Getting started with the STEVAL-DPSLLCK1 evaluation kit for the 3 kW full bridge LLC digital power supply

Introduction

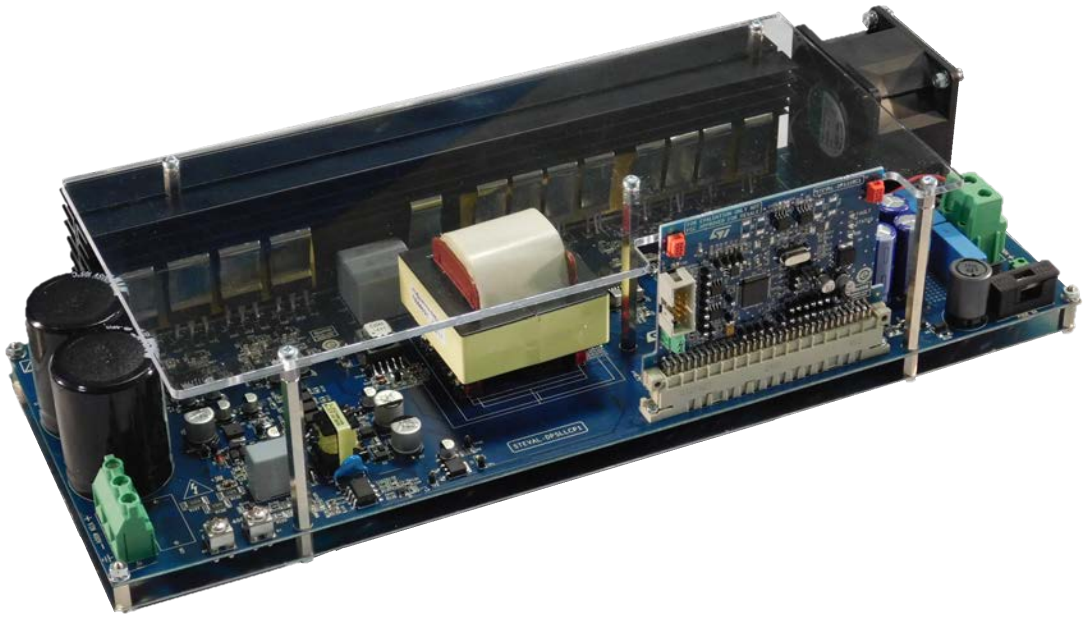
The 3 kW isolated full bridge LLC DC-DC resonant converter evaluation kit can convert 375 V to 425 V DC input voltage to 48 V output voltage, 63 A maximum current. This type of conversion is often required in telecommunication applications.

The kit (STEVAL-DPSLLCK1) consists of a power board (STEVAL-DPSLLCP1), a control board (STEVAL-DPS334C1), and an adapter board (STEVAL-DPSADP01).

The primary side of the power board is based on MDmesh™ DM2 Power MOSFETs, while the secondary side is based on STripFET™ F7 LV MOSFETs, both in full bridge configuration.

The control board includes an STM32F334 microcontroller which controls the LLC converter, manages adaptive synchronous rectification (SR) MOSFET and high frequency burst mode under light loads to reduce conduction losses.

Figure 1. 3 kW full bridge LLC digital power supply evaluation kit



1 Safety and operating instructions

1.1 General precautions

During assembly and operation, the 3 kW full bridge LLC digital power supply poses several inherent hazards, including bare wires, rotating fan components, and hot surfaces. There is danger of serious personal injury and damage to property if the DC-DC converter or its components are not used or installed correctly.

All operations involving transportation, installation and use, and maintenance must be performed by skilled technical personnel able to understand and implement national accident prevention regulations. For the purposes of these basic safety instructions, “skilled technical personnel” are suitably qualified people who are familiar with the installation, use and maintenance of power electronic systems.

1.2 3 kW full bridge LLC power supply intended use

The technical data and information concerning the power supply conditions shall be taken from the documentation and strictly observed.

1.3 Electronic connection

Important:

The electrical installation shall be completed in accordance with the appropriate requirements (for example, cross-sectional areas of conductors, fusing, and GND connections).

The kit is intended for evaluation purposes only.

Supply the STEVAL-DPSLLCK1 only with a DC-DC source lab power supply.

1.4 Evaluation kit operation

Danger:

Do not touch the boards immediately after disconnection from the voltage supply *as several parts and power terminals may contain energized capacitors that need time to discharge.*

Do not touch the boards after disconnection from the voltage supply *as several parts like heat sinks and transformers may still be very hot.*

Important: *Always use the STEVAL-DPSLLCK1 with the Plexiglas provided with the kit.*

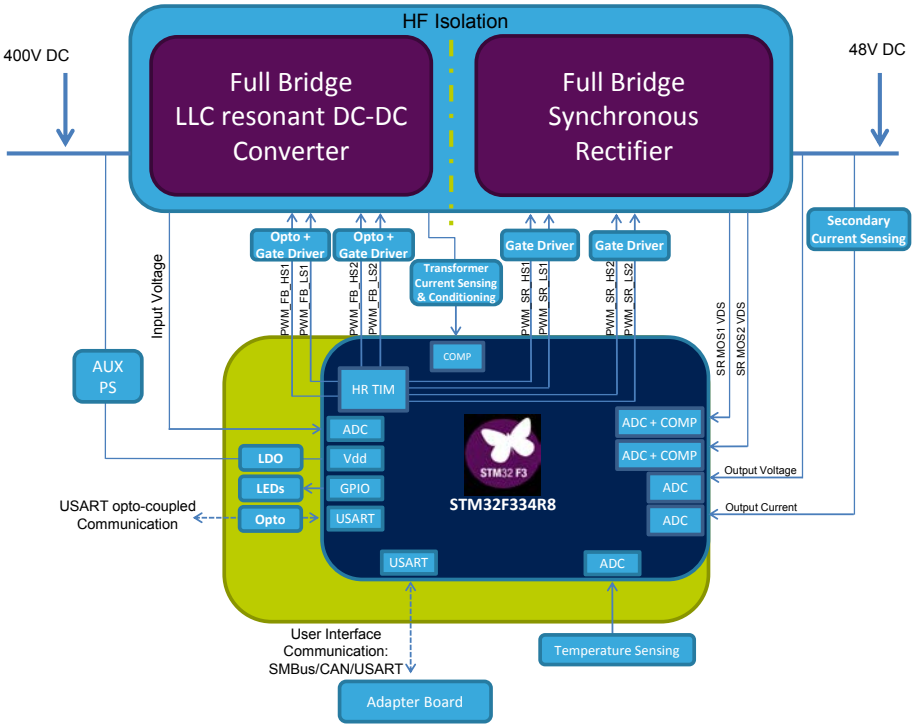
Do not use the kit without the aluminium plate attached under the PCB.

Always connect the earth ground connection on the input connector before you turn on the board.

2 Full bridge DC to DC converter evaluation kit overview

The DC/DC power converter consists of a full bridge LLC resonant converter and a full bridge synchronous rectifier output stage.

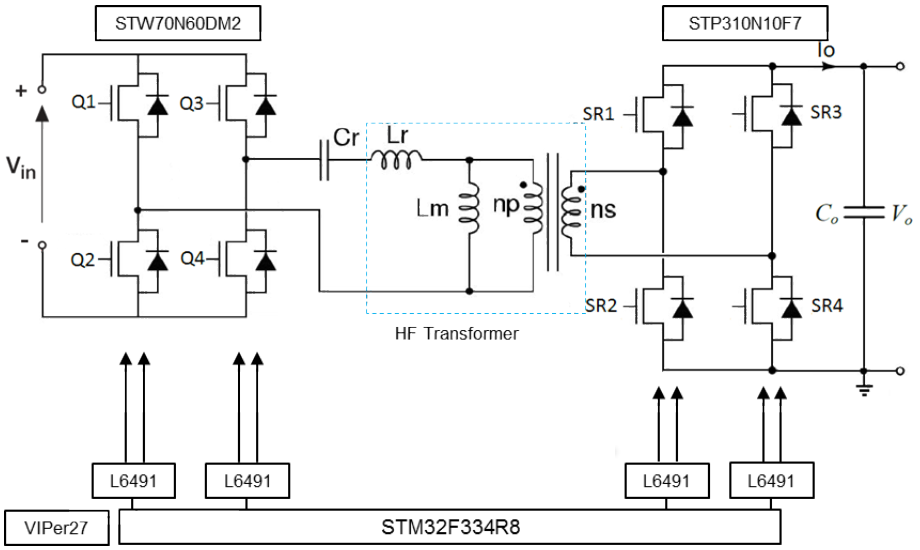
Figure 2. STEVAL-DPSLLCK1 block diagram



The primary side and secondary side MOSFETs are digitally controlled by a 32-bit STM32F3 series microcontroller.

The 3 kW full bridge LLC power supply converts an input voltage from 375 to 425 V into a 48 V regulated output. The continuous power rating of the unit is 3 kW. The high input to low output DC voltage conversion is performed through a high frequency transformer; high efficiency is achieved thanks to zero voltage switching (ZVS).

