How to use the 300 W digitally controlled high voltage AC input HB LED driver

Introduction

The STEVAL-LLL009V1 digitally controlled 300 W power supply consists of power factor correction (PFC) and DC-DC power (half-bridge LCC resonant converter) stages, with secondary side synchronous rectification. An STM32F334 microcontroller implements digital DC-DC and output synchronous rectification control, while the PFC is driven in transition mode by the L6562AT controller. The system supports constant voltage (CV) and constant current (CC) operation.

MDmesh K5 and MDmesh DK5 Power MOSFETs are used in the PFC and LCC half-bridge, respectively, to ensure maximum efficiency, while the STripFET F7 Power MOSFET is employed to reduce conduction losses in the synchronous rectification stage on the secondary side.

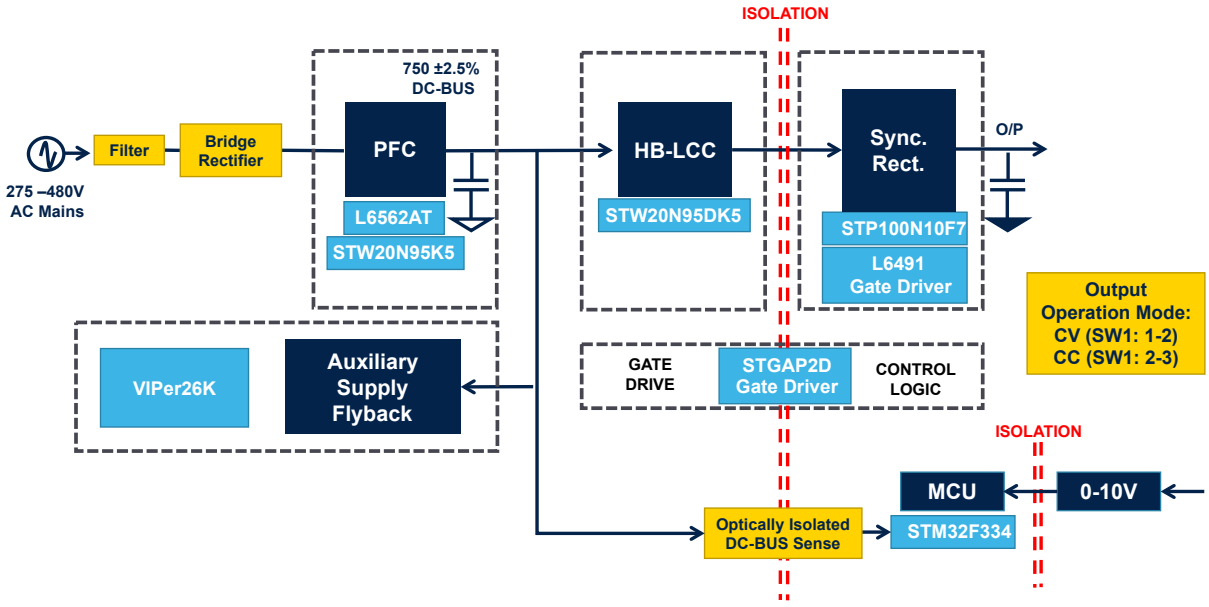
Both the primary and secondary sections are supplied by an off-line flyback circuit based on VIPer267KDTR which provides regulated voltages to the control board, the gate driver ICs and the signal conditioning circuits.

Formal testing and measurement results confirm the ability of performance ST power products combined with comprehensive digital control to deliver high efficiency, power factor near unity, and low THD across wide input voltage and load conditions.

Figure 1. STEVAL-LLL009V1 evaluation kit

1 STEVAL-LLL009V1 overview

Figure 2. **STEVAL-LLL009V1 block diagram**



The STEVAL-LLL009V1 evaluation kit is a digital power supply which convert 270 V to 480 V AC mains input voltage to 48 V DC, 6.25 A maximum current in a constant voltage (CV) mode while in constant current (CC) mode it can delivers 6.25 A of current with output voltage ranging from 36 - 48V. The evaluation kit can either be configured in CV mode or CC mode by using the toggle switch SW1 mounted on the Power Board (as explained in Table 4).

The DC-DC power stage is referred to the primary ground while the microcontroller is referred to the secondary ground. Thanks to STGAP2DM galvanically isolated half bridge gate driver which drives the DC-DC power stage MOSFETs with the control signal coming from the microcontroller.

A PFC voltage sensing daughter board with isolated amplifier provides feedback information regarding the PFC output voltage that becomes the input voltage for the DC-DC power stage.

The auxiliary power supply supplies the control board, drivers and signal conditioning circuitry. The presence of the input voltage is signaled by red LED D9 on the main power board, red LED D22 on the Daughter board and the green LED D1 on the control board.

The system remains in input undervoltage state between 100 and 200 V_{AC}, during which you can safely reprogram the microcontroller using IAR Embedded Workbench for ARM ver.8.42 or higher, or any other appropriate programming tool. When the input voltage is raised to the required 270 to 480 V_{AC} input voltage range, the converter becomes operational after a default wait time of 1250 ms.

Table 1. **Converter characteristics**

Parameter	Value / Range / Comments
Input AC voltage	270 to 480 V
PFC Output Voltage	725 ±2.5%
PFC Operating Mode	Transition Mode
Power factor at full load (270-480 V_{AC})	> 0.95
Power factor over input voltage span 270V-480 V_{AC}	> 0.9 for load > 33% max. load
THD at full load (270V-480 V_{AC})	< 10%

Parameter	Value / Range / Comments
THD over input voltage range 270-480 V_{AC}	< 20% for load > 25% max. load
Evaluation kit peak efficiency at maximum load	> 93.5%
Maximum Output power	300 W
Output Configuration	Constant Voltage (CV) or Constant Current (CC)
Output: Constant Voltage (CV) Mode	48.5 V ±1% with maximum of 6.25 A
Output: Constant Current (CC) Mode	6.25A ±2.5% with output voltage ranging from 36 to 48 V
DC-DC converter topology	Half bridge LCC resonant converter
Half bridge LCC resonant converter: closed loop switching frequency	90 to 275 kHz
Half bridge LCC resonant converter: Start-up switching frequency	280 kHz
Synchronous rectification topology	Full bridge
HF transformer isolation	3 kV
Cooling	Natural air
Dimming method	Analog dimming
Dimming control	0-10 V
Default brightness level	100%
Dimming resolution	1%

1.1 Startup and safety mechanisms

A ramp-up procedure at startup to avoid high current spikes is implemented by driving the high voltage MOSFETs on the main power board at the maximum switching frequency of 280 kHz, which gradually decreases over 1500 ms to the minimum 90 kHz.

If the output voltage reaches the reference value during ramp-up, the PI control loop is closed and the system commences normal operation. If the ramp-up time expires before the nominal voltage is reached, a startup failure is triggered and PWMs are stopped.

The evaluation kit includes the following protections:

- DC-DC Converter Input (PFC Output) overvoltage and undervoltage.
- Output overvoltage and undervoltage.
- Fast overcurrent.
- Output overcurrent.
- Startup failure.

Each fault is identified with a code and the system fault variable is then given by an OR operation of the codes of all the faults that have occurred. When a fault occurs, the PWM signals are stopped and the microcontroller sets the converter to the FAULT state. In this state, the blue status LED D2 is OFF and the red fault LED D3 blinks a certain number of times to indicate the type of fault that occurred. All blinking sequences are repeated after three seconds.

Table 2. Control board LED indications

Reference Number	Color	Indication
D1	GREEN	ON
D2	BLUE	OFF: system is OFF. Slow blinking: system is idle. Rapid blinking: system is ramping up. ON: system is operating normally.
D3	RED	Voltage-related faults: t_{ON} = 500 ms, t_{OFF} = 500 ms Other faults: t_{ON} = 250 ms, t_{OFF} = 250 ms

Input undervoltage and overvoltage faults are automatically cleared when the input voltage returns to within the correct operating range. To clear other faults, you must disconnect the input voltage and wait until the unit shuts down.

Table 3. STEVAL-LLL009V1 fault codes

Error Name	Code	Condition	Number of blinks	Blinking speed	Recoverable
DCDC_NO_ERROR	0x0000	-	-	-	-
DCDC_OUT_OVER_VOLT_ERROR	0x0001	V_{out} > 56 V	3	slow	N
DCDC_OUT_UNDER_VOLT_ERROR	0x0002	V_{out} < 35 V	2	slow	N
DCDC_IN_OVER_VOLT_ERROR	0x0004	V_{in} > 775 V	4	slow	Y
DCDC_IN_UNDER_VOLT_ERROR	0x0008	V_{in} < 575 V	5	slow	Y
DCDC_OVER_CURRENT_ERROR	0x0010	$I_{res(peak)}$ > 2 A	2	fast	N
DCDC_OUT_OVER_CURRENT_ERROR	0x0020	I_{out} > 7.5 A	3	fast	N
DCDC_STARTUP_FAILED_ERROR	0x0080	V_{out} < 47 V T_{ramp} > 1500 ms	4	fast	N

2 STEVAL-LLL009V1 kit components

The STEVAL-LLL009V1 kit consists of the following evaluation boards:

1. Main power board
2. PFC output voltage sensing daughter board
3. Microcontroller control board
4. Programming interface with ST-LINK board

Note: Depending on the requirement, the position of switch SW1 on the main power board should be set before powering up the evaluation kit.

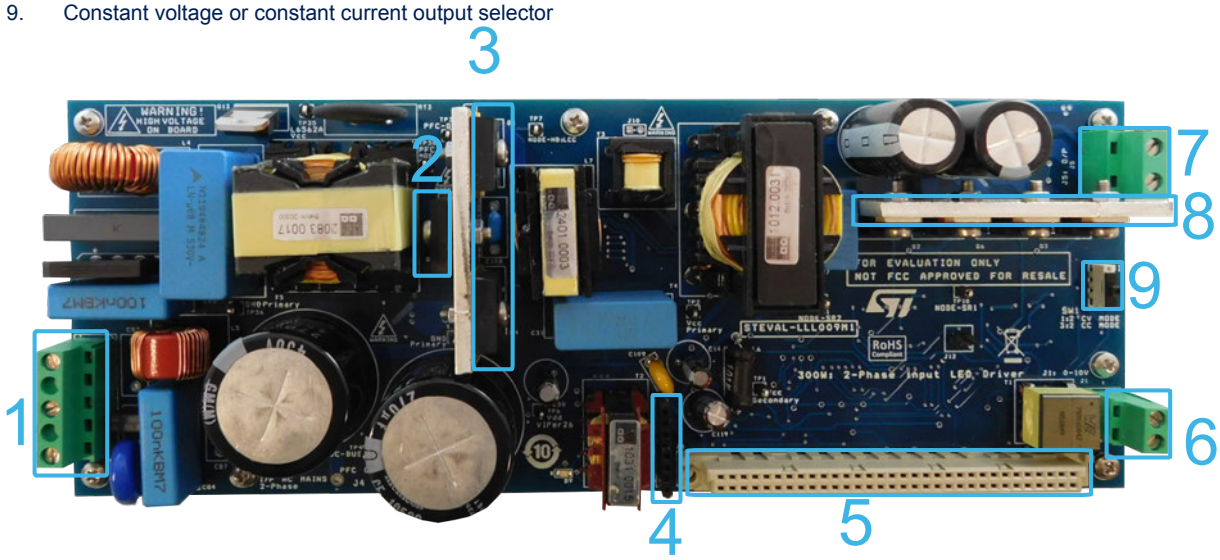
Table 4. Switch SW1 position for output configuration

SW1 Position	Ouput configuration
1:2	CONSTANT VOLTAGE (CV)
2:3	CONSTANT CURRENT (CC)

2.1 Main power board

Figure 3. Power board functional areas

1. Input connector
2. PFC MDmesh K5 Power MOSFET
3. Half-bridge LLC MDmesh DK5 Power MOSFETs
4. PFC output voltage sensing daughter board connector
5. Control board connector
6. 0-10V input
7. Output connector
8. Full-bridge SR STripFET F7 Power MOSFETs
9. Constant voltage or constant current output selector



2.1.1 Power factor correction (PFC)

The PFC section ensures the system complies with standard EN61000-3-2 (harmonic current distortion) for lighting equipment at an input active power above 25 W. It is implemented with an L6562ATD PFC controller, which drives the STW20N95K5 MDmesh K5 Power MOSFET in transition mode.

