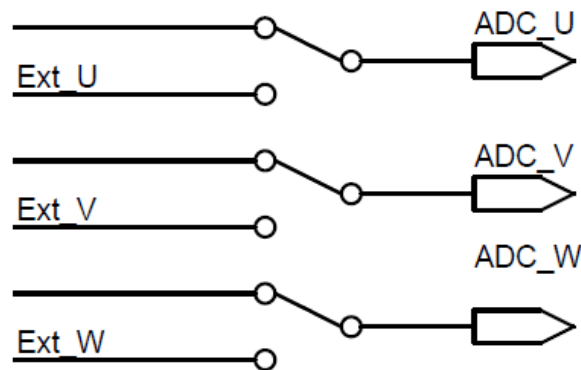
To set the embedded current sensors, it is mandatory to set the multiple switch SW1 and select **Int_Sense**. If properly set, the LED diode D23 turns on.

For more flexibility, you also can by-pass this embedded current sensing circuitry and use another external current sensing board (not included). In this case, it is mandatory to set the multiple switch SW1 and select **Ext_Sense**. If properly set, the LED diode D24 turns on.

Danger:

The signals coming out from the sensors have to be centered in 1.65 V (average value at zero current) with a range of 0 to 3.3 V max. A different range could damage some circuitry or even the microcontroller.

Figure 8. A2C35S12M3 multiple switch selection (external/internal current sensing)



Danger:

*Be aware that, depending on the current sensing methodology selected (**Int_Sense** via the embedded circuitry or **Ext_Sense** via an external board), a failure event may occur if the multiple switch SW1 is not selected accordingly.*

1.3.3 STEVAL-CTM001V1 evaluation board overview

The STEVAL-CTM001V1 evaluation board is mainly composed of the power supply section, the driving stage and the control board.

The driving section (STEVAL-CTM001V1D) has been designed around the galvanically isolated [STGAP1AS](#) that offers high-end performance with several features in terms of protection, diagnostics and the isolated DC/DC multi-output converter SPDC5WI (+15 V/-10 V) or SPDC5WS (+20 V/-5 V).

The power supply section is embedded in the driving section and provides the voltage necessary for the circuitry starting from the input voltage (V_{in}) on connector JP1.

The control board (STEVAL-CTM001V1C) is based on the high performance [STM32F303RBT7](#) microcontroller thanks to dedicated peripherals for motor control such as fast ADC conversions and high resolution timers.

The stand-alone control board is connected to the driving stage via the 34-pin motor control connector used in most motor control applications.

The standard motor control connector offers improved flexibility because you can connect any kind of control board.

Figure 9. STEVAL-CTM001V1 evaluation board



1.3.3.1 STEVAL-CTM001V1C control board

The STEVAL-CTM001V1C control board has been designed around the [STM32F303RBT7](#) microcontroller which belongs to a family based on the high-performance ARM® Cortex®-M4 32-bit RISC core with FPU operating at a frequency up to 72 MHz, and embedding a floating point unit (FPU), a memory protection unit (MPU) and an embedded trace macrocell (ETM).

The family embeds high-speed memories (up to 256 Kbytes of Flash memory, up to 40 Kbytes of SRAM) and an extensive range of enhanced I/O and peripherals connected to two APB buses. These devices offer up to four fast 12-bit ADCs (5Msps), seven comparators, four operational amplifiers, up to two DAC channels, a low-power RTC, up to five general-purpose 16-bit timers, one general-purpose 32-bit timer, and two timers dedicated to motor control. They also feature standard and advanced communication interfaces: up to two I²Cs, up to three SPIs (two SPIs are with multiplexed full-duplex I²Ss), three USARTs, up to two UARTs, CAN and USB.

To achieve audio class accuracy, the I²S peripherals can be clocked via an external PLL.

The STM32F303xB/STM32F303xC family operates in the -40 to +85 °C and -40 to +105 °C temperature ranges from a 2.0 to 3.6 V power supply. A comprehensive set of power-saving mode allows the design of low-power applications.

The STM32F303RBT7 microcontroller integrated in this evaluation board is a 64-pin package LQFP64 (Low-profile Quad Flat Package)(For further details, refer to the relevant datasheet on www.st.com.) It has a standard SWD/JTAG (Serial Wire Debug) 20-pin connector to access the registers and the MCU Flash memory for fast programming and debugging supported by the most popular IDE environments.

The control board features:

- 34-pin motor control connector, including signals like fault management, bus voltage monitoring, power module temperature sensing and dissipative braking
- 2 push buttons (1 for user general purpose and 1 for MCU reset)
- 3 user LEDs (2 green LEDs for two different +3.3 V, one specific for microcontroller supply and one for other functionalities; an orange LED for +5 V)
- SWD/JTAG programming connector
- RS232 DB9 male connector
- CAN DB9 male connector

Figure 10. STEVAL-CTM001V1C evaluation board

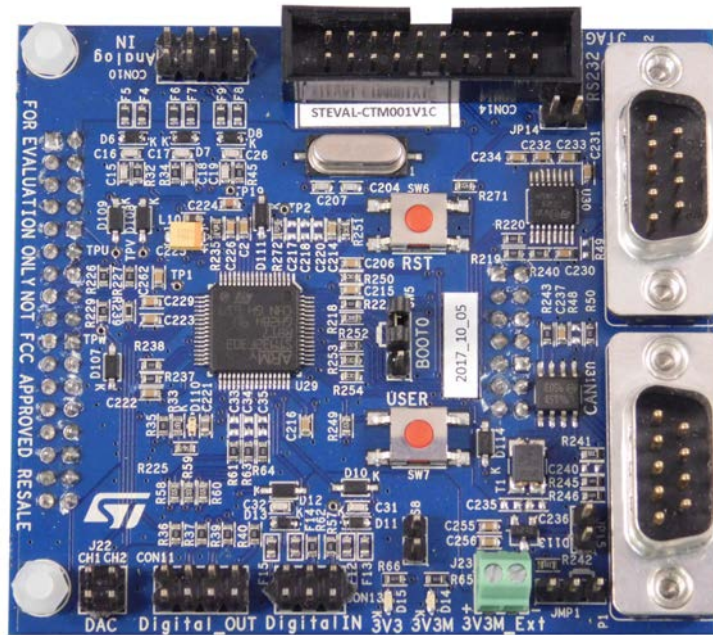
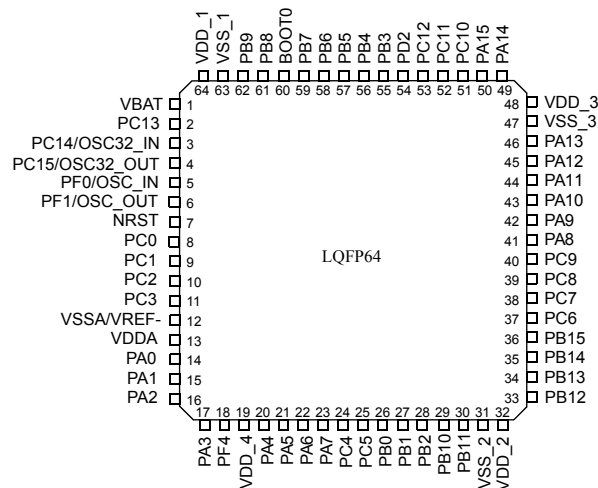


Figure 11. STM32F303xB LQFP64 pin-out



1.3.3.1.1 STM32 PMSM FOC SDK compatible software

The control board is fully compatible with ST Motor Control Workbench (software for motor control downloadable from [STSW-STM32100](#)).

This tool has been used to test the board on a 10 kW PMSM motor.

After installing the software aforementioned, you can connect the evaluation board to the PC or laptop via the [ST-LINK/V2](#) in-circuit debugger/programmer and a USB-to-serial converter with female to female DB9 serial cable.

1.3.3.2 STEVAL-CTM001V1D driver board power supply and connectors

The STEVAL-CTM001V1D driver board consists of some sections with specific functions:

- Power supply
- Connectors

- Gate drivers
- Bus voltage monitor
- Temperature monitor
- Dissipative braking

Figure 12. STEVAL-CTM001V1D evaluation board settings with control board



Power supply

The power supply section has been designed to provide the different voltage levels necessary for system operations. Seven insulated DC/DC have been used to provide the supply voltage for the seven gate drivers. The voltage input, to be provided at JP1 connector, must be in the range 8÷28 V.

The power supply section is able to provide the following voltage levels: +12 V available at CON9 for external functions, +5 V and +3.3 V for the control board, and +15 V/-10 V for the gate driver section.

Supply voltage connector

As aforementioned, the voltage input is provided at JP1 connector in the range 8÷28 V.

Power board connector

The CON8 connector is used for current sensing signals coming from the internal current sensors (based on the shunt resistor and assembled on the power board bottom layer) and for the relay driving functions.

Moreover, six connectors (from JP2 to JP7) are used for the IGBT, braking section driving signal and the NTC sensing.

A high-side emitter on the low side and a collector sensing on the high side are used for the gate driver functionality and for monitoring the DC bus voltage.

Control board connectors

The connectors for the control board are CON4 and CON5.

CON4 is used for serial peripheral interface (SPI) communication signals exchanged between the microcontroller and the gate driver. Through the SPI, you can program each gate driver function parameter and monitor the diagnostics functionality.

CON5 is the motor control connector for signals like fault management, bus voltage monitoring, power module temperature sensing and dissipative braking.

External signal connectors

CON2 (also called EXT_ENCODER connector) provides a +5 V supply voltage and is used for receiving external signals coming from the Encoder/Hall sensors.

CON16 (also called EXT_SENSE connector) also provides a +5 V supply voltage but allows receiving current signals from an external current sensor board.

1.3.3.2.1 STGAP1AS gate driver characteristics

The **STGAP1AS** gapDRIVE™ is a 4 kV galvanically isolated single gate driver IC for N-channel MOSFETs and IGBTs with advanced protections, configuration and diagnostics features.

The STGAP1AS architecture isolates the channel from the control and the low voltage interface circuitry through physical galvanic isolation.

The gate driver is characterized by a 5 A output current capability, making the device also suitable for high power inverter applications such as motor drivers in hybrid and electric vehicles and in industrial drives.

