5 kW low voltage high current inverter for automotive motor control applications

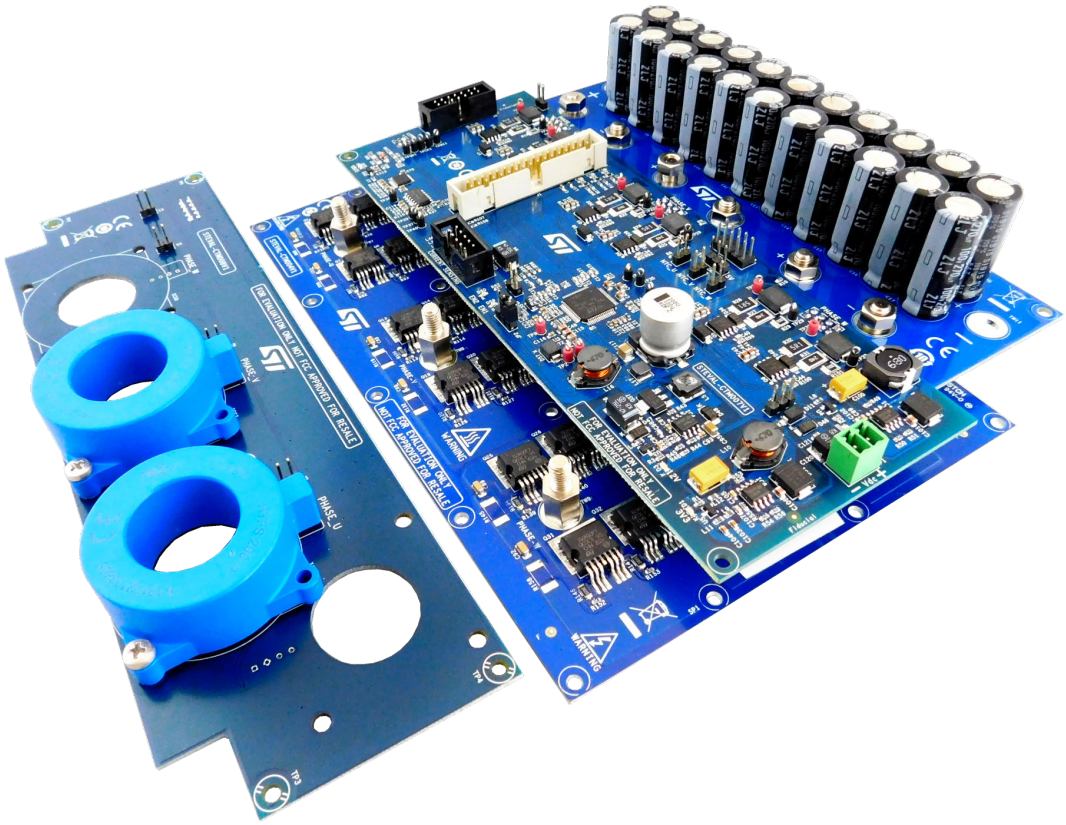
Introduction

The STEVAL-TTM001V1 evaluation kit is designed to demonstrate the highly efficient ST automotive-grade 100 V STripFET F7 series Power MOSFETs and BLDC motor driver IC operating in typical automotive low voltage (car battery up to 48 V), high current motor control applications.

The kit includes a board to sense and condition currents, and a driver board with a programmable L9907 FET driver with full diagnostics to manage all 36 STH315N10F7 Power MOSFETs on a power board also included in the kit.

The driver board also includes an ST motor control connector to interface with any compatible ST motor control board (not included in the kit), and various other connectors and jumpers for monitoring and protection, motor position feedback information, and auxiliary power.

Figure 1. STEVAL-TTM001V1 evaluation kit



1 Evaluation kit features

1.1 Electrical and functional characteristics

The kit features the following main characteristics:

- Power board with insulated metal substrate (IMS) hosting 36 STH315N10F7 power MOSFETS in the H²PAK-6 (6x switch) package for automotive applications.
- L9907 automotive gate drivers to drive the power MOSFETs providing full diagnostic and programmable parameters (cross conduction, dead time, gate current, etc.) via SPI.
- Maximum power 5 kW at 48 V.
- Isolated current sensing, bus voltage and temperature monitoring.

1.2 Target applications

The STEVAL-TTM001V1 kit is designed for applications involving motor drives for electric traction, such as:

- urban electric cars
- small city buses
- other 48V electric vehicles

2 Safety and operating instructions

2.1 General terms

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

2.2 Intended use of evaluation kit

This evaluation kit is designed for demonstration purposes 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.

2.3 Evaluation kit setup

- The evaluation kit must be set up in accordance with the specifications and the targeted application.
- The board contains electro-statically sensitive components that are prone to damage through improper use. Electrical components must not be mechanically damaged or destroyed.
- Avoid any contact with other electronic components.
- During the motor driving, converters must be protected against excessive strain. Do not bend or alter the isolating distances any components during transportation or handling.

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 board 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).

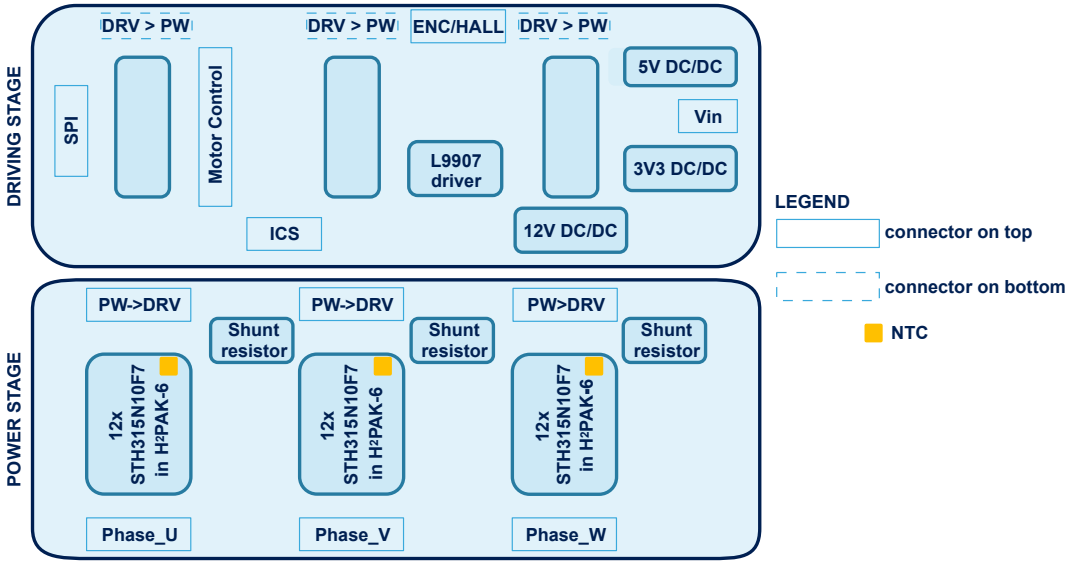
3 Evaluation kit overview

The STEVAL-TTM001V1 evaluation kit is designed to let you evaluate STH315N10F7 power MOSFETs, which are driven by the automotive grade L9907 three phase gate driver able to provide full diagnostic and programmable parameters via SPI. The system includes a bulk capacitor board and a current sensing board.

The STEVAL-TTM001V1 can be interfaced with any ST MCU evaluation board with embedded ST motor control connector and ST FOC firmware library support.

This kit has been tested with the STEVAL-TTM002V1 (not included in this kit) which features an SPC560P50L3 32-bit power architecture MCU for automotive applications.

Figure 2. STEVAL-TTM001V1 block diagram



4 STEVAL-CTM004V1 power board

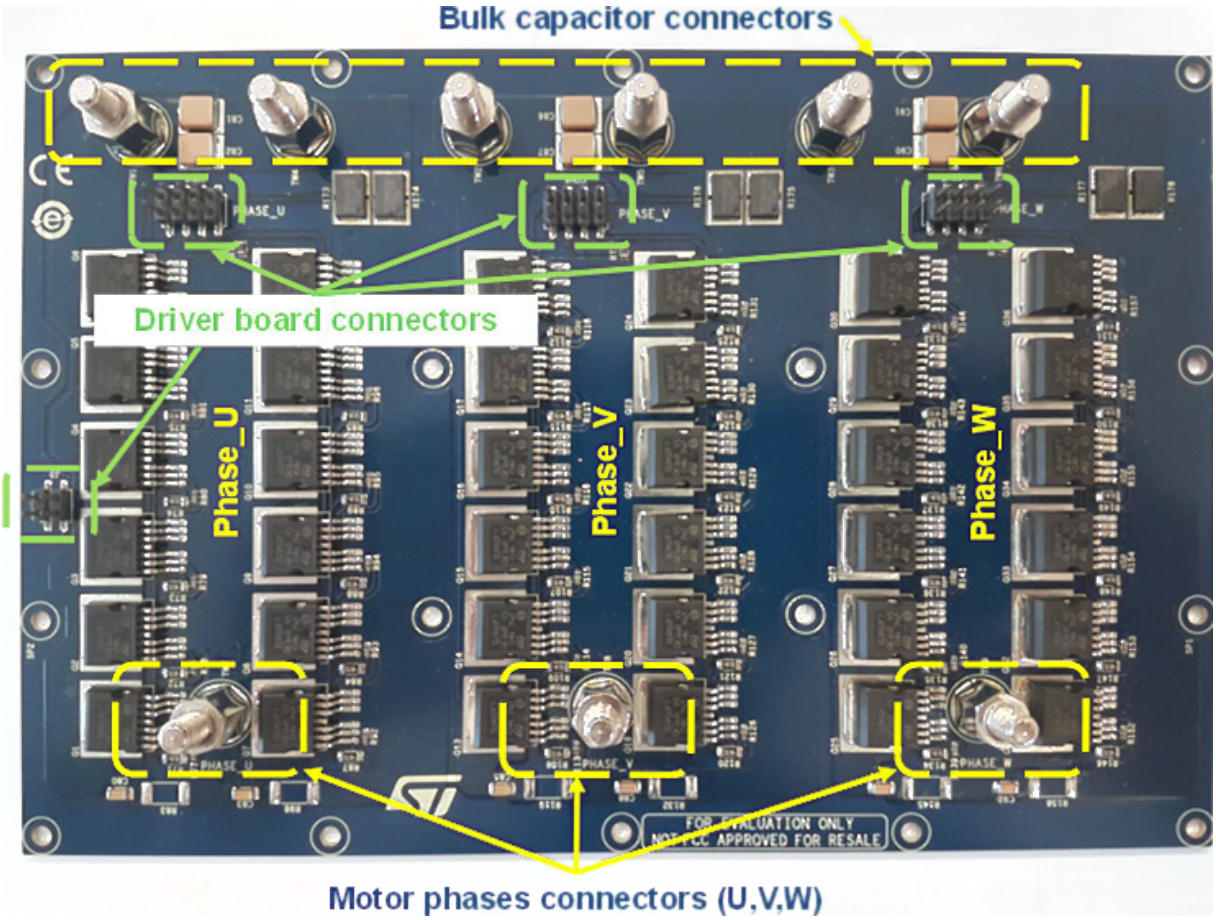
The STEVAL-CTM004V1 power board of the evaluation kit has 36 STH31*N10F7 N-channel Power MOSFETS in the H²PAK-6 package. A gate resistor is placed near each power MOSFET to eliminate parasitic oscillation. A pull-down resistor between the gate and the source of each transistor helps to avoid capacitive coupling driving the transistor and unwanted switch-on when gate is floating. A snubber RC circuit on each switch limits the rate of voltage change during switching transitions to reduce electromagnetic interference (EMI) and losses.

two decoupling capacitors close to the switching power MOSFETs reduce ringing on the VDS and voltage stress on the devices. The capacitors reduce voltage overshoot caused by abrupt current change in the parasitic inductors in the circuit.