Figure 3. **STEVAL-DPSLLCK1 topology**



Input and output current and voltage protections are included, together with over-temperature protection. Forced air cooling is regulated according to the output load and heatsink temperature.

Table 1. **3 kW LLC converter digital DC-DC power supply specifications**

Parameter	Value
Input DC voltage	375 V to 425 V
Output voltage	48 V
Max output current	63 A
Output power	3000 W
Closed loop switching frequency	120 kHz up to 250 kHz
Start-up switching frequency	380 kHz
Resonance frequency	175 kHz
HF transformer isolation	4 kV
Peak efficiency	95.3% @ 400 V 50% of load
Cooling	Forced air with fan speed modulation

2.1 STEVAL-DPSLLCP1 power board

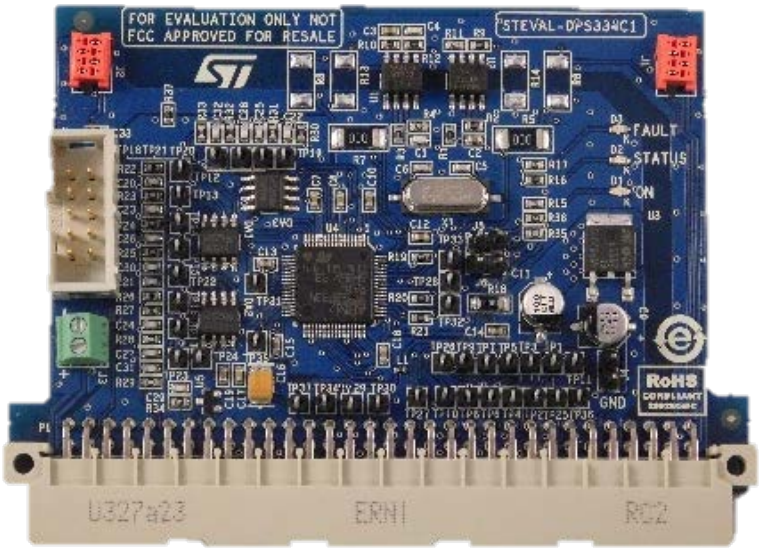
The power board includes power switches, a resonant tank with high frequency transformer, gate drivers, an auxiliary power supply and the sensing and conditioning circuits.

Figure 4. **STEVAL-DPSLLCP1 power board**

2.2 STEVAL-DPS334C1 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 5. **STEVAL-DPS334C1 digital control board**



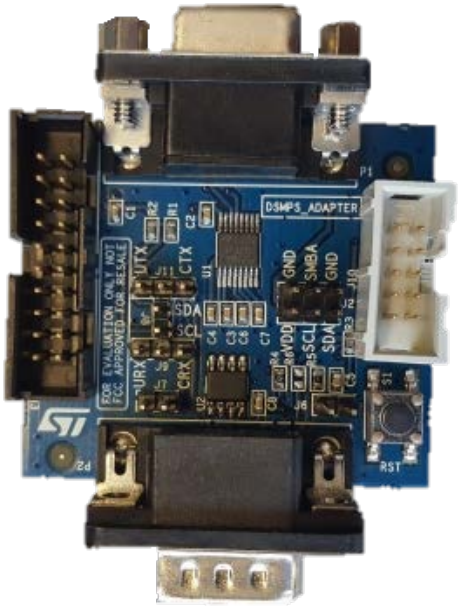
The MCU embeds a high resolution timer peripheral (HRTIM) designed to drive power conversion systems. It can drive the power stages with pulse width modulations (PWM) at a resolution of 217 ps, which allows very fine frequency adjustment steps and high precision output voltage regulation.

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.

2.3 STEVAL-DPSADP01 adapter board

The DC-DC converter kit 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 6. 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.

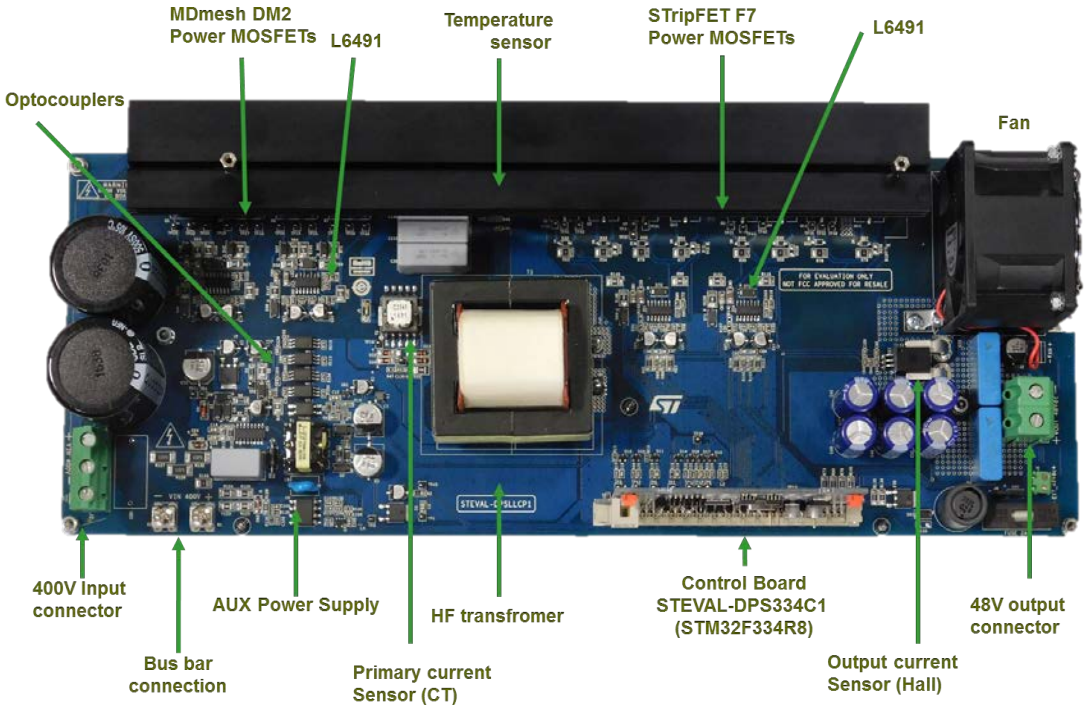
The USART interface of the adapter board can be set to RS-232, CAN or SMBus through appropriate jumper configuration.

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 Functional areas of the DC-DC converter

Figure 7. **Functional areas of the STEVAL-DPSLLCK1 kit**



The input DC voltage charges input capacitors C36 and C37. The primary side switches Q5, Q6, Q7, and Q8 supply a square voltage waveform between –Vin and +Vin at the applied switching frequency to the resonant tank circuit, with capacitors C39, C110, C130 and the leakage inductance of the main transformer T3.

The full bridge on the primary side of the converter is based on STW70N60DM2 MDmesh DM2 Power MOSFETs; these high voltage switches are driven two-by-two (Q5-Q7 and Q6-Q8) with 50 percent 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).

On the secondary side of the transformer, the input voltage waveform is rectified by the synchronous rectifier STP310N10F7 MOSFETs with STripFET F7 technology (Q1, Q2, Q3, Q4, Q9, Q10, Q11, and Q12 in full bridge configuration and two-by-two in parallel) and smoothed by output capacitors.

A synchronous rectification (SR) technique is used to turn on the channel of low voltage MOSFETs instead of the internal body diode, reducing conduction losses. The adaptive algorithm further reduces diode conduction time and improves converter efficiency.

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.

To reduce driver and switching losses under light loads, the microcontroller manages burst mode operation by skipping some PWM pulses in a defined burst interval, but continuing to control the output voltage.

L6491 gate drivers IC2 and IC3 drive the primary side switches, while gate drivers IC1 and IC4 drive the secondary side SR MOSFETs.

A current sensing circuit monitors the resonant tank current to provide overcurrent protection. The circuit consists of a current transformer (CT) T2 and a small signal diode rectification bridge.

The CS1 Hall Sensor monitors output current for output overcurrent protection, burst mode control, synchronous rectification and fan speed modulation.

An auxiliary power supply circuit based on the VIPER27HD in flyback configuration supplies the primary side and secondary side gate drivers, the primary side optocouplers (for PWM driving and bus voltage sensing), and the control board, which receives 5 V through the DSMPS connector.

Finally, a small buck circuit (Q13, L3, D61 and C132) regulates the 48 V output voltage to supply the mounted fan. Q13 is driven by the microcontroller through a 10 kHz auxiliary PWM signal and a duty cycle that is varied according to the load current. The fan can also be supplied externally through the J5 connector.

4 System setup and operation

4.1 Board and cable connections

The evaluation kit can manage up to 3 kW of power across the operating input voltage range. To perform functional and efficiency testing, you can use the following equipment:

- A 3200 W programmable DC voltage source up to 450V 10A max
- 60 V/65 A DC electronic load
- Power analyzer (optional)
- Digital oscilloscope (optional)

Step 1. Connect the programmable DC voltage source to J2 with cables, or to B1 and B2 with bus bars.