The output driver section provides a rail-to-rail output with the possibility of using a negative gate driver supply.

The input-to-output propagation delay is within 100 ns, providing high PWM control accuracy.

Protection functions, such as the Miller clamp, desaturation detection, dedicated sense pin for overcurrent detection, output 2-level turn-off, V_{CE} overvoltage protection, UVLO and OVLO, are included to easily design high reliability systems. Each function parameter can be programmed via the SPI, making the device very flexible and suitable for a wide range of applications. Separate sink and source output provides high flexibility and a reduced bill of materials for external components.

Figure 13. STGAP1AS gapDRIVE™ pin-out

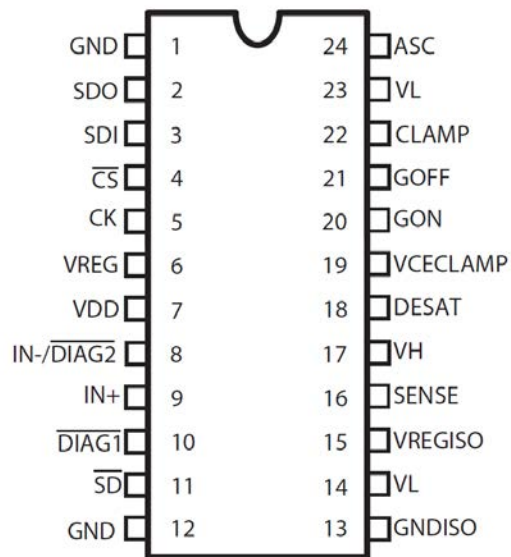


Table 1. STGAP1AS gapDRIVE™ pin description

Pin no.	Pin name	Type Function	Description
7	V_{DD}	Power supply	Internal 3.3 V regulator input supply pin
6	V_{REG}	Power supply	Internal 3.3 V regulator output and supply pin
11	\overline{SD}	Logic input	Shutdown input (active low)
9	IN+	Logic input	Gate command input
8	IN-/DIAG2	Logic input/open drain output	Gate command input /open drain diagnostic output
10	DIAG1	Open drain output	Open drain diagnostic output
1, 12	GND	Ground	Low voltage section ground
4	\overline{CS}	Logic input	SPI chip select (active low)
5	CK	Logic input	SPI clock
3	SDI	Logic input	SPI serial data input
2	SDO	Logic output	SPI serial data output
19	$V_{CECLAMP}$	Analog input	V_{CE} active clamping protection
18	DESAT	Analog input	Desaturation protection
15	V_{REGISO}	Power supply	Internal regulator output pin for decoupling
17	V_H	Power supply	Positive voltage supply

Pin no.	Pin name	Type Function	Description
20	GON	Analog output	Gate source output
21	GOFF	Analog output	Gate sink output
22	CLAMP	Analog output	Miller clamp
14, 23	V _L	Power supply	Negative supply voltage or ground
13	GNDISO	Ground	High voltage section (isolated) ground
16	SENSE	Analog input	Sense input for overcurrent protection
24	ASC	Analog input	Asynchronous stop command

1.3.3.2.2 Bus voltage monitoring

A bus voltage monitoring is implemented in the input voltage range 50 ÷ 650 V.

The following table lists the measured input voltage values and the corresponding voltage level of the STM32 microcontroller unit ADC input signal.

Table 2. Bus input voltage vs. STM32 ADC channel input signal

Input voltage	ADC input
325 V	1.6 V
650 V (max. value)	3.2 V

1.3.3.2.3 Temperature monitor

The power module embeds an NTC which provides information about the temperature monitored by the microcontroller that manages any kind of overload/overtemperature via an external signal conditioning and an ADC conversion. To protect the hardware, in case of overtemperature, a safe threshold has to be set and used in the STM32 FOC SDK software library.

Table 3. NTC electrical characteristics

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
R25	Resistance	T = -40°C		105.7		kΩ
R25	Resistance	T = 25°C		4.7		kΩ
R125	Resistance	T = 100°C		0.426		kΩ
B	B-constant	T = 25°C to 50°C		3500		
T	Operating temp range		-40		125	°C

1.3.3.2.4 Dissipative braking

If the motor spins faster than the target speed, it enters the “generation” phase where a certain quantity of energy flows from the motor to the inverter.

This energy has to be dissipated to avoid any hardware failure, due to an overvoltage on the DC bus.

Thanks to the seventh IGBT (embedded in the ACEPACK™ module) and its dedicated freewheeling diode, it is possible to dissipate the energy via an external power resistor.

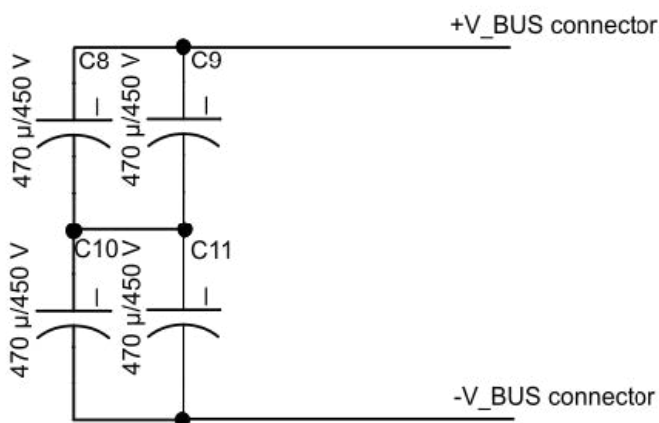
1.3.4 Hardware settings

Follow the steps below to set properly the industrial evaluation system.

- Step 1.** Connect the STEVAL-CTM001V1 evaluation board to the STEVAL-CTM002V1 evaluation board by using the STEVAL-CTM001V1 connectors (from JP2 to JP7) and the STEVAL-CTM002V1 connectors (from JP8 to JP13)
- Step 2.** On the STEVAL-CTM001V1:
 - a. Set switch SW1 to INT_SENSE position, the D23 LED turns on as soon as the board is switched on

- b. Close jumper S7
 - c. Close jumper SW5 in the default position (indicated near the switch)
 - d. Connect the ST-LINK to connector CON14
 - e. Connect the USB-to-serial converter to P2 connector by using the serial cable DB9 female to female
 - f. Connect the 12 V DC power supply to JP1 connector
 - g. Turn on the power supply
- Step 3.** Connect the flat cable between CON8 on the STEVAL-CTM001V1 and CON1 on the STEVAL-CTM002V1
- Step 4.** Connect the bulk capacitor bank, made by the series of two parallel capacitors (four capacitors), between the + and – of the V_BUS connections (on the STEVAL-CTM002V1) as shown below.

Figure 14. STEVAL-CTM002V1 bulk capacitor bank



- Step 5.** On the STEVAL-CTM002V1:
- a. Connect the three-phase AC power supply 400 V_{AC} to the J5 connector, including the earth cable
 - b. Turn the power supply on at 400 V_{AC} and limit the current to 10 Apk. The D4 LED turns on.

1.3.5 Motor control board connectors

Figure 15. STEVAL-CTM001V1: 34-pin motor control connector (CON3)



Table 4. Motor control connector pin-out

Pin number	Pin name/Function
1	FAULT
2	GND
3	PWM_U_H
4	GND

Pin number	Pin name/Function
5	PWM_U_L
6	GND
7	PWM_V_H
8	GND
9	PWM_V_L
10	GND
11	PWM_W_H
12	GND
13	PWM_W_L
14	Bus voltage monitoring
15	ADC_U
16	GND
17	ADC_V
18	GND
19	ADC_W
20	GND
21	Not connected
22	GND
23	Dissipative brake
24	GND
25	5VC
26	Heatsink temperature signal
27	Not connected
28	3.3VC
29	Not connected
30	GND
31	Enc A/H1
32	GND
33	Enc B/H2
34	Enc Z/H3

Figure 16. RS232 DB9 female connector

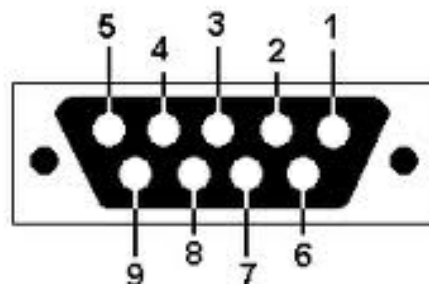
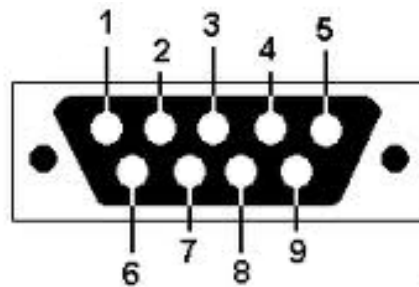
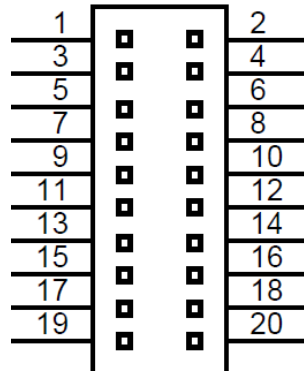


Table 5. RS232 connector pin-out

Pin number	Pin name/Function
1	Not connected
2	RD – Received data
3	TD – Transmitted data
4	Not connected
5	SG – Signal ground
6	Not connected
7	Not connected
8	Not connected
9	Not connected

Figure 17. CAN DB9 male connector

Table 6. CAN connector pin-out

Pin number	Pin name/Function
1	Not connected
2	CAN L
3	Ground
4	Not connected
5	Ground
6	Ground
7	CAN H
8	Not connected
9	Not connected

Figure 18. STEVAL-CTM001V1: JTAG connector (CON14)

Table 7. JTAG connector pin-out

Pin number	Pin name/Function
1	3.3 V
2	3.3 V
3	JTRST
4	Ground
5	JTDI
6	Ground
7	JTMS/SWDIO
8	Ground
9	JTCK/SWCLK
10	Ground
11	Not connected
12	Ground
13	JTDO
14	Ground
15	JTRST
16	Ground
17	Not connected
18	Ground
19	Not connected
20	Ground