RELATED LINKS

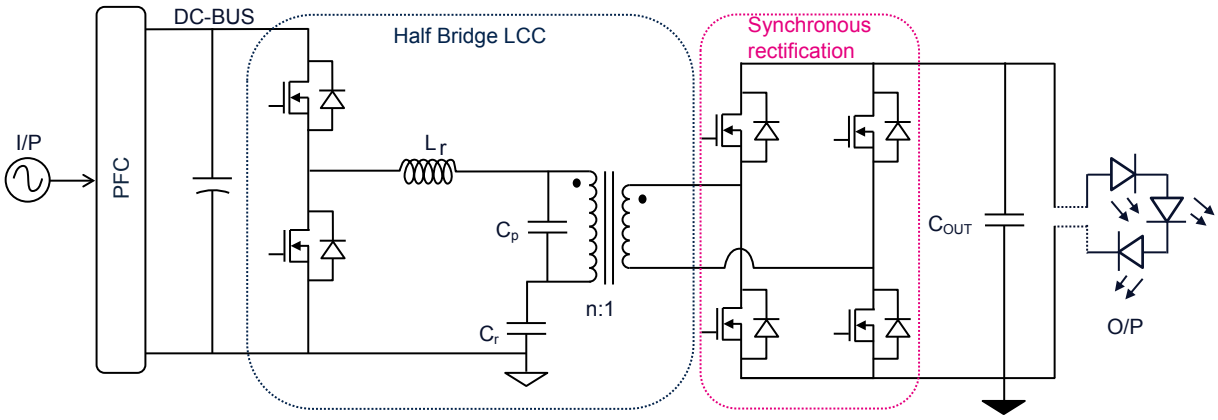
For more information in PFC operation in transition mode, see application note AN2761: "Solution for designing a transition mode PFC pre-regulator with the L6562A"

2.1.2 DC-DC power stage based on half-bridge LCC topology

The DC-DC power stage is implemented in a half-bridge LCC resonant topology to allow a wide input voltage range for various LED lighting applications.

As the parallel capacitor C_p is connected to the secondary of the transformer, the parasitic capacitances of the synchronous rectification and the leakage inductance of the transformer become part of the LCC resonant tank consisting of capacitor C_r, capacitor C_p (placed in secondary), inductor L_r and the isolation transformer.

Figure 4. Half-bridge LCC resonant converter with synchronous rectification



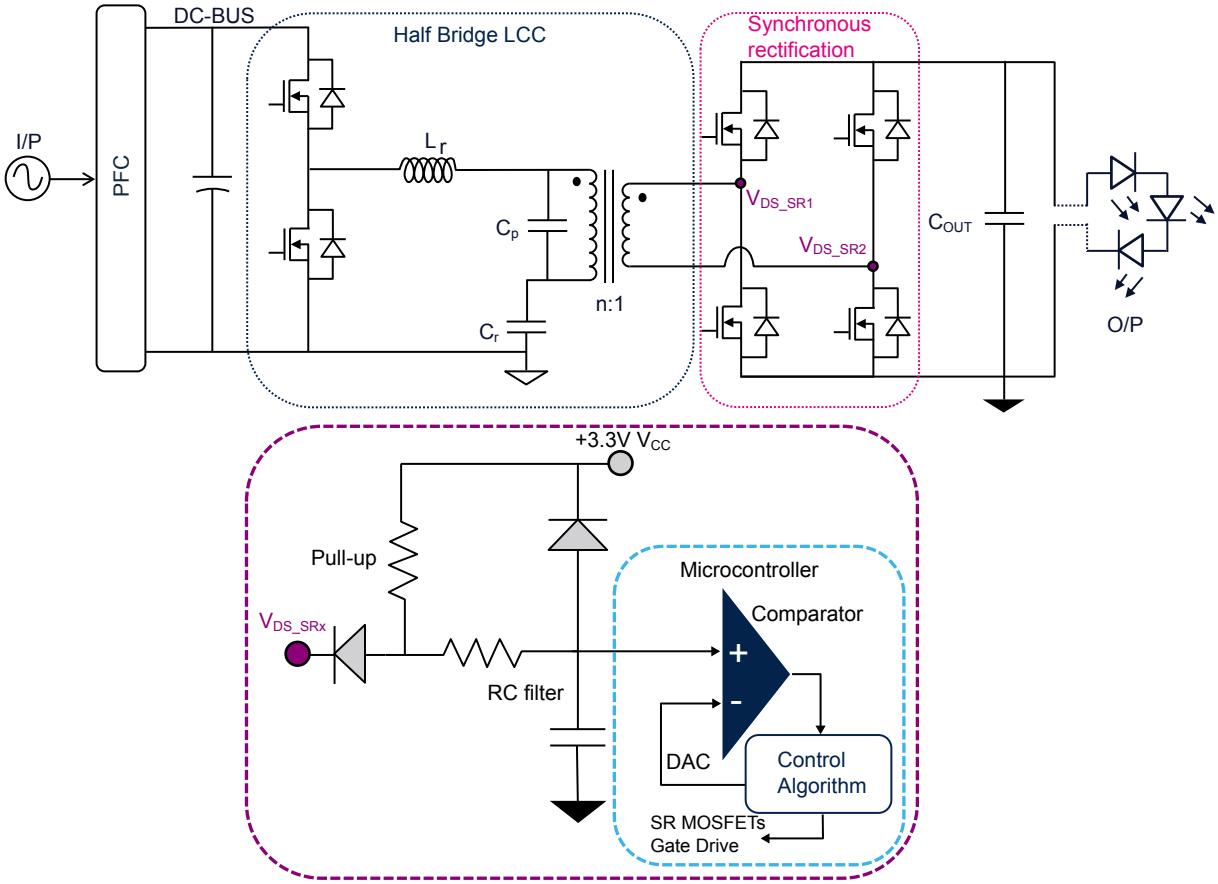
The PFC output voltage charges the bulk capacitor to generate a stable DC-BUS, and the MOSFETs in half-bridge configuration generate a square voltage waveform between GND and DC-BUS. The square voltage is applied to the LCC resonant tank.

The high voltage MDmesh DK5 power MOSFETs in the half-bridge of the LCC resonant converter are driven at 50% PWM duty cycle and an appropriate dead time. As the approximately sinusoidal resonant tank current always lags the voltage waveform (inductive region), the MOSFET output capacitance has time to discharge during the dead time before the next turn-on and achieve zero voltage switching (ZVS). PWM switching frequency control is used to regulate the voltage gain of the resonant tank and keep the converter in the inductive region. This allows ZVS over the entire operating range and reduced switching losses.

2.1.3 Synchronous rectification (SR)

The voltage waveform on the secondary side of the transformer is rectified by the synchronous rectifier consisting of STripFET F7 series MOSFETs in full-bridge configuration, digitally controlled by the STM32F334 MCU based on MOSFET Drain-Source voltage (V_{DS_SR1} and V_{DS_SR2}) feedback.

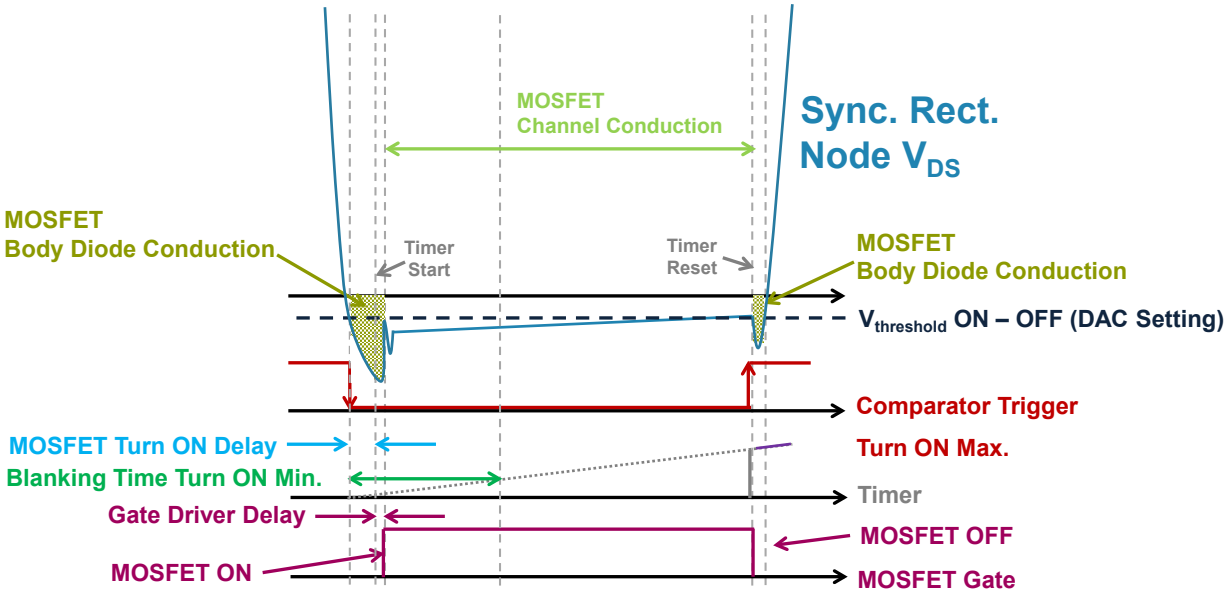
Figure 5. **Synchronous rectification with V_{DS} sensing**



The sensing network consists of a fast diode and a pull-up resistor connected to the microcontroller (MCU) supply voltage. When the SR MOSFET drain voltage is above the MCU V_{CC}, the diode is reverse biased and the sensed voltage is pulled up to V_{CC}. When drain voltage is below V_{CC}, the diode is forward biased and the sensed voltage is equal to this voltage plus the voltage drop of the diode that gives a positive shift. The current during positive biasing is limited by the pull-up resistor.

Initially, the body diodes of SR MOSFETs start conducting and V_{DS} is sensed. When the voltage (V_{DS}) falls below the set threshold ($V_{threshold\ ON\ -\ OFF}$ set by MCU DAC peripheral), the comparator output (falling edge) triggers the MCU TIMER peripheral in one pulse non-retriggerable mode.

Figure 6. **Synchronous rectification digital control algorithm**



The MCU TIMER peripheral initiates a pulse to the corresponding synchronous rectification gate driver, which is sustained for a minimum time, $T_{ON\ min}$.

When the voltage (V_{DS}) increases above the set threshold ($V_{threshold\ ON\ -\ OFF}$ set by MCU DAC peripheral), the comparator output (rising edge) resets the MCU TIMER peripherals and the pulse is stopped at the corresponding synchronous rectification gate driver.

The MCU continuously monitors the DC-DC power stage (HB-LCC) frequency and the output current. If the frequency exceeds the set threshold with hysteresis or the output current falls below set threshold with hysteresis, the MCU disables the gate drive to the synchronous rectification stage. The synchronous rectification gate drives are enabled when the conditions return inside the threshold settings.

Depending on the DC-DC power stage (HB-LCC) operating frequency, the threshold ($V_{threshold\ ON\ -\ OFF}$) is adjusted from the look-up table stored in the MCU.

RELATED LINKS

For more information on synchronous rectification, see application note AN4674: "SRK2001 adaptive synchronous rectification controller for LLC resonant converter evaluation board family"

2.1.4 Analog dimming control

The evaluation kit implements analog dimming with 1% resolution via a 0-10V input to control the amount of current in the LEDs.