The output load must be connected to the J3 connector with a cable of appropriate cross-section to carry the desired load current (63 A max).

Note: Always connect the earth to the J2 connector.

Step 2. The on-board cooling should always be enabled; ensure that it is not disconnected as this may provoke system damage from overheating.

– To perform efficiency measurements without fan consumption drawn from the output, remove jumper J4 and apply an external voltage (up to 48 V, 240 mA) to the J5 connector.

– You can also disable on-board fan control in the FW or via the UI, but remember to remove J4 before applying the external voltage.

Step 3. Ensure that the STEVAL-DPSLLCP1 power board is not powered.

Step 4. Connect the STEVAL-DPS334C1 digital control board to the STEVAL-DPSLLCP1 power board through the 64 pin DSMPS connector P1.

The control board in the kit is already programmed and ready to use, you do not need to load firmware.

To program a new control board, you should power it with an external 5 V supply through the J3 connector on the control board

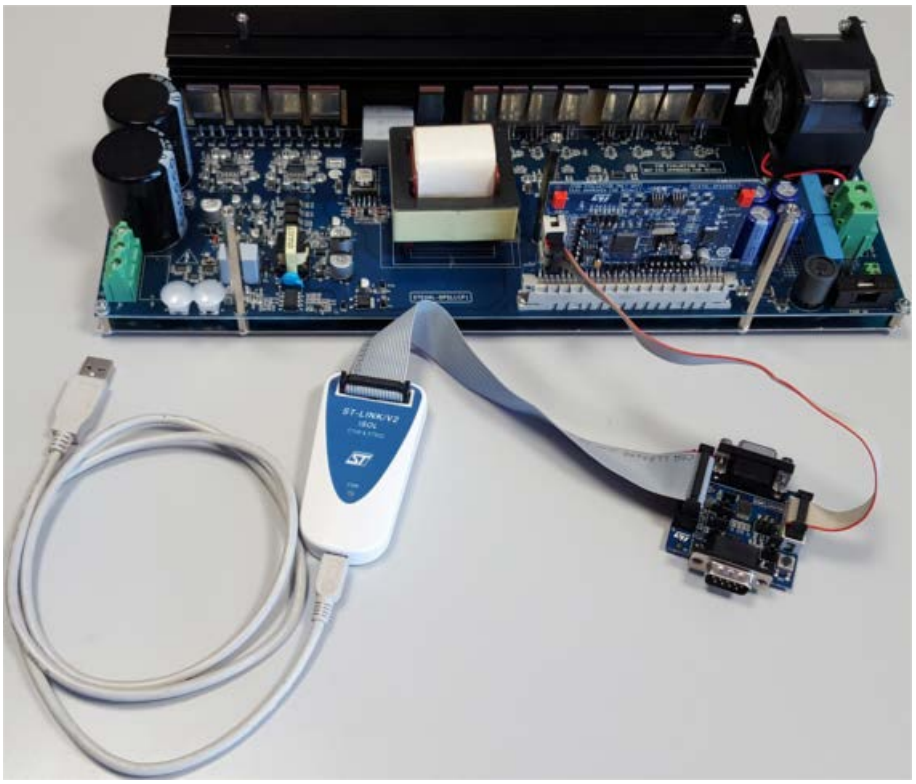
Note: Do not connect the control board to the power board for this operation.

Step 5. To update or debug the FW, connect a 10 wire flat cable to J7 on the control board and J1 on the adapter board.

Step 6. Connect a standard programmer (like ST-LINK or J-Link) through the J3 standard 20 pin JTAG connector on the adapter board.

Note: Do not apply any voltage to the power board for these operations.

Figure 8. **STEVAL-DPSLLCK1 connection scheme**



4.2 Board use

The auxiliary power supply supplies the control board, drivers and signal conditioning circuitry once the input voltage rises above 100 V. The presence of the input voltage is signaled by the red LED D64 on the power board and the green LED D1 on the control board.

While the input voltage remains above 100 V, but below 375 V, the system is in an input undervoltage state in which you can safely reprogram the microcontroller using IAR Embedded Workbench for ARM ver.7.80 or higher, or any other appropriate programming tool.

When the input voltage is raised to the required 375 V to 425 V input voltage range, the converter becomes operational after a default wait time of 1000 ms.

To avoid high current spikes a board start up, a ramp-up procedure is implemented. In this procedure, the high voltage MOSFETs are driven at the maximum switching frequency of 380 kHz, which decreases linearly to the minimum 120 kHz value over 500 ms.

If the output voltage reaches the reference 47 V 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 blue LED D2 on the control board shows the state of the converter:

- off when the system is off
- slow blinking while the system is idle
- rapid blinking during ramp-up
- on during normal operation

During normal operation, the system implements burst mode and synchronous rectification techniques to increase conversion efficiency.

The evaluation kit includes the following protections:

- Input overvoltage and undervoltage
- Output overvoltage and undervoltage
- Fast overcurrent
- Output overcurrent

- Over temperature
- 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. The blinking rate also indicates fault type:

- voltage-related faults: t_{ON} = 500 ms, t_{OFF} = 500 ms
- other faults: t_{ON} = 250 ms, t_{OFF} = 250 ms

All blinking sequences are repeated after three seconds.

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 use the user interface or disconnect the input voltage and wait until the unit shuts down.

Table 2. DC-DC converter 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} > 430 V	4	slow	Y
DCDC_IN_UNDER_VOLT_ERROR	0x0008	V_{in} < 370 V	5	slow	Y
DCDC_OVER_CURRENT_ERROR	0x0010	$I_{res\ (peak)}$ > 14.4 A	2	fast	N
DCDC_OUT_OVER_CURRENT_ERROR	0x0020	I_{out} > 66 A	3	fast	N
DCDC_OVER_TEMP_ERROR	0x0040	T > 55 °C	4	fast	N
DCDC_STARTUP_FAILED_ERROR	0x0080	V_{out} < 47 V and T_{ramp} > 500 ms	6	fast	N
DCDC_PRIMARY_SIDE_ERROR (from PFC if any)	0x0100	Error sent via UART communication	5	fast	Y

5 User serial communication

The STEVAL-DPSLLCK1 kit can operate without the User Interface (UI), as the default FW automatically activates power conversion when the input voltage enters the correct operating range.

The User Interface is based on RS-232 serial communication and provides a simple way to set some real-time control parameters, enable and disable driving signals, and read sensed values without changing the default FW.

To use the UI, connect a RS-232/USB adapter between the DSMPS adapter board and your PC. Use a communication tool like HyperTerminal to send command strings and read feedback messages from the system.

The default communication parameters are listed below:

- Baud Rate: 57600
- Word Length bit: 8
- Stop bits: 1
- Parity: none
- Flow control: none

The following commands can be sent in real-time while the application is running:

- Start or stop voltage regulation
- Enable or disable open loop mode
- Enable or disable SR driving
- Enable or disable adaptive SR
- Enable or disable burst mode for light load operation
- Enable or disable fan driving
- Set or get PWM frequency (in open loop mode)
- Set or get PWM dead time
- Set or get SR delays (when adaptive SR is not active)
- Set or get voltage PI regulator gains
- Read monitored values (V_{IN}, V_{OUT}, I_{OUT} and heat-sink temperature)
- Get and clear last fault occurred
- Read configuration parameters
- Get FW and UI version

The frames that can be sent to the system are help frames, command frames, set frames and get frames.

Help frames give information regarding FW and UI versions, and the syntax of each frame category:

- - COMMAND FRAME:
  - <COMMAND_ID> <STATE>
- SET FRAME:
  - <SET_PARAM_ID> <NUM_VAL>
- GET FRAME:
  - <GET_PARAM_ID>

Table 3. Help frames

Description	Help ID
Show frame type list	help
Show command frame list	help cmd
Show set frame list	help set
Show get frame list	help get
Show Firmware and UI version information	fwi

Table 4. Command frames

Description	Command ID	State
Enable/disable converter output	out	on/off
Enable/disable Open loop mode	ol	on/off
Enable/disable Synchronous Rectification	sr	on/off
Enable/disable adaptive Synchronous Rectification	asr	on/off
Enable/disable burst mode	bm	on/off
Enable/disable cooling fan	fan	on/off

Table 5. Set frames

Description	Set Param ID	Min Val	Max Val
Set kp gain of voltage regulator	kp	0	32767
Set ki gain of voltage regulator	ki	0	32767
Set frequency in open loop mode in Hz	freq	120000	250000
Set dead time in ns	dead	200	800
Set delay rising 1 for SR when adaptive SR is disabled in ns	sr1	0	500
Set delay falling 1 for SR when adaptive SR is disabled in ns	sf1	10	600
Set delay rising 2 for SR when adaptive SR is disabled in ns	sr2	0	500
Set delay falling 2 for SR when adaptive SR is disabled in ns	sf2	10	600