1.3.6 Signal LEDs and push buttons

Table 8. LED description

Name	Color	Description	Location
D2	RED	12 V	STEVAL-CTM002V1
D3	RED	3V3	STEVAL-CTM002V1

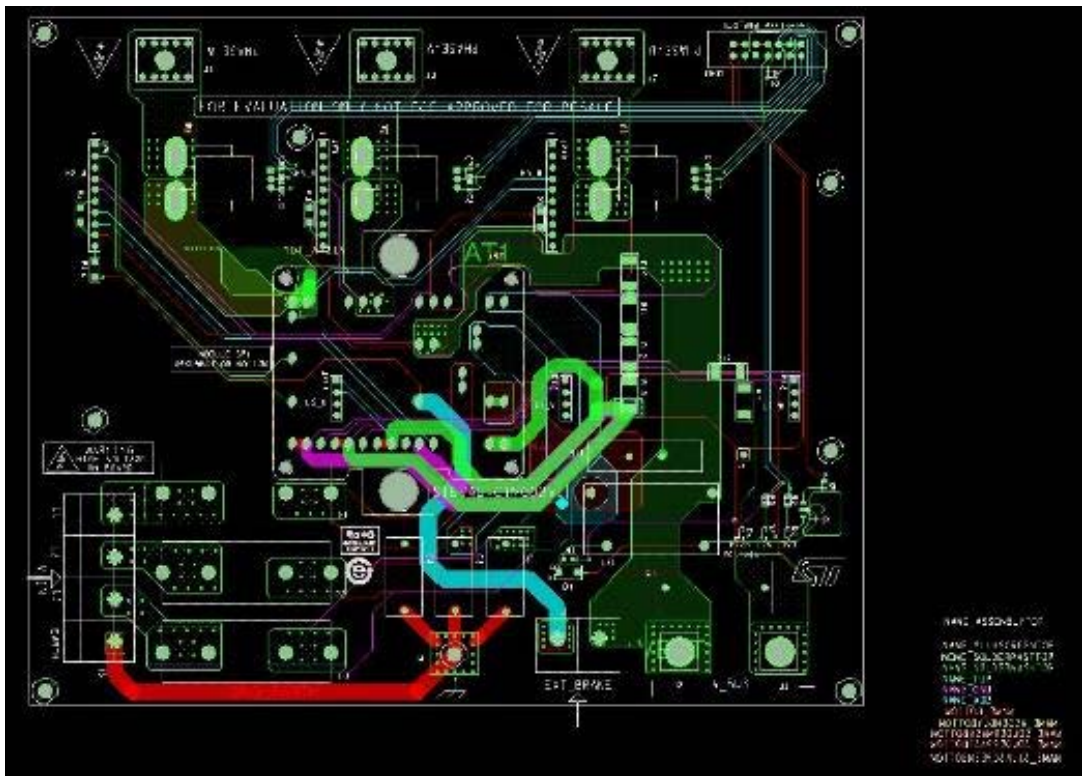
Name	Color	Description	Location
D4	RED	DC BUS VOLTAGE	STEVAL-CTM002V1
D5	RED	DC BUS VOLTAGE	STEVAL-CTM002V1
D14	GREEN	3V3_Microcontroller	STEVAL-CTM001V1C
D15	GREEN	3V3	STEVAL-CTM001V1C
D18	RED	12 V	STEVAL-CTM001V1
D19	RED	3V3	STEVAL-CTM001V1
D20	RED	5 V	STEVAL-CTM001V1
D23	GREEN	INT_SENSE	STEVAL-CTM001V1
D24	GREEN	EXT_SENSE	STEVAL-CTM001V1
D31-D42-D53-D64-D75-D86-D97	RED	IN_/DIAG	STEVAL-CTM001V1
D32-D43-D54-D65-D76-D87-D98	RED	DIAG	STEVAL-CTM001V1

Name	Description	Location
SW6	STM32 microcontroller reset	STEVAL-CTM001V1C
SW7	User push-button	STEVAL-CTM001V1C

2 PCB layout

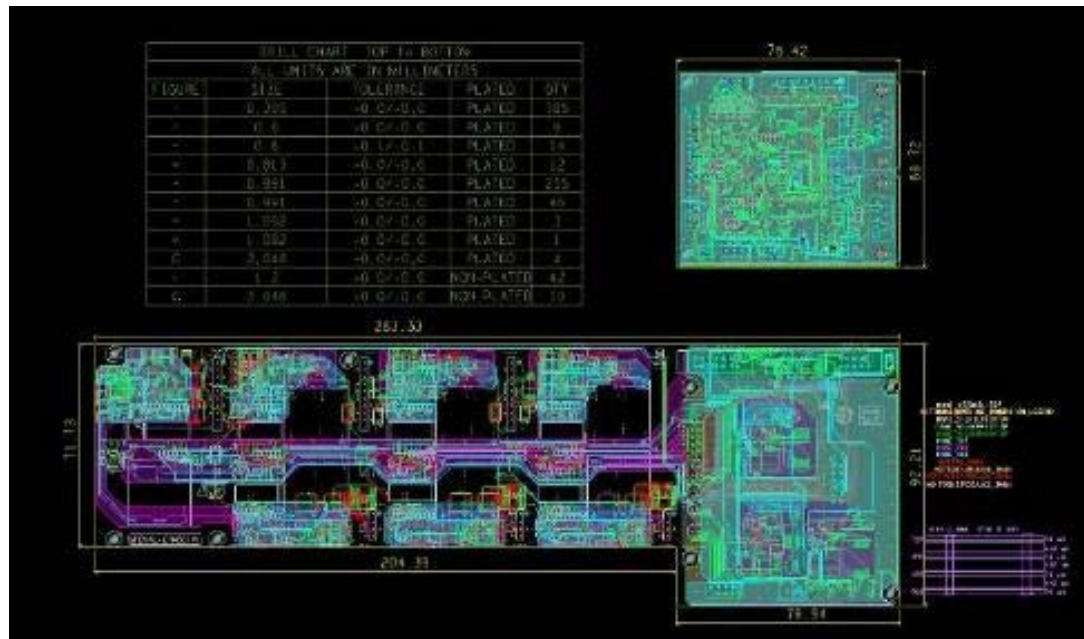
The STEVAL-CTM001V1 and STEVAL-CTM002V1 evaluation boards have different technical characteristics. The STEVAL-CTM002V1 evaluation board is the power section composed by 2 layers with a PCB thickness of 1.6 mm and a copper thickness of 100 μm . This composition allows a better management of the power module high current capability and thermal behavior.

Figure 19. STEVAL-CTM002V1 layout



The STEVAL-CTM001V1C and STEVAL-CTM001V1D have common characteristics: 4 layers with PCB thickness of 1.6 mm and copper thickness of 35 μm .

Figure 20. STEVAL-CTM001V1 layout



3 Schematic diagrams

Figure 21. STEVAL-CTM002V1 circuit schematic (1 of 2)

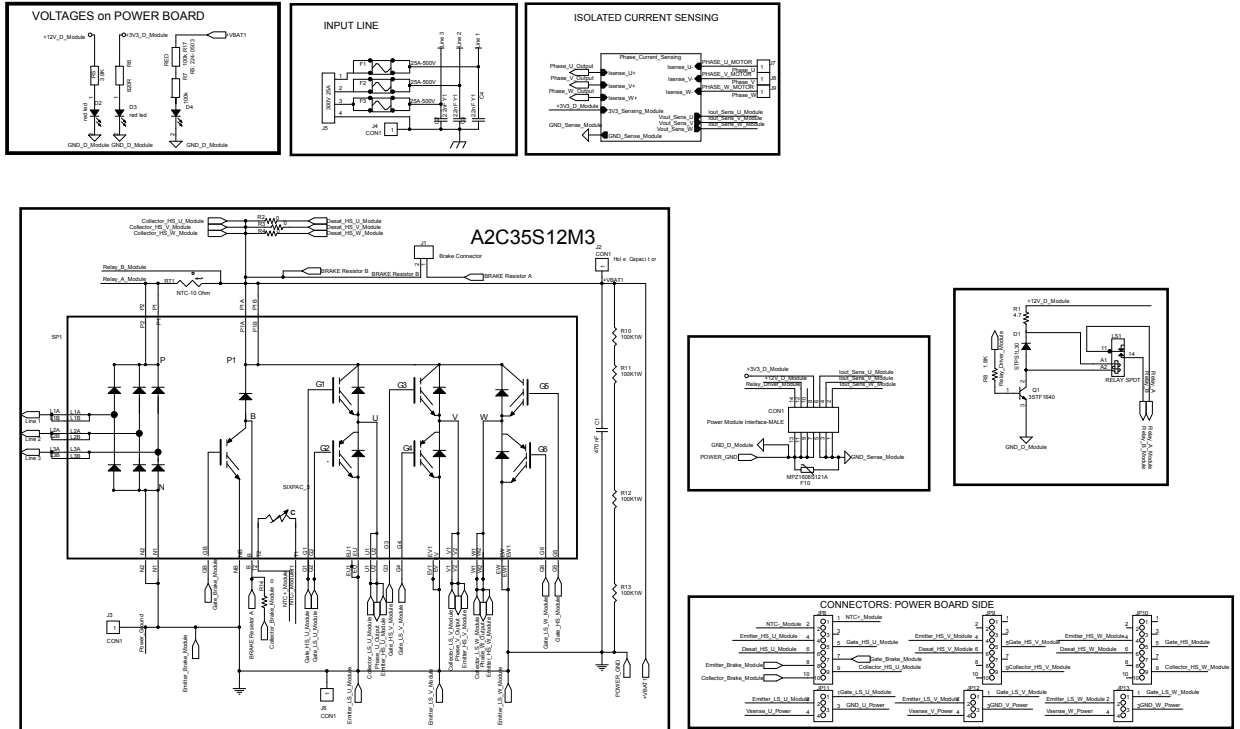


Figure 22. STEVAL-CTM002V1 circuit schematic (2 of 2)

