UM2309
User manual

Getting started with the 45 W wall adapter solution for USB Type-C Power Delivery

Introduction

This board has been physically tested and validated; it is not for sale.

This USB Power Delivery wall adapter is a USB-IF certified solution with a 45 W isolated power supply with USB Power Delivery controller.

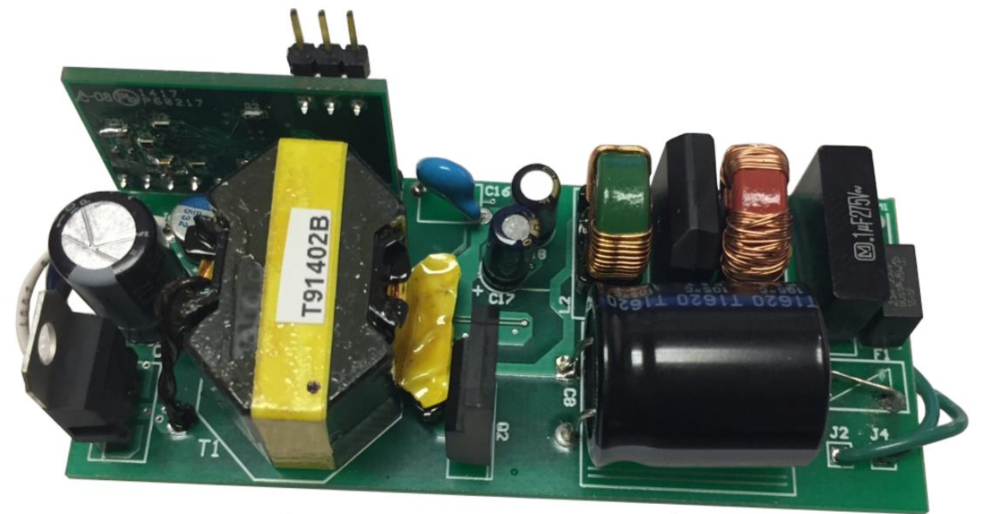
This USB Type-C PD wall power adapter design is for universal line voltage applications based on the STCH02 Primary controller and STUSB4700 USB PD controller.

The 5 V, 9 V and 15 V USB output voltage profiles all have a 3 A rating.

The offline power supply is implemented in an isolated flyback topology based on the STCH02 quasi-resonant controller with ultra-low standby power consumption. The USB Power Delivery (PD) is managed by the STUSB4700 and is Type-C compatible: power negotiation, Vbus discharge, protections, etc. are entirely managed by the IC.

The USB power supply architecture connects a power board with a controller board. This design optimizes the form factor and lets you scale the power section up or down to suit different USB Power Adapter applications.

Figure 1: STEVAL-USBPD45H evaluation board



NOT FOR SALE

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1.1 Main characteristics

- USB wall power adapter input: 85 V_{AC} to 264 V_{AC}
- USB voltage output: 5 V, 9 V and 15 V
- Current limit: 3 A for all voltage level profiles
- Load power limited to 45 W
- Cable compensation
- Isolated quasi-resonant flyback
- Efficiency 90% (approx.)
- USB Type-C Power Delivery compatible
- USB-IF certified

2 Schematics and list of components

To improve form factor, the solution is integrated on two separate boards: one for the offline flyback converter and one for the USB control.

Figure 2: Power board schematic diagram

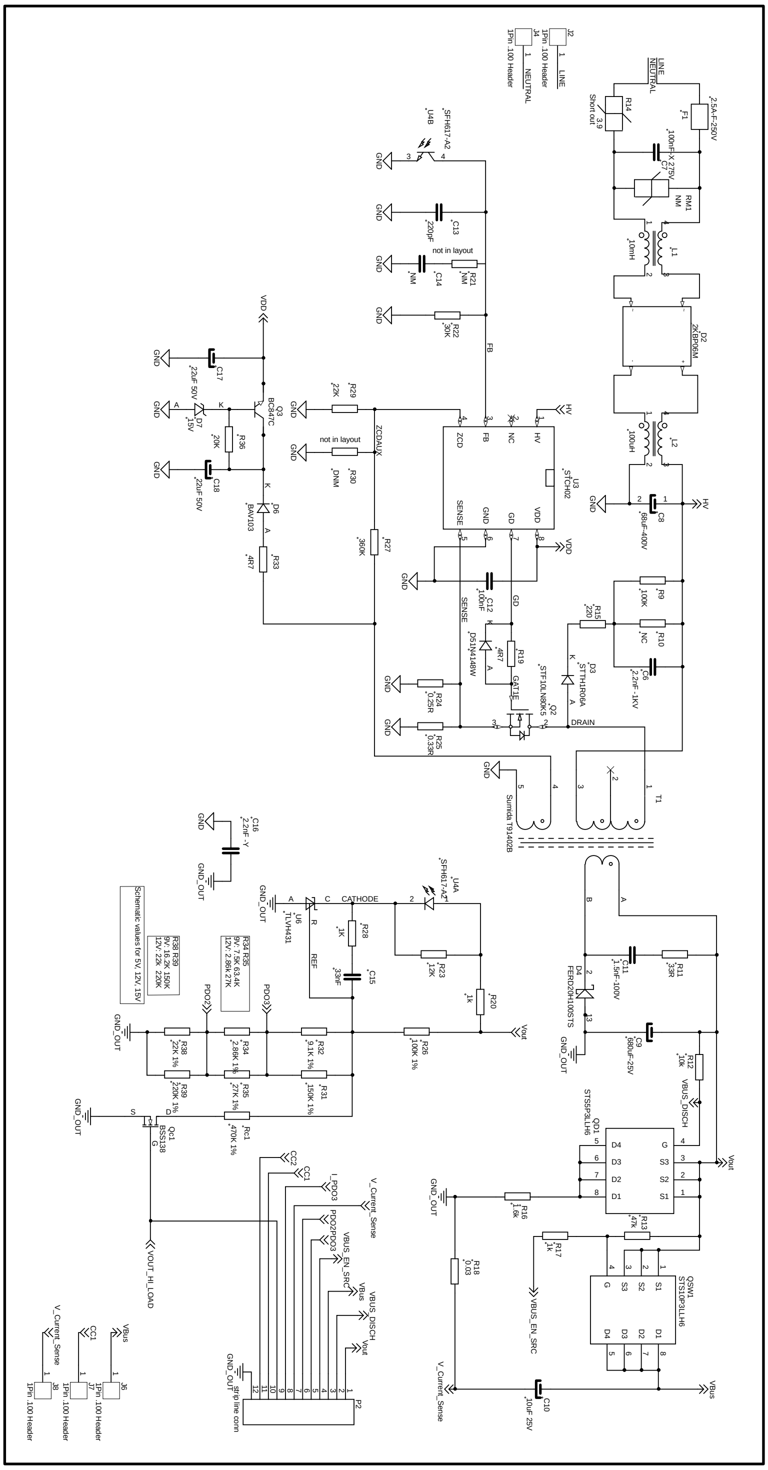


Table 1: Power board bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	1	C6	2.2 nF 1 KV 1206	Capacitor	Murata	490-3496-1
2	1	C7	100 nF X 275 V BOXCAP18.5X7.0LS15.0	Capacitor	EPCOS	495-1389-ND
3	1	C8	68 µF 400 V CAPE Laydown 18DX7.5LS+L	Capacitor	Rubycon	1189-3150
4	1	C9	680 µF 25 V CAPE10DX5LS	Capacitor	Rubycon	1189-1855
5	1	C10	10 µF 25 V CAPE5.0DX2.5LS	Capacitor	Kemet	A758BG106M1EAAE070-ND
6	1	C11	1.5 nF 100 V 1206	Capacitor	AVX	478-1451-6
7	1	C12	100 nF 0603	Capacitor	Any	
8	1	C13	220 pF 0603	Capacitor	Any	
9	1	C15	33 nF 0603	Capacitor	Any	
10	1	C16	2.2 nF -Y DISCAP7.0X5.0LS7.5	Capacitor	Murata	490-9459
11	2	C17, C18	22 µF 50 V CAPE5DX2.0LS	Capacitors	Rubycon	1189-1853
12	1	D2	2KBP06M 2KBP06M	Bridge rectifier	Vishay	625-2KBP06M-E4/51
13	1	D3	STTH1R06A SMA	Turbo 2 ultrafast high voltage rectifier	ST	STTH1R06A
14	1	D4	FERD20H100STS TO220INLINE	100 V field-effect rectifier diode	ST	FERD20H100STS
15	1	D5	1N4148W SOD123	Fast switching diode	Vishay	1N4148WS
16	1	D6	BAV103 SOD123	Diode	Vishay	BAV103-GS18CT
17	1	D7	15 V SOD123	Diode	Micro Commercial	SMAJ4744ATPCT
18	1	F1	2.A -F-250 V SS-5F BK	Fuse	Bussmann/Eaton	SS-5F-2.5A
19	1	L1	10 mH 744841210	Leaded inductor	Wurth Elektronik	744821110
20	1	L2	100 µH 744841210	Inductor	Wurth Elektronik	744841210
21	1	P2	HDR1X12	HDR1X12	Samtec	HDR1X12
22	1	Q2	STF10LN80K5 TO220FP	Power MOSFET	ST	STF10LN80K5