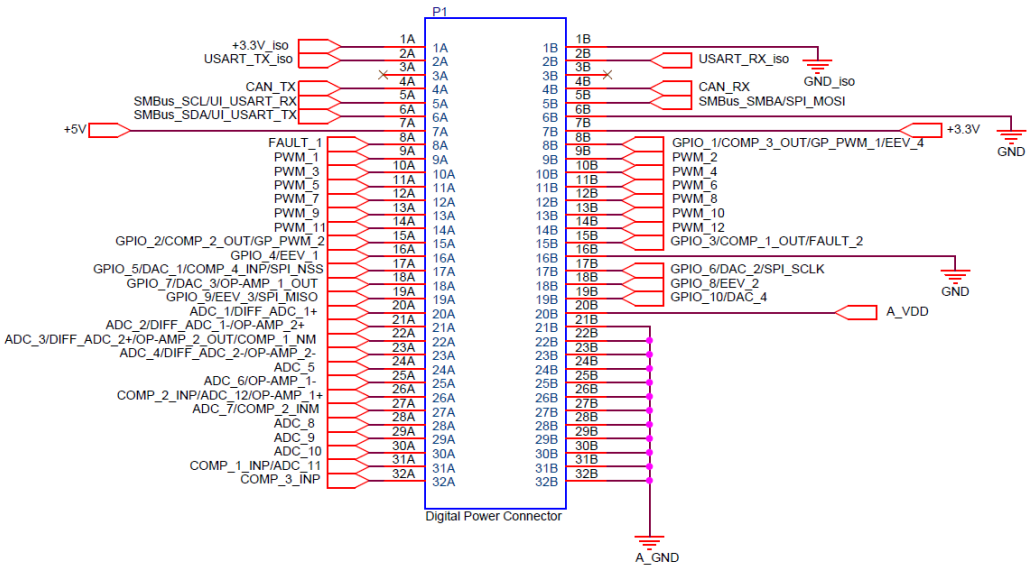
Table 6. Get frames

Description	Get Param ID
Get control parameters (kp and ki)	ctr
Get measured values (Vin, Vout, Iout and Temperature)	meas
Read and clear last system fault	flt
Get configuration parameters (see Table 4. Command frames)	config
Get PWM parameters (see Table 5. Set frames)	pwm

6 Pinouts and resources

The STEVAL-DPS334C1 control board and STEVAL-DPSLLCP1 power board are connected through a standard DIN 41612 type B connector. The pinout of the DSMPS connector is designed to provide digital and analog functions for a wide range of DSMPS applications.

Figure 9. DSMPS connector pinout



The following table shows the MCU pinout and the corresponding DSMPS connector functions on the STEVAL-DPS334C1 board. The last column shows the functions used for the full bridge LLC application.

Table 7. STEVAL-DPS334C1 MCU pinout and resources

MCU pin num	MCU Pin name	MCU Peripheral	DSMPS Connector function	Specific FB LLC functions
1	Vbat	Vdd	+3.3V	-
2	PC13*	GPIO	GPIO_10/DAC_4	-
3	PC14*	-	-	-
4	PC15*	-	-	-
5	PF0	Osc-in	-	-
6	PF1	Osc-out	-	-
7	NRST	NRST	-	-
8	PC0	ADC12_IN6	ADC_8	Temperature sensing
9	PC1	ADC12_IN7	ADC_9	-
10	PC2	ADC12_IN8	ADC_10	-
11	PC3	GPIO	-	-
12	VSSA	A_Gnd	A_GND	-
13	VDDA	A_Vdd	A_VDD	-
14	PA0	ADC1_IN1	ADC_1/DIFF_ADC_1+	Vout sensing
15	PA1	ADC1_IN2	ADC_2/DIFF_ADC_1-/OP-AMP_2+	Iout sensing

MCU pin num	MCU Pin name	MCU Peripheral	DSMPS Connector function	Specific FB LLC functions
16	PA2	ADC1_IN3	ADC_3/DIFF_ADC_2+/OP-AMP_2_OUT/ COMP_1_INM	Vbus sensing
17	PA3	ADC1_IN4	ADC_4/DIFF_ADC_2-/OP-AMP_2-	VDS_SR1 sensing
18	VSS_4	Gnd	GND	-
19	VDD_4	Vdd	+3.3V	-
20	PA4	GPIO	GPIO_5/DAC_1/COMP_4_INP/SPI_NSS	-
21	PA5	GPIO	GPIO_6/DAC_2/SPI_SCLK	-
22	PA6	GPIO	GPIO_7/DAC_3/OP-AMP_1_OUT	-
23	PA7	COMP2_INP	COMP_1_INP/ADC_11	VDS_SR1 comp
24	PC4	ADC2_IN5	ADC_5	Vout sensing
25	PC5	ADC2_IN11	ADC_6/OP-AMP_1-	Ires sensing
26	PB0	COMP4_INP	COMP_2_INP/ADC_12/OP-AMP_1+	VDS_SR2 comp
27	PB1	GPIO	GPIO_2/COMP_2_OUT/GP_PWM_2	FAN_PWM
28	PB2	ADC2_IN12	ADC_7/COMP_2_INM	VDS_SR2 sensing
29	PB10	GPIO	-	-
30	PB11	COMP6_INP	COMP_3_INP	Bridge Current comp
31	VSS_2	Gnd	GND	-
32	VDD_2	Vdd	+3.3V	-
33	PB12	HRTIM_CHC1	PWM_5	PWM_SR_HS2
34	PB13	HRTIM_CHC2	PWM_6	PWM_SR_LS1
35	PB14	HRTIM_CHD1	PWM_7	PWM_SR_HS1
36	PB15	HRTIM_CHD2	PWM_8	PWM_SR_LS2
37	PC6	GPIO	GPIO_1/COMP_3_OUT/GP_PWM_1/ EEV_4	-
38	PC7	HRTIM_FLT5	FAULT_1	-
39	PC8	HRTIM_CHE1	PWM_9	-
40	PC9	HRTIM_CHE2	PWM_10	-
41	PA8	HRTIM_CHA1	PWM_1	PWM_FB_HS1
42	PA9	HRTIM_CHA2	PWM_2	PWM_FB_LS1
43	PA10	HRTIM_CHB1	PWM_3	PWM_FB_HS2
44	PA11	HRTIM_CHB2	PWM_4	PWM_FB_LS2
45	PA12	GPIO	GPIO_3/COMP_1_OUT/FAULT_2	-
46	PA13	SWDIO	-	-
47	VSS_3	Gnd	GND	-
48	VDD_3	Vdd	+3.3V	-
49	PA14	SWCLK	-	-
50	PA15	TIM2_ETR	-	-
51	PC10	GPIO	-	-
52	PC11	GPIO	GPIO_8/EEV_2	SD/OD_4
53	PC12	GPIO	GPIO_4/EEV_1	SD/OD_3
54	PD2	TIM3_ETR	-	-

MCU pin num	MCU Pin name	MCU Peripheral	DSMPS Connector function	Specific FB LLC functions
55	PB3	HRTIM1_SCOUT	-	-
56	PB4	GPIO	GPIO_9/EEV_3/SPI_MISO	-
57	PB5	I2C1_SMBA	SMBus_SMBA/SPI_MOSI	UI_SMBA
58	PB6	USART1_TX	UART_TX_iso	UART_TX_iso
59	PB7	USART1_RX	UART_RX_iso	UART_RX_iso
60	BOOT0	Gnd	GND	-
61	PB8	I2C1_SCL	SMBus_SCL/UI_USART_RX and CAN_RX	UI_RX
62	PB9	I2C1_SDA	SMBus_SDA/UI_USART_TX and CAN_TX	UI_TX
63	VSS_1	Gnd	GND	-
64	VDD_1	Vdd	+3.3V	-