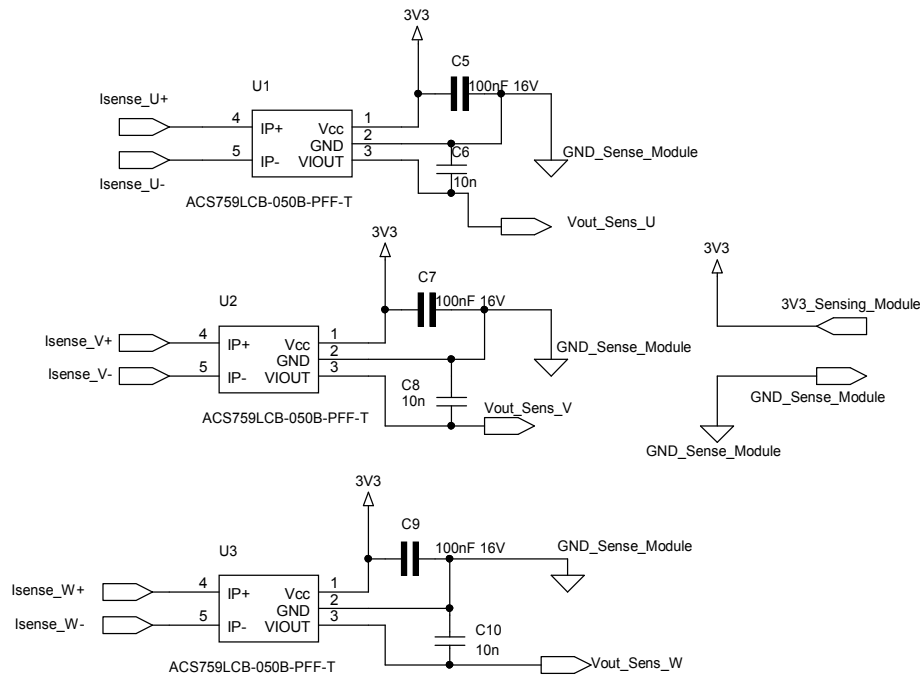


Figure 23. STEVAL-CTM001V1D circuit schematic (1 of 6)

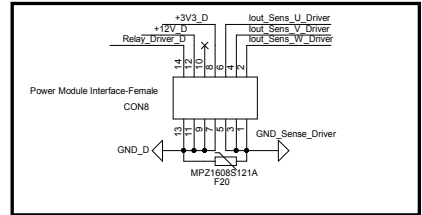
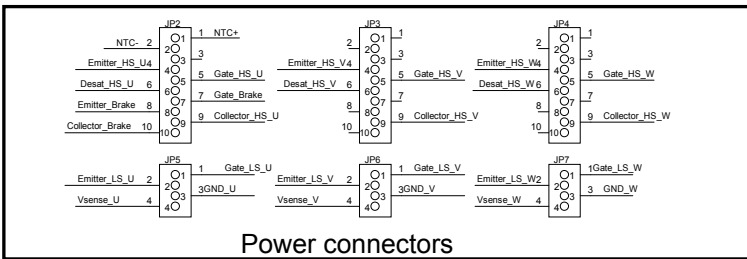
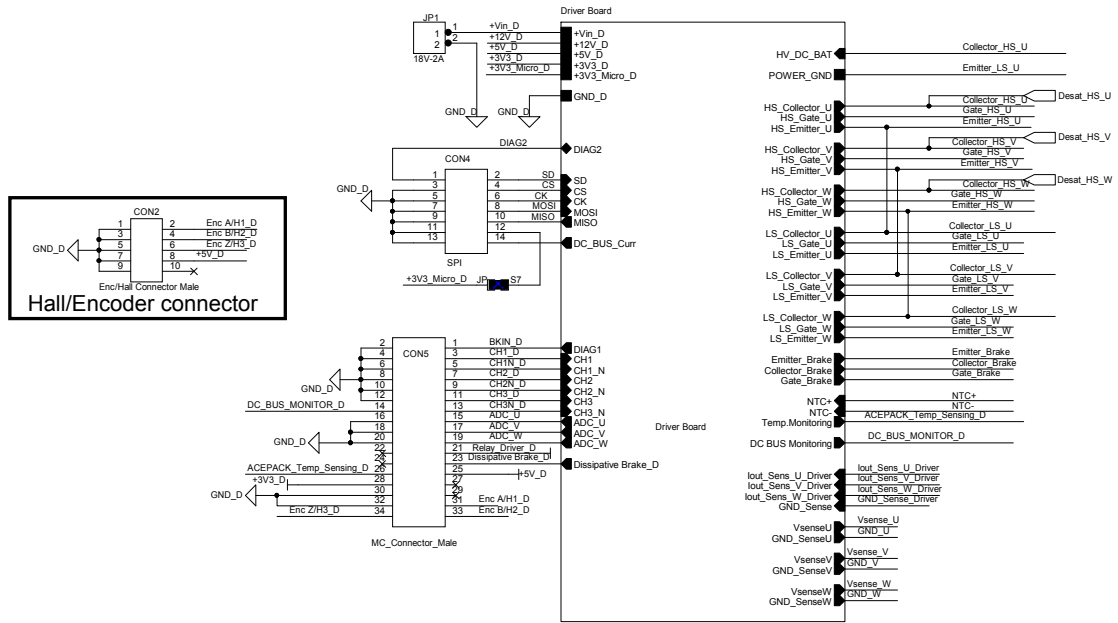


Figure 24. STEVAL-CTM001V1D circuit schematic (2 of 7)

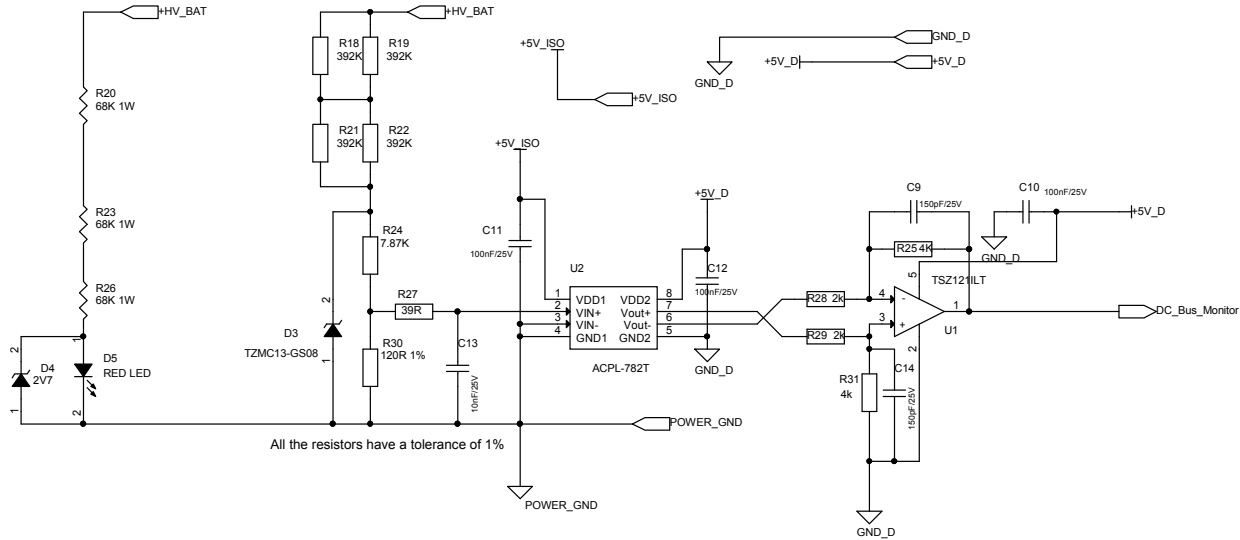


Figure 25. STEVAL-CTM001V1D circuit schematic (3 of 6)

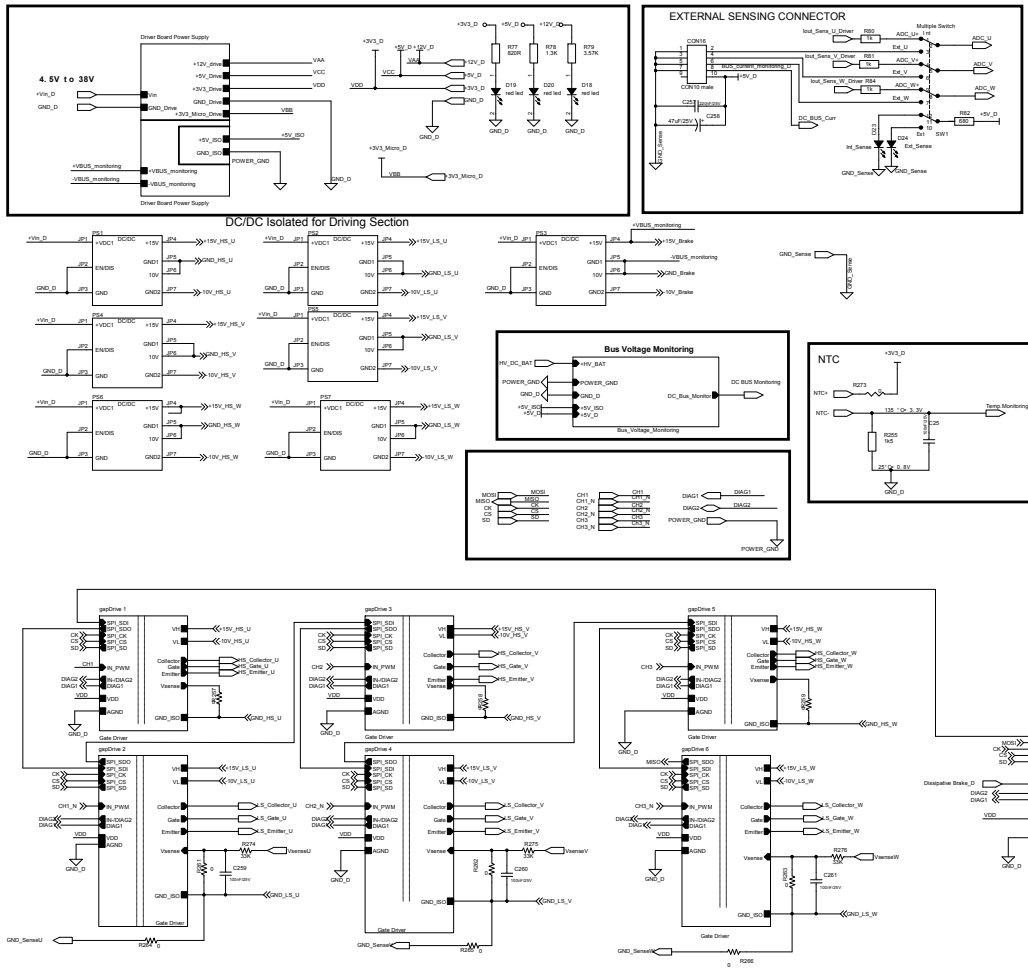


Figure 26. STEVAL-CTM001V1D circuit schematic (4 of 6)