To monitor the temperature of the power board and provide over-temperature protection, three NTCs are placed on the power board near the drain of one power MOSFET for each inverter leg.

The power section also has connectors for the driver board, with CON5 (phase_U), CON6 (phase_V) and CON7 (phase_W) for gate driving and NTC sensing, and J3 for bus voltage. The board also hosts six towers near the bulk capacitor board connection and three towers near the motor connection.

Figure 3. Main blocks of the STEVAL-CTM004V1 power board



4.1 STH315N10F7 N-channel Power MOSFET characteristics

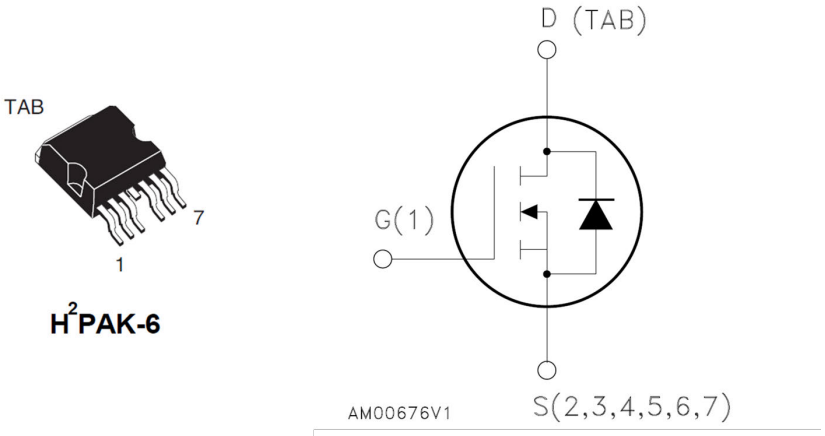
The N-channel Power MOSFETs use STripFET™ F7 technology with an enhanced trench gate structure for very low on-state resistance and reduces internal capacitance and gate charge for faster and more efficient switching.

The STH315N10F7 N-channel Power MOSFET has the following features:

- Designed for automotive applications and AEC-Q101 qualified
- Among the lowest $R_{DS(on)}$ on the market

- Excellent figure of merit (FoM)
- Low C_{rss}/C_{iss} ratio for EMI immunity
- High avalanche ruggedness

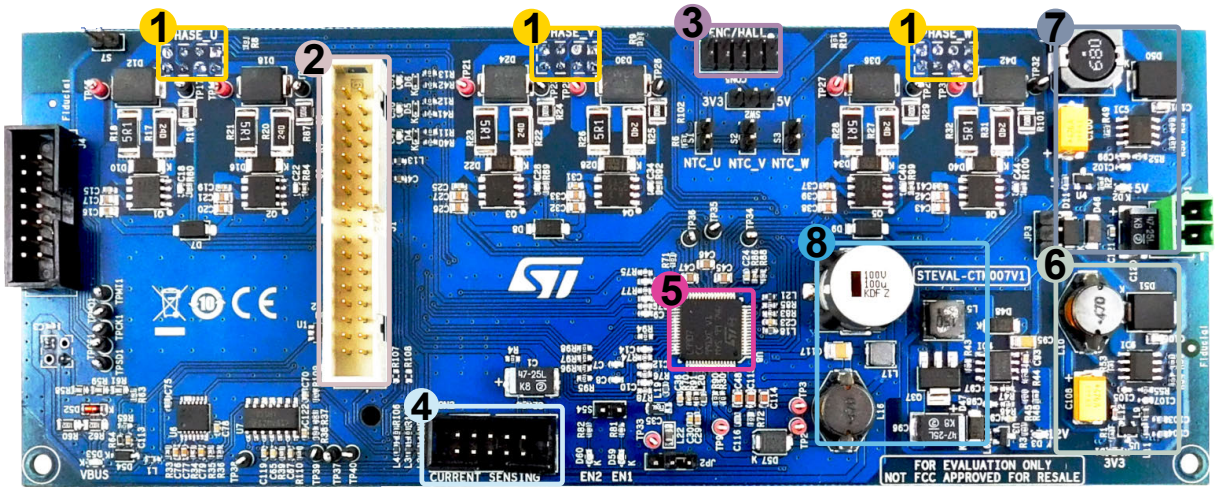
Figure 4. Package and internal schematic diagram



5 STEVAL-CTM007V1 driver board

Figure 5. **STEVAL-CTM007V1 driver board functional blocks**

1. connections to power board
2. motor control connector
3. ENC/HALL connector
4. ICS connector compatible with STEVAL-CTM008V1
5. L9907 driver
6. 3V3 DC/DC regulation
7. 5V DC/DC regulation
8. 12V DC/DC regulation



5.1 Power supply section

The power supply section provides all the voltages necessary for the circuitry. The required input voltage is 8 to 25 V input, which is supplied through connector JP1.

The input voltage is then converted to the following voltage levels:

- +12V for gate driver section (via an A7986 which is a 3 A step-down switching regulator)
- +5V and +3.3V for the control board (via an A6902 which is a 1 A switch step-down regulator)

5.2 Bus voltage monitoring

Bus voltage monitoring is implemented across an input voltage range of 5 to 75 V.

The following table shows the measured input voltage and the corresponding voltage level sent to the ADC input of the SPC5 microcontroller unit.

Table 1. **Input voltage bus and input signal to SPC5 ADC channel**

Input Voltage	ADC input
48V	2.0V
75V (max value)	3.1V

5.3 Temperature monitor

Three NTCs are placed on the power section to provide temperature information, although only one NTC may be chosen at a time. Close one of the three jumpers S1, S2 or S3 to read the temperature near the U, V or W phase, respectively. The microcontroller monitors processed signals to determine the temperature of the driver board and manage any overload or over-temperature conditions.

To protect the hardware from excess temperature, a safe threshold is set in SPC5-MCTK-LIB.

Table 2. **NTC electrical characteristics**

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

5.4 L9907 gate driver characteristics

The main features of the L9907 gate driver are listed below:

- dV/dt immunity ±50 V/ns in full temperature range
- AEC-Q100 qualified
- Supply voltage from 6 V to 54 V for working battery applications
- The device can withstand -7 V to 90 V at the FET high-side Driver pins
- Low standby current consumption
- 3.3 V internal regulator supplied by V_{CC} pin
- Boost regulator for full R_{DSON} down to 6 V and over voltage protection
- 3 low-side plus 3 high-side drivers
- PWM operation up to 20 kHz
- Gate driver current adjustable via SPI in 4 steps.
  - Range set via external resistor.
  - Maximum gate controlled current 600 mA
- Source connection to each MOSFET
- Input pin for each gate driver

RELATED LINKS

For detailed information and pin-out details regarding the L9907 gate driver, see the device datasheet

5.5 L9907 supply voltage configuration for 48 V applications

The L9907 automotive 3 phase BLDC driver has a default typical overvoltage threshold of 36 V. if 48 V is applied to the VB pin, an OV error is triggered in the start phase with (B11) = ‘1’ in the DIAG register and the FS_FLAG pin set to low.

As the VB pin is supplied from 48 V, the overvoltage protection VBov (B9) has to be disabled setting ‘0’ in CMD1 register. The overvoltage protection set on the boost regulator BST_C pin also needs to be disabled (default is set to '0') by setting bit DIS_BSTov (B12) in CMD3 register to ’1’.

Note: This bit is only acknowledged if AND (EN1, EN2) = '0'. Trying to write it without lowering AND (EN1, EN2) will not generate an SPI error, but the command will be ignored for the specific bit.

While setting CMD3 B12 to 1 disables the overvoltage protection on the BST_C pin, this solution does not allow use of the FS_FLAG pin (which would always be low) to trigger an error in the microcontroller. This is due to the fact that only the fault effect is disabled when VBov (B9) is set to ‘0’, while the fault is still latched in the SPI register DIAG. Continuous polling must therefore be performed to query the device to verify whether errors are present.

RELATED LINKS

See application note AN5124 for more details

6 Bus link capacitor board and current sensing board

6.1 STEVAL-CTM005V1 bus link capacitor board

In EV inverter systems, bus link capacitors reduce ripple current and suppress voltage spikes caused by leakage inductance and switching operations. These capacitors provide a low impedance path for the ripple currents caused by output inductance load, the bus voltage and PWM frequency.

The bus link capacitors must sustain a ripple current given by the following formula:

$$\Delta I_{0.5t} = 0.25 \times \frac{V_{bus}}{(f \times L)}$$

Where:

- $\Delta I_{0.5t}$ is the maximum ripple current when duty cycle is 50%
- V_{bus} is the bus voltage
- f is the switching frequency
- L is the load inductance.

For a very low inductance motor (worst case scenario), $\Delta I_{0.5t}$ is about 48 A_{RMS} (V_{bus} = 52 V, f = 8 kHz and L = 12 µH). If we add 10% to $\Delta I_{0.5t}$ and choose electrolytic capacitors with a ripple current of 2.4 A, 22 electrolytic capacitors are required. The resulting capacitance is about 6 mF, leading to a negligible ripple voltage on the bus.

Figure 6. STEVAL-CTM005V1 bus link capacitor board

6.2 STEVAL-CTM008V1 current sensing board

The STEVAL-CTM008V1 current sensing board is a general purpose board for motor control that can read up to three phase motor currents and DC bus currents if four ICS are on-board. The board included in the kit hosts two ICS to read two phase currents.

This sensing feature determines motor currents for digital control based on FOC algorithms. The sensors provide high accuracy, with 4 mV/A over a temperature range of -40 °C to +105 °C and a nominal current of 200 A_{RMS}.