Note: The 0-10V dimming control is only available when the evaluation kit operates in constant current (CC) mode.

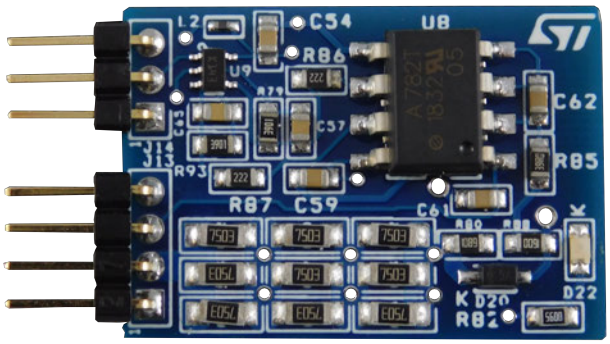
Table 5. **Comparison of digital dimming and analog dimming**

Digital dimming	Analog dimming
No color shift as LED current remains the same	Color shift as LED current changes
Possible current inrush problems	No inrush current
Very linear change in brightness	Brightness linearity not as good
Lower optical to electrical efficiency	Higher optical to electrical efficiency
Frequency limitations and issues	No frequency issues

2.2 PFC Output voltage sensing daughter board

The PFC output voltage sensing board ensures input undervoltage and overvoltage protection for the DC-DC power (HB-LCC) converter stage on the power board.

Figure 7. PFC output voltage sensing daughter board



The output of the isolated amplifier is sensed at the ADC peripheral of the microcontroller, and if the sensed value of the DC-BUS (PFC output voltage) voltage breaches the set operating range, the microcontroller interrupts PWM modulation and sets the converter to the FAULT state, which is signaled by the blinking red LED D3 on the control board.

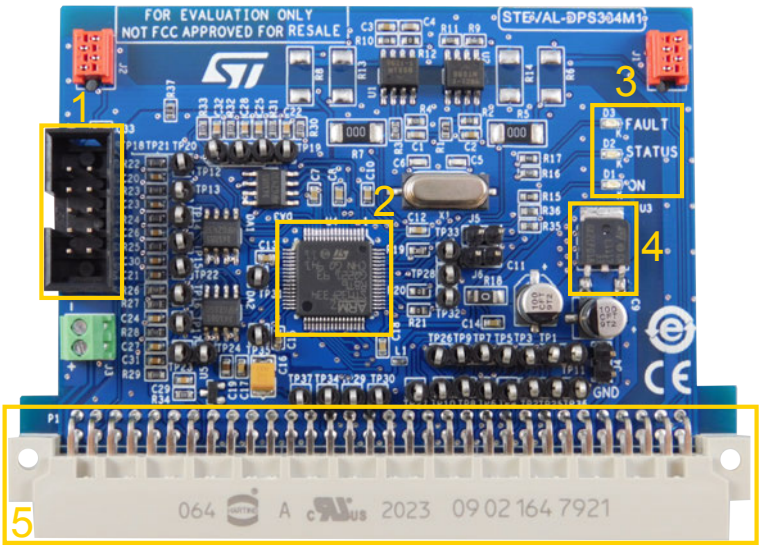
The DC-DC power stage input undervoltage and overvoltage faults are automatically cleared when the input voltage returns to the correct operating range.

2.3 Microcontroller control board

The digital control board is based on the STM32F334R8 microcontroller and is connected to the power board through a standard 64-pin DIN 41612 connector with a specific pinout for DSMPS applications.

Figure 8. STEVAL-DPS334M1 digital control board

1. Debugger connector
2. STM32F334 microcontroller
3. Indication LEDs
4. 3.3. V LDO
5. Control board connector



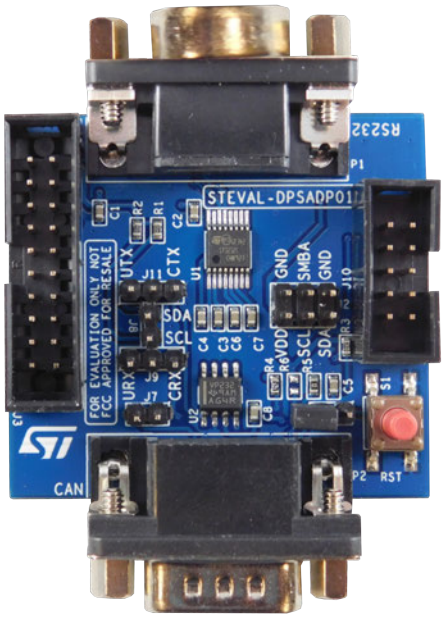
The MCU embeds a high resolution timer peripheral (HRTIM) designed to drive power conversion systems. It can drive the power stages with pulse width modulations (PWM) at a resolution of 217 ps, which allows very fine frequency adjustment steps and high precision output voltage regulation.

The control board includes an LDO regulator to supply 3.3 V to the microcontroller, two optocouplers for isolated bidirectional UART communication, RC filters with protection diodes for each analog channel, and three LEDs to signal the presence of a supply voltage, the state of the converter and any faults.

2.4 Programming interface with ST-LINK board

The adapter board provides various communication interface options for the microcontroller unit on the control board. The adapter board interfaces with the control board through a 10-pin connector that provides the SWD interface for debugging and USART communication for user interface.

Figure 9. STEVAL-DPSADP01 adapter board



The adapter board has a 20-pin JTAG connector to allow programming and debugging communication between a standard debugger (ST-LINK, J-Link, etc.) and the microcontroller on the control board.

The USART interface of the adapter board can be set to RS-232, CAN or SMBus through appropriate jumper configuration.

The adapter board also has embedded transceivers for the RS-232 (through DB9 male connector) and CAN (through DB9 female connector) protocols.

The adapter board also has a reset button and a system management bus (SMBus) connector.

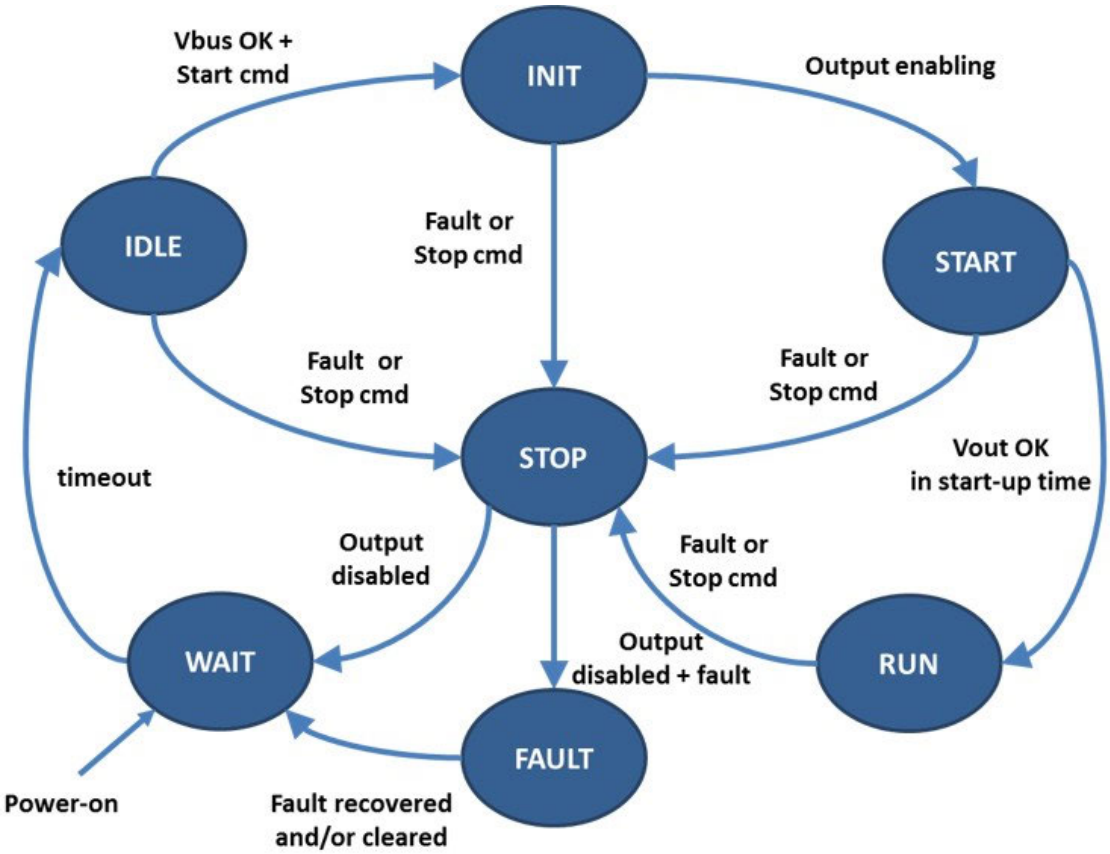
3 Firmware implementation

The STSW-LLL009FW firmware on the STM32F334 MCU controls the HB-LCC resonant converter, synchronous rectification, dimming and safety mechanisms in the evaluation kit.

Some of the features of the firmware include:

- 50 kHz PI voltage control loop
- PWMs generation with 217 ps resolution (HRTIM)
- Startup with decreasing linear frequency to avoid current spikes
- Startup protection on mismatch of output voltage
- Adaptive SR based on embedded comparators and voltage sensing
- Automatic SR activation according to output load
- Fast overcurrent protection with internal comparator
- Analog watchdog on output voltage for overvoltage protection
- Open loop mode