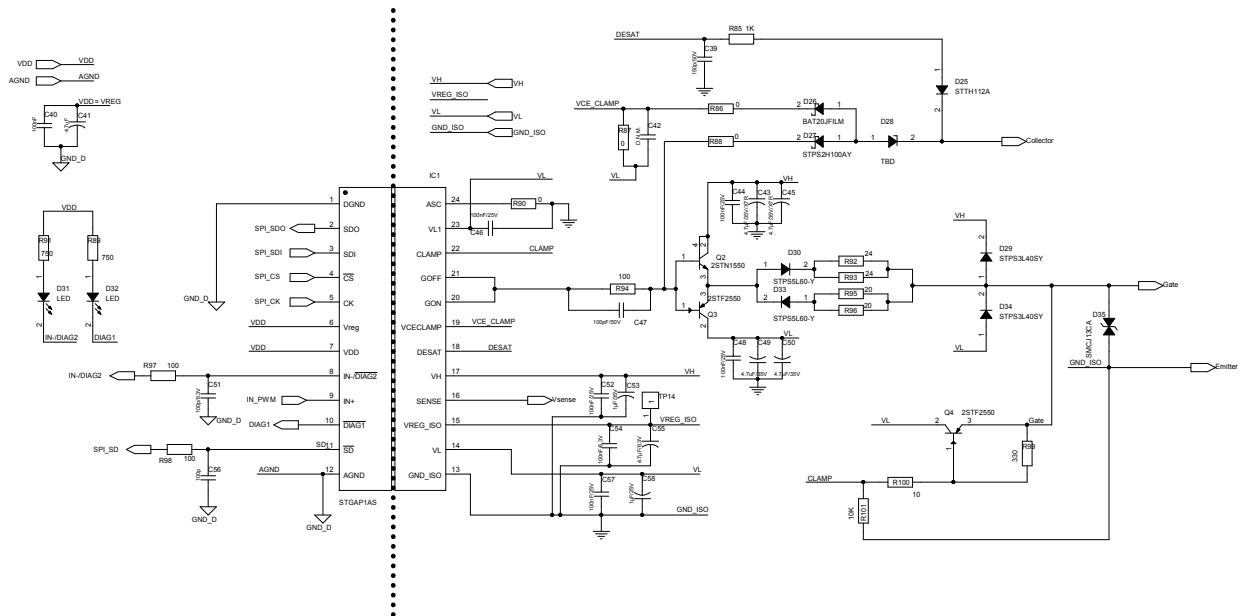


Figure 27. STEVAL-CTM001V1D circuit schematic (5 of 6)

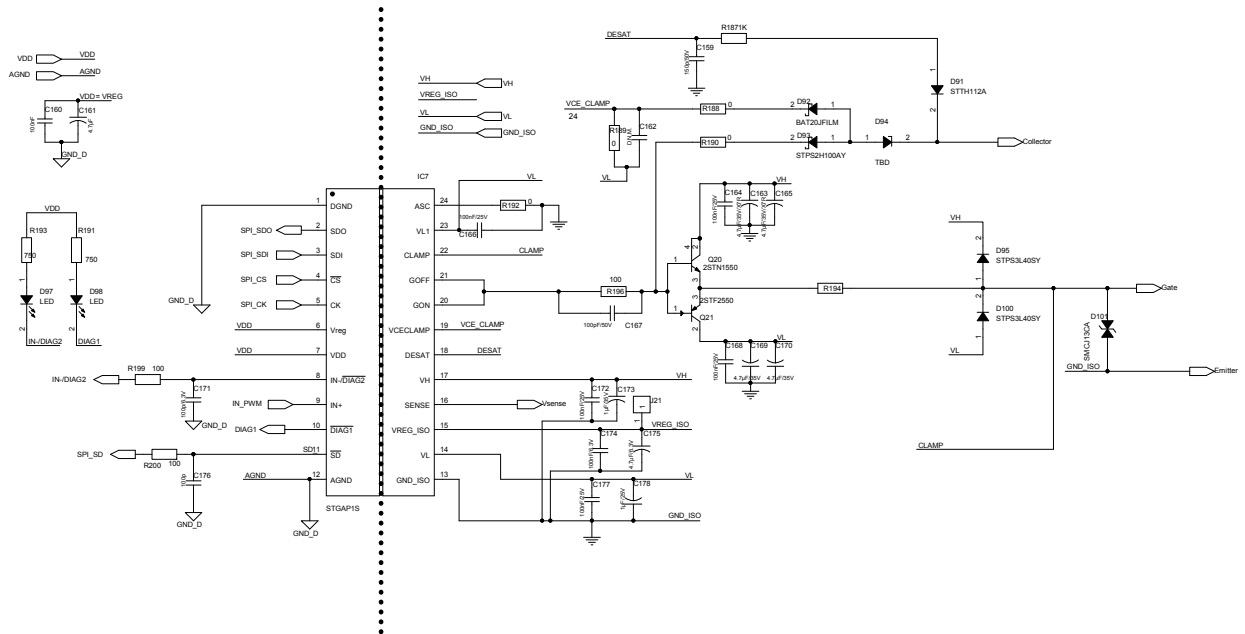


Figure 28. STEVAL-CTM001V1D circuit schematic (6 of 6)