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
23	1	Q3	BC847C SOT23	General-purpose transistor	Nexperia	BC847
24	1	Qc1	BSS138 SOT23_FET	N-Channel transistor	Fairchild	BSS138KCT
25	1	QD1	STS5P3LLH6 NFET_SO8	Power MOSFET	ST	STS5P3LLH6
26	1	QSW1	STS10P3LLH6 NFET_SO8	Power MOSFET	ST	STS10P3LLH6
27	1	R9	100 K 1206	Resistor	Any	
28	1	R10	NC 1206	Resistor	Any	
29	1	R11	33 R 1206	Resistor	Any	
30	1	R12	10 k 0603	Resistor	Any	
31	1	R13	47 k 0603	Resistor	Any	
32	1	R14	0 R	Jumper	Any	
33	1	R15	220 SM/R_2010	Resistor	Yageo	YAG3386CT-ND
34	1	R16	1.6 K 1210	Resistor	Any	
35	3	R17, R20, R28	1 k 0603	Resistor	Any	
36	1	R18	0.03 SM/R_2010	Resistor	Stackpole Electronics	CSRN2010FK30L0CT-ND
37	2	R19, R33	4R7 0805	Resistor	Any	
38	1	R22	30 K 0603	Resistor	Any	
39	1	R23	12 K 0603	Resistor	Any	
40	1	R24	0.25 R 1206	Resistor	Stackpole Electronics	CSR1206FKR330CT-ND
41	1	R25	0.33 R 1206	Resistor	Stackpole Electronics	CSR1206FKR330CT-ND
42	1	R26	100 K ±1% 0603	Resistor	Any	
43	1	R27	360 K 0603	Resistor	Any	
44	1	R29	22 K 0603	Resistor	Any	
45	1	R31	150 K ±1% 0603	Resistor	Any	
46	1	R32	9.1 K ±1% 0603	Resistor	Any	
47	1	R34	7.5 K ±1% 0603	Resistor	Any	
48	1	R35	63.4 K ±1% 0603	Resistor	Any	
49	1	R36	20 K 0603	Resistor	Any	
50	1	R38	16.2 K ±1% 0603	Resistor	Any	
51	1	R39	150 K ±1% 0603	Resistor	Any	
52	1	Rc1	470 K ±1% 0603	Resistor	Any	

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
53	1	RM1	NM MOV5X7LS5	Resistor	Any	
54	1	T1	Sumida T91402B	Power inductor	Sumida	Sumida T91402B
55	1	U3	STCH02 SO8	PWM quasi resonant controller	ST	STCH02
56	1	U4	SFH617-A2 HPCL-B17-560E OPTOCOUP_SM	Optocoupler	Vishay	SFH617-A2
57	1	U6	TLVH431 TL432_SOT23-3	Adjustable shunt voltage reference	ST	TLVH431
58	1	Heatsink	6043PBG 25.4 mm x 20.32 mm	Heat sink	Aavid Thermalloy	6043BG-ND

Figure 3: Control board schematic diagram

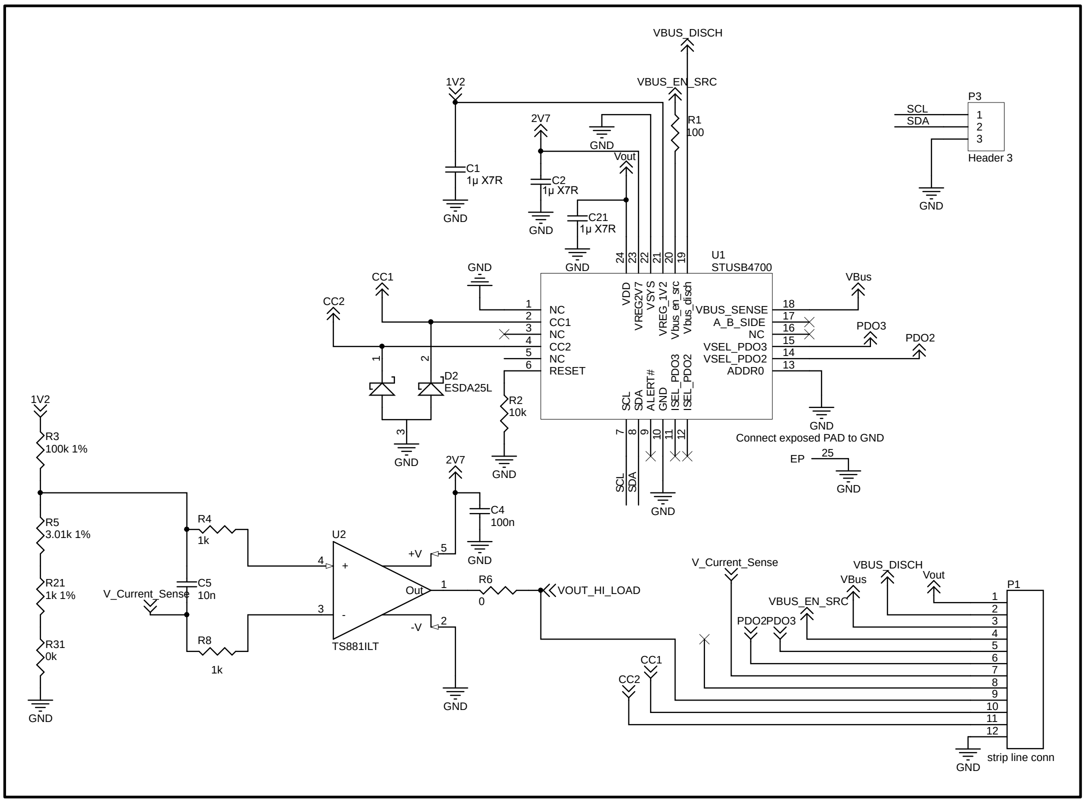


Table 2: Control board bill of materials

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	3	C1, C2, C21	1µ X7R 0805	Capacitors	Any	
2	1	C4	100 n 0805	Capacitor	Kemet	C0805C104K5RACTU

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
3	1	C5	10 n 0805	Capacitor	Any	
4	1	D2	ESDA25L SOT-23	Dual Transil™ array for ESD protection	ST	ESDA25L
5	1	R1	100 0603	Resistor	Any	
6	1	R2	10 k 0603	Resistor	Any	
7	1	R3	100 k ±1% 0603	Resistor	Any	
8	2	R4, R8	1k 0603	Resistor	Any	
9	1	R5	3.01 k ±1% 0603	Resistor	Any	
10	1	R6	0 0603	Resistor	Any	
11	1	R21	1 k ±1% 0603	Resistor	Any	
12	1	R31	0 k 0603	Resistor	Any	
13	1	U1	STUSB4700 QFN24_L	Stand-alone USB power delivery controller	ST	STUSB4700
14	1	U2	TS881 SOT23-5	Rail-to-rail 0.9V nanopower single comparator	ST	TS881

3 Description of main components

3.1 STUSB4700 stand-alone USB PD controller with integrated discharge path (control board component U1)

This fully hardware integrated USB power delivery controller is compliant with USB Type-C r1.2 and certified as USB PDr2.0. The solution is entirely hardware based and requires no embedded software development. The protocol uses configuration channel pins (CC) to negotiate the requested power profile.

The device can be configured via the I2C interface for up to 5 power profiles, with selectable current, voltage and configurable transition characteristics, including V_{BUS} discharge.

The device manages communication and power profile control in line with USB PD 2.0 standard, including the following functionality:

- Detects connection between two USB ports (attach detection)
- Establishes a valid host to device connection
- Discovers and configures VBUS: Type-C low, medium or high current mode
- Resolves cable orientation
- Negotiates a USB power delivery contract with a PD capable device
- Configures the power source accordingly
- Monitors V_{BUS}, manages transitions, handles protections and ensures user and device safety

3.2 STCH02 offline PWM quasi resonant controller for ultra-low standby power supplies (power board component U3)

This quasi-resonant controller with primary side constant current (CC) regulation is specifically designed for AC/DC chargers and adapters for smart phones, tablets and other handheld personal electronics applications. The IC uses optocoupler feedback for secondary side voltage regulation which ensures safety isolation from the high voltage side. *STCH02* features a 650 V integrated start-up circuit, adjustable output over-voltage protection, frequency jitter for EMI suppression and ultra-low power consumption.

The device is supplied from an auxiliary winding of the transformer. Because of the wide range of possible output voltage profile settings, a simple regulator (Q3 and D7) is required to ensure V_{DD} does not exceed 23 V (V_{DDmax}) at 15 V output voltage.

R27 and R29, the zero-current detection network (ZCD) senses demagnetization of the transformer, which is used for quasi-resonant operation. Overvoltage protection is also triggered according to the voltage information sampled via this pin. Primary current is sensed with series resistor pair R24 and R25 for current control, ensuring output voltage fold-back at maximum load current (above 3 A).

3.3 Flyback transformer (power board component T1)

The transformer is custom made by Sumida. The core used is an RM10 type.

Figure 4: Flyback transformer

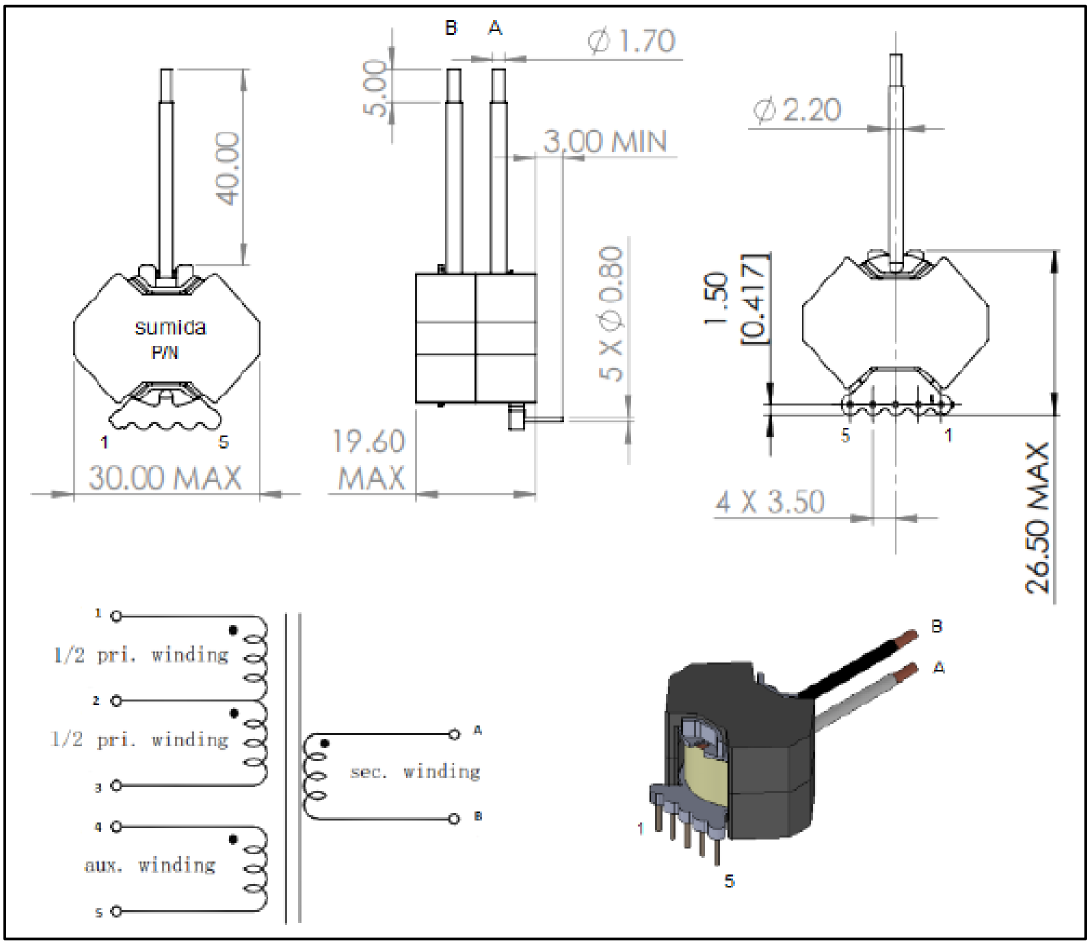


Table 3: Electrical specifications (at 25°C unless otherwise specified)