Figure 10. STSW-LLL009FW firmware logic



4 STEVAL-LLL009V1 layout

Figure 11. **STEVAL-LLL009V1 top layer silk screen and drill**

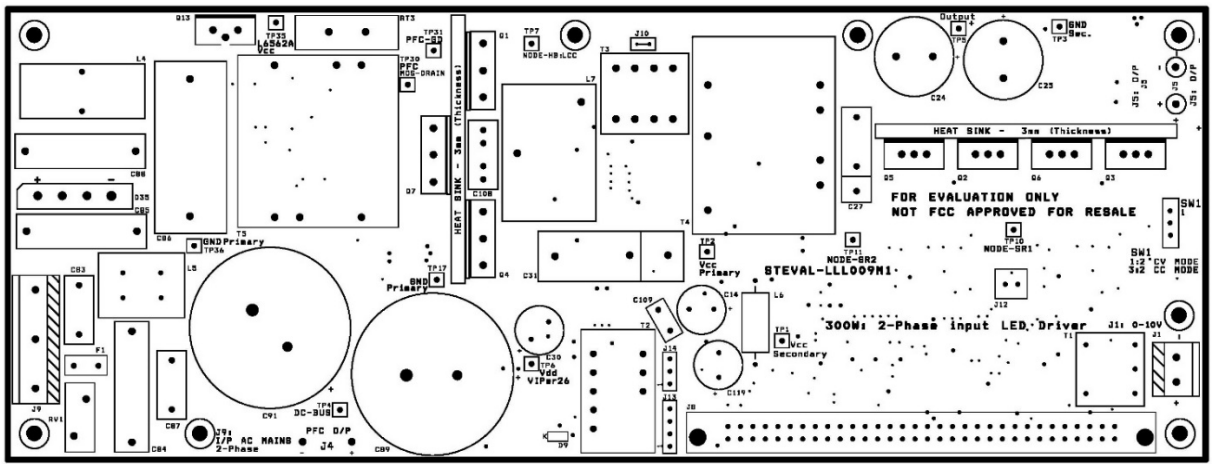


Figure 12. **STEVAL-LLL009V1 top layer**

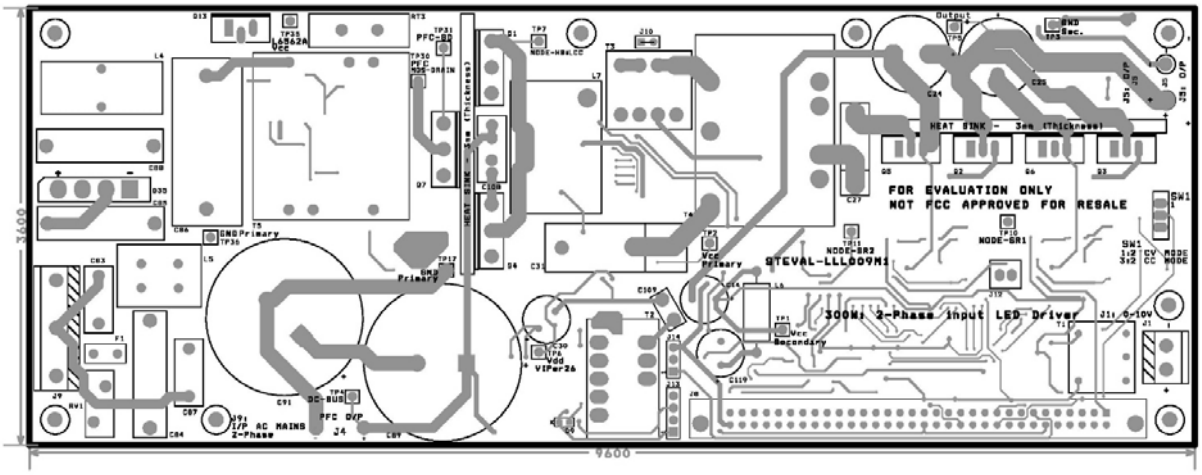


Figure 13. **STEVAL-LLL009V1 bottom layer silk screen and drill**

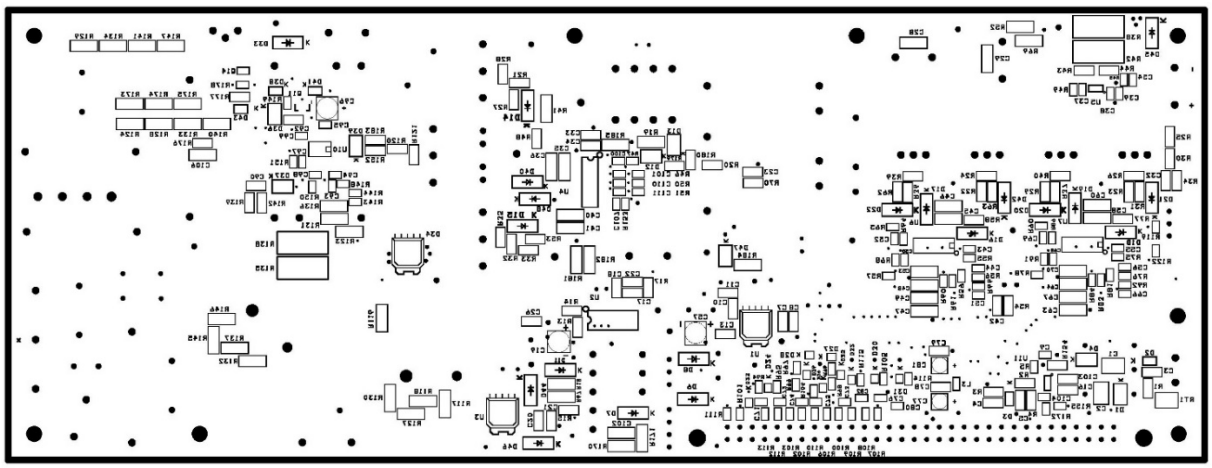
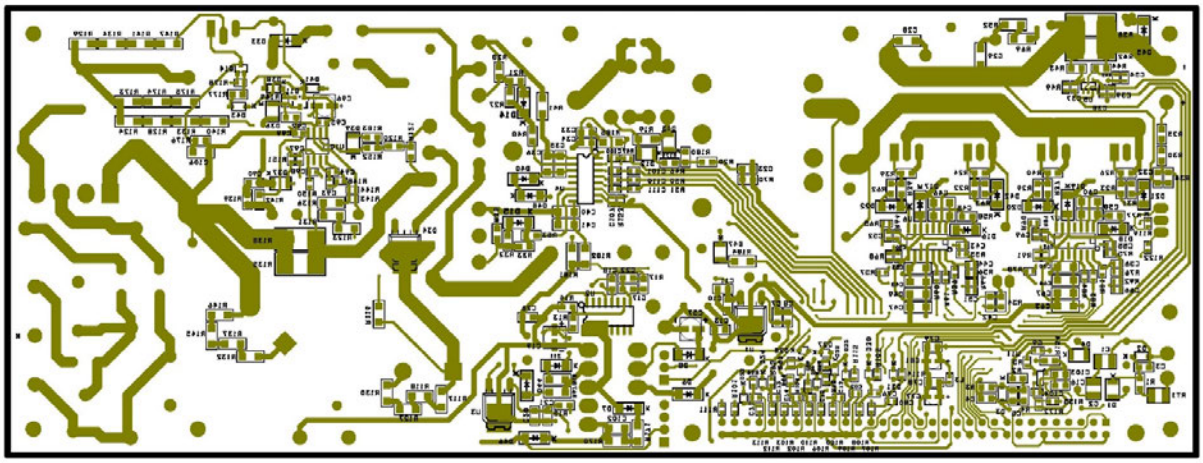