The internal reference voltage of the ICSs (according to their V_{CC}) is generally used, but the reference voltage can be overdriven by providing an external reference voltage through the J1 connector. A female to female flat cable is used to connect CON2 on the driver board with J1 on the current sensing board.

The signals from the sensors center around 1.65 V (average value at zero current).

Figure 7. **STEVAL-CTM008V1 current sensing board**

7 How to set up the system

Follow the steps below to set up the evaluation kit.

Note: The following boards referenced below are part of the STEVAL-TTM001V1 evaluation kit and are not available for separate sale:

- *STEVAL-CTM004V1 power board*
- *STEVAL-CTM005V1 bus link capacitor board*
- *STEVAL-CTM007V1 driver board*
- *STEVAL-CTM008V1 current sensing board*

Step 1. Mount the STEVAL-CTM004V1 power board on the heatsink.
Use standard thermal interface material or a graphite sheet for high thermal conductivity.

Step 2. Connect the STEVAL-CTM004V1 power board with the STEVAL-CTM007V1 driver board.
- Use connectors CON5, CON6, CON7 and J3 on the STEVAL-CTM004V1 power board.
- Use connectors CON1, CON3, CON4 and J2 on the STEVAL-CTM007V1 driver board.

Step 3. Connect the control board:
- If you use the STEVAL-TTM002V1 control board (not included in the kit):
  - Use connectors J1 and J4 on the STEVAL-CTM007V1 driver board.
  - Use connectors CON5 and CON2 on the STEVAL-TTM002V1 control board.
- If you use a different control board:
  - Use connectors J1 and J4 on the driver board to connect your control board.

Step 4. Mount the STEVAL-CTM005V1 bus link capacitor board on the STEVAL-CTM004V1 power board.

Step 5. Set up the STEVAL-TTM002V1 control board (optional, if present).

Step 6. Set up the STEVAL-CTM007V1 driver board.
Close jumper S1, S2 or S3 to read one of the three NTCs on the power stage.

Step 7. Connect the flat cable between CON2 on the STEVAL-CTM007V1 driver board and J1 on the STEVAL-CTM008V1 current sensing board.

Step 8. Connect a 48 V_{DC} power supply to the CTM005V1 bus link capacitor board.

Step 9. Connect a 12 V_{DC} power supply to the JP1 connector to the STEAVL-CTM007V1.

Step 10. Connect the phase motor cables to the STEVAL-CTM004V1 power board.

Step 11. Turn on the 48 V_{DC} power supply to the CTM005V1 bus link capacitor board.

Step 12. Turn on the 12 V_{DC} power supply to the STEVAL-CTM007V1.

7.1 Connectors

In addition to the connector used for the supply voltage, the driving board has connectors to plug it to the power board and the control board, and to receive external signals.

- Connector for supply voltage: provided at JP1 (8 to 36 V).
- Connectors to the power board:
  - CON1, CON3 and CON4: for power MOSFET driving and NTC sensing.
  - J2: connector for DC bus voltage sensing (for undervoltage and overvoltage protection).
- Connectors to the control board
  - J1: motor control connector, including signals like fault management, bus voltage monitoring, power board temperature sensing and current sensing.
  - J4: connector used for SPI communication.

- Connectors for external signals
  - CON8 (ENC/HALL connector): to receive external signals from Encoder/Hall sensors and provides +3V3 or +5V supply voltages.
  - CON2 (CURRENT SENSING connector): to receive current signals from the external current sensor board and provide a +5V supply voltage.

Figure 8. Current sensing connector (CON2 on driver board)

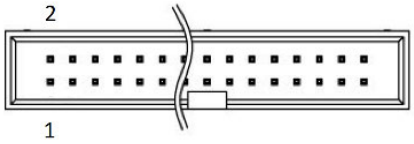


Table 3. Current sensing connector pinout

Pin number	Pin name / Function
1	Ground
2	ADC_U
3	Ground
4	ADC_V
5	Ground
6	ADC_W
7	Ground
8	Not Connected
9	Ground
10	Vcc_ICS

Figure 9. 34-pin motor control connector (J1 on the driver board)

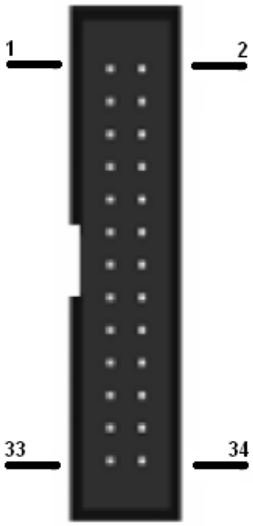


Table 4. Motor control connector pinout

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

7.2 Signal LEDs

Table 5. LED indicators on board

Name	Color	Description	Location
D1	RED	3V3	STEVAL-CTM007V1(1)
D2	RED	5V	STEVAL-CTM007V1(1)
D3	RED	12V	STEVAL-CTM007V1(1)
D53	RED	48V	STEVAL-CTM004V1(1)

1. *Board is supplied with kit and not available for separate sale*

7.3 Push buttons

Table 6. Push buttons descriptions

Name	Description	Location
S2	Microcontroller reset	Control Board
S1	User push-button	Control Board

8 SPC5 Software Development Tools

This evaluation kit is compatible with latest automotive Motor Control FOC Library SPC5-MCTK-LIB and with the SPC5-STUDIO IDE tool.

RELATED LINKS

SPC5-MCTK-LIB SPC5 Motor Control Tool Kit FOC Library

SPC5-STUDIO Code Generator, Quick resources configurator and Eclipse development environment for SPC5 MCUs

8.1 Firmware for SPC560P50L3

You can use the SPC5Studio IDE tool to customize the FOC library (installed together with the SPC5-MCTK-LIB FW package).

Table 7. Required parameters for STEVAL-TTM002V1 power stage

Parameter	Value	Unit
Inrush current limiter	disabled	-
Dissipative brake	disabled	-
Bus voltage sensing	Enabled	-
R1 (Bus voltage sensing)	63.9	kΩ
R2 (Bus voltage sensing)	2.7	kΩ
Min. rated voltage	8	V
Max. rated voltage	60	V
Nominal voltage	48	V
Temperature sensing	Enabled	-
V0	761	mV
T0	25	°C
ΔV/ΔT	21	mV/°C
Max. working temperature on sensor	125	°C
Current sensing	Enabled	-
Current reading topology	Two insulated current sensors	-
ICS gain	0.004	V/A
Overcurrent protection	disabled	-
Power switches - switching frequency	12 (can be changed according the requirements)	kHz
Power switches - dead-time	2.5 (can be changed according the requirements)	µs
U,V,W driver High side driving signal polarity	Active high	-
U,V,W driver Low side driving signal Complemented from high side	disabled	-
U,V,W driver Low side driving signal Polarity	Active low	-

Parameter	Value	Unit
U,V,W driver Force same values for U, V, W driver	disabled	-
U,V,W driver Use STGAP1S gap drive	disabled	-

9 Experimental measurements

The experimental results were obtained by testing the system at maximum power rating.

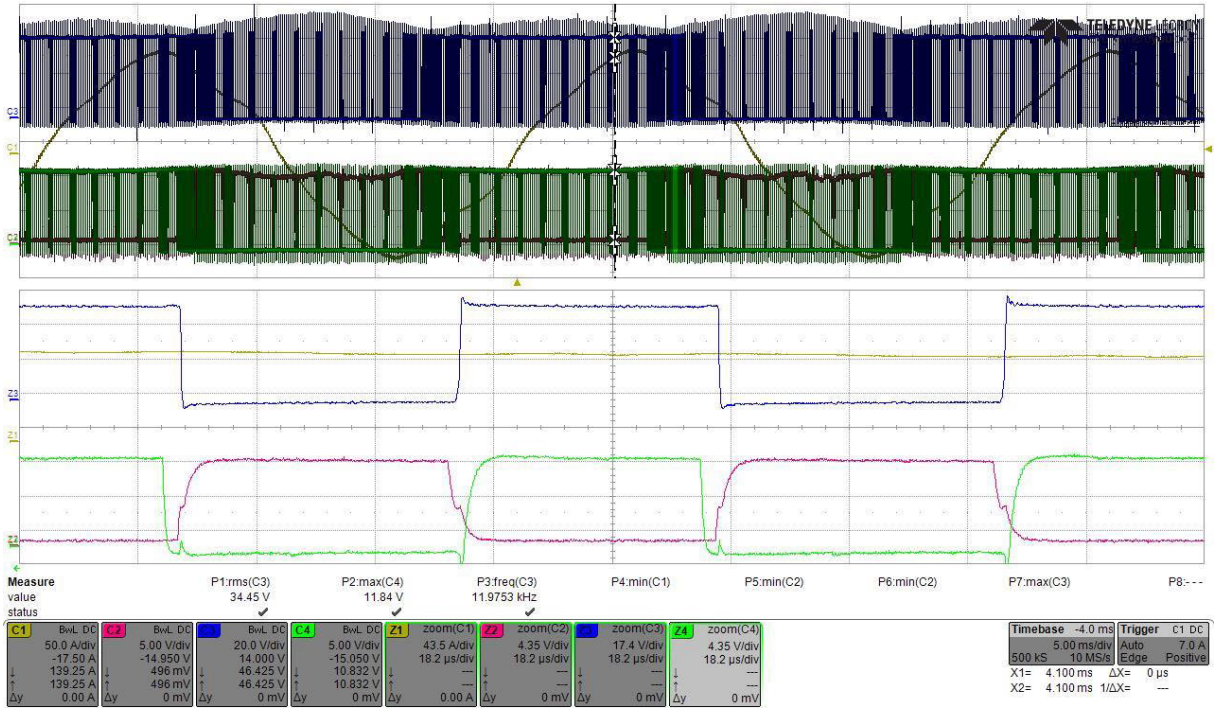
The power board was mounted with a heatsink (manuf.: ABL Components; manuf. order code: 159AB2000B; Rth: 0.36 °C/W; dimensions: 200x160x40mm, or equivalent), using a thermal interface material with high thermal conductivity (1300 W/mK) to form a natural convection cooling system.

A 48 V bus voltage was applied to drive a PMSM connected to a brake dynamometer.

The system was set at 5 kW output power to monitor the behavior of V_{GS}, V_{DS}, phase current and device temperatures measured by an infrared thermo-camera.