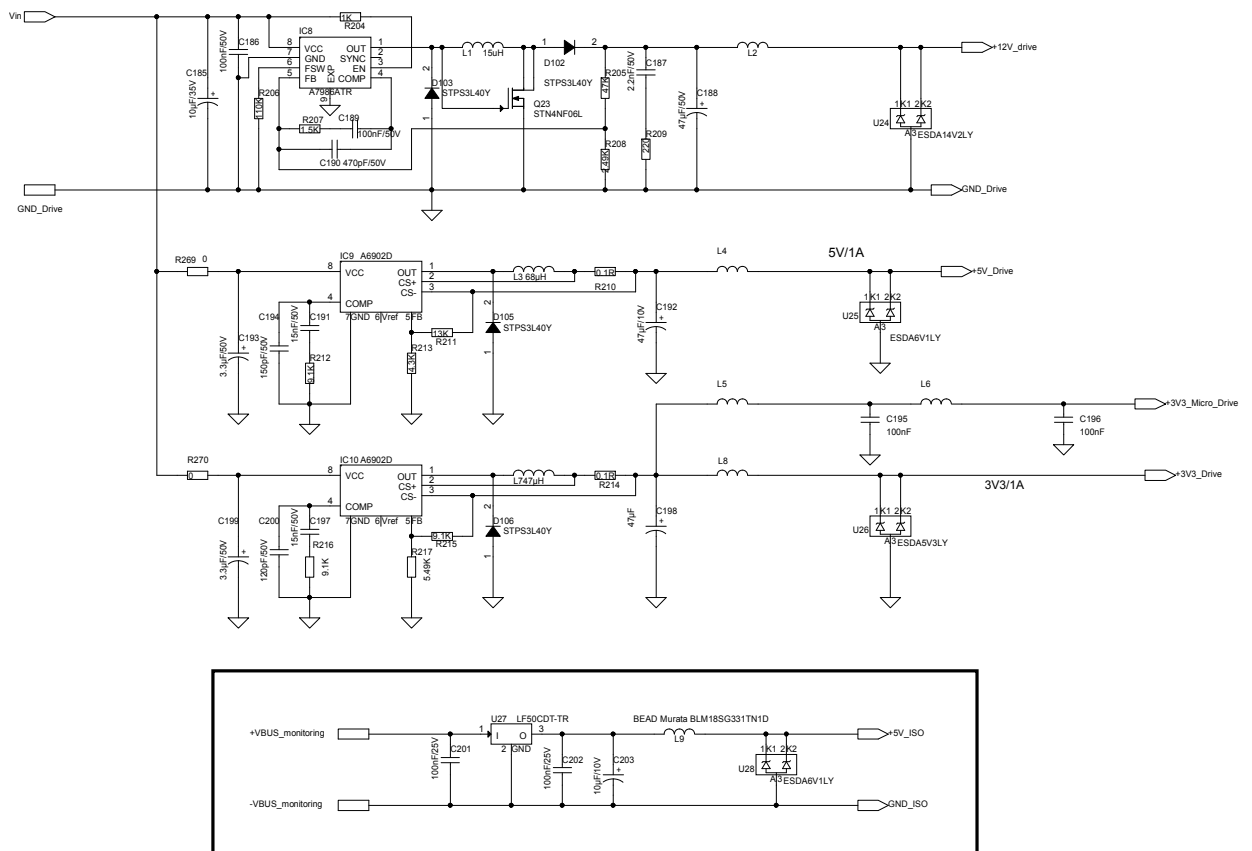


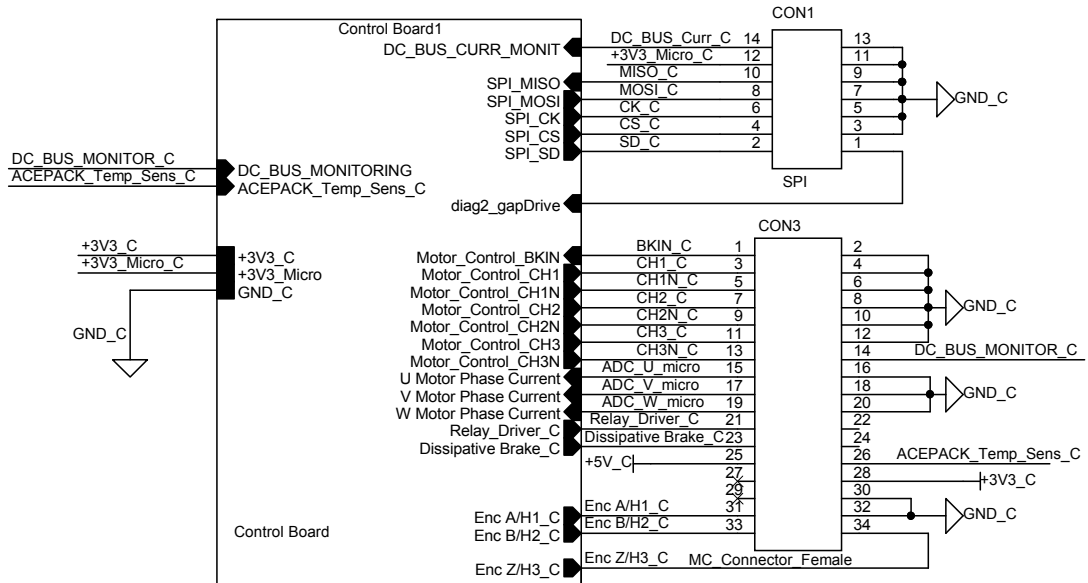
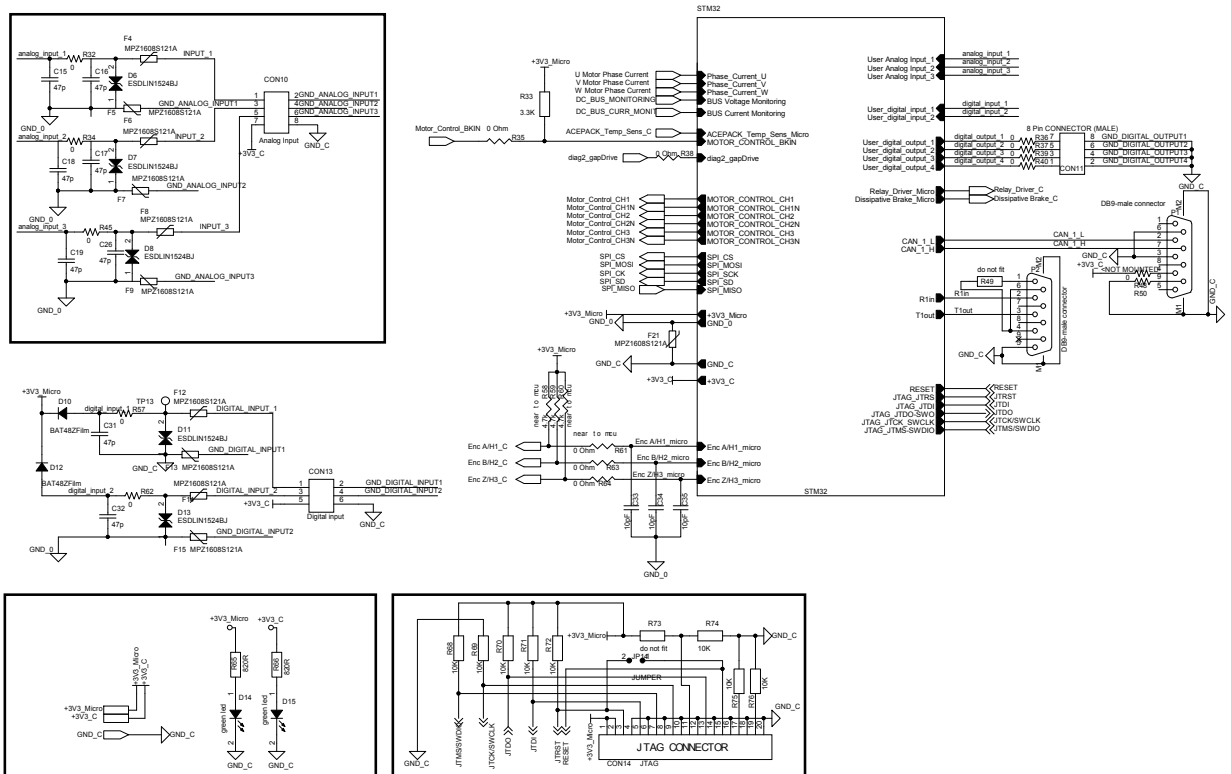
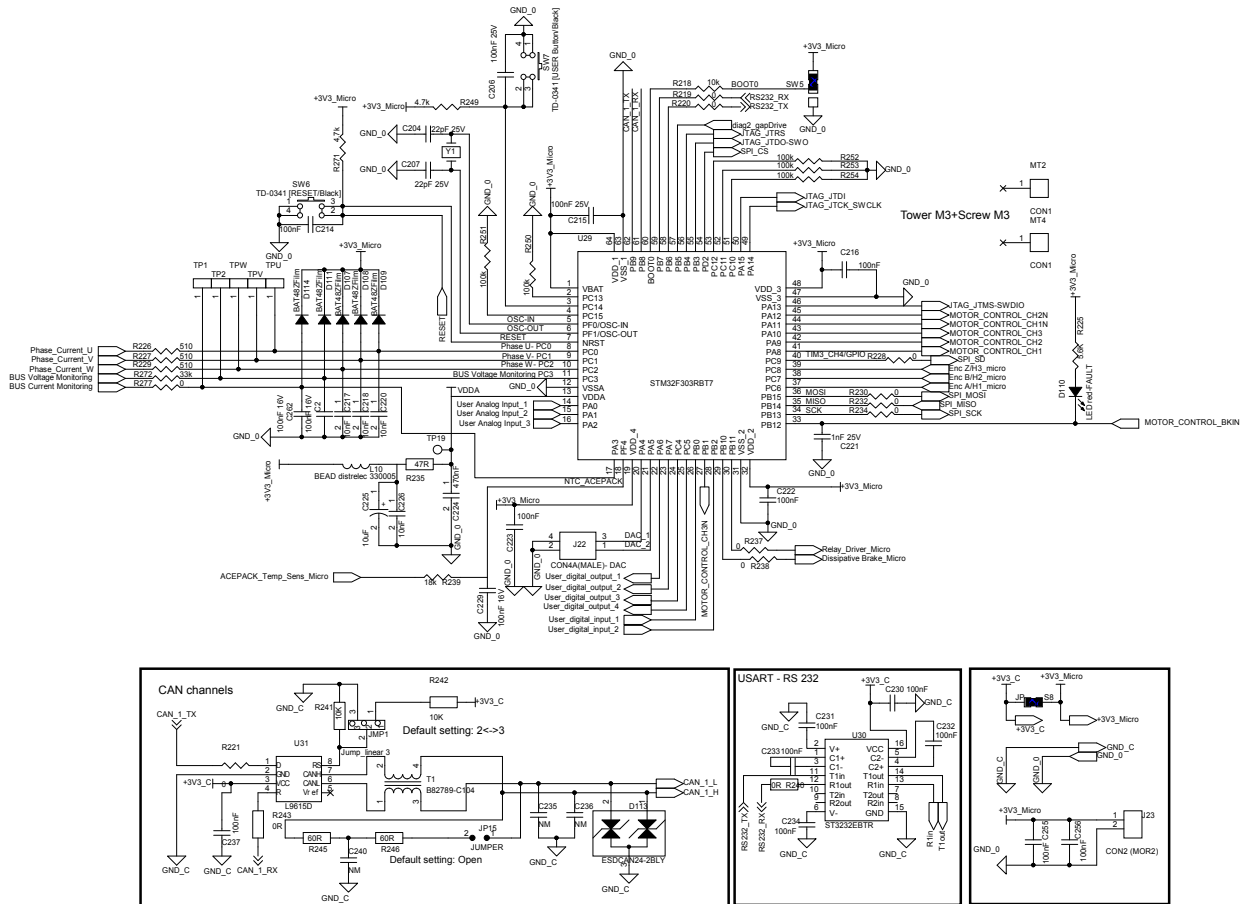
Figure 29. STEVAL-CTM001V1C circuit schematic (1 of 3)

Figure 30. STEVAL-CTM001V1C circuit schematic (2 of 3)


Figure 31. STEVAL-CTM001V1C circuit schematic (3 of 3)



4 Bill of materials

Table 9. STEVAL-CTM001V1 bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	CON1	SPI_Connector_Female blkcon100vhtm2oew 20014	Connector	Sullins Connector Solution	SFH11-PBPC-D07-ST-BK
2	1	CON2	Enc/Hall Connector Male blkcon100vhtm2oew 20010	Double Strip Line male 2X5 pitch 2.54mm	Any	Any
3	1	CON3	MC_Connector_Female-SPI blkcon100vhtm2oew 20034	Connector	Sullins Connector Solution	SFH11-PBPC-D17-ST-BK
4	1	CON5	MC_Connector_Male walcon100vhtm2oew 32534	Connector	Sullins Connector Solution	SBH11-PBPC-D17-ST-BK
5	2	CON4, CON8	SPI-Power module interface (Male) walcon100vhtm2oew 32514	Connector	Sullins Connector Solution	SBH11-PBPC-D07-ST-BK
6	2	CON10,CON11	Analog Input-Digital Output-Ext encoder blkcon100vhtm2oew 2008	Double Strip Line male 2X4 pitch 2.54mm	Any	Any
7	1	CON13	Digital Input blkcon100vhtm2oew 2006	Double Strip Line male 2X3 pitch 2.54mm	Any	Any
8	1	CON14	JTAG walcon100vhtm2oew 32520	Connector	Sullins Connector Solution	SBH11-PBPC-D10-ST-BK
9	1	CON16	CON10 male	Connector	Sullins Connector Solution	SBH11-PBPC-D05-ST-BK