Figure 14. **STEVAL-LLL009V1 bottom layer**



5 Schematic diagrams

Figure 15. Power board - PFC

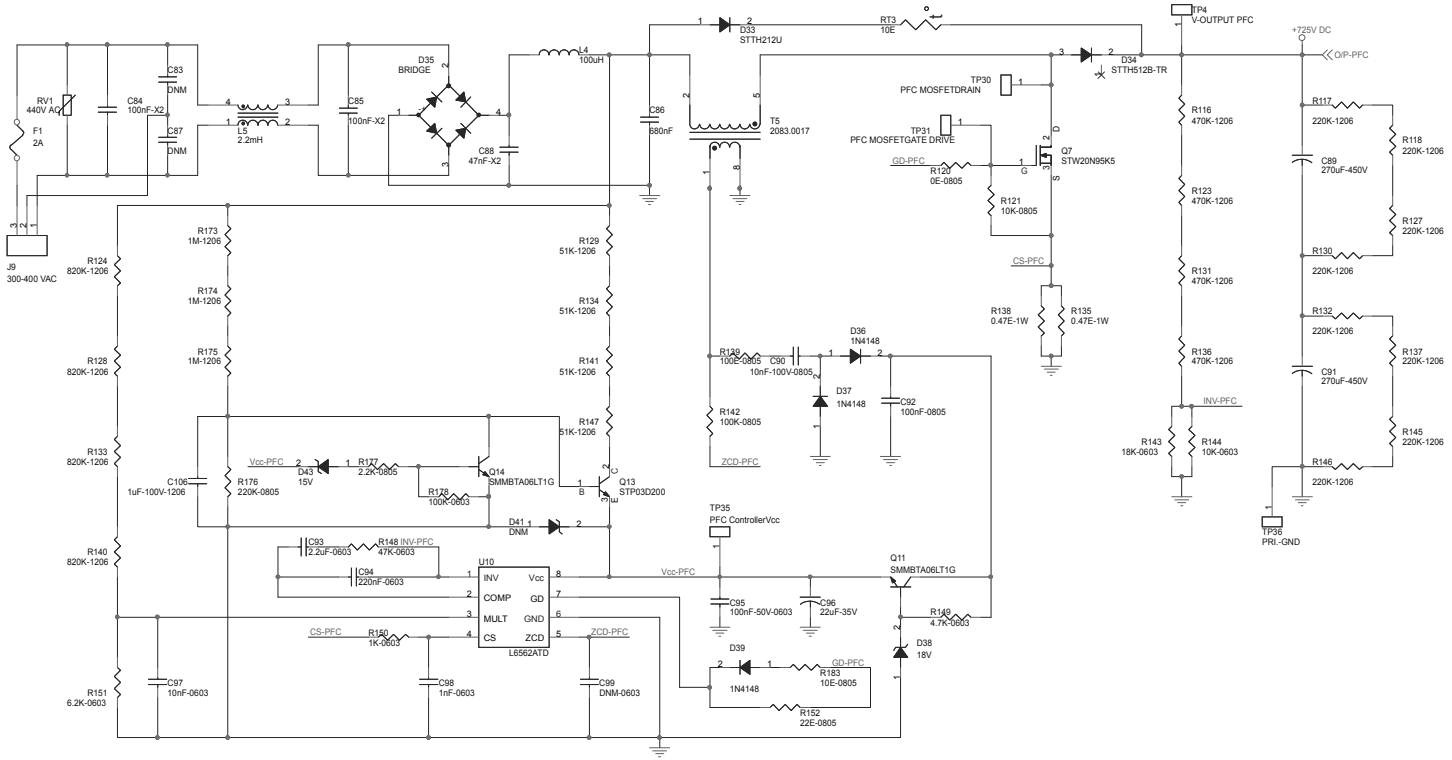


Figure 16. Power board - DC-DC converter

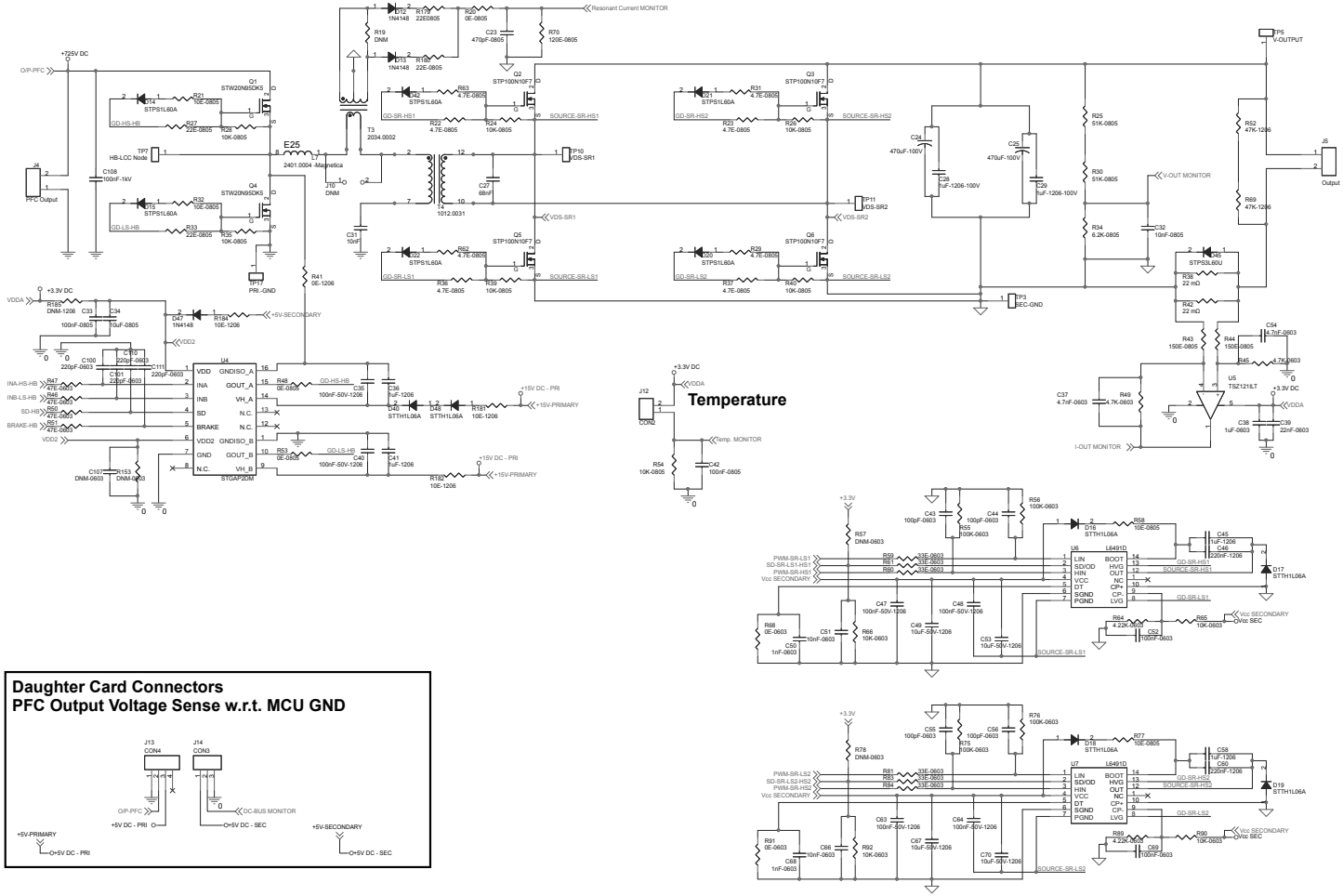


Figure 17. Power board - Aux power supply

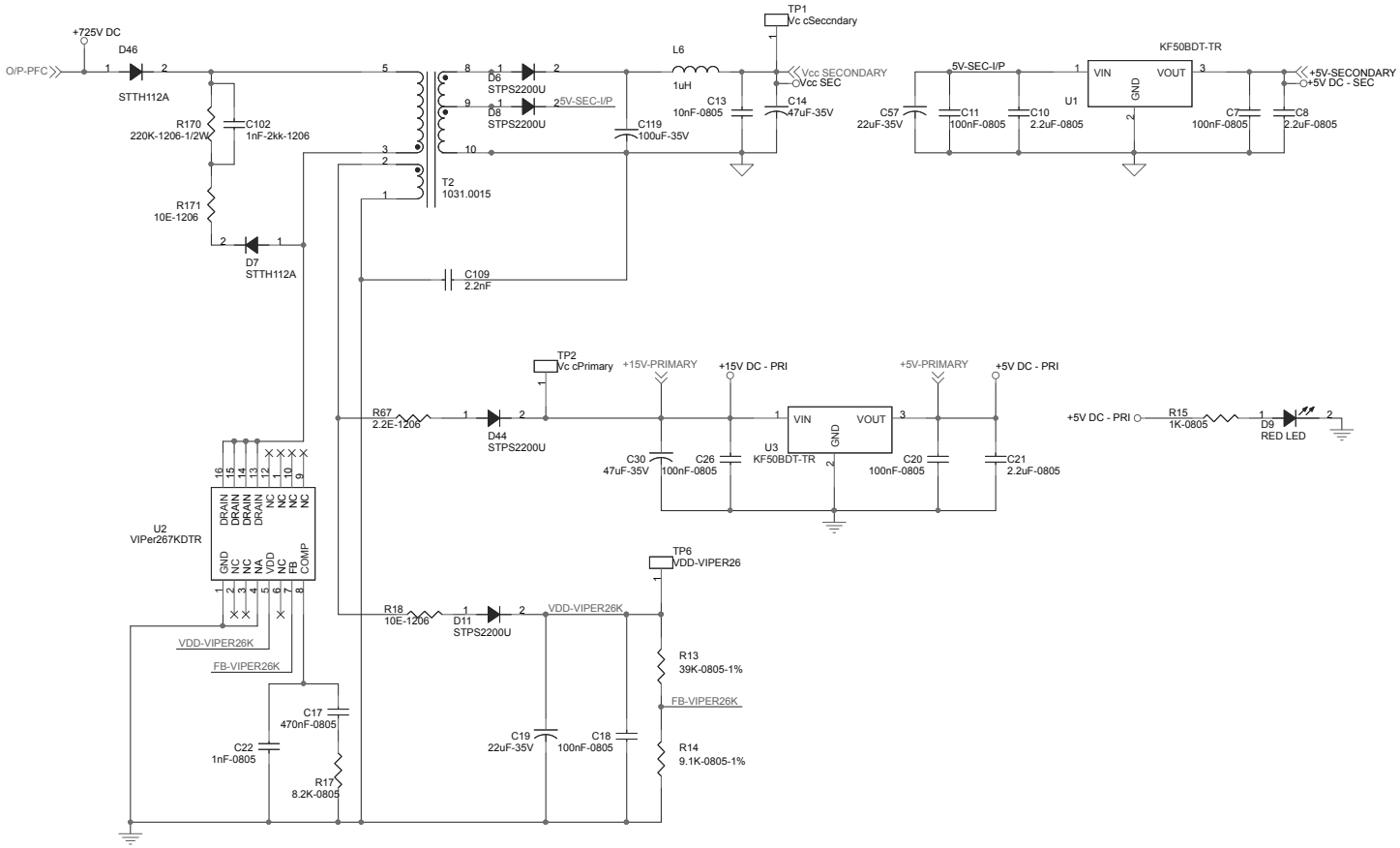
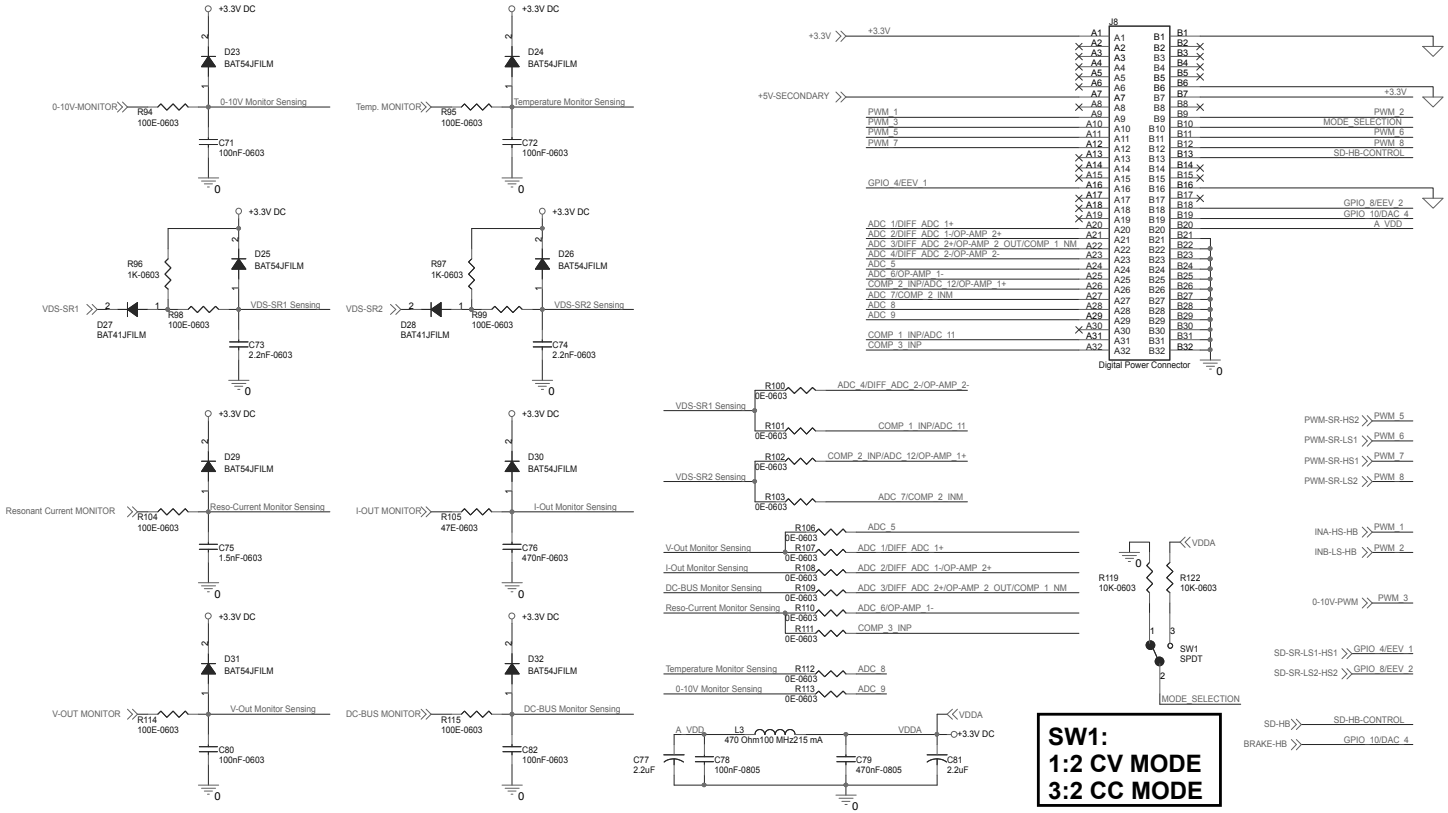


Figure 18. Power board - MCU connector



Note: The microcontroller ground is referenced to the power converter secondary side. The secondary side ground of the power converter and the ground denoted by 0 are combined on the microcontroller daughter card.

The analog and control signals ground are denoted by 0 to get star ground connection and reduce switching noise interference.