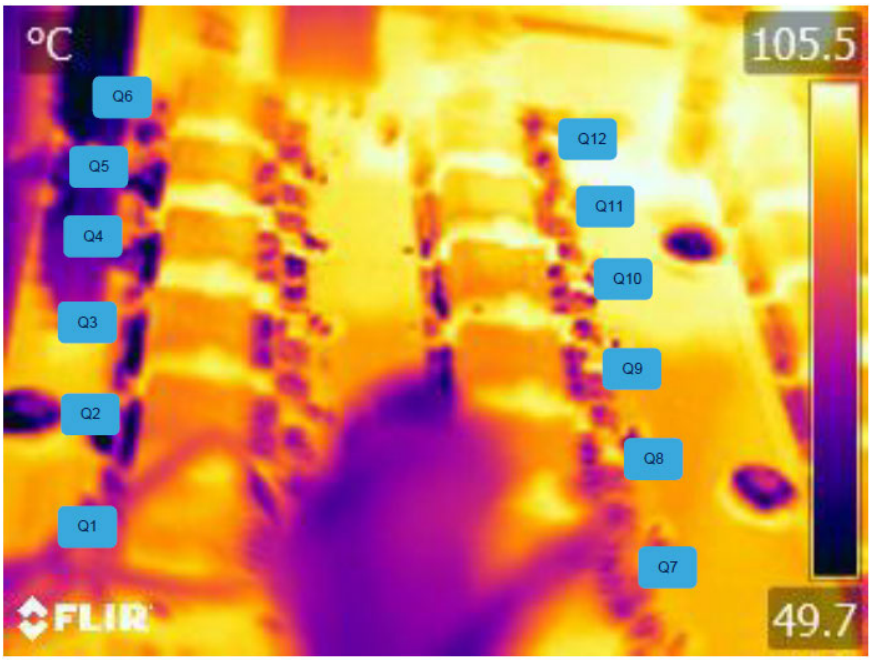
Figure 10. Measured waveforms

Ch1: Ids; Ch2: Vgs HS; Ch3: Vds HS; Ch4: Vgs LS



The figure below shows the temperature of phase U devices after 40 minutes of continuous operation at full power. The devices operated in safe conditions and the temperature did not exceed the absolute max ratings. The maximum measured temperature is about 105 °C.

Figure 11. **Measured temperatures of U_phase Power MOSFETs**



The following table shows the MOSFET maximum, minimum and average temperature values.

Table 8. **Measured case temperatures of the STH315N10F7 power MOSFETs**

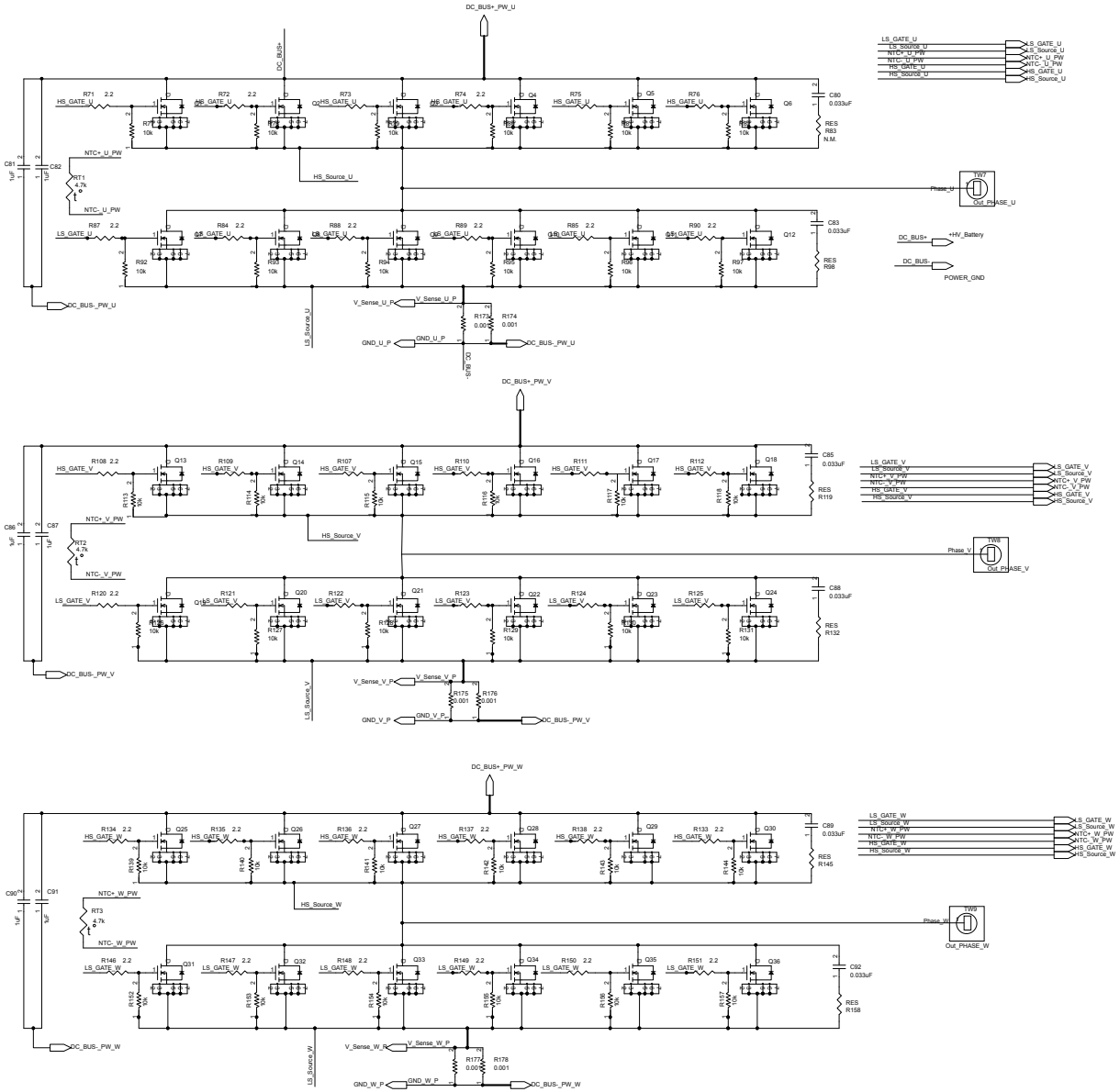
Case Temperature [°C]	High Side Uphase devices						Low Side Uphase devices					
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12
max.	99.5	99.8	100.4	101.2	102.4	101.5	98.5	101.9	103.4	104.5	104.3	104.9
min.	85.9	81.1	91.9	91.9	87.9	93.3	NA (1)	NA(1)	88.6	90.1	94.9	103.5
Average	94.6	91.6	98.8	96.2	96.7	97.4	NA(1)	NA(1)	94.5	96.7	99.9	101.9