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
10	79	C2, C10, C11, C12, C25, C40, C44, C46, C48, C52, C54, C57, C60, C64, C66, C68, C72, C74, C77, C80, C84, C86, C88, C92, C94, C97, C100, C104, C106, C108, C112, C114, C117, C120, C124, C126, C128, C132, C134, C137, C140, C144, C146, C148, C152, C154, C157, C160, C164, C166, C168, C172, C174, C177, C186, C195, C196, C201, C202, C206, C214, C215, C216, C222, C223, C229, C230, C231, C232, C233, C234, C237, C255, C256, C259, C260, C261, C262	100 nF 50 V ±10% smc0603	Capacitors	Any	Any
11	10	C9, C14, C39, C59, C79, C99, C119, C139, C159, C194	150 pF 50 V ±10% smc0603	Capacitors	Any	Any
12	2	C13, C226	10 nF 50 V ±10% smc0603	Capacitors	Any	Any
13	8	C15, C16, C17, C18, C19, C26, C31, C32	47 pF 50 V ±10% smc0603	Capacitors	Any	Any
14	3	C33, C34, C35	10 pF 50 V ±10% smc0603	Capacitors	Any	Any
15	14	C41, C55, C61, C75, C81, C95, C101, C115, C121, C135, C141, C155, C161, C175	4.7 μF 25 V ±10% smc0603	Capacitors	Samsung Electro	CL10A475KA8NQNC

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
16	13	C42, C62, C82, C102, C217, C218, C220, C122, C235, C236, C240, C142, C162	NOT ASSEMBLY ±10% smc0603	Capacitors		
17	28	C43, C45, C49, C50, C63, C65, C69, C70, C83, C85, C89, C90, C103, C105, C109, C110, C123, C125, C129, C130, C143, C145, C149, C150, C163, C165, C169, C170	4.7 µF 35 V ±10% smc0805	Capacitors	TDK	CGA4J3X5R1H475K125AB
18	21	C47, C51, C56, C67, C71, C76, C87, C91, C96, C107, C111, C116, C127, C131, C136, C147, C151, C156, C167, C171, C176	100 pF 50 V ±10% smc0603	Capacitors	Any	Any
19	14	C53, C58, C73, C78, C93, C98, C113, C118, C133, C138, C153, C158, C173, C178	1 µF 50 V ±10% smc0603	Capacitors	Any	Any
20	1	C185	10 µF 35 V ±10% tantalioc	Capacitor	Kemet	T491C106K035AT
21	1	C187	2.2 nF 50 V ±10% smc0603	Capacitor	Any	Any
22	2	C188, C258	47 µF 25 V ±10% tantaliode	Capacitors	Kemet	T491D476K025AT
23	1	C190	470 pF 50 V ±10% smc0603	Capacitor	Any	Any
24	2	C191, C197	15 nF 50 V ±10% smc0603	Capacitors	Any	Any
25	2	C192, C198	47 µF 16 V ±10% tantalioc	Capacitors	AVX	TPSC476K016R0110
26	2	C193, C199	3.3 µF 50 V ±10% tantalioc	Capacitors	AVX	TAJC335K050R
27	1	C200	120 pF 50 V ±5% SMC0603	Capacitor	Any	Any
28	2	C203, C225	10 µF 10 V ±10% tantaliob	Capacitors	AVX	TAJB106K010RNJ

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
29	2	C204, C207	22 pF 50 V ±5% SMC0603	Capacitors	Any	Any
30	1	C221	1 nF 50 V ±10% smc0603	Capacitor	Any	Any
31	1	C224	470 nF 50 V ±10% smc0603	Capacitor	Any	Any
32	1	C257	220 nF 25 V ±10% smc0603	Capacitor	Any	
33	18	D5, D18, D19, D20, D31, D32, D42, D43, D53, D54, D64, D65, D75, D76, D86, D87, D97, D98, 110	SMD SMR0603	Red LEDs	Osram Opto	LR Q396
34	1	D3	TZMC13-GS08 13 V/0.5 W ±5% smdo213ac21	Zener diode	Vishay	TZMC13-GS08
35	1	D4	TZMB2V7-GS08 2.7 V/0.5 W ±2% smdo213ac21	Zener diode	Vishay	TZMB2V7-GS08
36	5	D6, D7, D8, D11, D13	ESDLIN1524BJ sod323f	Transil™, transient voltage surge suppressor diode for ESD protection	ST	ESDLIN1524BJ
37	7	D10, D12, D107, D108, D109, D111, D114	BAT48ZFilm SOD123	Small signal Schottky diodes	ST	BAT48ZFILM
38	2	D14, D15	SMD smd0603	Green LEDs	Osram Opto	LT Q39G-Q1S2-25-1
39	7	D25, D36, D47, D58, D69, D80, D91	STTH112A SMA	High voltage ultrafast rectifier diode	ST	STTH112A
40	7	D26, D37, D48, D59, D70, D81, D92	BAT20JFILM SOD323f	High efficiency switching and ultra low leakage current Schottky diode	ST	BAT20JFILM
41	7	D27, D38, D49, D60, D71, D82, D93	STPS2H100AY 100V/2A SMA	Automotive high voltage power Schottky rectifier	ST	STPS2H100AY
42	7	D28, D39, D50, D61, D72, D83, D94	TBD smb	Diode	ST	
43	18	D29, D34, D40, D45, D51, D56, D62, D67, D73, D78, D84, D89, D95, D100, D102, D103, D105, D106	STPS3L40SY 40V/3A SMC	Automotive power Schottky rectifier	ST	STPS3L40SY

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
44	12	D30, D33, D41, D44, D52, D55, D63, D66, D74, D77, D85, D88	STPS5L60SY 60V/5A SMC	Automotive power Schottky rectifier	ST	STPS5L60SY
45	7	D35, D46, D57, D68, D79, D90, D101	SMCJ13CA SMDO214AB21	1500 W TVS	ST	SMCJ13CA
46	1	D113	ESDCAN24-2BLY smsot23123	Automotive dual- line Transil, transient voltage suppressor (TVS) for CAN bus	ST	ESDCAN24-2BLY
47	12	F4,F5,F6,F7,F 8,F9,F12,F13, F14,F15,F20,F 21	MPZ1608S121A sml0603	Filter	Würth (or TDK)	742 792 625 (or MPZ1608S121A)
48	7	IC1,IC2,IC3,IC 4,IC5,IC6,IC7	STGAP1AS sog05024wg425I650	Automotive galvanically isolated single gate driver	ST	STGAP1AS
49	1	IC8	A7986ATR sog0508wg244I200e xposure	3 A step-down switching regulator for automotive applications	ST	A7986ATR
50	2	IC9,IC10	A6902D sog0508wg244I200	Up to 1 A switch step down regulator with adjustable current limit for automotive applications	ST	A6902D
51	1	JMP1	Jumper siptm3003	Strip line male 1X3 pitch 2.54mm	Any	Any
52	1	JP1	Vin Low Voltage 36V-2A mor2X3812204822		Phoenix Contact	1803426
53	3	JP2, JP3, JP4	61301015721 WURTH ELEKTRONIK- FEMALE conwurth613020157 21		Würth	61301015721
54	3	JP5, JP6, JP7	61300415721 WURTH ELEKTRONIK- FEMALE conwurth613004157 21		Würth	61300415721
55	2	JP14, JP15	Jumper siptm2002	Strip line male 1X2 pitch 2.54mm	Any	Any
56	1	J22	DAC blkcon100vhtm2oew 2004	Double strip line male 2X2 pitch 2.54mm	Any	Any

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
57	1	J23	Connector Vdc in mor2X254	Supply Connector	Phoenix Contact	1725656
58	1	L1	15uH indnrs5040t150m	Inductor	Würth Elektronik	74404054150
59	1	L3	68uH INDLMAXSJM680FT AS	Inductor	Würth Elektronik	744771168
60	6	L2, L4, L5, L6, L8, L9	BEAD Murata BLM18SG331TN1D sml0603	Filter	Murata	BLM18SG331TN1D
61	1	L7	47 µH indBOURNSSRR124 0470M		Würth Elektronik	7447715470
62	1	L10	BLM18SG700TN1D smr0603	Bead	Murata	BLM18SG700TN1D
63	2	MT2,MT4	Tower M3X10mm MTHOLE3	Tower	Any	Any
64	7	PS1, PS2, PS3, PS4, PS5, PS6, PS7	DC/DC 15 V/-10 V powersupplstm	Power supply 10-15 V	Any	Any
65	2	P1, P2	DB9-male connector dsubrp318tm9mcon	Connectors	Amphenol	L717TSEH09POL2R M5
66	7	Q2, Q5, Q8, Q11, Q14, Q17, Q20	2STN1550 sot223	Low voltage high performance NPN power transistors	ST	2STN1550
67	13	Q3, Q4, Q6, Q7, Q9, Q10, Q12, Q13, Q15, Q16, Q18, Q19, Q21	2STF2550 smsot89	Low voltage high performance NPN power transistors	ST	2STF2550
68	1	Q23	STN4NF06L sot223	Automotive-grade N-channel 60 V, 0.07 Ohm typ., 4 A STripFET II Power MOSFET in SOT-223 package	ST	STN4NF06L

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
69	71	R32, R34, R35, R36, R37, R38, R39, R40, R45, R50, R57, R61, R62, R63, R64, R86, R87, R88, R90, R103, R104, R105, R107, R120, R121, R122, R124, R137, R138, R139, R141, R154, R155, R156, R158, R171, R172, R173, R175, R188, R189, R190, R192, R219, R220, R221, R226, R227, R228, R229, R230, R232, R234, R237, R238, R240, R243, R257, R258, R259, R260, R261, R262, R263, R264, R265, R266, R269, R270, R273, R277	0 1/16 W ±1% smr0603	Thick film resistors	Any	Any
70	17	R68, R69, R70, R71, R72, R74, R75, R76, R101, R118, R135, R152, R169, R186, R218, R241, R242	10 K 1/16 W ±1% smr0603	Thick film resistors	Any	Any
71	4	R10, R11, R12, R13	100 K 1 W ±5% smr2512	Thick film resistors	Any	Any
72	1	R79	3.57 K 1/16 W ±1% smr0603	Thick film resistors	Any	Any
73	3	R65, R66, R77	820 R 1/16 W ±1% smr0603	Thick film resistors	Any	Any
74	4	R18, R19, R21, R22	392 K 1/2 W ±5% smr1210	Thick film resistors	Vishay	CRCW1210392KFKE A
75	3	R20, R23, R26	68 K 1 W ±5% smr2512	Thick film resistors	TE Connector	352068KJT
76	1	R24	7.87K 1/4 W ±1% smr1206	Thick film resistors	Any	Any
77	2	R25,R31	4 k 1/16 W ±1% smr0603	Thick film resistors	Any	Any