Parameter	Conditions	Value	Units	Tolerance
Inductance (OCL)	(1-3) 0.1Vrms, 10KHz	600	µH	±15%
DCR (PRI)	(1-3)	0.380	Ω	MAX
DCR (SEC)	(A-B)	16.00	mΩ	MAX
DCR (AUX)	(4-5)	0.640	Ω	MAX
Leakage Inductance (LL)	(1-3) [tie 4+5, A+B], 0.1Vrms, 100KHz	8.0	µH	MAX
Turns Ratio	(1-3) : (A-B)	5.2:1	N/A	±2%
Turna Ratio	(1-3) : (4-5)	2.6:1	N/A	±2%
HI-POT	(1,2,3,4,5) : (A,B)	3000	Vrms	2S, 1mA, 50/60Hz

3.4 Other components

STF10LN80K5 **(Power board component Q2)**: 800 V N-channel Power MOSFET designed using MDmesh™ K5 technology. Its very low on-resistance of 0.63 Ω (max) and ultra-low gate charge is very well suited for this application and helps achieve high efficiency.

FERD20H100STS **(Power board component D4)**: 100 V/20 A secondary side FERD rectifier with low forward voltage, low leakage current; appropriate for high frequency switching applications.

STTH1R06 **(Power board component D3)**: 600 V/1 A ultrafast soft recovery diode forming part of the RCD peak clamp circuit.

TLVH431 **(Power board component U6)**: 1.24 V voltage reference used as part of the feedback error amplifier.

STS10P3LLH6 **(Power board component QSW1)**: PMOS load switch with minimal on-resistance to minimize conduction losses at high load current. It is a 12 A device with 12m Ω drain-source resistance.

TS391 **(Power board component U2)**: Nano-power rail-to-rail comparator with push-pull output used for cable drop compensation. At load currents higher than 1.5 A, the comparator output activates a MOSFET that changes the feedback divider of the flyback that sets output voltage.

4 Layout of the PCB

Figure 5: Power board PCB layout (top)

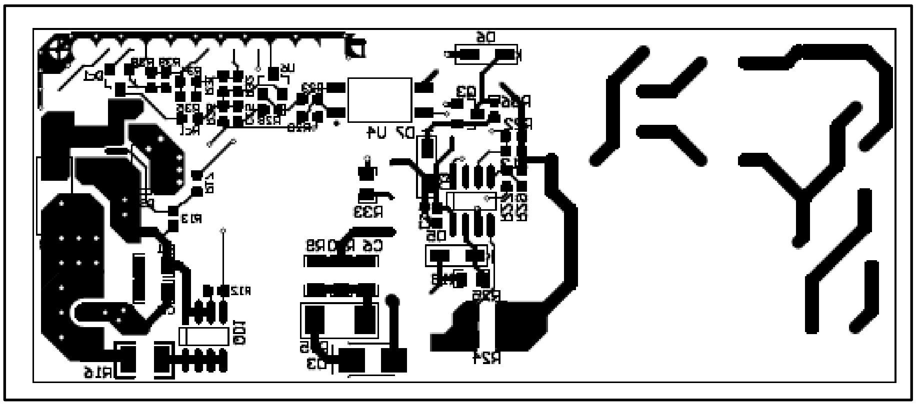


Figure 6: Power board PCB layout (bottom)

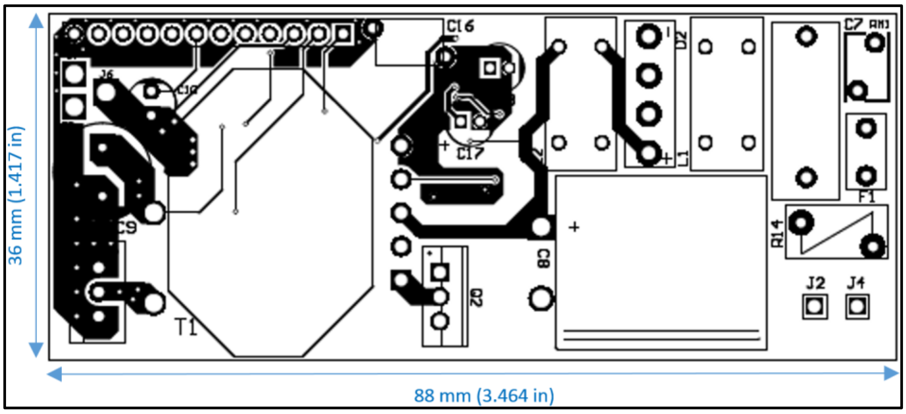


Figure 7: Control board PCB layout (top)

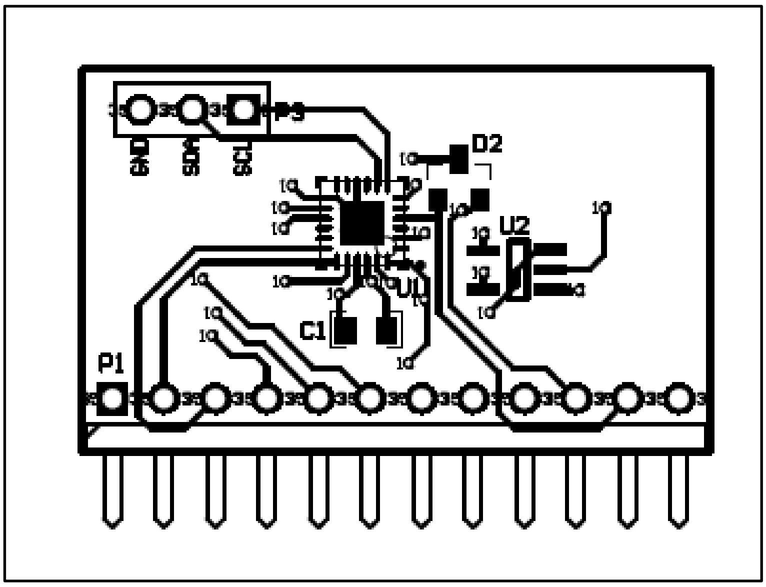
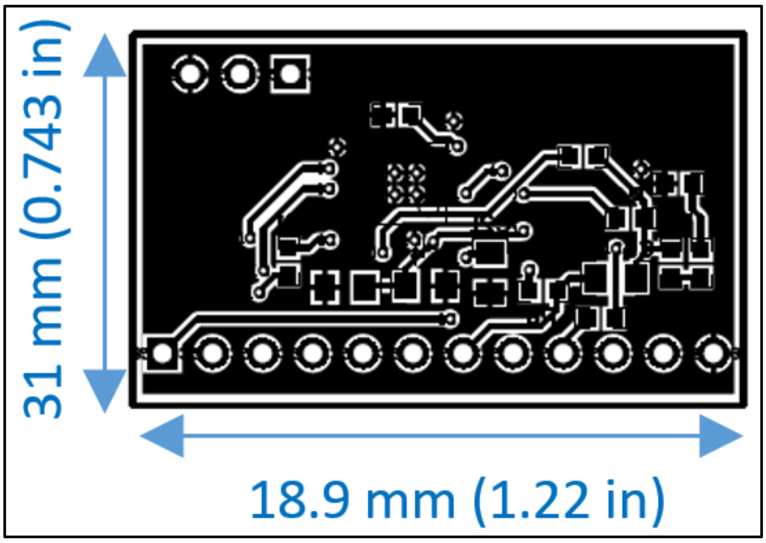


Figure 8: Control board PCB layout (bottom)



5 Electrical safety

The STEVAL-USBPD45H solution is designed to comply with UL and other safety standards, but is nonetheless only intended for functional demonstration purposes. ST reference designs and demonstration boards are intended to help and facilitate development of products. Using a direct copy of any of them does not waive the requirement for testing and certification of products mandated by the governing agencies and authorities.

The power supply solution is implemented in isolated flyback topology. The secondary low-voltage side is isolated from the high-voltage primary side by the transformer, opto-coupler, Y-capacitor and minimum creepage between copper tracks on either side.