1. *Not measured due to an obstacle along the measurement line*

10 STEVAL-TTM001V1 kit schematic diagrams

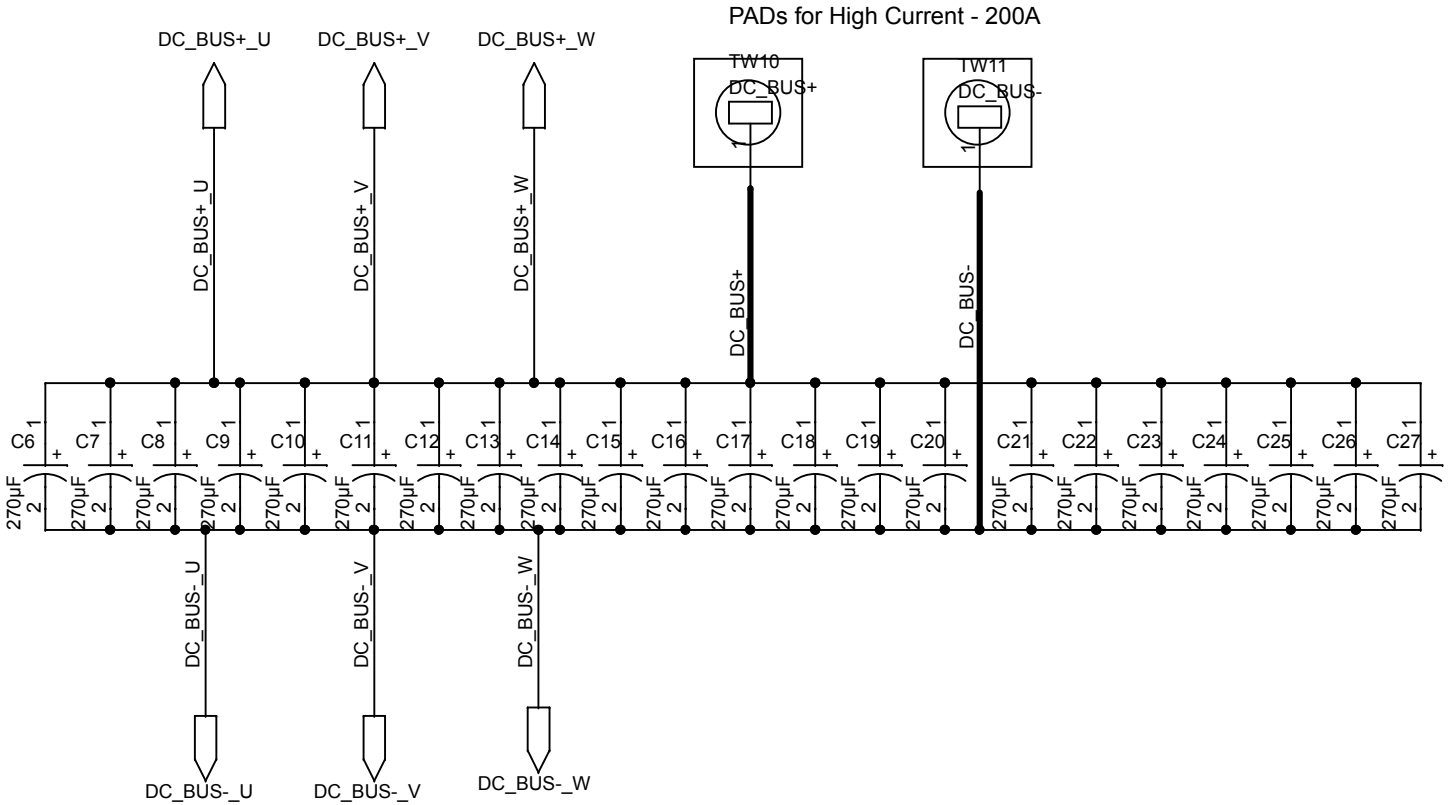
10.1 Power board schematic diagrams

Figure 12. Power board schematics



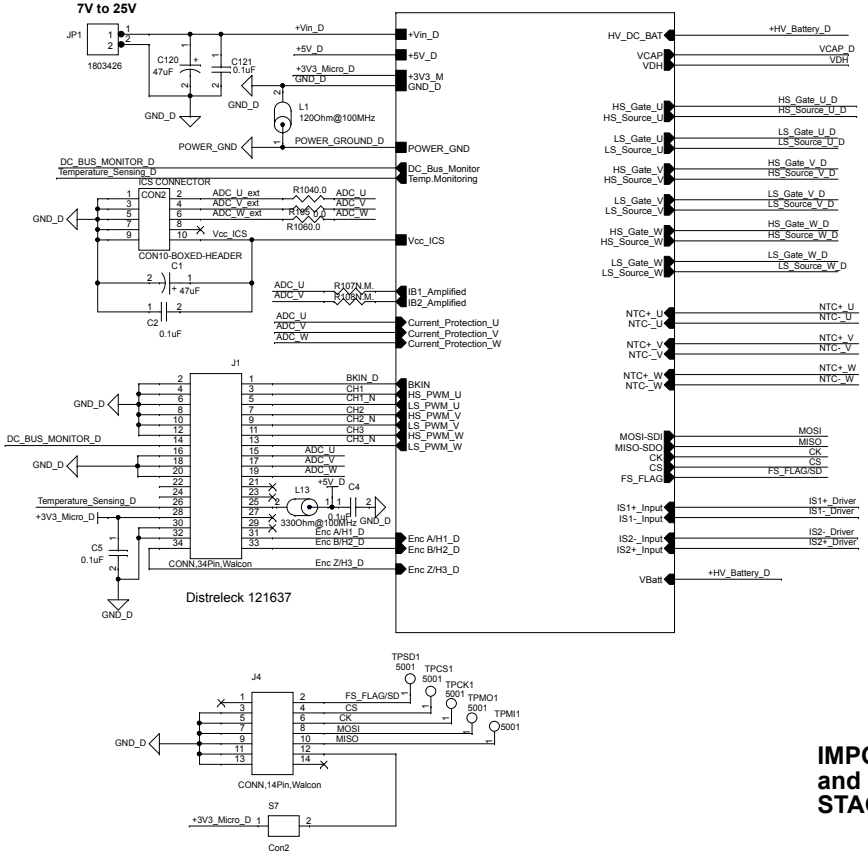
10.2 Bulk capacitor board schematic diagrams

Figure 13. Capacitor board schematics

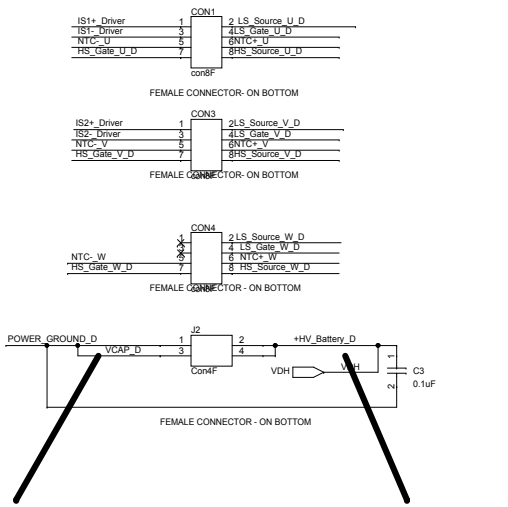


10.3 Driver board schematic diagrams

Figure 14. **Driver board schematics - main with connectors**



Connectors for POWER STAGE



to be CONNECTED to the POWER GROUND in the POWER STAGE - CHECK on POWER STAGE

to be CONNECTED to + VBATT in the POWER STAGE - CHECK on POWER STAGE

IMPORTANT: TO BE PLUGGED according to TOP and BOTTOM-TO BE CONNECTED to the IMS POWER STAGE