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
78	1	R27	39 R 1/16 W ±1% smr0603	Thick film resistors	Any	Any
79	2	R28,R29	2 k 1/16 W ±1% smr0603	Thick film resistors	Any	Any
80	1	R30	120 1/16 W ±1% smr0603	Thick film resistors	Any	Any
81	1	R33	3.3 K 1/16 W ±1% smr0603	Thick film resistors	Any	Any
82	5	R35, R38, R61, R63, R64	0 Ohm 1/16 W ±1% smr0603	Thick film resistors	Any	Any
83	3	R48, R49, R73	NOT ASSEMBLY 1/16W ±1% smr0603	Thick film resistors	Any	Any
84	5	R58, R59, R60, R249, R271	4.7 k 1/16 W ±1% smr0603	Thick film resistors	Any	Any
85	3	R65, R66, R77	820 1/16 W ±1% smr0603	Thick film resistors	Any	Any
86	1	R78	1,3K 1/16 W ±1% smr0603	Thick film resistors	Any	Any
87		R79	3.57 K 1/16 W ±1% smr0603	Thick film resistors	Any	Any
88	11	R80, R81, R84, R85, R102, R119, R136, R153, R170, R187, R204	1 K 1/16 W ±1% smr0603	Thick film resistors	Any	Any
89	1	R82	680 1/16 W ±1% smr0603	Thick film resistors	Any	Any
90	14	R89, R91, R106, R108, R123, R125, R140, R142, R157, R159, R174, R176, R191, R193	750 1/16 W ±1% smr0603	Thick film resistors	Any	Any
91	13	R92, R93, R109, R110, R126, R127, R143, R144, R160, R161, R177, R178, R194	24 1 W ±5% SMR2512	Thick film resistors	Any	Any
92	21	R94, R97, R98, R111, R114, R115, R128, R131, R132, R145, R148, R149, R162, R165, R166, R179, R182, R183, R196, R199, R200	100 1/16 W ±1% smr0603	Thick film resistors	Any	Any

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
93	12	R95, R96, R112, R113, R129, R130, R146, R147, R163, R164, R180, R181	20 1 W $\pm 1\%$ smr2512	Thick film resistors	Any	Any
94	6	R99, R116, R133, R150, R167, R184	330 1/16 W $\pm 1\%$ smr0603	Thick film resistors	Any	Any
95	6	R100, R117, R134, R151, R168, R185	10 1/16 W $\pm 1\%$ SMR0603	Thick film resistors	Any	Any
96	1	R205	47 K 1/16 W $\pm 1\%$ sMr0603	Thick film resistors	Any	Any
97	1	R206	110 K 1/16 W $\pm 1\%$ sMr0603	Thick film resistors	Any	Any
98	1	R207	1.5 K 1/16 W $\pm 1\%$ sMr0603	Thick film resistors	Any	Any
99	1	R208	2.49 K 1/16 W $\pm 1\%$ sMr0603	Thick film resistors	Any	Any
100	1	R209	220 1/16 W $\pm 1\%$ sMr0603	Thick film resistors	Any	Any
101	2	R210, R214	0.1 R 1/16 W $\pm 1\%$ smr0603	Thick film resistors	Any	Any
102	1	R211	13 K 1/16 W $\pm 1\%$ SMR0603	Thick film resistors	Any	Any
103	3	R212, R215, R216	9.1 K 1/16 W $\pm 1\%$ smr0603	Thick film resistors	Any	Any
104	1	R213	4.3 K 1/16 W $\pm 1\%$ sMr0603	Thick film resistors	Any	Any
105	1	R217	5.49 K 1/16 W $\pm 1\%$ sMr0603	Thick film resistors	Any	Any
106	1	R225	5.6 K 1/16 W $\pm 1\%$ smR0603	Thick film resistors	Any	Any
107	1	R235	47 R 1/16 W $\pm 1\%$ smr0603	Thick film resistors	Any	Any
108	1	R239	18 K 1/16 W $\pm 1\%$ smr0603	Thick film resistors	Any	Any
109	2	R245, R246	60 R 1/16 W $\pm 1\%$ smr0603	Thick film resistors	Any	Any
110	5	R250, R251, R252, R253, R254	100 K 1/16 W $\pm 1\%$ sMr0603	Thick film resistors	Any	Any
111	1	R255	1 K5 1/16 W $\pm 1\%$ SMR0603	Thick film resistors	Any	Any
112	4	R274, R275, R276, R272	33 K 1/16 W $\pm 1\%$ SMR0603	Thick film resistors	Any	Any
113	1	SW1	SWITCHMULT	Multiple switch	TE Connectivity Alcoswitch Switchs	1-1825010-4
114	1	SW5	1X3 pitch 2.54 mm Jumper siptm3003	Strip line male	Any	Any

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
115	2	SW6, SW7	0.05 A-12 V SMDPULSE4	Push button	APEM	DTSMW69RW
116	2	S7, S8	JP siptm2002		Any	Any
117	1	T1	B82789-C104 indB82789C104		EPCOS	B82789-C104
118	1	U1	TSZ121ILT SOT23L5	Very high accuracy (5 μ V) zero drift 5 V CMOS Op-Amp, single, GBP = 400 kHz	ST	TSZ121ILT
119	1	U2	ACPL-782T SWG1008WG387L4 30	Opto-isolator	Avago	ACPL-782T-500E
120	1	U24	ESDA14V2LY smsot23123		ST	ESDA14V2LY
121	2	U25, U28	ESDA6V1LY smsot23123	Automotive dual Transil™ array for ESD protection	ST	ESDA6V1LY
122	1	U26	ESDA5V3LY smsot23123	Automotive dual Transil™ array for ESD protection	ST	ESDA5V3LY
123	1	U27	LF50CDT-TR	Very low drop voltage regulator with inhibit	ST	LF50CDT-TR
124	1	U29	STM32F303RBT7 quad50m64wg1200	Mainstream mixed signals MCUs ARM Cortex-M4 core with DSP and FPU	ST	STM32F303RBT7
125	1	U30	ST3232EBTR sog065m16wg820I63 5	15 KV ESD proected, 3 to 5.5 V low power up to 250 KBPS	ST	ST3232EBTR
126	1	U31	L9615D sog0508wg244I200	High speed Can bus transceiver	ST	L9615D
127	1	Y1	SMD	Quartz	FOX	SDLF/080-20

Table 10. STEVAL-CTM002V1 bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	CON1	walcon100vhtm2oew32514	Power module Interface	Sullins Connector Solution	SBH11-PBPC-D07-ST-BK
2	3	J7, J8, J9	Out connector 40 A PowerTerm40A	Connectors	ERNI	214786
3	3	C5, C7, C9	100 nF 25 V \pm 20% smc0603	Capacitors	Any	Any
4	1	C1	470 nF 630 V DC \pm 5% rad1000x425ls750H39	Polyfilm capacitor	EPCOS	B32653A6474J000
5	3	C2, C3, C4	STPS1L30A 30V/1A SMA	Capacitors	EPCOS	B81123C1222M000
6	3	C6, C8, C10	10 nF 25 V \pm 20% smc0603	Capacitors	Any	

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
7	1	D1	STPS1L30A 30 V/1 A SMA	Low drop power Schottky rectifier	ST	STPS1L30A
8	3	D2, D3, D4	red led Led SMR0603	LED	Osram Opto	LR Q396
9	3	F1, F2, F3	20 A-500 V 500V/25A fuse10X38M + Clip Bussman	Clips+FUSE	SIBA + Bussmann	60-033-05 25A + 1A3400-09
10	1	F10	MPZ1608S121A sml0603	Filter	Würth (TDK)	742 792 625 (MPZ1608S121A)
11	3	JP8, JP9, JP10	1X10 pitch 2.54 mm High 13.5 mm blkcon100vhtm1sqw100X10	Strip line male	FCI	77311-462K10LF
12	3	JP11, JP12, JP13	1X4 pitch 2.54 mm High 13.5 mm siptm4004	Strip line male	FCI	77311-462K04LF
13	5	J4 and other 4	M3X10 mm MTHole3	Tower	RS Pro	606-686
14	1	J6		Testpoint	NOT ASSEMBLY	
15	2	J2, J3	VBUS mthole5	Screw M5 + Nut M5	RS Pro	482-8739+483-0546
16	1	J1	30 A/400 V mors2x9X52	Brake connector	Phonex contact	1714971
17	1	J5	300 V 25 A 25A/300V mors4x9X52	EXT_Brake	Phonex contact	1906129
18	1	LS1	SPST 12VDC SPST releTE112H2MG	Relay	TE CONNECTIVITY / OEG	PCFN-112H2MG,000
19	1	Q1	3STF1640 sot89	Low voltage high performance NPN power transistor	ST	3STF1640
20	1	RT1	NTC-10 Ohm NTC-10 rad26NTC		EPCOS	B57464S0100M00
21	4	R2, R3, R4, R14	0 ¼ W ±1% SMR1206	Thick film resistors	Any	Any
22	1	R1	4.7 1/8 W ±1% smr805	Thick film resistors	Any	Any
23	1	R8	1.8 K 1/16 W ±1% smr0603	Thick film resistors	Any	Any
24	6	R7, R10, R11, R12, R13, R17	100 K 1 W ±5% smr2512	Thick film resistors	Any	Any
25	1	R5	3.9 K 1/16 W ±1% smr0603	Thick film resistors	Any	Any
26	1	R6	820 R 1/16 W ±1% smr0603	Thick film resistors	Any	Any
27	1	SP!		ACEPACK 2 converter inverter brake	ST	A2C35S12M3-F
28	3	U1, U2, U3	SenseACS755XCB		Allegro	ACS759LCB-050B-PFF-T

Revision history

Table 11. Document revision history

Date	Version	Changes
12-Mar-2018	1	Initial release.
14-Jan-2019	2	Updated Section 3 Schematic diagrams and Section 4 Bill of materials .

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