Figure 19. Daughter board - PFC voltage read with isolation

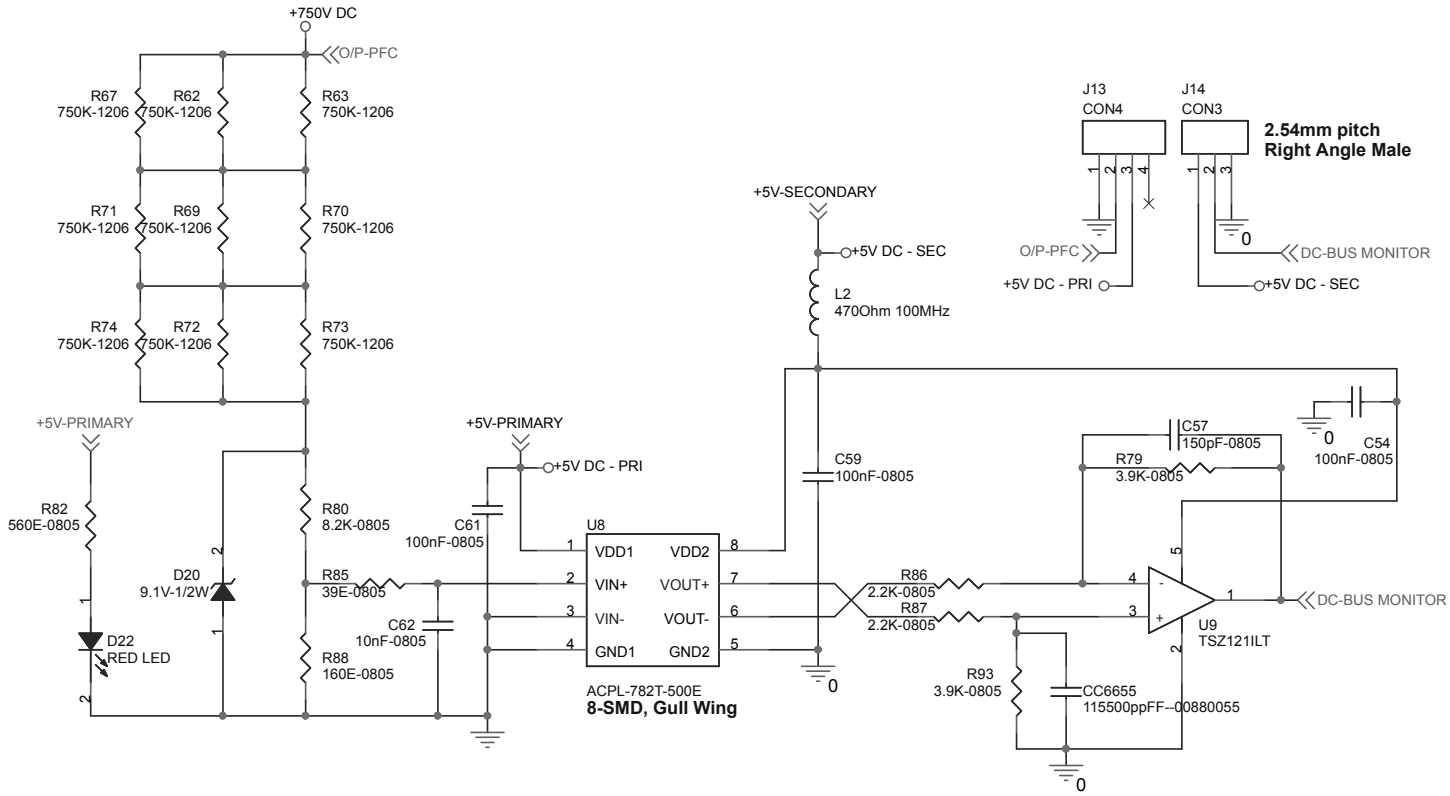
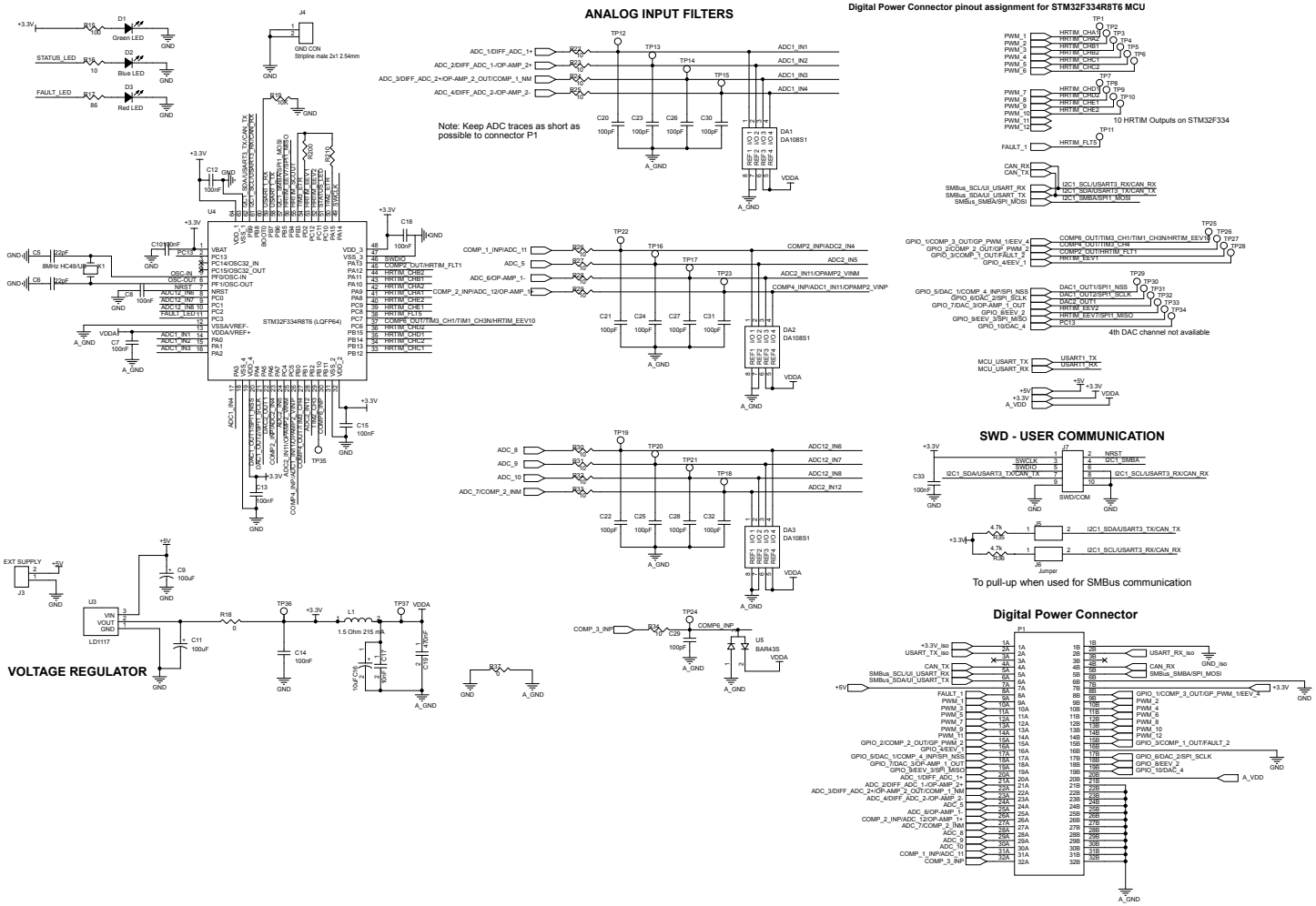


Figure 20. Control board - MCU and connector schematic



Note: The microcontroller ground is referenced to the power converter secondary side.

On the microcontroller schematic, the ground symbol is denoted by GND and A_GND (Analog Signal Ground). Different symbols have been used for better PCB layout. Both GND and A_GND are combined on the microcontroller at R37.

Figure 21. Control board - opto-isolated communication

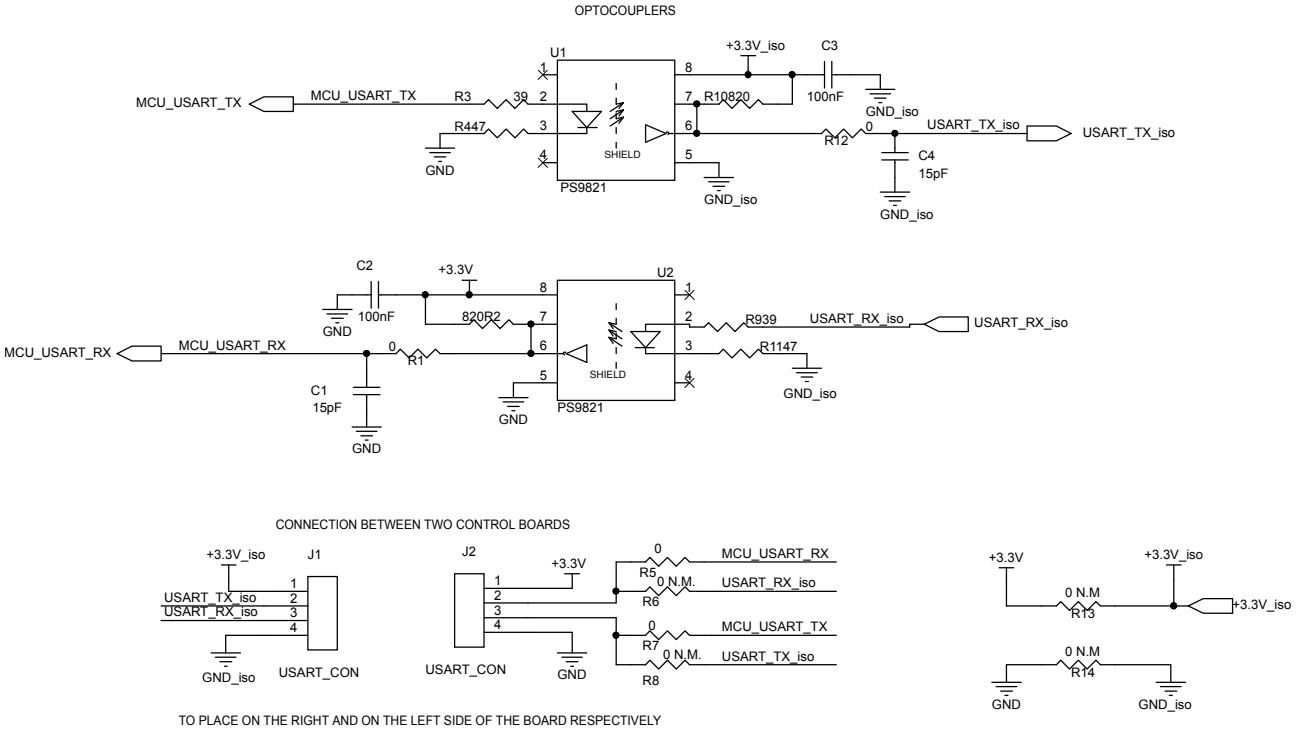
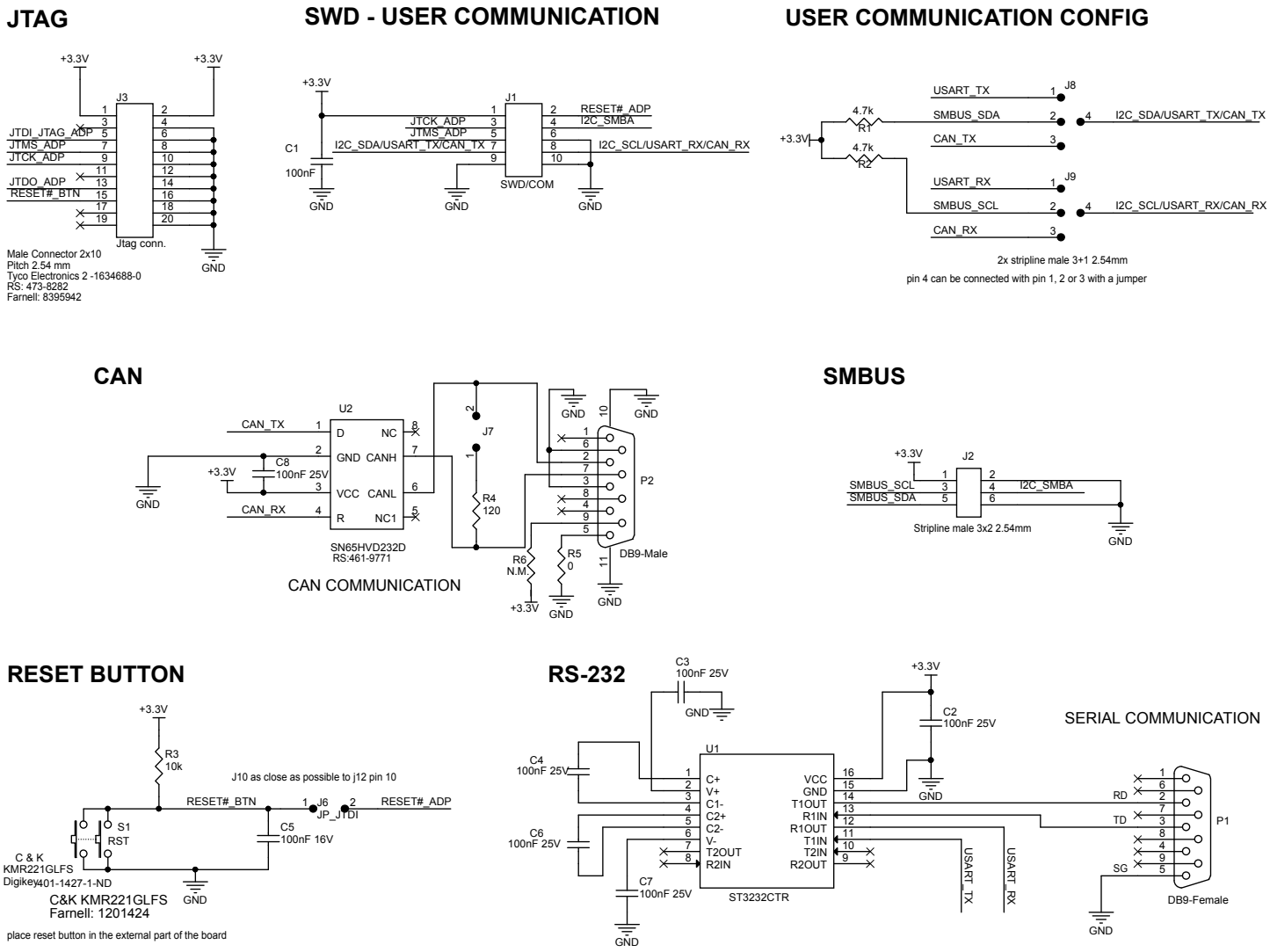