Figure 15. Driver board schematics - sensing and status

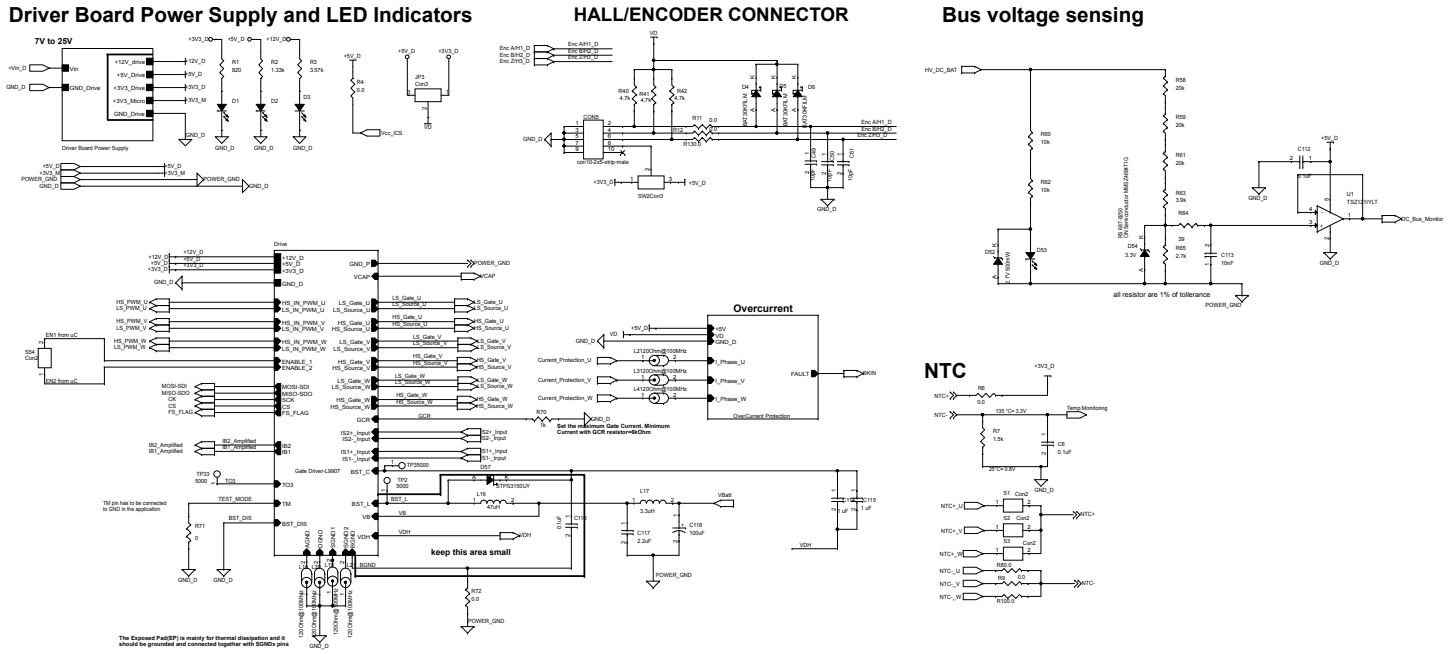


Figure 16. Driver board schematics - gate driver section

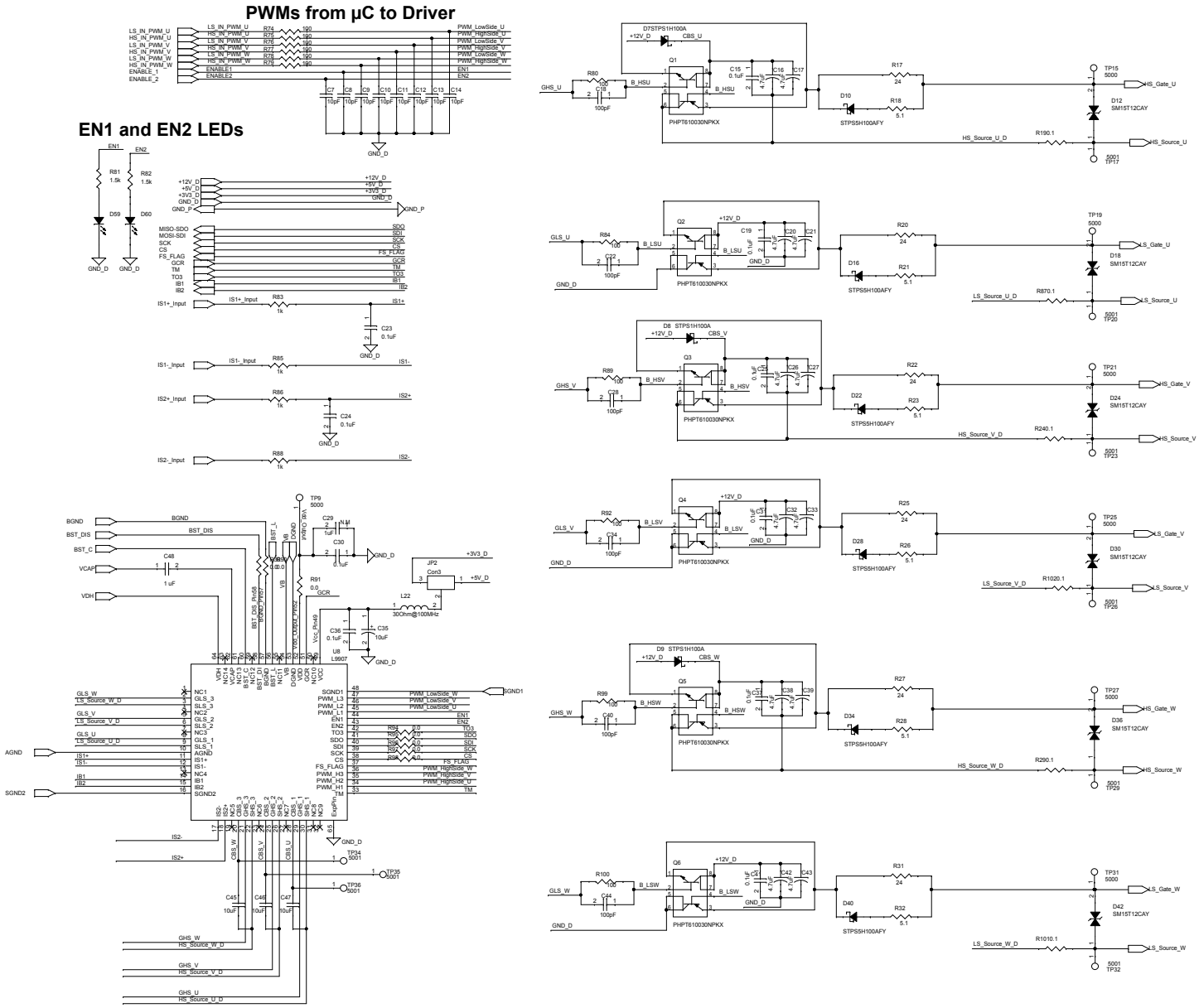


Figure 17. Driver board schematics - overcurrent protection

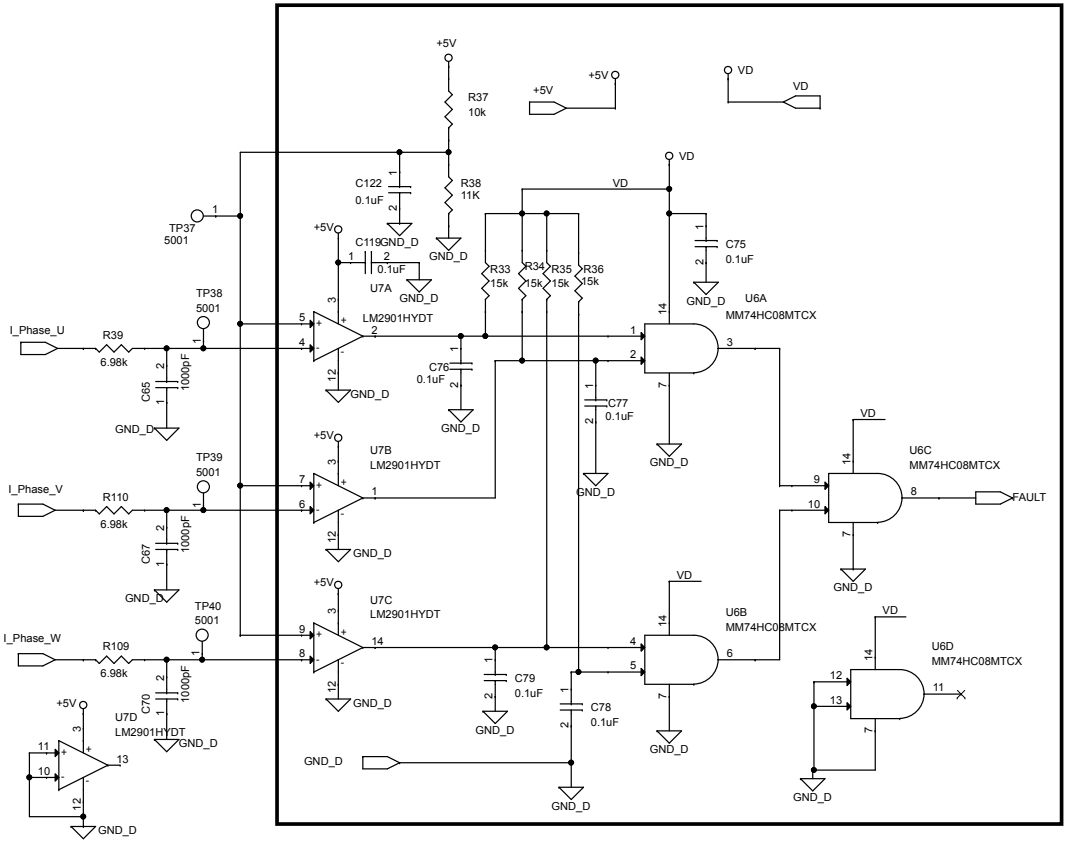
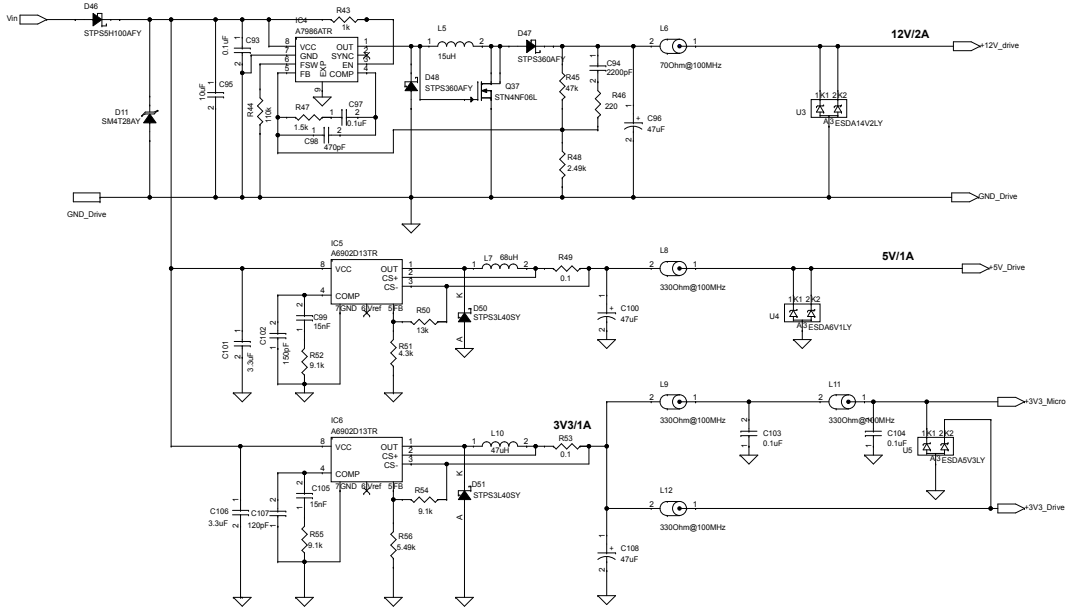
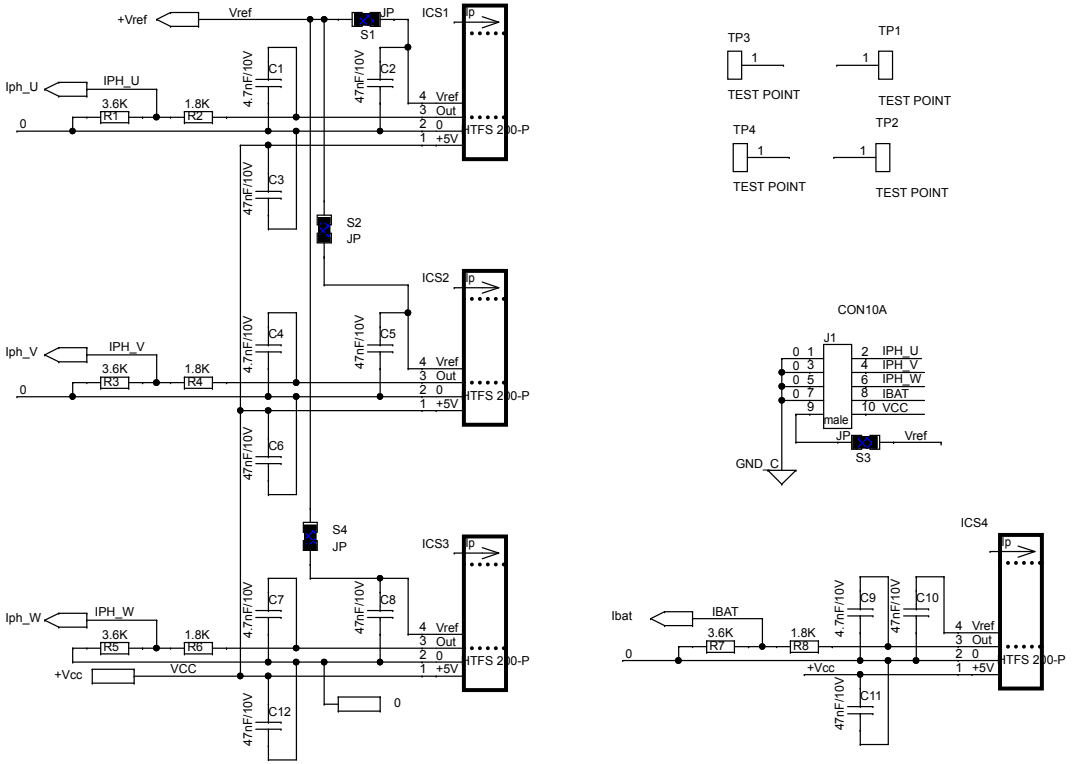


Figure 18. Driver board schematics - power supply



10.4 Current sensor board schematic diagrams

Figure 19. **Current sensor board schematics**



11 STEVAL-TTM001V1 bill of materials

Table 9. STEVAL-TTM001V1 evaluation kit bill of materials

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	1	-	STEVAL-CTM004V1	Power board	ST	not available separately
2	1	-	STEVAL-CTM005V1	Capacitor board	ST	not available separately
3	1	-	STEVAL-CTM007V1	Driver board	ST	not available separately
4	1	-	STEVAL-CTM008V1	Current sensing board	ST	not available separately

11.1 Power board bill of materials

Table 10. Power board bill of materials

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	6	C80, C83, C85, C88, C89, C92	0.033µF, 250V, ±20%	CAP CER, 1206 (3216 Metric)	TDK Corporation	CGA5L3X7R2E333M160AA
2	6	C81, C82, C86, C87, C90, C91	1µF, 250V, ±10%	CAP CER 1UF 250V X7R 2220, 2220 (5750 Metric)	TDK Corporation	CGA9N3X7R2E105K230KA
3	3	CON5, CON6, CON7	2X4 Pitch 2.54	Double Strip Line Male SMD	Molex. LLC	15-91-1088
4	3	CON5, CON6, CON7	2X4 Pitch 2.54	Double Strip Line Male SMD	Harvin	M20-8750442
5	1	J3	2X4 Pitch 2.54	Double Strip Line Male SMD	Molex. LLC	0015912040
6	36	Q1, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14, Q15, Q16, Q17, Q18, Q19, Q20, Q21, Q22, Q23, Q24, Q25, Q26, Q27, Q28, Q29, Q30, Q31, Q32, Q33, Q34, Q35, Q36	STH315N10F7-6, 100V, 180A	MOSFET N-CH H2PAK-6, TO-263-7, D²Pak (6 Leads + Tab)	ST	STH315N10F7-6
7	36	R71, R72, R73, R74, R75, R76, R84, R85, R87, R88, R89, R90, R107, R108, R109, R110, R111, R112, R120, R121, R122, R123, R124, R125, R133, R134, R135, R136, R137, R138, R146, R147,	2.2, 1/4W, ±1%	1206 (3216 Metric)		-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
		R148, R149, R150, R151				
8	36	R77, R78, R79, R80, R81, R82, R92, R93, R94, R95, R96, R97, R113, R114, R115, R116, R117, R118, R126, R127, R128, R129, R130, R131, R139, R140, R141, R142, R143, R144, R152, R153, R154, R155, R156, R157	10k, 1/10W, ±1%	RES SMD, 0603 (1608 Metric)	Yageo	RC0603FR-0710KL
9	6	R83, R98, R119, R132, R145, R158	not mounted	-	-	-
10	6	R173, R174, R175, R176, R177, R178	1mΩ, 7W, ±1%	RES SMD 2818	Vishay Dale	WSHM28181L000FEA
11	3	RT1, RT2, RT3	4.7k, ±5%	NTC THERMISTOR, 0805 (2012 Metric)	Murata Electronics North America	NCP21XM472J03RA
12	9	TW1, TW2, TW3, TW4, TW5, TW6, TW7, TW8, TW9, TW10, TW11	M5x10mm	Male-Femal Hexagonal Tower	RS PRO	806-6632
13	2	SP1, SP2	M3x10mm	Stainless Steel Spacer Studs, metric, internal/ external WA-SSSIE, standoff	KEYSTONE ELECTRONICS	24296
14	18	0	M3x8mm	Machine Screw with flat + spring lock washer	Ettinger	81,58,336
15	9 +9 +9	0	Size M5	Nut + Washer + shakeproof	RS PRO	483-0546 + 482 7720 + 526-833