7 STEVAL-DPSLLCK1 schematics

Figure 10. **STEVAL-DPSLLCP1 power board - LLC power stage schematic**

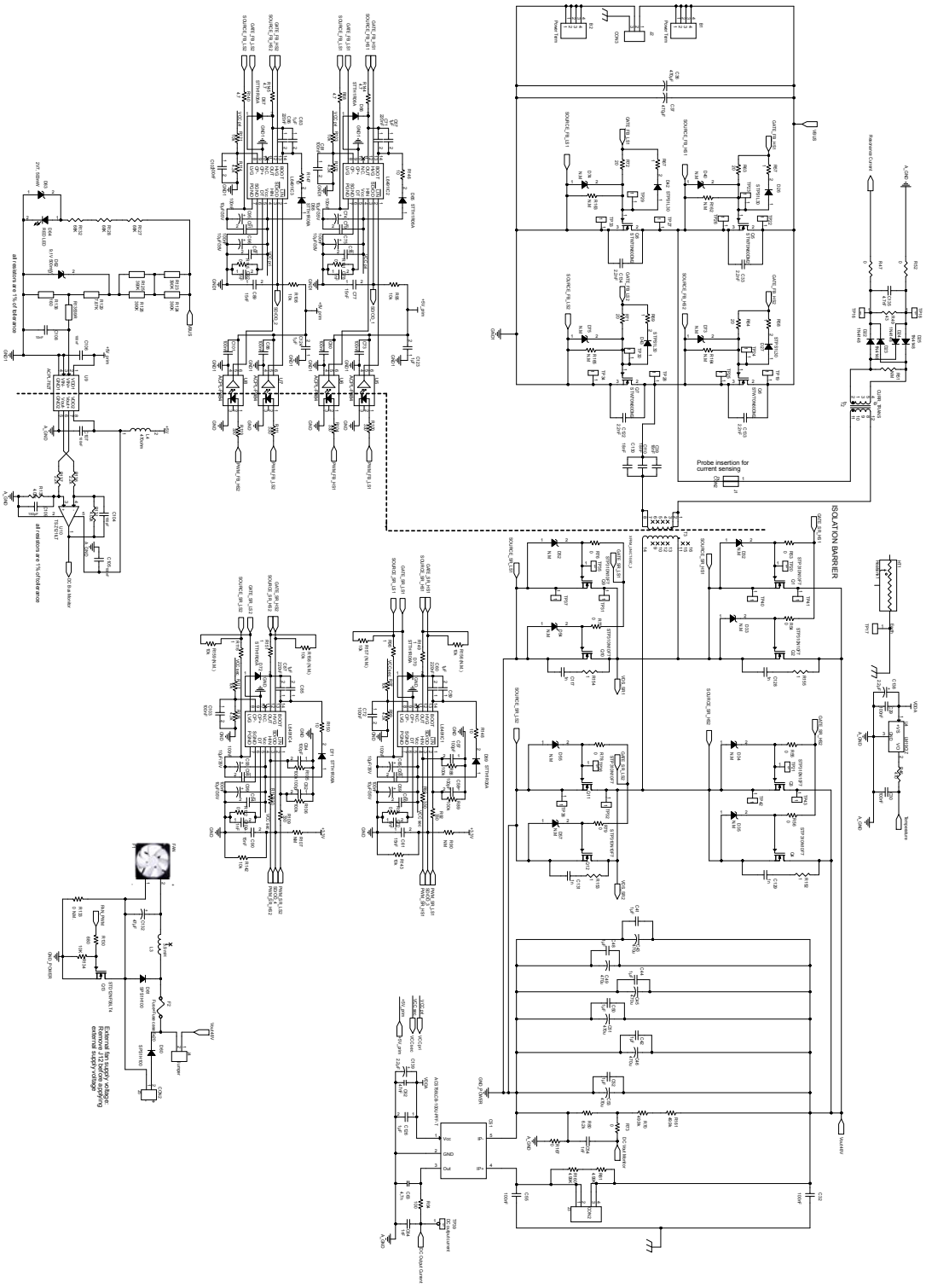


Figure 11. **STEVAL-DPSLLCP1 power board - Aux SMPS schematic**

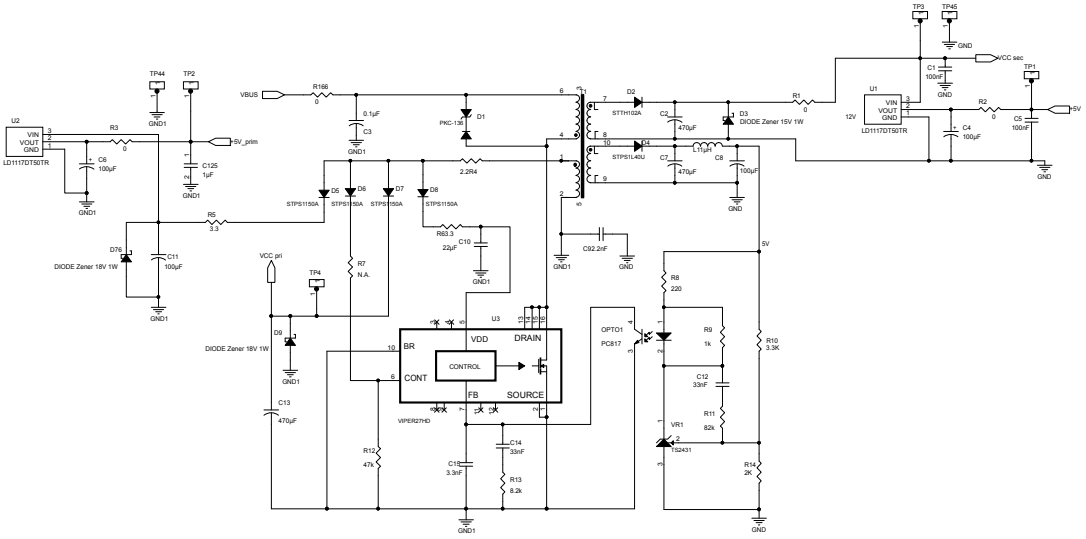


Figure 12. **STEVAL-DPSLLCP1 power board - filtering and connector schematic**

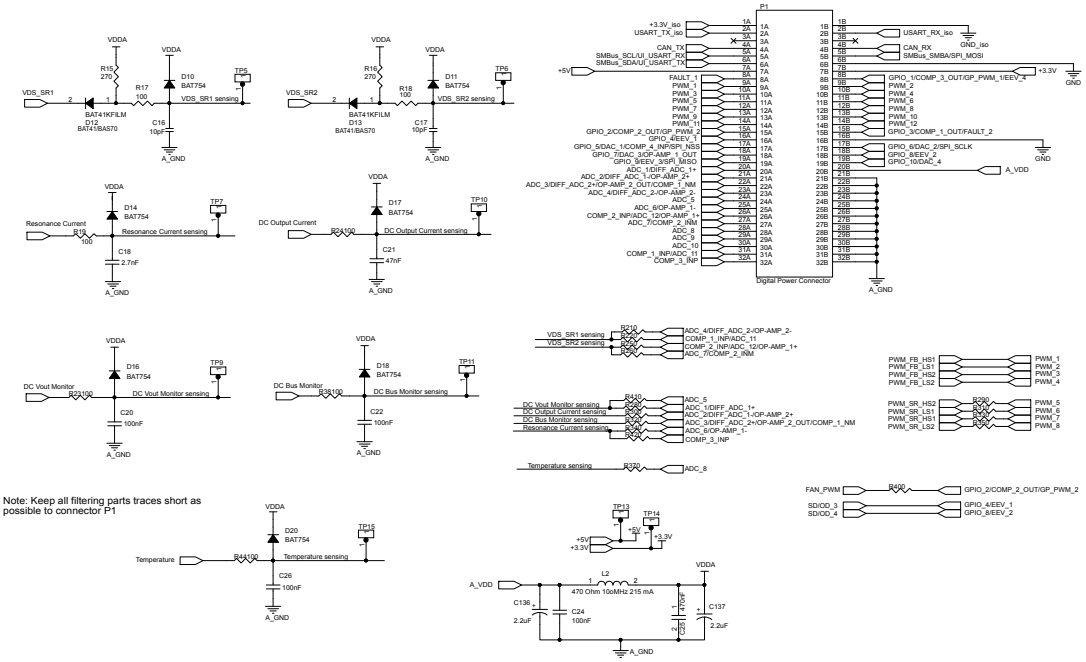