Table 4: Primary-Secondary Isolation elements - key parameters

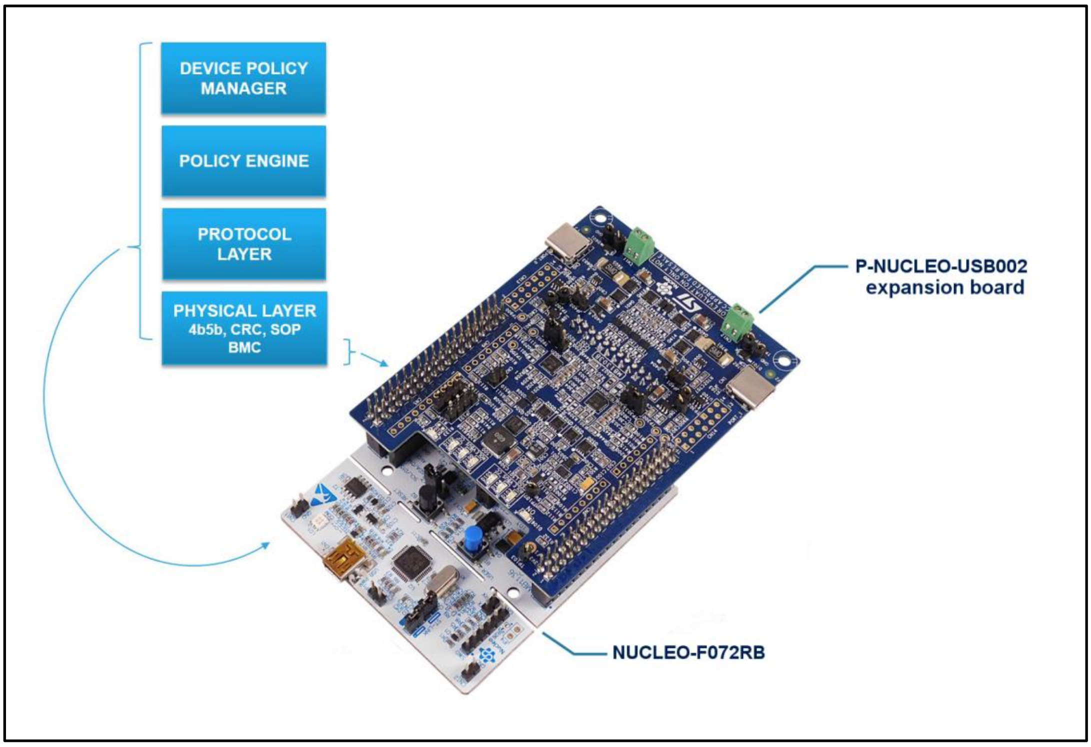
Transformer	Hi-Pot Isolation	3000 VRMS, 50/60Hz	Tested 2s
Y cap	Y2 Rated	250VAC 2000V lead dielectric strength	
Copper Track Creapage	200 mil (5mm)	1000VDC	

6 Getting started with the STEVAL-USBPD45H

6.1 Host system: P-NUCLEO-USB002 USB Type-C expansion pack

To evaluate the full functionality of the STEVAL-USBPD45H, a compatible USB Type-C host device must be used in conjunction with the evaluation board.

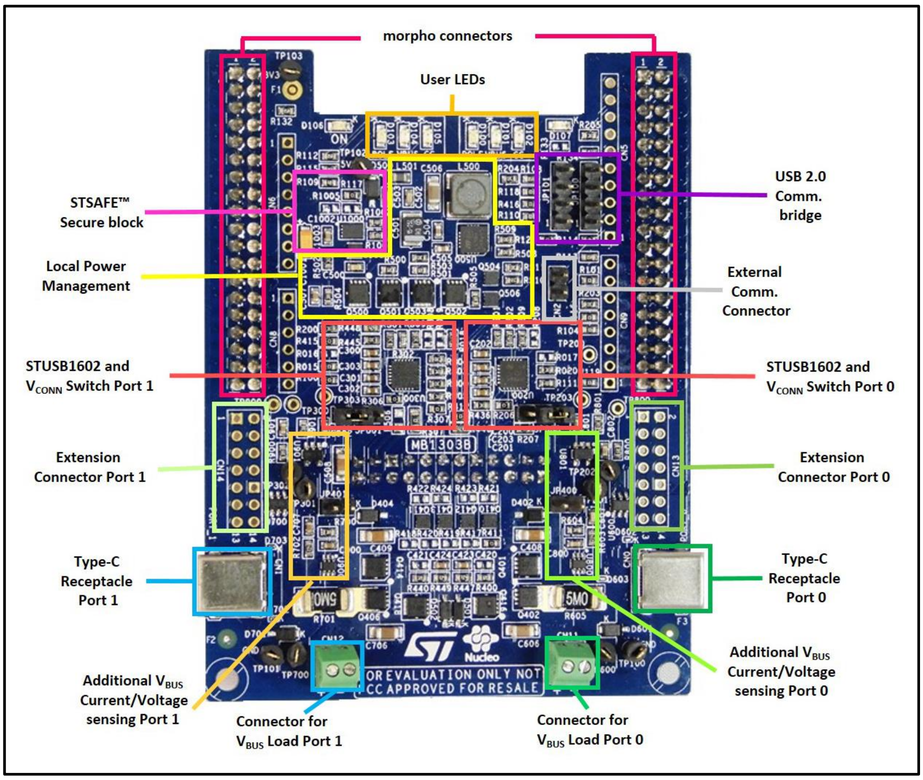
Figure 9: P-NUCLEO-USB002 STM32 Nucleo Pack for USB Type-C expansion



The *P-NUCLEO-USB002* is an *STM32 Nucleo* USB Type-C expansion pack that supports USB PD Stack. The development kit includes the following boards:

1. The *NUCLEO-F072RB* development board with embedded software compliant with USB Type-C (Rev 1.2) and Power Delivery (Rev. 2.0). Visit the *NUCLEO-F072RB* product folder to download the necessary firmware drivers.
2. The *P-NUCLEO-USB002* expansion board is based on the *STUSB1602* Type-C controller and has two full-featured USB Type-C ports configurable for Provider, Consumer or DRP roles.

Figure 10: P-NUCLEO-USB002 Nucleo Pack with USB1602 Expansion Board



6.2 System setup

1. On *NUCLEO-F072RB* board, verify jumper settings:
   - JP1 closed
   - JP5 (PWR) set to U5V
   - JP5 closed (IDD)
2. On the *P-NUCLEO-USB002* expansion board, verify jumper settings:
   - JP400 closed
   - JP000 closed on pins 1-2
3. Connect the NUCLEO-F072RB to a PC using a USB Type-A to Mini-B cable (not provided)
4. Connect the NUCLEO-F072RB serial coms (RX/TX) to the P-NUCLEO-USB002 expansion board.

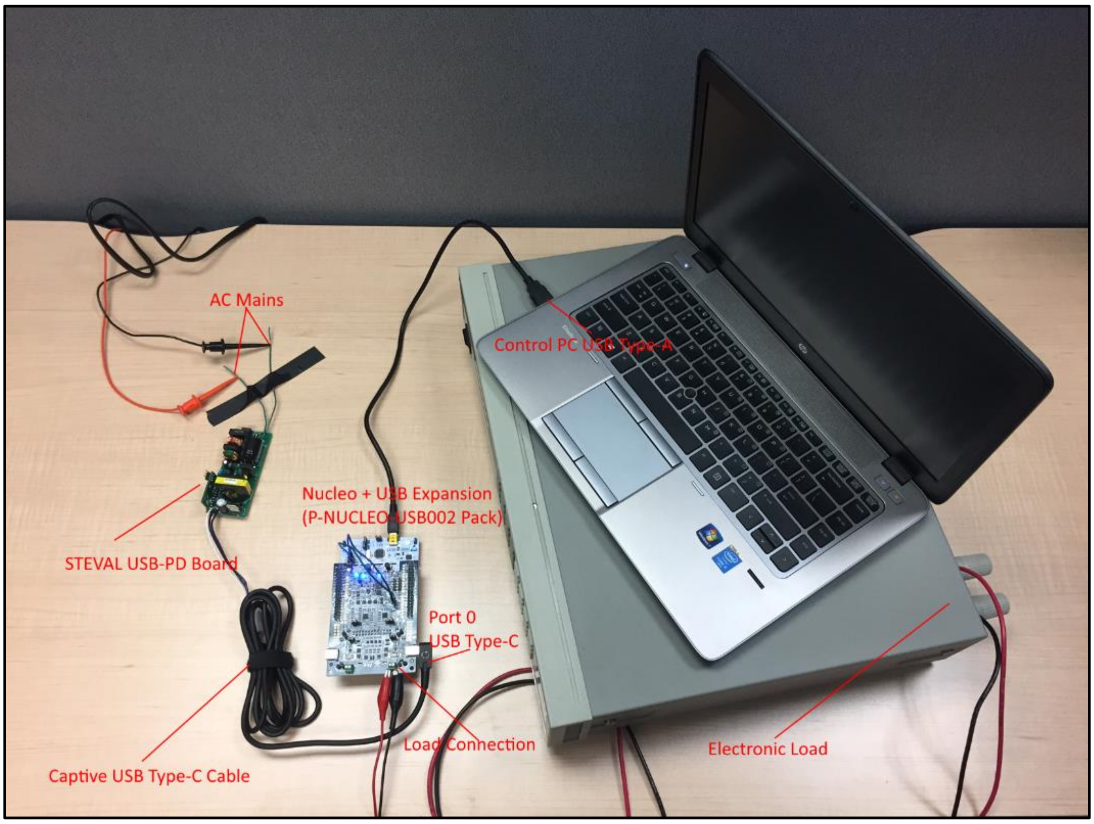
   The two blue LEDs identify the role of each of the two ports – blink once for Provider, twice for Consumer, and three times for DRP role
5. Connect the STEVAL-USBPD45H to either of the two Type-C receptacles
6. The two orange LEDs light up when a cable is detected in port 0 or 1 respectively, and blink once or twice depending on cable orientation
7. Two green LEDs blink when Vbus is detected

6.3 Connect STEVAL-USBPD45H and load test

The AC Mains connection to the STEVAL-USBPD45H evaluation board accepts a wide range of voltages from 85 V_{AC} to 265 V_{AC}.

For safety reasons, you should connect the board via an isolating transformer, considering the exposed components and tracks on the board and the fact that it is intended for electrical evaluation.

Figure 11: Setting up the complete testing environment



The STEVAL-USBPD45H is connected to the P-NUCLEO-USB002 board via the USB Type-C captive cable. You can connect to either of the two available ports (Port 0 or 1). The USB expansion board connector is a good point for voltage measurements as it accurately represents cable drop losses and voltage drops at end of the USB cable.