11.2 Bulk capacitor board bill of materials

Table 11. Capacitor board bill of materials

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	22	C6, C7 ,C8 ,C9, C10, C11, C12, C13, C14, C15, C16, C17, C18, C19, C20, C21, C22, C23, C24, C25, C26, C27	270µF, 100V, ±20%	CAPACITOR, ALUM, Radial	Rubycon	100ZLJ270M12.5X30

11.3 Driver board bill of materials

Table 12. Driver board bill of materials

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	3	C1, C96, C120	47µF, 25, ±10%	CAPACITOR, TANT, 2917 (7343 Metric)	AVX Corporation	TAJD476K025RNJ
2	28	C2, C3, C4, C5, C6, C15, C19, C23, C24, C25, C30, C31, C36, C37, C41, C75, C76, C77, C78, C79, C93, C97, C103, C104, C112, C119, C121, C122	0.1µF, 50V, ±10%	CAPACITOR, CER, 0603 (1608 Metric)	KEMET	C0603C104K5RACTU
3	8	C7, C8, C9, C10, C11, C12, C13, C14	10pF, 50V, ±10%	CAPACITOR, CER, 0603 (1608 Metric)	TDK Corporation	CGA3E2C0G1H100D080AD
4	12	C16, C17, C20, C21, C26, C27, C32, C33, C38, C39, C42, C43	4.7µF, 25V, ±10%	CAPACITOR, CER, 0805 (2012 Metric)	TDK Corporation	C2012X5R1E475K125AB
5	6	C18, C22, C28, C34, C40, C44	100pF, 50V, ±5%	CAPACITOR, CER, 0603 (1608 Metric)	Murata Electronics North America	GRM1885C1H101JA01D
6	1	C29	1µF, 50V, ±10%	CAPACITOR, CER, 0603 (1608 Metric)	Samsung Electro-Mechanics America, Inc.	CL10A105KB8NNNC
7	1	C35	10µF, 10V, ±20%	CAPACITOR, TANT, 1206 (3216 Metric)	KEMET	T491A106M010AT
8	3	C45, C46, C47	10µF, 35V, ±10%	CAPACITOR, CER, 0805 (2012 Metric)	TDK Corporation	C2012X5R1V106K125AC
9	3	C48, C114, C115	1 µF, 100V, ±10%	CAPACITOR, CER, 0805 (2012 Metric)	TDK Corporation	C2012X7S2A105K125AB
10	3	C49, C50, C51	10pF, 50V, ±0.5pF	CAPACITOR, CER, 0603 (1608 Metric)	TDK Corporation	CGA3E2C0G1H100D080AD
11	3	C65, C67, C70	1000pF, 50V, ±10%	CAPACITOR, CER, 0603 (1608 Metric)	AVX Corporation	06035C102KAT2A
12	1	C94	2200pF, 50V, ±10%	CAPACITOR, CER, 0603 (1608 Metric)	TDK Corporation	CGA3E2X7R1H222K080AD
13	1	C95	10µF, 50V, ±20%	CAPACITOR, CER, 1206 (3216 Metric)	TDK Corporation	CGA5L3X5R1H106M160AB
14	1	C98	470pF, 50V, ±5%	CAPACITOR, CER, 0603 (1608 Metric)	TDK Corporation	CGA3E2C0G1H471J080AD
15	2	C99, C105	15nF, 50V, ±10%	CAPACITOR, CER, 0603 (1608 Metric)	Murata Electronics North America	GRM188R71H153KA01D
16	2	C100, C108	47µF, 10V, ±10%	CAPACITOR, TANT, 2917 (7343 Metric)	AVX Corporation	TAJD476K010RNJ

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
17	2	C101, C106	3.3µF, 50V, ±10%	CAPACITOR, CER, 0805 (2012 Metric)	TDK Corporation	C2012X5R1H335K125AB
18	1	C102	150pF, 100V, ±5%	CAPACITOR, CER, 0603 (1608 Metric)	TDK Corporation	CGA3E2C0G2A151J080AD
19	1	C107	120pF, 50V, ±5%	CAPACITOR, CER, 0603 (1608 Metric)	TDK Corporation	CGA3E2C0G1H121J080AD
20	1	C113	10nF, 50V, ±10%	CAPACITOR, CER, 0603 (1608 Metric)	Murata Electronics North America	GRM188R71H103KA01D
21	1	C116	0.1µF, 100V, ±10%	CAPACITOR, CER, 0603 (1608 Metric)	TDK Corporation	CGA3E3X7S2A104K080AB
22	1	C117	2.2µF, 100V, ±10%	CAPACITOR, CER, 1210 (3225 Metric)	KEMET	C1210C225K1RACTU
23	1	C118	100µF, 100V, ±20%	CAPACITOR, ALUM, Radial, Can - SMD	Vishay BC Components	MAL215099907E3
24	3	CON1, CON3, CON4	8 pin, 2.54mm	CONN HEADER FEMALE DL TIN	Sullins Connector Solutions	PPTC042LFBN-RC
25	1	CON2	10 pin, 2.54 mm	CONN HEADER 2.54MM GOLD	Sullins Connector Solutions	SBH11-PBPC-D05-ST-BK
26	1	CON5	10 pin, 2.54 mm	CONN HEADER STR TIN MALE	Amphenol FCI	67997-410HLF
27	4	D1, D2, D3, D53	Green, 20mA	LED DIFFUSED 0603 SMD, 0603 (1608 Metric)	OSRAM Opto Semiconductors Inc.	LP L296-J2L2-25-Z
28	3	D4, D5, D6	530mV @ 300mA, (DC)	DIODE, SCHOTTKY, SC-79, SOD-523	ST	BAT30KFILM
29	3	D7, D8, D9	1A	DIODE, SCHOTTKY, DO-214AC, SMA	ST	STPS1H100A
30	7	D10, D16, D22, D28, D34, D40, D46	5A	DIODE, SCHOTTKY, SOD-128	ST	STPS5H100AFY
31	1	D11		TVS, DIODE, DO-214AC, SMA	ST	SM4T28AY
32	6	D12, D18, D24, D30, D36, D42		TVS, DIODE, DO-214AB, SMC	ST	SM15T12CAY
33	2	D47, D48	3A	DIODE, SCHOTTKY, SOD-128	ST	STPS360AFY
34	2	D50, D51	500mV @ 3A	DIODE, SCHOTTKY, DO-214AB, SMC	ST	STPS3L40SY
35	1	D52	2.7V, 1.5V @ 200mA, 10µA @ 1V, 500mW	DIODE, ZENER, DO-213AC, MINI-MELF, SOD-80	Vishay Semiconductor Diodes Division	TZMB2V7-GS08
36	1	D54	3.3V, 900mV @ 10mA, 7.5µA @ 1.5V, 500mW	DIODE, ZENER, SOD-123	ON Semiconductor	MMSZ4684T1G
37	1	D57	820mV @ 3A	DIODE, SCHOTTKY, DO-214AA, SMB	ST	STPS3150UY

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
38	2	D59, D60	Red, 624nm	Standard LEDs - SMD, 0603 (1608 metric)	OSRAM Opto Semiconductors	LR Q396-P1Q2-1
39	1	IC4	3A	IC REG BUCK ADJ 3A 8HSOP, 0.154", 3.90mm width, Exposed Pad	ST	A7986ATR
40	2	IC5, IC6	1A	IC REG BUCK ADJ 1A 8SOIC, 0.154", 3.90mm width	ST	A6902D13TR
41	1	J1	34 pin	CONN, Walcon, Vertical	HARTING	09185346324
42	1	J2	4 pin, 2.54mm	CONN HEADER FEMALE DL TIN	Sullins Connector Solutions	PPTC022LFBN-RC
43	1	J4	14Pin, 2.54mm	CONN HEADER GOLD	Sullins Connector Solutions	SBH11-PBPC-D07-ST-BK
44	1	JP1	2pin, 3.81mm	TERM BLOCK HDR VERT	Phoenix Contact	1803426
45	3	JP2, JP3, SW2	Con3	SIL VERTICAL PC TAIL PIN HEADER	Harwin Inc.	M20-9990345
46	8	L1, L2, L3, L4, L18, L19, L20, L21	120Ω@100MHz	FERRITE BEAD 0603 1LN, 0603 (1608 Metric)	Wurth Electronics Inc.	742792625
47	1	L5	15µH, 1.45A, 125MΩ, ±20%	FIXED IND, Nonstandard	Wurth Electronics Inc.	74404063150
48	1	L6	70Ω@100MHz	FERRITE BEAD 0603 1LN, 0603 (1608 Metric)	Murata Electronics North America	BLM18SG700TN1D
49	1	L7	68µH, 1.9A, 132MΩ, ±20%	FIXED IND 1.9A SMD, WE_PD1050	Wurth Electronics Inc.	7447714680
50	5	L8, L9, L11, L12, L13	330Ω@100MHz	FERRITE BEAD 0603 1LN, 0603 (1608 Metric)	Murata Electronics North America	BLM18SG331TN1D
51	2	L10, L16	47µH, 1.8A, 190MΩ, ±10%	FIXED IND SMD, WE_PD4	Wurth Electronics Inc.	74456147
52	1	L17	3.3µH, 2A, 22MΩ, ±20%	FIXED IND SMD, Nonstandard	Wurth Electronics Inc.	74404042033
53	1	L22	30Ω@100MHz	FERRITE BEAD 0805 1LN, 0805 (2012 Metric)	Wurth Electronics Inc.	74279206
54	6	Q1, Q2, Q3, Q4, Q5, Q6	100V, 3A, 1.25W	TRANS NPN/PNP 8LFPAK, SOT-1205	Nexperia USA Inc.	PHPT610030NPKX
55	1	Q37	60V, 4A, 3.3W (Tc)	MOSFET N-CH SOT-223, TO-261-4, TO-261AA	ST	STN4NF06L