Figure 22. **Adapter board**



6 Bill of materials

6.1 Power board

Table 6. Power board bill of materials

This board is marked STEVAL-LLL009M1 and can only be ordered with the STEVAL-LLL009V1 kit

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	2	U1, U3	5V, 500mA	Low drop voltage regulators, DPAK	ST	KF50BD-TR
2	1	U2	1050V	High voltage converter, SO16N	ST	VIPER267KDTR
3	1	U4	4A	Isolated Half-Bridge gate driver, SO-16	ST	STGAP2DMTR
4	1	U5	-	Operational amplifier, SOT23-5	ST	TSZ121ILT
5	2	U6, U7	4A	High voltage high and low-side gate driver, SO-14	ST	L6491DTR
6	1	U10	-	Transition-mode PFC controller, SO-8	ST	L6562ATDTR
7	1	U11	1A	Low-side gate driver, SOT23-5	ST	PM8841D
8	2	Q1, Q4	950V	N-channel MOSFET, TO-247	ST	STW20N95DK5
9	4	Q2, Q3, Q5, Q6	100V	N-channel MOSFET, TO-220	ST	STP100N10F7
10	1	Q7	950V	N-channel MOSFET, TO-247	ST	STW20N95K5
11	1	Q13	2kV	NPN Darlington transistor, TO-220	ST	STP03D200
12	6	D14, D15, D20, D21, D22, D42	60V, 1A	Schottky rectifier, SMA	ST	STPS1L60A
13	8	D23, D24, D25, D26, D29, D30, D31, D32	40V, 300mA	Schottky diode, SOD323	ST	BAT54JFILM
14	2	D27, D28	100V, 200mA	Schottky diode, SOD-323	ST	BAT41JFILM
15	1	D34	1200V, 5A	Ultrafast recovery diode, DPAK	ST	STTH512B-TR
16	4	D6, D8, D11, D44	200V, 2A	Power Schottky diode, SMB	ST	STPS2200U
17	1	D33	1200V, 2A	High Voltage diode, SMB	ST	STTH212U
18	2	D7, D46	1200V, 1A	Ultrafast rectifier, SMA	ST	STTH112A
19	6	D16, D17, D18, D19, D40, D48	600V, 1A	Ultrafast high voltage rectifier, SMA	ST	STTH1L06A

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
20	1	D45	60V, 3A	Power Schottky rectifier, SMB	ST	STPS3L60U
21	2	Q11, Q14	80V, 500mA	NPN Transistor, SOT-23	ON Semiconductor	SMMBTA06LT1G
22	8	D1, D4, D12, D13, D36, D37, D39, D47	75V, 200mA	Switching Diode, DO - 213AA	Microsemi Corporation	1N4148UR-1
23	1	D2	12V, 500mW, ±5%	Zener Diode, SOD123	Any	Any
24	1	D3	3.6V, 500mW, ±5%	Zener Diode, SOD123	Any	Any
25	1	D9	RED, 30mA	Indication Red LED, SMD 0805	Any	Any
26	1	D35	1000V	Bridge Rectifier, Through Hole	Comchip Technology	GBU1510-G
27	1	D38	18V, 500mW, ±5%	Zener Diode, SOD123	Any	Any
28	1	D43	15V, 500mW, ±5%	Zener Diode, SOD123	Any	Any
29	1	D41 (not mounted)	-	SOD123, (not mounted)	-	-
30	2	C1, C2	1nF, 2kV, ±10%	High Voltage Ceramic Capacitor, SMD 1210	AVX Corporation	1210GC102KAT1A
31	13	C3, C4, C5, C7, C11, C18, C20, C26, C33, C42, C78, C92, C103	100nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
32	3	C8, C10, C21	2.2µF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
33	4	C9, C50, C68, C98	1nF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
34	1	C90	10nF, 100V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
35	2	C13, C32	10nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
36	2	C14, C30	47µF, 35V or above, ±20%	Electrolytic Capacitor, 105°C, Through Hole 5mm Pitch	Any	Any
37	2	C16, C34	10µF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
38	2	C17, C79	470nF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
39	3	C19, C57, C96	22µF, 35V or above, ±20%	Electrolytic Capacitor, SMD, Length: 5.8 mm, Height: 6.1 mm	Panasonic	EEE-FT1V220AR
40	1	C22	1nF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
41	2	C24, C25	470µF, 100V or above, ±20%	Electrolytic Capacitor, 105°C, Through Hole 7.5mm Pitch	Any	Any
42	1	C27	68nF, 630V, ±5%	Film Capacitor, Through Hole 15mm Pitch	EPCOS / TDK	B32672L6683J189
43	3	C28, C29, C106	1µF, 100V or above, ±10%	Ceramic Capacitor, X7R, SMD 1206	Any	Any
44	4	C36, C41, C45, C58	1µF, 35V or above, ±10%	Ceramic Capacitor, X7R, SMD 1206	Any	Any
45	1	C31	10nF, 2kV, ±5%	Film Capacitor, Through Hole 22.5mm Pitch	EPCOS / TDK	B32653A8103J
46	2	C37, C54	4.7nF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
47	1	C38	1µF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
48	1	C93	2.2µF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
49	1	C23	470pF, 25V or above, ±5%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
50	1	C39	22nF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
51	4	C43, C44, C55, C56	100pF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
52	2	C46, C60	220nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 1206	Any	Any
53	6	C35, C40, C47, C48, C63, C64	100nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 1206	Any	Any
54	4	C49, C53, C67, C70	10µF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 1206	Any	Any
55	1	C94	220nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
56	8	C52, C69, C71, C72, C80, C82, C95, C104	100nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
57	1	C76	470nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
58	3	C51, C66, C97	10nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
59	1	C75	1.5nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
60	2	C73, C74	2.2nF, 25V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
61	2	C77, C81	2.2µF, 16V or above, ±20%	Electrolytic Capacitor, SMD, Length: 5.4 mm, Height: 3.3 mm	Nichicon	UWT1V2R2MCL2GB
62	2	C84, C85	100nF-X2, 440 VAC, ±10%	Film Capacitor, Through Hole 22.5mm Pitch	KEMET	PHE844RD6100KR06L2

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
63	1	C86	680nF, 530V AC, ±20%	Film Capacitor, Through Hole 27.5mm Pitch	EPCOS / TDK	B32914A5684M
64	1	C88	47nF-X2, 440 VAC, ±10%	Film Capacitor, Through Hole 22.5mm Pitch	KEMET	R474N24705001K
65	2	C89, C91	270µF, 450V, ±20%	Electrolytic Capacitor, Through Hole 10mm Pitch	Nichicon	LGM2W271MELB25
66	4	C100, C101, C110, C111	220pF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0603	Any	Any
67	1	C102	1nF, 2kV, ±20%	Ceramic Capacitor, SMD 1206	Yageo	CC1206MKX7RDBB102
68	1	C108	100nF, 1kV, ±10%	Ceramic Capacitor, Through Hole 5mm Pitch	Murata Electronics	RDER73A104K5B1H03B
69	1	C119	100µF, 35V, ±20%	Electrolytic Capacitor, 105°C, Through Hole 5mm Pitch	Any	Any
70	1	C109	2.2nF, 440V AC, ±20%	Safety Ceramic Disc Capacitor, Through Hole 5mm Pitch	Vishay / BC Components	VY2222M35Y5US6TV5
71	2	C83, C87 (not mounted)	-	Through Hole 10mm Pitch, (not mounted)	-	-
72	2	C99, C107 (not mounted)	-	SMD 0603, (not mounted)	-	-
73	1	R1	680E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
74	1	R2	24K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
75	9	R3, R24, R26, R28, R35, R39, R40, R54, R121	10K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
76	1	R4	18K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
77	1	R5	510E, 1/10W, ±5%	Metal Film Resistor, SMD 0603	Any	Any
78	1	R13	39K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
79	1	R14	9.1K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
80	1	R15	1K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
81	1	R17	8.2K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
82	5	R18, R171, R181, R182, R184	10E, 1/4W, ±1%	Metal Film Resistor, SMD 1206	Any	Any
83	1	R70	120E, 1/4W, ±1%	Metal Film Resistor, SMD 0805	Any	Any

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
84	6	R21, R32, R58, R77, R154, R183	10E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
85	2	R25, R30	51K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
86	5	R27, R33, R152, R179, 180	22E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
87	8	R22, R23, R29, R31, R36, R37, R62, R63	4.7E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
88	1	R34	6.2K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
89	2	R38, R42	22mΩ, 2W, ±1%	Current Sense Resistor, SMD 2512	TE Connectivity / Holsworthy	RLP73M3AR022FTDF
90	1	R41	0E, 1/4W, ±1%	Metal Film Resistor, SMD 1206	Any	Any
91	2	R43, R44	150E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	-
92	1	R139	100E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	-
93	1	R151	6.2K, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
94	3	R45, R49, R149	4.7K, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
95	5	R46, R47, R50, R51, R105	47E, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
96	4	R20, R48, R53, R120	0E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	-
97	2	R52, R69	47K, 1/4W, ±5%	Metal Film Resistor, SMD 1206	Any	-
98	5	R55, R56, R75, R76, R178	100K, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
99	6	R59, R60, R61, R81, R83, R84	33E, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
100	3	R64, R89, R172	4.2K, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
101	8	R65, R66, R90, R92, R119, R122, R144, R155	10K, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
102	1	R67	2.2E, 1/4W, ±1%	Metal Film Resistor, SMD 1206	Any	-
103	7	R94, R95, R98, R99, R104, R114, R115	100E, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
104	3	R96, R97, R150	1K, 1/10W, ±5%	Metal Film Resistor, SMD 0603	Any	-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
105	14	R68, R91, R100, R101, R102, R103, R106, R107, R108, R109, R110, R111, R112, R113	0E, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
106	4	R116, R123, R131, R136	470K, 1/4W, ±1%	Metal Film Resistor, SMD 1206	Any	-
107	9	R117, R118, R127, R130, R132, R137, R145, R146, R170	220K, 1/4W, ±1%	Metal Film Resistor, SMD 1206	Any	-
108	4	R124, R128, R133, R140	820K, 1/4W, ±1%	Metal Film Resistor, SMD 1206	Any	-
109	4	R129, R134, R141, R147	51K, 1/4W, ±1%	Metal Film Resistor, SMD 1206	Any	-
110	2	R135, R138	0.47E, 1W, ±1%	Current Sense Resistor, SMD 2512	Yageo	-
111	1	R142	100K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	-
112	1	R143	18K, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
113	1	R148	47K, 1/10W, ±1%	Metal Film Resistor, SMD 0603	Any	-
114	3	R173, R174, R175	1M, 1/4W, ±1%	Metal Film Resistor, SMD 1206	Any	-
115	1	R176	220K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	-
116	1	R177	2.2K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	-
117	2	R19, R185 (not mounted)	-	SMD 1206, (not mounted)	-	-
118	3	R57, R78, R153 (not mounted)	-	SMD 0603, (not mounted)	-	-
119	1	L3	470Ω 100MHz, 250mA, ±25%	Ferrite Bead, SMD 0402	Wurth Electronics	-
120	1	L4	100µH, ±20%	Common Mode Choke / Filter, Through Hole	Wurth Electronics	-
121	1	L5	2.2mH	Common Mode Choke / Filter, Through Hole	Wurth Electronics	-
122	1	L6	1µH, ±10%	Fixed Inductor, Through Hole	ABRACON	-
123	1	L7	-	LCC Inductor, Through Hole	AQ Magnetica	-
124	1	T1	-	0-10V Isolation Transformer, Through Hole	Wurth Electronics	-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
125	1	T2	-	Flyback Transformer, Through Hole	AQ Magnetica	-
126	1	T3	-	Current Sense Transformer, Through Hole	AQ Magnetica	-
127	1	T4	-	LCC Transformer, Through Hole	AQ Magnetica	-
128	1	T5	-	PFC Transformer, Through Hole	AQ Magnetica	-
129	1	F1	2A	Fuse, Through Hole	Bel Fuse	-
130	1	J1	-	Connector 0-10V Input, Fixed Terminal Block - 2 Position, Through Hole 5mm Pitch	Phoenix Contact	-
131	1	J4 (not mounted)	-	PFC Output, Through Hole 10mm Pitch, (not mounted)	-	-
132	1	J5	-	Output Connector, Through Hole 7.5mm Pitch	Phoenix Contact	-
133	1	J8	-	Power Control Card Connector, Through Hole	ERNI	-
134	1	J9	265-525V AC	Input Connector , Through Hole 10mm Pitch	282858-3	-
135	1	J10 (not mounted)	-	Through Hole, (not mounted)	-	-
136	1	J12	Connector 2x1	2.54mm Pitch Berg Stick Male, Through Hole 2.54mm Pitch	Any	-
137	1	J13	Connector 4x1	2.54mm Pitch Berg Stick Female, Through Hole 2.54mm Pitch	Any	-
138	1	J14	Connector 3x1	2.54mm Pitch Berg Stick Female, Through Hole 2.54mm Pitch	Any	-
139	1	RT1	0.05A 30V, 30V DC	PTC Resettable Fuse, SMD	Bourns	-
140	1	RT3	10E	Inrush Current Limiter, Through Hole 7.5mm Pitch	EPCOS / TDK	-
141	1	SW1	12 VDC	Slide Switches, Through Hole	EAO	-
142	1	RV1	440V AC	Varistor, Through Hole	EPCOS / TDK	-