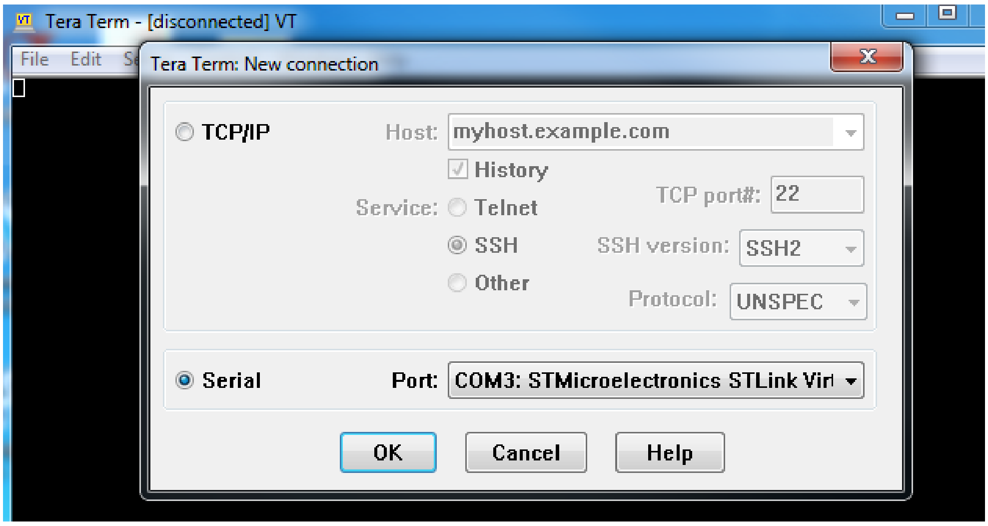
The load range of the STEVAL-USBPD45H is 0 A to 3 A for all 3 voltage profiles. For load currents above 3 A, current protection is activated to limit load power and ultimately disconnect the output. Further reconnection will initiate the default 5 V output setting.

You can use either an active load, as shown in *Figure 11: "Setting up the complete testing environment"*, or a resistive load. In both cases, they have to be rated for the tested power level.

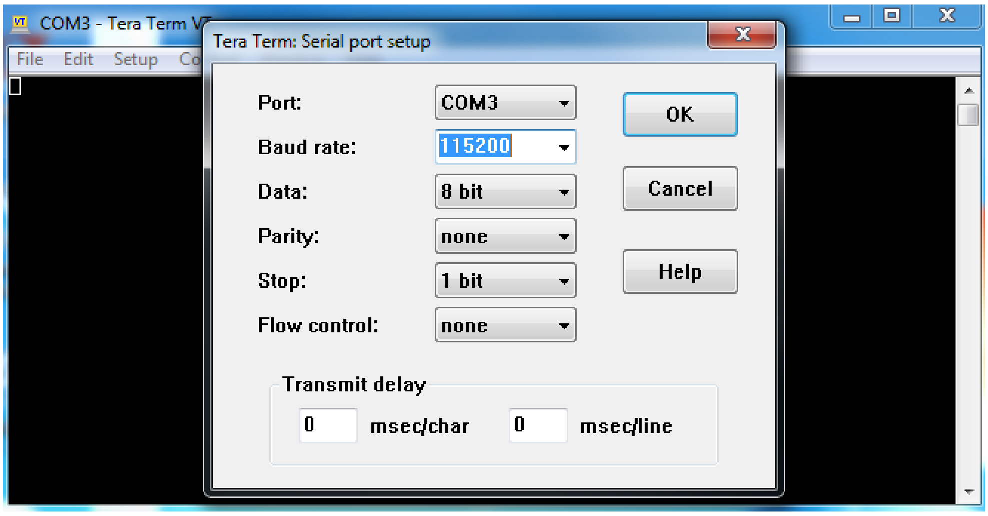
6.4 Profile change request

A simple software terminal emulator for serial port communication, such as Tera Term (freeware) can be used to send configuration status queries and profile change commands.

1. Set up the serial port emulator for STMicroelectronics ST-LINK and install the Nucleo drivers.



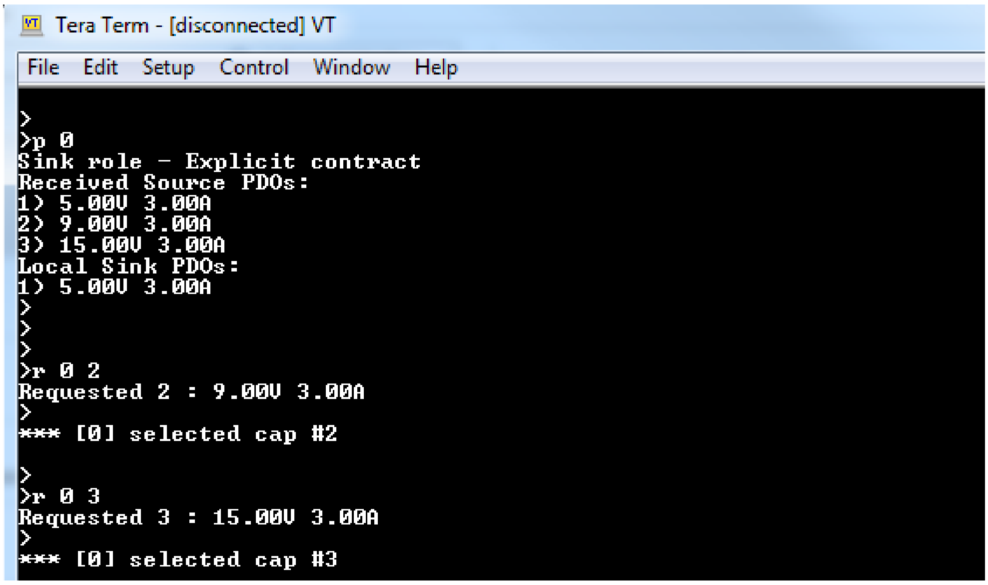
2. Select the right baud rate in the serial port setup menu.



Communication should be established.

3 Use the following commands to request output profile change:

- p 0/1 – shows the programmed profile for port 0 or 1
- r 0 1/2/3 – request change to profile 1, 2 or 3 (for port 0 – 5V, 9V, 15V respectively)



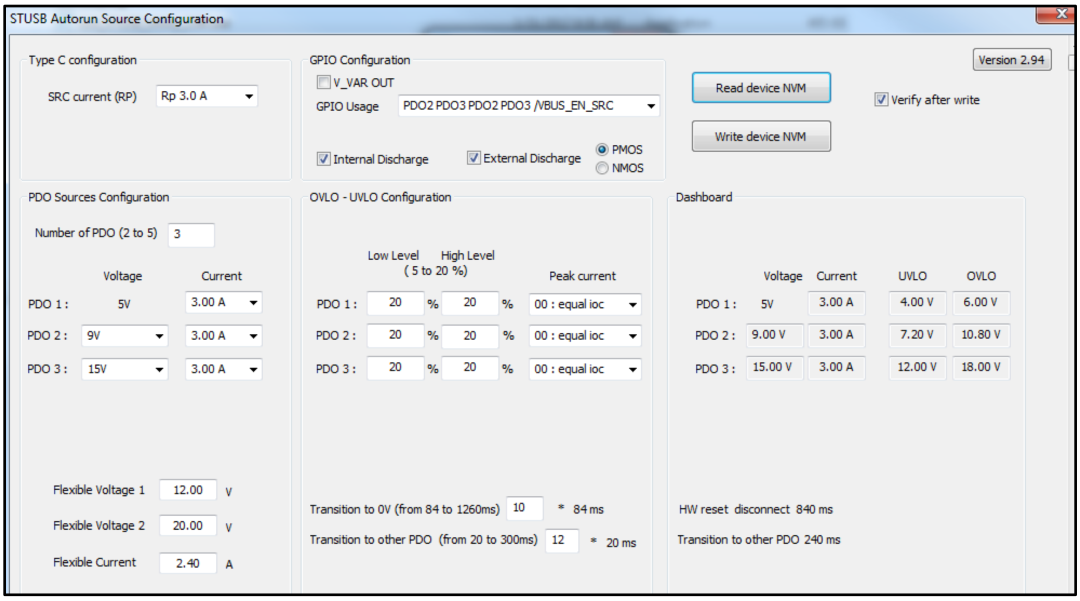
6.5 Configuration of STUSB4700 standalone USB PD controller

The *STUSB4700* standalone USB PD controller is configurable via a simple GUI interface.

You can download the GUI and corresponding installation guide from *STSW-STUSB001* or from the *STUSB4700* product page under the TOOLS AND SOFTWARE tab.

The NVM configuration lets you modify PDO (output profile) settings including current and voltage, number of PDOs, discharge mechanism, undervoltage and overvoltage tolerances and settling time.

Figure 12: STUSB graphical user interface tool



To run the GUI on a Windows laptop, you can use a standard *NUCLEO-F072RB* as a USB to I²C interface between the USB port on your PC to the I²C port on the *STUSB4700*.

7 Test measurement reports

7.1 STEVAL-USBPD45H efficiency measurements

All tests were performed using the *P-NUCLEO-USB002* expansion board. All measurements were taken at room temperature after at least 20 minutes of operation to minimize the effect of transformer core warm up.

The efficiency of the solution was tested at the following typical line voltages:

- 120 V_{AC} (see *Figure 13: "Efficiency measurement at 120 V_{AC} line voltage"*)
  - efficiency for load current at 5 V - *Table 5: "Efficiency measurement for 5 V at 120 V_{AC} line voltage"*
  - efficiency for load current at 15 V - *Table 6: "Efficiency measurement for 15 V at 120 V_{AC} line voltage"*
  - 230 V_{AC} (see *Figure 14: "Efficiency measurement at 230 VAC line voltage"*)
  - efficiency for load current at 5 V - *Table 7: "Efficiency measurement for 5 V at 230 V_{AC} line voltage"*
  - efficiency for load current at 15 V - *Table 8: "Efficiency measurement for 5 V at 230 V_{AC} line voltage"*

Voltage measurements were taken at the output capacitor and did not account for output load switch and cable drops.