Figure 13. **STEVAL-DPSLLCP1 power board - mechanical parts**

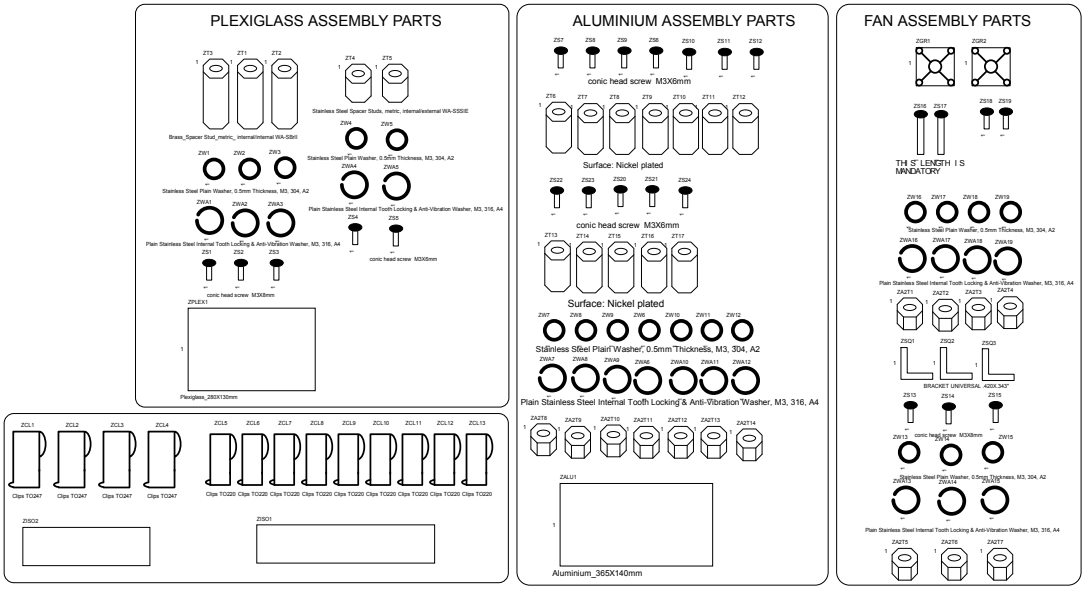


Figure 14. **STEVAL-DPS334C1 control board - MCU and connector schematic**

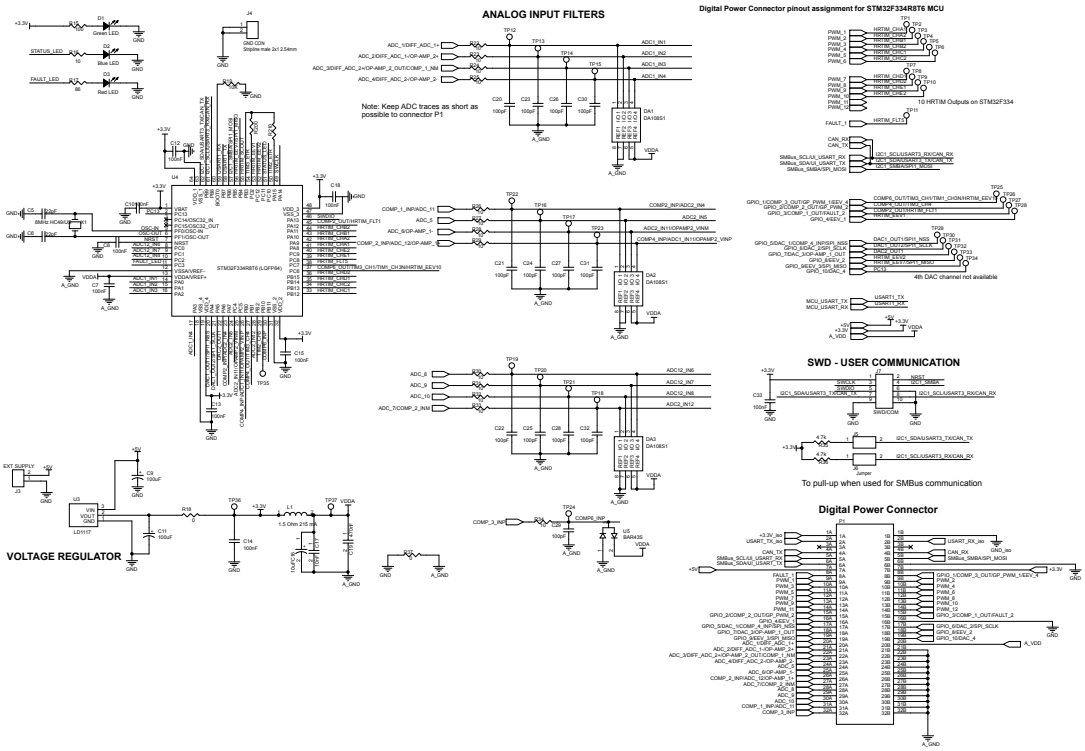


Figure 15. STEVAL-DPS334C1 control board - opto-isolated communication schematic

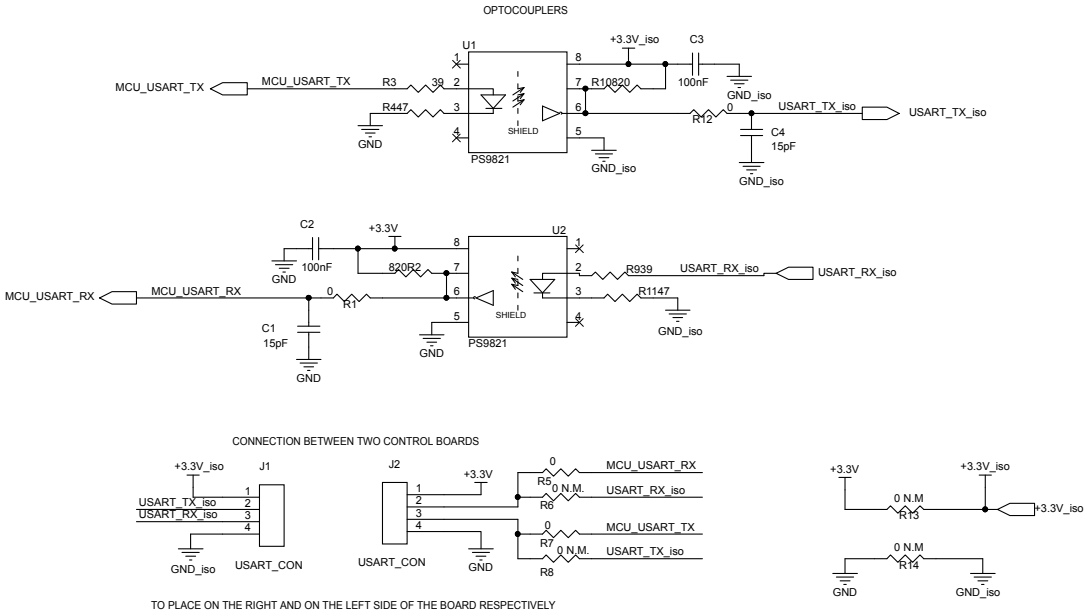
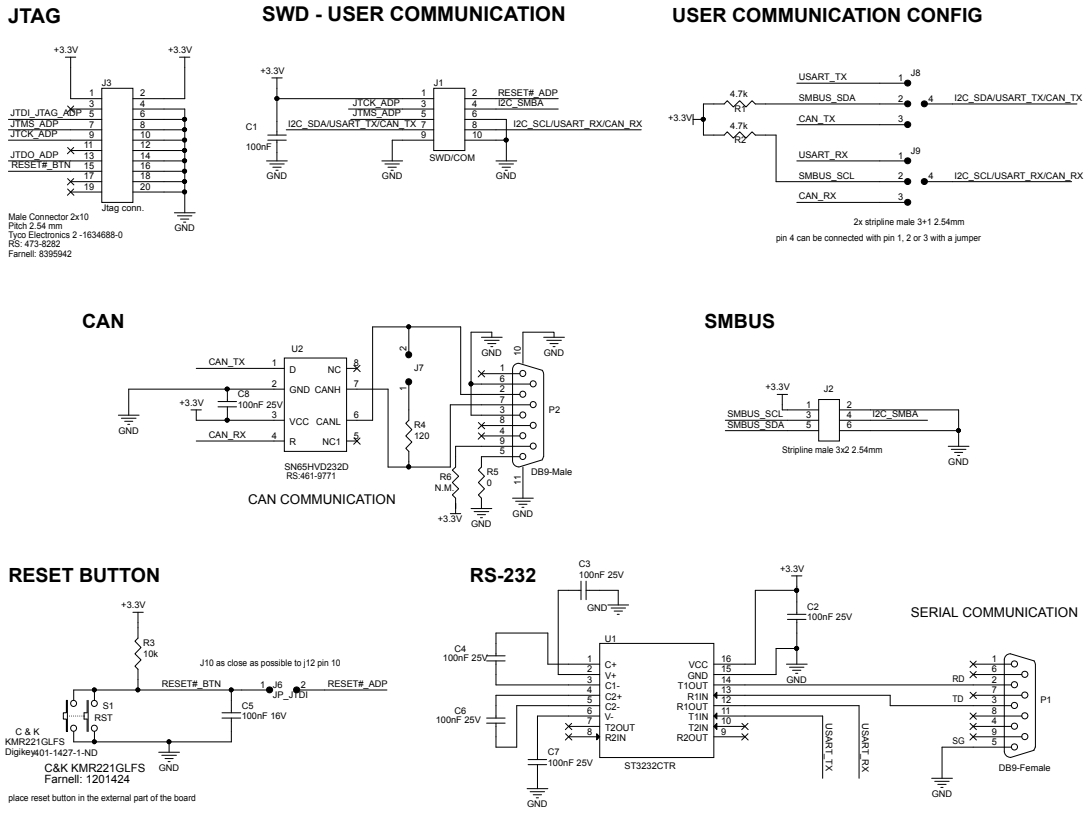