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
143	8	MH1, MH2, MH3, MH4, MH5MH6, MH7, MH8	Mounting Holes, Spacer and Screw	Spacers (M3x12), Screw (M3x6) , Through Hole	-	-
144	1	TP1	Vcc Secondary	Test Point, Through Hole	Any	-
145	1	TP2	Vcc Primary	Test Point, Through Hole	Any	-
146	1	TP3	SEC.-GND	Test Point, Through Hole	Any	-
147	1	TP4	DC-BUS V-OUTPUT PFC	Test Point, Through Hole	Any	-
148	1	TP30	PFC MOSFET DRAIN	Test Point, Through Hole	Any	-
149	1	TP31	PFC MOSFET GATE DRIVE	Test Point, Through Hole	Any	-
150	1	TP35	PFC Controller Vcc	Test Point, Through Hole	Any	-
151	1	TP5	V-OUTPUT	Test Point, Through Hole	Any	-
152	1	TP6	VDD-VIPER26K	Test Point, Through Hole	Any	-
153	1	TP7	HB-LCC Node	Test Point, Through Hole	Any	-
154	1	TP10	NODE VDS-SR1	Test Point, Through Hole	Any	-
155	1	TP11	NODE VDS-SR2	Test Point, Through Hole	Any	-
156	1	TP17 (not mounted)	-	Test Point, Through Hole, (not mounted)	-	-
157	1	TP36	PRI.-GND	Test Point, Through Hole	Any	-
158	1	Heat-Sink (Q1, Q7, Q4)	3mm Thickness, 54mm x 25mm	Aluminium Heat Sink (Anodized), 3-Holes	-	-
159	1	Heat-Sink (Q5, Q2, Q6, Q3)	3mm Thickness, 60mm x 25mm	Aluminium Heat Sink (Anodized), 4-Holes	-	-
160	3	Isolation Pad (Q1, Q7, Q4)	Heat-Sink (Q1, Q7, Q4), TO-247	Thermal Pad	Wakefield-Vette	-
161	4	Isolation Pad (Q5, Q2, Q6, Q3)	Heat-Sink (Q5, Q2, Q6, Q3), TO-220	Thermal Pad	Wakefield-Vette	-
162	3	Screw and Nut (Q1, Q7, Q4)	Heat-Sink (Q1, Q7, Q4), TO-247	Screw (M3x12), Nut (M3)	Any	-
163	4	Screw and Nut (Q5, Q2, Q6, Q3)	Heat-Sink (Q5, Q2, Q6, Q3), TO-220	Screw (M3x10), Nut (M3)	Any	-
164	4	Bush (Q5, Q2, Q6, Q3)	Heat-Sink (Q5, Q2, Q6, Q3), TO-220	Bush TO-220	MULTICOMP	-

6.1.1 Daughter board

Table 7. Daughter board bill of materials

This board is marked STEVAL-LLL009D1 and can only be ordered with the STEVAL-LLL009V1 kit

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	1	U9	-	Operational amplifier, SOT23-5	ST	TSZ121ILT
2	1	U8	-	Optically Isolated Amplifier, SMD	Broadcom / Avago	ACPL-782T-500E
3	3	C54, C59, C61	100nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
4	2	C57, C65	150pF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
5	1	C62	10nF, 50V or above, ±10%	Ceramic Capacitor, X7R, SMD 0805	Any	Any
6	1	D20	9.1V, 500mW, ±5%	Zener Diode, SOD123	Any	Any
7	1	D22	RED, 30mA	Indication Red LED, SMD 0805	Any	Any
8	1	J14	Connector 3x1	2.54mm Pitch Berg Stick Right Angle Male, Through Hole	Any	Any
9	1	J13	Connector 4x1	2.54mm Pitch Berg Stick Right Angle Male, Through Hole	Any	Any
10	1	L2	470Ω 100 MHz, 250mA, ±25%	Ferrite Bead, SMD 0402	Wurth Electronics	7427927141
11	9	R62, R63, R67, R69, R70, R71, R72, R73, R74	750K, 1/4W, ±1%	Metal Film Resistor, SMD 1206	Any	Any
12	1	R82	560E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
13	2	R79, R93	3.9K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
14	1	R80	6.8K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
15	1	R85	39E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
16	2	R86, R87	2.2K, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any
17	1	R88	160E, 1/8W, ±1%	Metal Film Resistor, SMD 0805	Any	Any

6.2 Control board

Table 8. Control board bill of materials

This board is marked STEVAL-DPS334C1 and can only be ordered with the kit

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	2	C1, C4	15pF 25V ±10%	Capacitor Ceramic XR7	Any	-

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
2	11	C2, C3, C7, C8, C10, C12, C13, C14, C15, C18, C33	100nF 25V ±10%	Capacitor Ceramic XR7	Any	-
3	2	C5, C6	22pF 25V ±10%	Capacitor Ceramic XR7	Any	-
4	2	C9, C11	100µF 16V ±20%	ELEC CAP	PANASONIC	EEEFT1C101AR
5	1	C16	10µF 16V ±10%	Tantalium Capacitor	KEMET	T491B106K010AT
6	1	C17	10nF 25V ±10%	Capacitor Ceramic XR7	Any	-
7	1	C19	470nF 25V ±10%	Capacitor Ceramic XR7	Any	-
8	13	C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31, C32	100pF 25V ±10%	Capacitor Ceramic XR7	Any	-
9	3	DA1, DA2, DA3	-	Diode array	ST	DA108S1
10	1	D1	-	LED diode	Kingbright	KP-1608CGCK
11	1	D2	-	LED diode	Kingbright	KP-1608QBC-D
12	1	D3	-	LED diode	Kingbright	KP-1608 SRC-PRV
13	2	J1, J2	-	Through Hole Vertical 1.27mm	TE Connectivity	7-215079-4
14	1	J3	-	-	Phoenix Contact	1725656
15	3	J4, J5, J6	-	Strip Line Male 2X1 pitch 2, 54mm	Any	-
16	1	J7	-	-	HARTING	9185106324
17	1	L1	470 Ω 100MHz 250 mA	-	WURTH ELEKTRONIK	7427927141
18	1	P1	-	Male DIN 41612 Through Hole 90 degree	Erni	533406
19	5	R1, R12, R20, R21, R37	0 1/16W ±1%	SMD Thick Film Resistor	Any	-
20	2	R2, R10	820 1/16W ±1%	SMD Thick Film Resistor	Any	-
21	2	R3, R9	39 1/16W ±1%	SMD Thick Film Resistor	Any	-
22	2	R4, R11	47 1/16W ±1%	SMD Thick Film Resistor	Any	-
23	2	R5, R7	0 750mW ±5%	SMD Thick Film Resistor	Vishay	CRCW20100000ZOEF
24	2	R6, R8	0Ω 750mW ±5%	SMD Thick Film Resistor	Any	-
25	2	R13, R14	0Ω 750mW ±5%	SMD Thick Film Resistor	Any	-
26	1	R15	100 1/16W ±1%	SMD Thick Film Resistor	Any	-

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
27	14	R16, R22, R23, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33, R34	10 1/16W ±1%	SMD Thick Film Resistor	Any	-
28	1	R17	86.6 1/16W ±1%	SMD Thick Film Resistor	Any	-
29	1	R18	0 1/4W ±1%	SMD Thick Film Resistor	Any	-
30	1	R19	10K 1/16W ±1%	SMD Thick Film Resistor	Any	-
31	2	R35, R36	4.7k 1/16W ±1%	SMD Thick Film Resistor	Any	-
32	37	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP25, TP26, TP27, TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP35, TP36, TP37	-	Test Point	Any	-
33	2	U1, U2	-	Optocoupler 1 chanel	NEC	PS9821-1-F3-AX
34	1	U3	-	LDO 5V/3.3V	ST	LD1117DT33TR
35	1	U4	-	32 bit microcontroller	ST	STM32F334R8T6
36	1	U5	-	Small Signal Schottky Diode	ST	BAR43ASFILM
37	1	X1	-	8MHz Cristal Oscillator	EUROQUARTZ	8.000MHZ 49USMX/30/50/40/18PF/ ATF
37	1	10 position cable assembly rectangular socket to socket female	-	Flat cable 10 pin female-female 2.54mm	Samtec Inc.	HCSD-05-D-11.40-01-N-G-R
38	1	Micro-Match 4 ways, 9.9"", 250mm, 1.27mm	-	AMP Micro-MaTch	TE Connectivity	1483350-3

6.2.1 Adapter board

Table 9. Adapter board bill of materials

This board is marked STEVAL-DPSADP01 and can only be ordered with the kit

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
1	8	C1, C2, C3, C4, C5, C6, C7, C8	100nF 25V ±10%	Capacitor Ceramic XR7	Any	-
2	1	J2	-	Stripline male 3x2 2.54mm	Any	-
3	1	J3	-	JTAG connector	TE-Connectivity	5103308-5
4	2	J6, J7	-	Jumper pitch 2, 54 mm	Any	-
5	1	J8	-	Stripline Male 2X1 pitch 2, 54 mm	Any	-
6	2	J9, J11	-	Stripline Male 3X1 pitch 2, 54 mm	Any	-
7	1	J10	-	Prog Connector	HARTING	9185106324
8	1	P1	-	90° Through Hole	TE-Connectivity	1-1634584-2
9	1	P2	-	90° Through Hole	RS-Pro	-
10	2	R1, R2	4.7k 1/16W ±1%	SMD Thick Film Resistor	Any	-
11	1	R3	10k 1/16W ±1%	SMD Thick Film Resistor	Any	-
12	1	R4	120 1/16W ±1%	SMD Thick Film Resistor	Any	-
13	1	R5	0 1/16W ±1%	SMD Thick Film Resistor	Any	-
14	1	R6	1/16W ±1% (not mounted)	SMD Thick Film Resistor	Any	-
15	1	S1	-	Surface Mount Tactile Switch	TE-Connectivity	FSM4J (L=5.0MM)
16	1	U1	-	RS-232 transceiver	ST	ST3232CTR
17	1	U2	-	CAN transceiver	TI	SN65HVD232D

Revision history

Table 10. **Document revision history**

Date	Version	Changes
11-Dec-2020	1	Initial release.

Contents

List of figures

List of tables