- No Load Power – only tested at 5 V output (power adapter always defaults to 5 V output when host device is disconnected).
  - 7.5 mW at 120 V_{AC}
  - 12 mW at 230 V_{AC}

Figure 13: Efficiency measurement at 120 V_{AC} line voltage

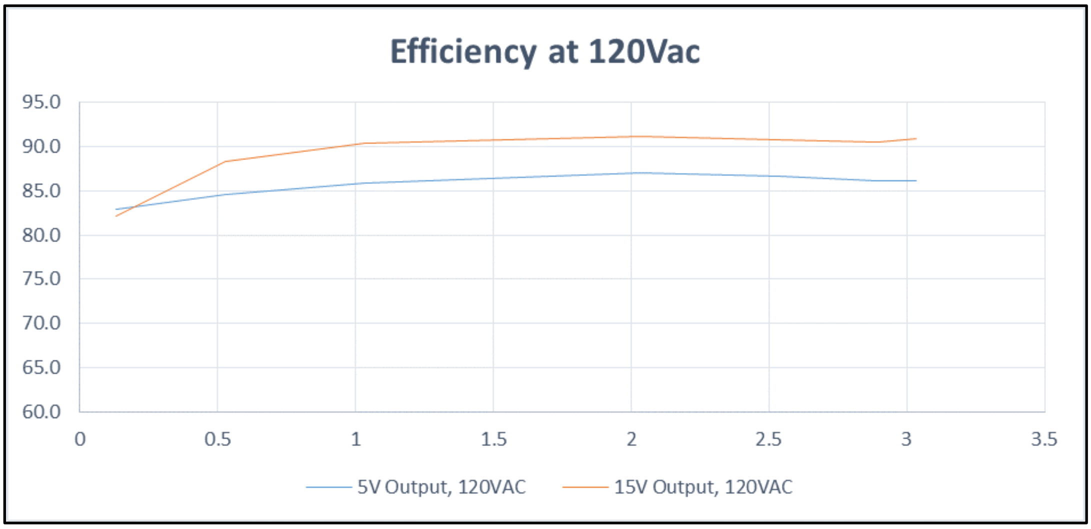


Table 5: Efficiency measurement for 5 V at 120 V_{AC} line voltage

Pin, W	Iout, A	Vout, V	Pout, W	Efficiency, %
0.82	0.13	5.23	0.6799	82.9
3.26	0.527	5.23	2.75621	84.5
6.29	1.035	5.22	5.4027	85.9

Pin, W	Iout, A	Vout, V	Pout, W	Efficiency, %
12.2	2.035	5.22	10.6227	87.1
15.32	2.543	5.22	13.27446	86.6
17.5	2.892	5.21	15.06732	86.1
18.41	3.036	5.22	15.84792	86.1

Table 6: Efficiency measurement for 15 V at 120 V_{AC} line voltage

Pin, W	Iout, A	Vout, V	Pout, W	Efficiency, %
2.46	0.13	15.53	2.0189	82.1
9.25	0.527	15.51	8.17377	88.4
17.76	1.035	15.5	16.0425	90.3
34.54	2.035	15.46	31.4611	91.1
43.35	2.543	15.47	39.34021	90.8
49.5	2.892	15.48	44.76816	90.4
51.23	3.036	15.34	46.57224	90.9

Figure 14: Efficiency measurement at 230 V_{AC} line voltage

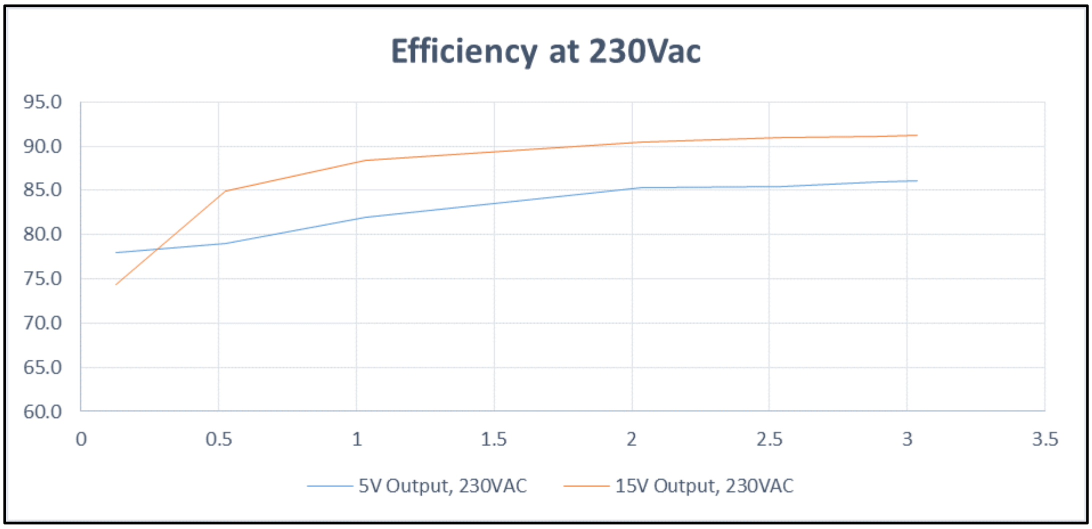


Table 7: Efficiency measurement for 5 V at 230 V_{AC} line voltage

Pin, W	Iout, A	Vout, V	Pout, W	Efficiency, %
0.87	0.13	5.22	0.6786	78.0
3.47	0.527	5.2	2.7404	79.0
6.54	1.035	5.18	5.3613	82.0
12.35	2.035	5.18	10.5413	85.4
15.44	2.543	5.19	13.19817	85.5
17.45	2.892	5.19	15.00948	86.0
18.3	3.036	5.19	15.75684	86.1

Table 8: Efficiency measurement for 5 V at 230 V_{AC} line voltage

Pin, W	Iout, A	Vout, V	Pout, W	Efficiency, %
2.71	0.13	15.49	2.0137	74.3
9.57	0.527	15.42	8.12634	84.9
18.02	1.035	15.39	15.92865	88.4
34.52	2.035	15.35	31.23725	90.5
42.89	2.543	15.35	39.03505	91.0
48.7	2.892	15.35	44.3922	91.2
51.11	3.036	15.36	46.63296	91.2

7.2 STEVAL-USBPD45H voltage profile transition measurements

Full USB-PD compliance measurements were performed for the USB-IF certification workshop. The following positive and negative voltage transitions waveforms illustrate some of the critical timing requirements.