Figure 16. STEVAL-DPSADP01 adapter board schematic



8 STEVAL-DPSLLCK1 bill of materials

Table 8. **STEVAL-DPSLLCP1 power board bill of materials**

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
1	2	B1, B2	-	Power Term	KEYSTONE	K-8191
2	1	CS1	-	Hall Sensor	ALLEGRO	ACS758LCB-100U-PFF-T
3	2	C1, C5	100nF 50V ±10%	X7R CERAMIC CAP	any	any
4	3	C2, C7, C13	470µF 25V ±10%	ELEC. CAP	PANASONIC	EEEHBE471UAP
5	1	C3	0.1µF 630V ±20%	Y2 CAP	Vishay	BFC233610104
6	3	C4, C6, C8, C11	100µF 16V ±20%	ELEC CAP	PANASONIC	EEUFC1E101S
7	1	C9	2.2nF 250V ±20%	CERAMIC DISC CAP	MURATA	DE1E3KX222MA4BN01F
8	1	C10	22µF 25V ±20%	X7R CERAMIC CAP	PANASONIC	EEEFK1E220R
9	2	C12, C14	33nF 25V ±10%	X7R CERAMIC CAP	any	any
10	1	C15	3.3nF 50V ±10%	X7R CERAMIC CAP	any	any
11	2	C16, C17	10pF 50V ±10%	X7R CERAMIC CAP	any	any
12	1	C18	2.7nF 25V ±10%	X7R CERAMIC CAP	any	any
13	5	C20, C22, C26, C29, C30	100nF 25V ±10%	X7R CERAMIC CAP	any	any
14	1	C21	47nF 25V ±10%	X7R CERAMIC CAP	any	any
15	1	C24	100nF 25V ±10%	X7R CERAMIC CAP	any	any
16	1	C25	470nF 25V ±10%	X7R CERAMIC CAP	any	any
17	2	C32, C55	100nF 400V ±10%	Cap Polypropylene film	Epcos	B32023A3104M000
18	4	C33, C122, C133, C134	2.2nF 1000V ±5%	COG CERAMIC CAP	KEMET	C1812C222JDGACTU
19	2	C36, C37	470µF 450V ±20%	ELCTR. CAP	Cornell-Dubilier	SLP471M450H4P3
20	3	C39, C110, C130	18nF 2000V ±5%	X7R CERAMIC CAP	Vishay	BFC238364183
21	6	C41, C42, C44, C48, C50, C52	1µF 100V ±10%	X7R CERAMIC CAP	any	any
22	6	C43, C45, C46, C49, C51, C53	470u 63V ±20%	ELCTR. CAP	UNITED CHEMI CON	ELXZ630ELL471MK30S
23	6	C54, C64, C70, C78, C92, C100	1nF 25V ±10%	X7R CERAMIC CAP	any	any
24	4	C57, C58, C82, C84	100pF 25V ±10%	X7R CERAMIC CAP	any	any

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
25	4	C59, C67, C83, C85	1µF 50V ±10%	X7R CERAMIC CAP	TDK	C3216JB1H105K160AA
26	4	C60, C71, C86, C87	220nF 50V ±10%	X7R CERAMIC CAP	TDK	C2012JB1H224K125AA
27	4	C61, C77, C89, C90	15nF 50V ±10%	X7R CERAMIC CAP	any	any
28	1	C62	47nF 25V ±10%	X7R CERAMIC CAP	any	any
29	2	C63, C135	4.7n 25V ±10%	X7R CERAMIC CAP	any	any
30	8	C65, C69, C74, C75, C93, C95, C96, C99	10µF/35V 35V ±10%	ELEC.CAP SMD	PANASONIC	EEEFC1V100R
31	18	C66, C68, C72, C73, C76, C79, C80, C81, C88, C91, C94, C97, C98, C101, C103, C105, C106, C107	100nF 25V ±10%	X7R CERAMIC CAP	any	any
32	1	C102	100nF 25V ±10%	X7R CERAMIC CAP	any	any
33	2	C104, C109	150pF 25V ±10%	X7R CERAMIC CAP	any	any
34	1	C108	10nF 25V ±10%	X7R CERAMIC CAP	any	any
35	4	C117, C128, C129, C131	1n 630V ±5%	CERAMIC	TDK	CGA5F4C0G2J102J085AA
36	2	C123, C124	1µF 50V ±10%	X7R CERAMIC CAP	any	any
37	1	C125	1µF 50V ±20%	X7R CERAMIC CAP	any	any
38	1	C126	1µF 50V ±10%	X7R CERAMIC CAP	any	any
39	1	C132	47µF 63V ±20%	ELEC.CAP	PANASONIC	EEETG1J470UP+
40	4	C136, C137, C138, C139	2.2µF 10V ±10%	Tantalum	KENET	T491A225K010AT
41	1	D1	160V 1.5W	ASD TRANSIL AND BLOCKING DIODE	ST	PKC136
42	1	D2	1A 20V	SCHOTTKY DIODE	ST	STTH102A
43	1	D3	15V 1W ±5%	Zener Diode	DIODES INC.	DFLZ15-7
44	1	D4	1A 40V	SCHOTTKY DIODE	ST	STPS1L40U
45	4	D5, D6, D7, D8	100V 150mA	SMALL SIG. SCHOTTKY	ST	STPS1150A
46	1	D9	18V 1W ±5%	Zener Diode	Vishay	ZM4746A-GS08
47	7	D10, D11, D14, D16, D17, D18, D20	30V 0.1A	Schottky Diode	NXP	BAT754

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
48	2	D12, D13	100V	Schottky Diode	ST	BAT41KFILM
49	4	D22, D23, D24, D25	75V	Signal DIODE	any	any
50	4	D26, D27, D42, D43	30V 100mA	SMALL SIGNAL SCHOTTKY	ST	STPS1L30A
51	8	D32, D33, D34, D35, D52, D54, D55, D57	N.M 500mW 18V	ZENER DIODE	Vishay	MMSZ4705-V-GS08
52	4	D40, D73, D74, D75	N.M 500mW 18V	ZENER DIODE	ST	SMCJ18A-TR
53	2	D60, D61	1A 100V	SMALL SIGNAL SCHOTTKY	ST	STPS1H100A
54	1	D62	9.1V 500mW	ZENER DIODE	Vishay	BZT55C9V1
55	1	D63	2V7 500mW	ZENER DIODE	Vishay	BZV55-C2V7, 115
56	1	D64	20mA	LED DIODE	OSRAM	LSQ976-Z
57	8	D65, D66, D67, D68, D69, D70, D71, D72	600V 1A	SMALL SIGNAL SCHOTTKY	ST	STTH1R06A
58	1	D76	18V 1W ±5%	Zener Diode	ROHM	KDZVTR18B
59	1	F1	48V 240mA	COOLING FAN	SUNON	PMD4806PMB1A
60	1	F2	220V 2A	Fuse + Box low profile 5x20	MultiComp	MCHTC-100M +70-001-40 2A
61	1	HT1	53x35x275cm	Heatsink	AAVID THERMALLOY	Type 78075
62	4	IC1, IC2, IC3, IC4	-	High Voltage gate driver	ST	L6491D
63	1	J1	-	Power Jumper	Harwin Inc	D3080-05
64	1	J2	30A 600V	3WAY CONNECTOR	Phoenix Contact	1714984
65	1	J3	60A	2WAY CONNECTOR	Phoenix Contact	MKDSP 10N/2-10, 16
66	1	J4	2.54mm	Strip line male pin header +Jumper	any	any
67	1	J5	3.81 mm, 2 way, 26 AWG, 16 AWG	Terminal block	Multicomp	MC000044
68	1	L1	1µH 2.6A	HF INDCUTOR	COILCRAFT	ME3220-102ML
69	1	L2	470 Ω 100MHz 250 mA 250mA	Ferrite bead	WURTH ELEKTRONIK	7427927141
70	1	L3	3.9 mH 470mA ±10%	Inductor	PANASONIC	ELC15E392L
71	1	L4	470 Ω 250mA ±25%	Ferrite EMI suppression	WURTH ELEKTRONIK	7427927141
72	1	OPTO1	5kV 20mA	OPTOCOUPLER	SHARP	PC817X2NIP0F
73	1	P1	64P 2.54MM	Connector female DIN 41612 Through Hole	ERNI	284166

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
74	8	Q1, Q2, Q3, Q4, Q9, Q10, Q11, Q12	100V 180A	STripFET VII DeepGATE	ST	STP310N10F7
75	4	Q5, Q6, Q7, Q8	600V 36A	MDmesh DM2	ST	STW70N60DM2
76	1	Q13	60V 0.07 Ω 12A	STripFet MOSFET	ST	STD12NF06LT4
77	4	R1, R2, R3, R73	0 0.25W ±1%	SMD	any	any
78	1	R4	2.2 0.5W ±1%	SMD	any	any
79	1	R5	3.3 1/2W ±1%	SMD	any	any
80	1	R6	3.3 0.25W ±1%	SMD	any	any
81	1	R7	N.M. 0.25W ±1%	SMD	any	any
82	1	R8	220 0.125W ±1%	SMD	any	any
83	1	R9	1k 0.125W ±1%	SMD	any	any
84	1	R10	3.3K 0.125W ±1%	SMD	any	any
85	1	R11	82k 0.125W ±1%	SMD	any	any
86	1	R12	47k 0.25W ±1%	SMD	any	any
87	1	R13	8.2k 0.25W ±1%	SMD	any	any
88	1	R14	2K 0.125W ±1%	SMD	any	any
89	2	R15, R16	270 0.065W ±1%	SMD	any	any
90	7	R17, R18, R19, R23, R24, R38, R44,	100 0.065W ±1%	SMD	any	any
91	18	R21, R22, R25, R26, R28, R29, R30, R31, R32, R33, R34, R35, R37, R40, R41, R42, R47, R52	0 0.065W ±1%	SMD	any	any
92	1	R46	470 0.065W ±1%	SMD	any	any
93	1	R49	43 0.25W ±1%	SMD	any	any
94	1	R51	NM 0.25W ±1%	SMD	any	any
95	8	R53, R54, R55, R56, R76, R78, R79, R166	0 0.5W ±1%	SMD	any	any
96	11	R57, R58, R67, R69, R96, R149, R151, R152, R153, R154, R155	1 0.5W ±1%	SMD	any	any
97	4	R63, R64, R71, R72	20 0.5W ±1%	SMD	any	any
98	4	R68, R140, R144, R145	4.7 0.5W ±1%	SMD	any	any
99	2	R70, R161	50k 0.25W ±1%	SMD	any	any
100	1	R77	0 0.25W ±1%	SMD	any	any
101	1	R80	6.2k 0.25W ±1%	SMD	any	any
102	2	R81, R160	4, 99k 1.5W ±1%	SMD	any	any