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
56	1	R1	820Ω, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-07820RL
57	1	R2	1.33k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-071K33L
58	1	R3	3.57k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-073K57L
59	20	R4, R6, R8, R9, R10, R11, R12, R13, R30, R72, R90, R91, R94, R95, R96, R97, R98, R104, R105, R106	0.0, 0.1W, 1/10W	RES SMD JUMPER 0603, 0603 (1608 Metric)	Yageo	RC0603JR-070RL
60	4	R7, R47, R81, R82	1.5k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-071K5L
61	6	R17, R20, R22, R25, R27, R31	24, 2W, ±5%	RES SMD 2512, 2512 (6432 Metric)	Stackpole Electronics Inc.	RMCF2512JT24R0
62	6	R18, R21, R23, R26, R28, R32	5, 1, 1W, ±5%	RES SMD 2512, 2512 (6332 metric)	Panasonic Electronic Components	ERJ-1TYJ5R1U
63	6	R19, R24, R29, R87, R101, R102	0.1, 1/2W, ±5%	RES SMD 1210, 1210 (3225 Metric)	Yageo	RL1210FR-070R1L
64	4	R33, R34, R35, R36	15k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-0715KL
65	1	R37	10k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-0710KL
66	1	R38	11K, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-0711KL
67	3	R39, R109, R110	6.98k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-076K98L
68	3	R40, R41, R42	4.7k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-074K7L
69	6	R43, R70, R83, R85, R86, R88	1k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-071KL
70	1	R44	110k, 0.1W, 1/10W, ±5%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603JR-07110KL
71	1	R45	47k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-0747KL
72	1	R46	220, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-07220RL
73	1	R48	2.49k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Stackpole Electronics Inc.	RMCF0603FT2K49
74	2	R49, R53	0.1, 0.333W, 1/3W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Panasonic Electronic Components	ERJ-3BWFR100V
75	1	R50	13k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-0713KL
76	1	R51	4.3k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-074K3L

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
77	3	R52, R54, R55	9.1k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-079K1L
78	1	R56	5.49k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-075K49L
79	3	R58, R59, R61	20k, 0.125W, 1/8W, ±1%	RES SMD 0805, 0805 (2012 Metric)	Yageo	RC0805FR-0720KL
80	2	R60, R62	10k, 0.25W, 1/4W, ±1%	RES SMD 1206, 1206 (3216 Metric)	Yageo	RC1206FR-0710KL
81	1	R63	3.9k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-073K9L
82	1	R64	39, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Panasonic Electronic Components	ERJ-3EKF39R0V
83	1	R65	2.7k, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-072K7L
84	1	R71	0, 0.1W, 1/10W, ±Jumper	RES SMD 0603, 0603 (1608 Metric)	Panasonic Electronic Components	ERJ-3GEY0R00V
85	6	R74, R75, R76, R77, R78, R79	100, 0.1W, 1/10W, ±1%	CHIP RESISTOR SMD 0603, 0603 (1608 Metric)		
86	6	R80, R84, R89, R92, R99, R100	100, 0.1W, 1/10W, ±1%	RES SMD 0603, 0603 (1608 Metric)	Yageo	RC0603FR-07100RP
87	2	R107, R108	0.1W, 1/10W, ±1%	CHIP RESISTOR SMD 0603 (not mounted), 0603 (1608 Metric)	-	-
88	5	S1, S2, S3, S7, S54	2 pin	CONN HEADER VERT T/H	Amphenol FCI	77311-118-02LF
89	10	TP2, TP3, TP9, TP15, TP19, TP21, TP25, TP27, TP31, TP33	5000	TEST POINT PC MINI .040"D RED, 0.100" Dia x 0.180" L (2.54mm x 4.57mm)	Keystone Electronics	5000
90	18	TP17, TP20, TP23, TP26, TP29, TP32, TP34, TP35, TP36, TP37, TP38, TP39, TP40, TPCK1, TPCS1, TPMI1, TPMO1, TPSD1	5001	TEST POINT PC MINI .040"D BLACK, 0.100" Dia x 0.180" L (2.54mm x 4.57mm)	Keystone Electronics	5001
91	1	U1	400KHz	IC OPAMP ZRO-DRFT SOT23-5, SC-74A, SOT-753	ST	TSZ121IYLT
92	1	U3	12VWM, 21VC	TVS DIODE SOT23-3L, TO-236-3, SC-59, SOT-23-3	ST	ESDA14V2LY
93	1	U4	5.2VWM, 16VC	TVS DIODE SOT23-3L, TO-236-3, SC-59, SOT-23-3	ST	ESDA6V1LY

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
94	1	U5	3VWM, 19VC	TVS DIODE SOT23-3L, TO-236-3, SC-59, SOT-23-3	ST	ESDA5V3LY
95	1	U6	-	IC GATE AND 4CH 2-INP, 14-TSSOP (0.173", 4.40mm Width)	Fairchild/ON Semiconductor	MM74HC08MTCX
96	1	U7	-	IC COMP QUAD LOW PWR, 14-SOIC (0.154", 3.90mm Width)	ST	LM2901HYDT
97	1	U8	-	Automotive Driver 3 phase BLDC	ST	L9907

11.4 Current sensor board bill of materials

Table 13. Current sensor board bill of materials

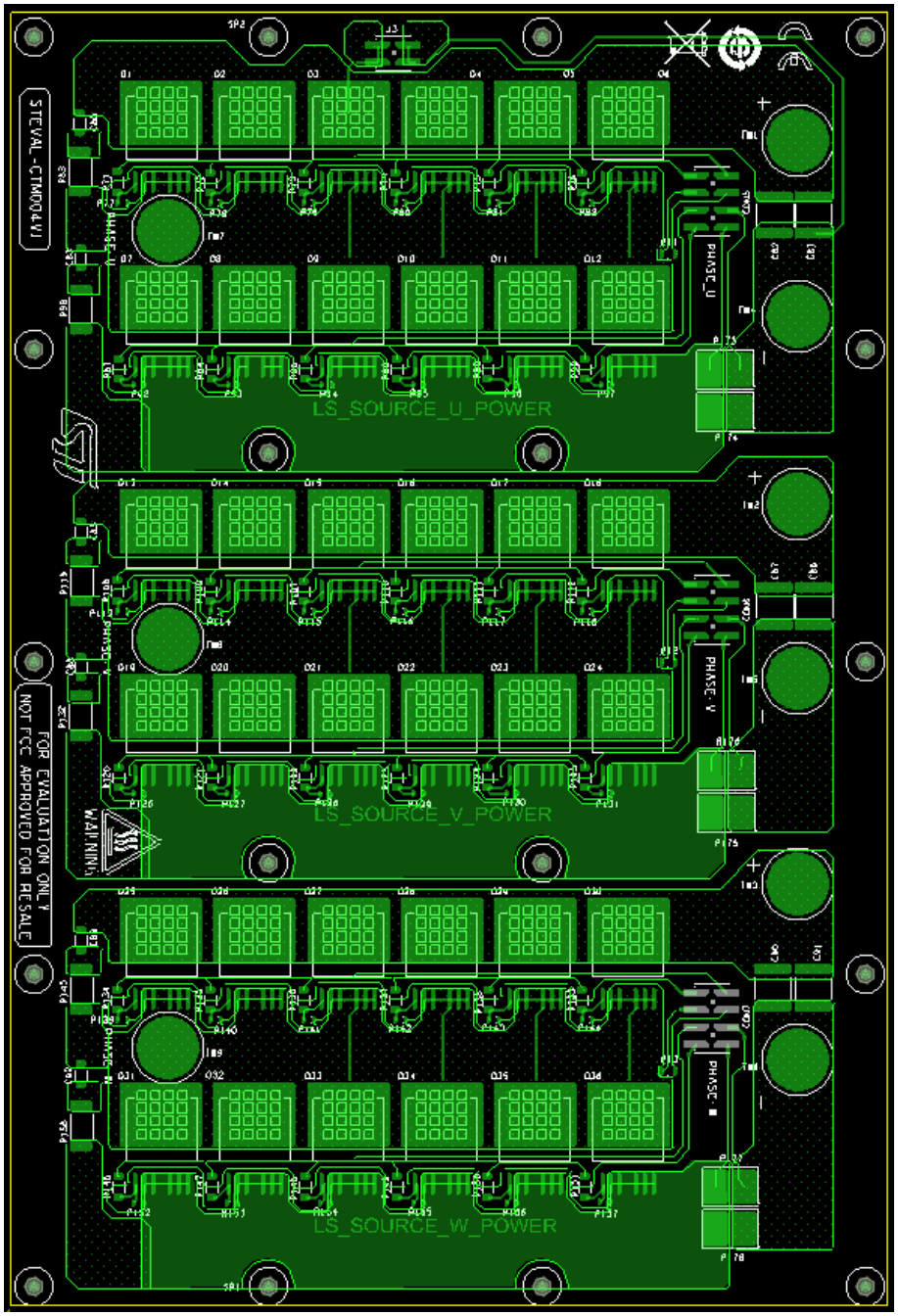
Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	4	C1, C4, C7, C9	4.7nF, 25V, ±10%	CAP CER X7R, SMC 0603	ANY	-
2	8	C2, C3, C5, C6, C8, C10, C11, C12	47nF, 25V, ±10	CAP CER X7R, SMC 0603	ANY	-
3	2	ICS1, ICS2	Current Sensing, 200A	CURRENT SENSOR HALL, (NOT MOUNTED)	LEM	HTFS 200-P
4	1	ICS3	Current Sensing, 200A	CURRENT SENSOR HALL 200A	LEM	HTFS 200-P
5	1	ICS4	Current Sensing, 200A	CURRENT SENSOR HALL 200A	LEM	HTFS 200-P
6	1	J1	Connector male 10X2 pitch 2,54mm	Connector male 10X2 pitch 2,54mm, ampmode10	Wurth_Elektronik	61201021621
7	4	R1, R3, R5, R7	3.6K, 1/10W, ±1%	RES SMD 3.6KΩ 1% 1/10W 0603, SMR 0603	ANY	-
8	4	R2, R4, R6, R8	1.8K, 1/10W, ±1%	RES SMD 1.8KΩ 1% 1/10W 0603, SMR 0603	ANY	-
9	1	Flat Cable	10 Position 0.500' (152.40mm, 6.00")	Cable Assembly Rectangular Socket to Socket	TE Connectivity	A3AAH-1006G
10	4	S1, S2, S3, S4	2X2.54mm	Strip line male + Jumper, siptm2002	ANY	-
11	4	screw M3x12mm	M3x12mm	fixed in two point each current sensor	ANY	-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
12	4	Nuts M3	Nuts M3	fixed in two point each current sensor	ANY	-

12 PCB layouts

The STEVAL-CTM004V1 power board is built on an IMS mono layer with a copper thickness of 175 µm. The board is designed for optimal thermal management under high current conditions.

Figure 20. STEVAL-CTM004V1 power board layout



Revision history

Table 14. **Document revision history**

Date	Version	Changes
08-Jan-2020	1	Initial release.

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