7.2.1 Positive output voltage transitions (5 V to 15 V)

Figure 15: Output voltage transition 5 V to 15 V - no load

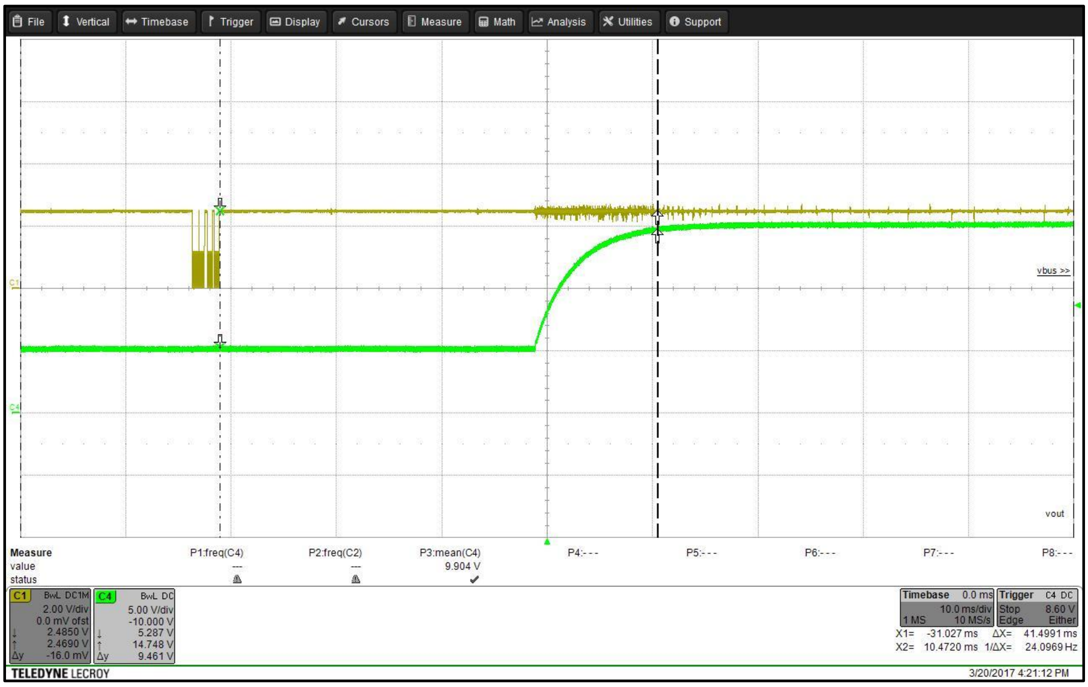


Figure 16: Output voltage transition 5 V to 15 V - full load

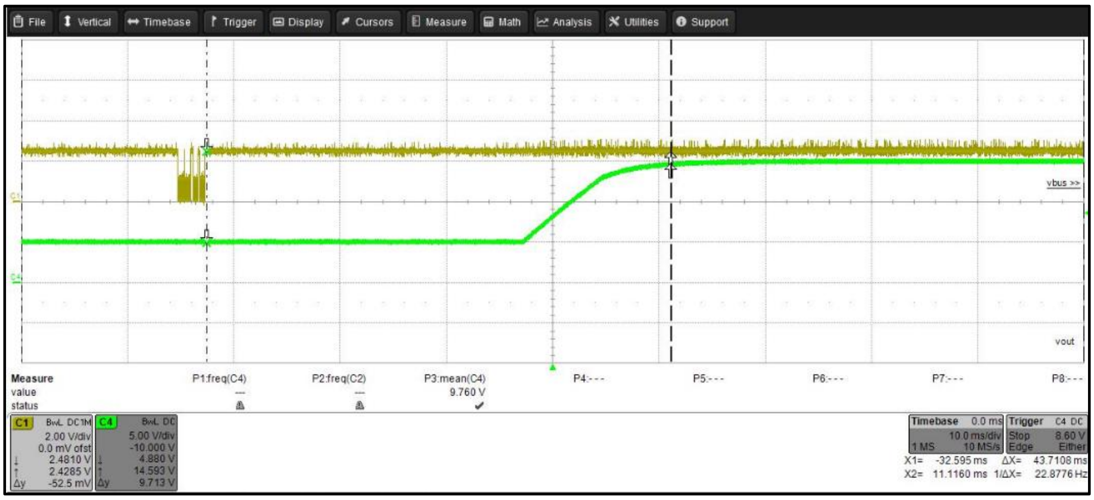


Figure 17: Positive voltage transition

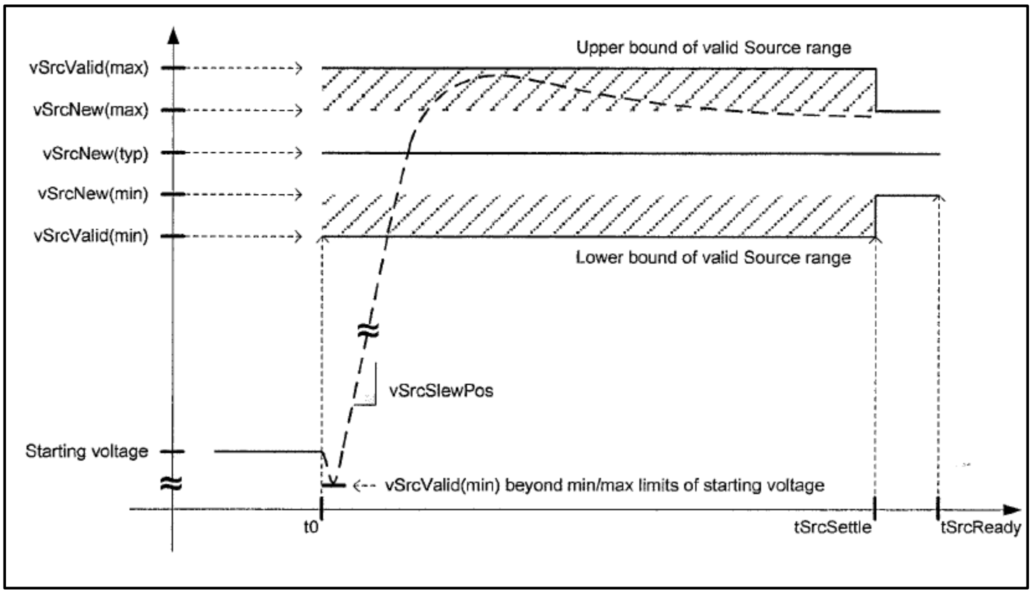


Table 9: Positive voltage transition results

Parameter	Specification	Measurement	Unit
tSrcSettle	275 max	44 @ 3 A 42 @ 0 A	ms
vSrcSlewPos	30 max	1 @ 3 A 2.7 @ 0 A	mV/µs
vSrcNew	0.95 to 1.05 of final voltage (14.25 to 15.75)	14.88 @ 3 A 14.75 @ 0 A	V
vSrcValid		No overshoot	-

7.2.2 Negative output voltage transitions (15 V to 5 V)

Figure 18: Output voltage transition 15 V to 5 V - no load

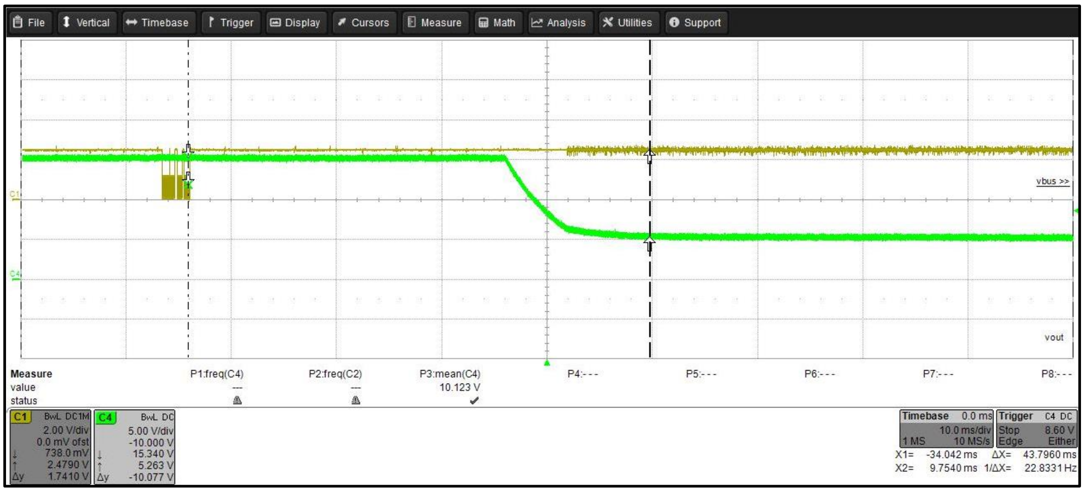


Figure 19: Output voltage transition 15 V to 5 V - full load

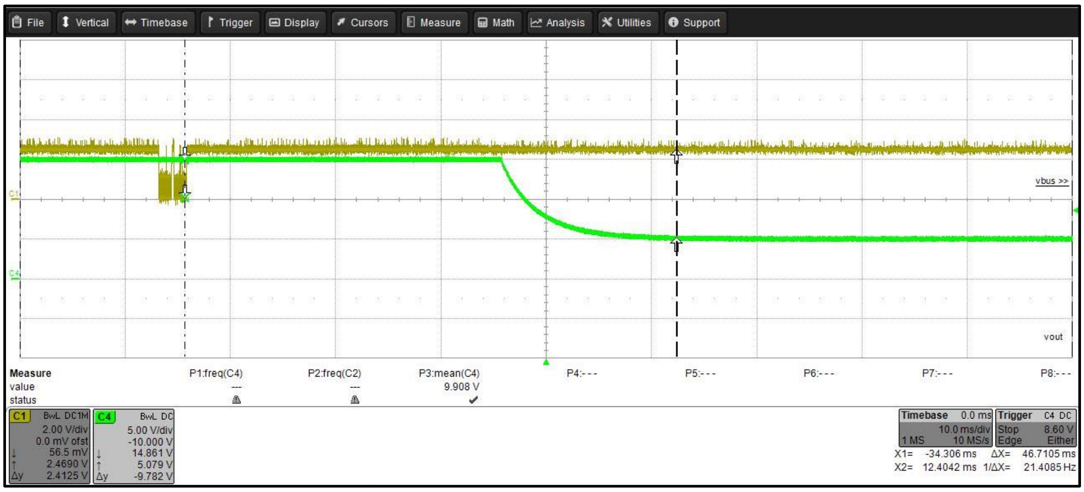


Figure 20: Negative voltage transition

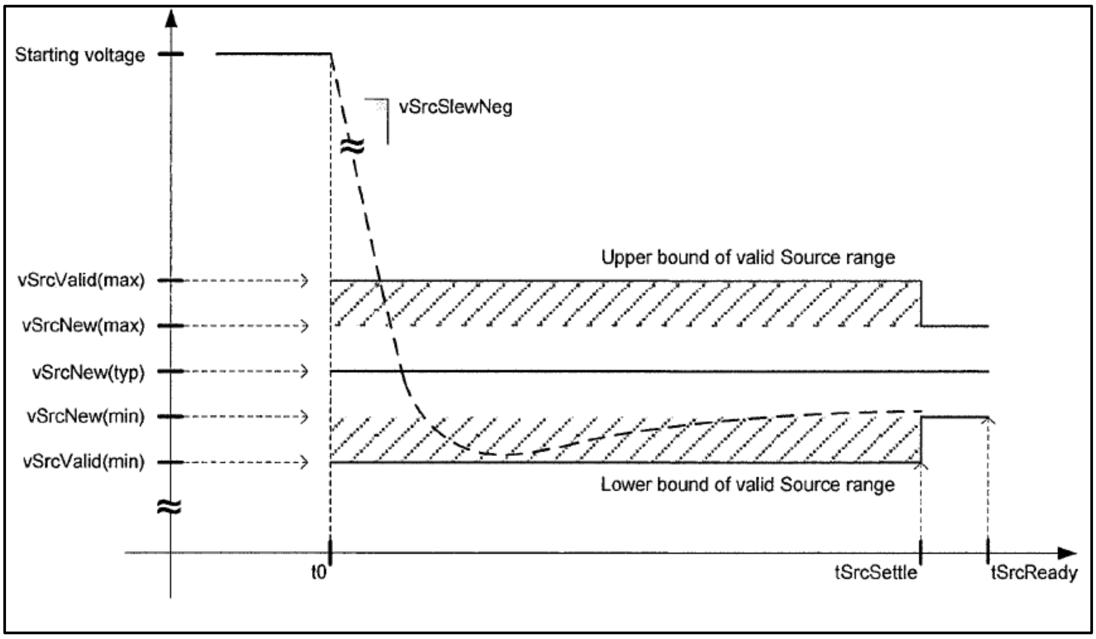


Table 10: Negative voltage transition results

Parameter	Specification	Measurement	Unit
tSrcSettle	275 max	41 @ 3 A 48 @ 0 A	ms
vSrcSlewPos	30 max	2 @ 3 A 2 @ 0 A	mV/µs
vSrcNew	0.95 to 1.05 of final voltage (4.94 to 5.46)	5.08 @ 3 A 5.26 @ 0 A	V
vSrcValid	±0.5 V from SrcNew	No overshoot	-