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
103	4	R88, R89, R105, R106	100k 0.25W ±1%	SMD	any	any
104	1	R90	NM 0.065W ±5%	SMD	any	any
105	4	R92, R93, R109, R112	330 0.25W ±1%	SMD	any	any
106	1	R94	100 0.065W ±1%	SMD	any	any
107	2	R95, R108	10k 0.065W ±5%	SMD	any	any
108	4	R97, R103, R117, R121	10k 0.065W ±1%	SMD	any	any
109	4	R98, R101, R115, R122	0 0.065W ±5%	SMD	any	any
110	4	R99, R102, R114, R118	4.3k 0.065W ±1%	SMD	any	any
111	4	R100, R104, R111, R119	330 0.065W ±5%	SMD	any	any
112	1	R107	NM 0.065W ±5%	SMD	any	any
113	1	R116	1 0.25W ±1%	SMD	any	any
114	4	R123, R124, R125, R126	390K 0.5W ±1%	SMD	any	any
115	3	R127, R128, R132	68K 1.5W ±1%	SMD	any	any
116	1	R129	7.87K 0.25W ±1%	SMD	any	any
117	1	R130	680 0.25W ±1%	SMD	any	any
118	1	R131	4k 0.065W ±1%	SMD	any	any
119	1	R133	0 N. M 0.25W ±1%	SMD	any	any
120	1	R134	10K 0.25W ±1%	SMD	any	any
121	1	R135	39R 0.065W ±1%	SMD	any	any
122	2	R136, R137	2.2k 0.065W ±1%	SMD	any	any
123	1	R138	160 0.065W ±1%	SMD	any	any
124	1	R139	4.02k 0.065W ±1%	SMD	any	any
125	2	R142, R143	10k 0.065W ±5%	SMD	any	any
126	4	R146, R147, R148, R150	10 0.5W ±1%	SMD	any	any
127	4	R156, R157, R158, R159	10k 0.125W ±5%	SMD	any	any
128	4	R162, R163, R164, R165	N.M 0.125W ±5%	SMD	any	any
129	1	R167	0 0.25w ±1%	SMD	any	any

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
130	41	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP9, TP10, TP11, TP13, TP14, TP15, TP16, TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP25, TP26, TP27, TP28, TP29, TP30, TP31, TP32, TP33, TP34, TP35, TP36, TP37, TP38, TP40, TP41, TP42, TP43, TP44, TP45	TEST POINT	-	any	any
131	1	TP17	-	Spacer Brass Nichel		-
132	1	TP39	-	DC output current	any	any
133	1	T1	CSM16VT-070 6W	FLYBACK HF TRANSFO	WURTH	750817436
134	1	T2	CURR_TRANS 1:200 Current Trans.	SMD CT	EPCOS	B82801C2245A200
135	1	T3	3 3.5kW, 62A, Vout=48V, Lp=118µH, Lr=20.32µH, n=9, Fr=250kHz, Lm=97µH	HF Transformer	PIEMME Elektra ITALY	TE65037
136	2	U1, U2	-	LD1117DT50TR 5V	ST	LD1117DT50TR
137	1	U3	-	VIPER27HD 800V	ST	VIPER27HD
138	1	U4	2.4V 10µA	Temperature Sensor, 3-pin TO-92	TEXAS INSTRUMENTS	LM19CIZ
139	4	U5, U6, U7, U8	7mA input	SMD	Broadcom	ACPL-P484-000E
140	1	U9	100KHZ 8DIPGW	SMD	Avago	ACPL-782T-500E
141	1	U10	5µV	Zero drift OP-AMP	ST	TSZ121ILT
142	1	VR1	2.5V To 24V	PR. SHUNT VOLTAGE REF.	ST	TS2431BILT
143	1	ZALU1	365X140mmx1mm	Aluminium	-	
144	14	ZA2T1, ZA2T2, ZA2T3, ZA2T4, ZA2T5, ZA2T6, ZA2T7, ZA2T8, ZA2T9, ZA2T10, ZA2T11, ZA2T12, ZA2T13, ZA2T14	Type 304 S15	A2 grade 18//8 stainless steel	-	

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
145	2	ZGR1, ZGR2	-	Protection Fan	MULTICOMP	MCSC60-W2
146	1	ZPLEX1	280X130x3mm	Plexiglass		
147	3	ZSQ1, ZSQ2, ZSQ3	.420X.343x0.032"	BRACKET UNIVERSAL, BRASS	KEYSTONE ELECTRONICS CORP.	615
148	8	ZS1, ZS2, ZS3, ZS13, ZS14, ZS15, ZS18, ZS19	M3X8mm	Conic head screw	-	-
149	14	ZS4, ZS5, ZS6, ZS7, ZS8, ZS9, ZS10, ZS11, ZS12, ZS20, ZS21, ZS22, ZS23, ZS24	M3X6mm	Conic head screw	-	-
150	2	ZS16, ZS17	M3X45mm	Conic head screw	WURTH ELEKTRONIK	02863 45
151	1	ZT1	-	Material Brass MTHOLE3 WURTH ELEKTRONIK 970100351	WURTH ELEKTRONIK	970100351
152	2	ZT4, ZT5, ZT6, ZT7, ZT8, ZT9, ZT10, ZT11, ZT12, ZT13, ZT14, ZT15, ZT16, ZT17	-	Material Brass WURTH ELEKTRONIK 971 0527 160 Nickel plated Material Brass	WURTH ELEKTRONIK	971 100 351
153	19	ZWA1, ZWA2, ZWA3, ZWA4, ZWA5, ZWA6, ZWA7, ZWA8, ZWA9, ZWA10, ZWA11, ZWA12, ZWA13, ZWA14, ZWA15, ZWA16, ZWA17, ZWA18, ZWA19	M3, 316, A4	Plain Stainless Steel Internal Tooth Locking & Anti-Vibration Washer	-	-
154	4	ZCL1, ZCL2, ZCL3, ZCL4		Clips TO247	AAVID Thermalloy	MAX03N
155	9	ZCL5, ZCL6, ZCL7, ZCL8, ZCL9, ZCL10, ZCL11, ZCL12, ZCL13		Clips TO220	AAVID Thermalloy	MAX10N
156	2	ZISO1, ZISO2	12, 5x2, 8cm e 8x2, 8cm	Isolation Materials	Bergquist	SP800-0.005-AC-1212

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
157	19	ZW1, ZW2, ZW3, ZW4, ZW5, ZW6, ZW7, ZW8, ZW9, ZW10, ZW11, ZW12, ZW13, ZW14, ZW15, ZW16, ZW17, ZW18, ZW19	0.5mm , M3, 304, A2	Stainless Steel Plain Washer	-	-

Table 9. STEVAL-DPS334C1 control board bill of materials

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

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
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	-
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

Item	Q.ty	Ref.	Part/Value	Description	Manuf.	Order code
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

Table 10. STEVAL-DPSADP01 adapter board bill of materials

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 11. **Document revision history**

Date	Version	Changes
13-Apr-2018	1	Initial release.
11-Sep-2018	2	Updated Figure 10. STEVAL-DPSLLCP1 power board - LLC power stage schematic and Table 2. DC-DC converter fault codes.
18-Dec-2018	3	Updated Table 2. DC-DC converter fault codes.

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Glossary

Burst mode

Replaces continuous cycles with discontinuous pulses over a specified burst period to regulate voltage and limit losses under light load conditions.

LLC resonant converter

A highly efficient conversion network based on natural electrical oscillation due to the presence of reactive components (2 inductors and a capacitance in series). It is able to regulate voltage across a wide output load range including no load.

Low-dropout regulator

A DC linear voltage regulator with a small input-output differential voltage.

MDmesh™ DM2

A proprietary STMicroelectronics silicon-based MOSFET technology with a fast-recovery intrinsic diode.

STripFET™ F7

A proprietary STMicroelectronics LV MOSFET technology offering the best R_{DSon} for higher power integration, improved body diode performance, EMI immunity and minimized Miller Effect.

synchronous rectification

Wave rectification through controlled switching of low resistance MOSFET transistors.

zero voltage switching

A soft commutation technique where MOSFET switching only occurs when the voltage across it is zero (or near zero), eliminating turn-on switching losses.