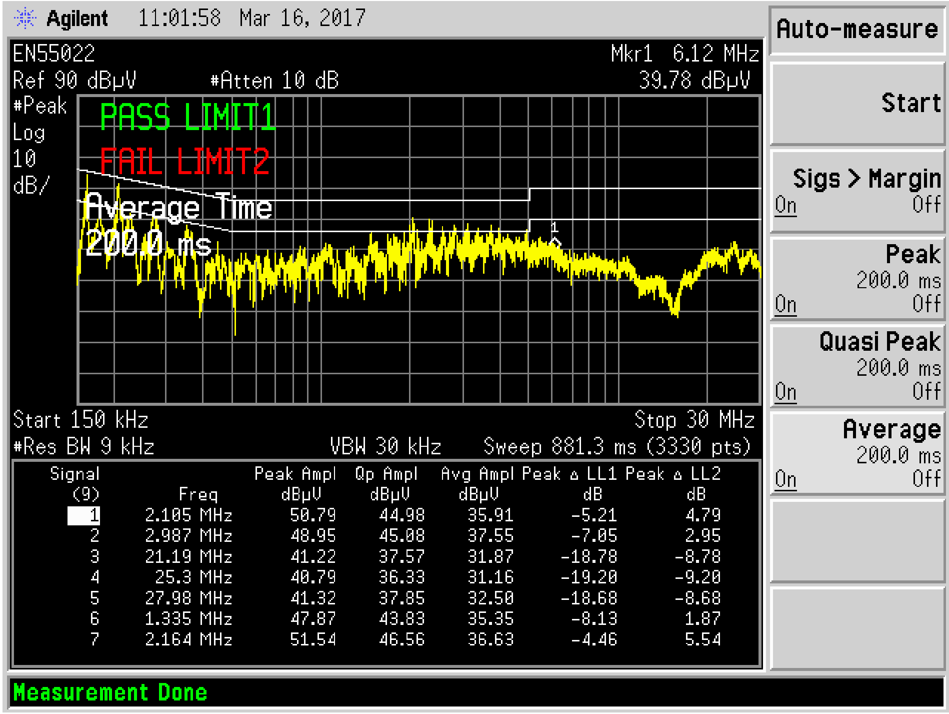
7.3 STEVAL-USBPD45H conducted EMI measurements

The STEVAL-USBPD45H evaluation board was tested for compliance with EMI EN55022 Class B standard.

Different were performed at different output voltage profile and power. Testing at different power levels is important due to the quasi-resonant principle of operation of the flyback controller, which results in different switching frequencies depending on load.

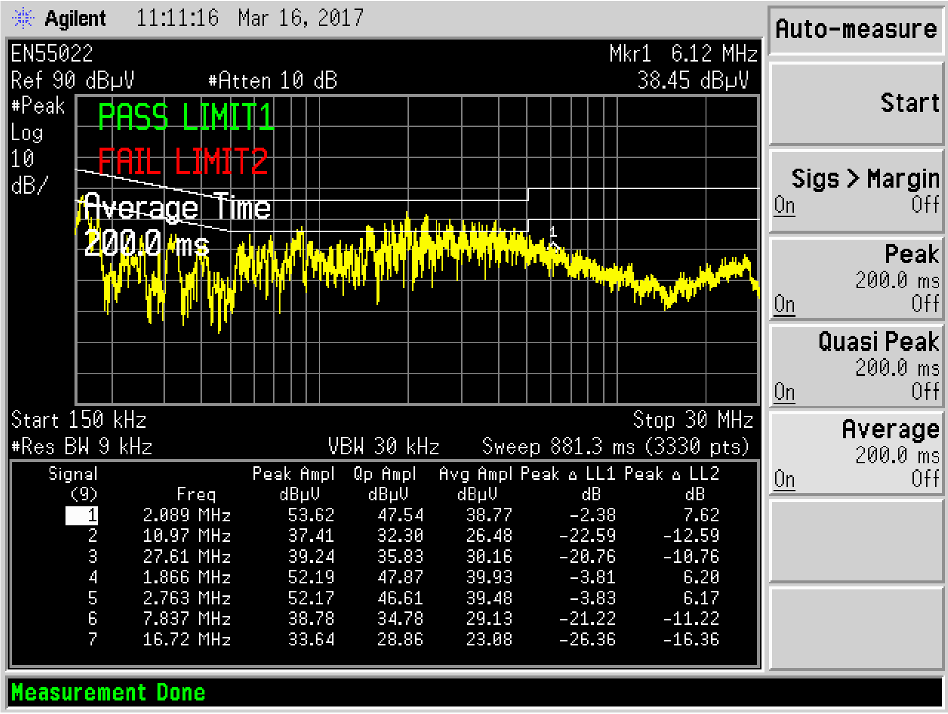
Testing was performed with Quasi-Peak and Average type detectors, and both pass with a sufficient margin below the respective EN55022 Class B limits.

Figure 21: EMI results at full load (45 W), 120 V_{AC}



Sig. #	Freq. (MHz)	Peak (dBuV)	QP (dBuV)	Avg (dBuV)	Comm.	Corr. (dB)	Limit1 (dBuV)	Limit2 (dBuV)	QP Delta L1 (dB)	Avg Delta L2 (dB)
1	2.105003	50.79	44.98	35.91		10.92	56.00	46.00	-11.02	-10.09
2	2.987059	48.95	45.08	37.55		10.97	56.00	46.00	-10.91	-8.45
3	21.194704	41.22	37.57	31.87		11.68	60.00	50.00	-22.43	-18.13
4	25.299395	40.79	36.33	31.16		11.97	60.00	50.00	-23.67	-18.84
5	27.984986	41.32	37.85	32.50		12.16	60.00	50.00	-22.15	-17.50
6	1.334994	47.87	43.83	35.35		10.84	56.00	46.00	-12.16	-10.65
7	2.164405	51.54	46.56	36.63		10.92	56.00	46.00	-9.44	-9.37
8	2.987066	49.29	45.22	38.13		10.97	56.00	46.00	-10.78	-7.87
9	25.150699	39.66	35.82	30.47		11.96	60.00	50.00	-24.18	-19.53

Figure 22: EMI results at half load (22.5 W), 120 V_{AC}



Sig. #	Freq. (MHz)	Peak (dBuV)	QP (dBuV)	Avg (dBuV)	Comm.	Corr. (dB)	Limit1 (dBuV)	Limit2 (dBuV)	QP Delta L1 (dB)	Avg Delta L2 (dB)
1	2.088520	53.62	47.54	38.77		10.92	56.00	46.00	-8.46	-7.23
2	10.970671	37.41	32.30	26.48		11.33	60.00	50.00	-27.70	-23.52
3	27.610575	39.24	35.83	30.16		12.13	60.00	50.00	-24.17	-19.84
4	1.865913	52.19	47.87	39.93		10.90	56.00	46.00	-8.13	-6.07
5	2.763338	52.17	46.61	39.48		10.96	56.00	46.00	-9.39	-6.52
6	7.837222	38.78	34.78	29.13		11.17	60.00	50.00	-25.22	-20.87
7	16.716603	33.64	28.86	23.08		11.50	60.00	50.00	-31.14	-26.92
8	20.747462	39.04	34.27	28.40		11.65	60.00	50.00	-25.73	-21.60
9	24.851467	44.32	39.86	34.29		11.94	60.00	50.00	-20.14	-15.71

For both full and half loads, at all frequencies where the Peak detector measurement violates either one of the limits, it then passes when retested with quasi-peak and average detector tests, in compliance with EN55022 standard.

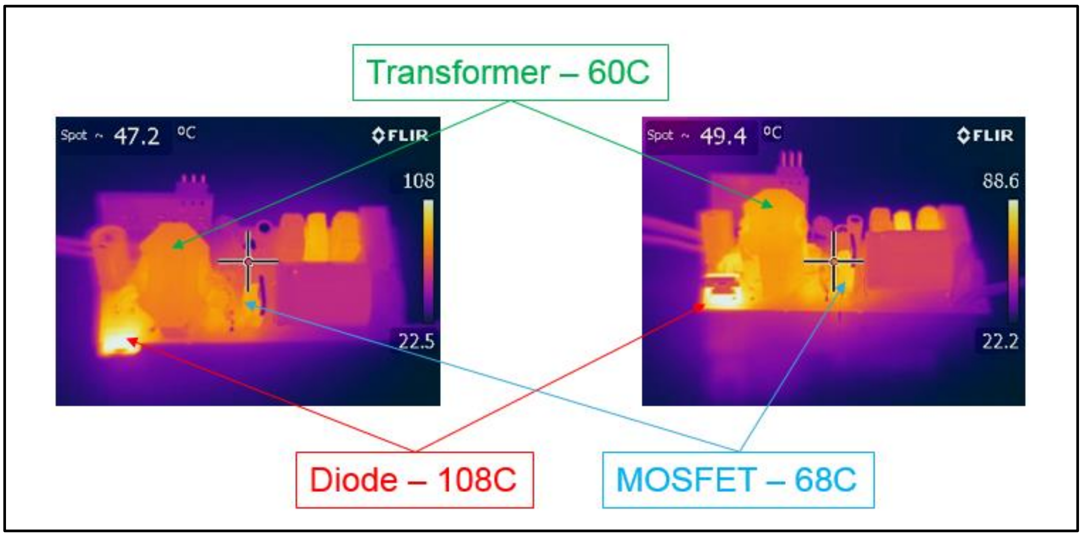
7.4 STEVAL-USBPD45H thermal measurements

The thermal map at full load measured at 120 V_{AC} at room temperature is shown in *Figure 23: "Thermal map at full load"*. Temperature measurements were taken with a FLIR camera at room temperature.

In the thermal image below, neither the MOSFET nor the FERD diode have heatsinks to help dissipate power losses, which can be considered a worst case scenario for the evaluation board. In any case, the components only experience a moderate temperature rise due to minimized losses.

Considering the diode can operate safely up to 175 °C and the MOSFET up to 150 °C, the temperature range of this power brick solution can be very wide.

Figure 23: Thermal map at full load



8 Revision history

Table 11: Document revision history

Date	Version	Changes
01-Dec-2017	1	Initial release

IMPORTANT NOTICE – PLEASE READ CAREFULLY