UM2404

User manual

STEVAL-USBPD45C 45 W USB Type-C™ Power Delivery adapter reference design

Introduction

The STEVAL-USBPD45C 45W AC-DC USB Type-C and Power Delivery adapter reference design kit consists of a digital control board stacked on a power supply board.

The STEVAL-USBPD45I digital control board (DCB) embeds an STM32F051K8 microcontroller to manage the USB Power Delivery stack and synchronous rectification, and an STUSB1602A USB Type-C controller.

The STEVAL-USBPD45P power supply board (PSB) is based on a flyback converter with STCH03 offline PWM controller for low standby adapters.

The STEVAL-USBPD45C provides 5 V, 9 V and 15 V output voltages (up to 3 A) from a wide input mains range, according to the source power rules of the USB Power Delivery specification.

The adapter is protected against destructive electrostatic discharge (ESD) from the USB Type-C connector by the ESDA25P35-1U1M high-power transient voltage suppressor (TVS) which exceeds the IEC61000-4-2 Level 4 standard by offering ESD protection higher than 30 kV on the V_{BUS} pin. This protection also provides surge immunity against electrical overstress (EOS) to prevent damage to the internal circuitry by offering up to 35 A 8/20 µs protection, as per IEC61000-4-5 standard.

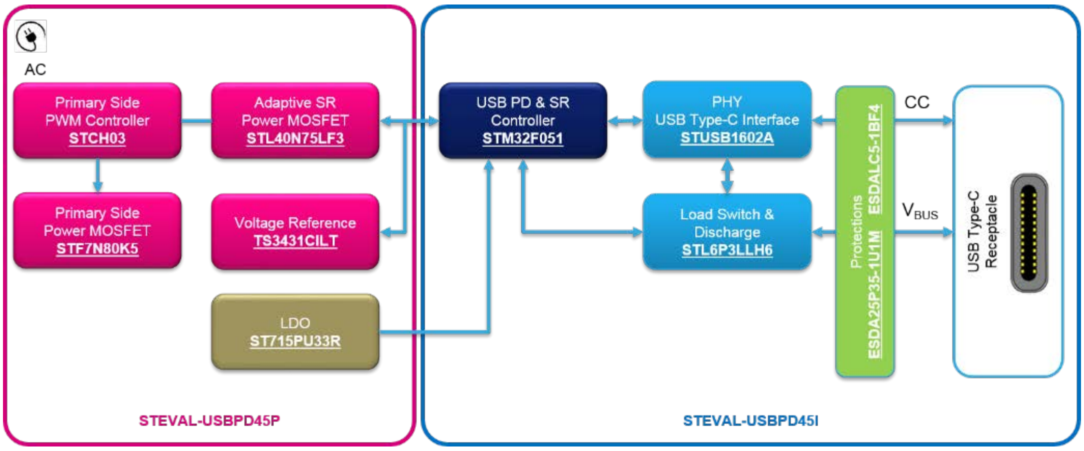
The adapter is designed to meet the most stringent energy saving recommendations (European CoC ver. 5 Tier 2).

Figure 1. STEVAL-USBPD45C reference design

1 STEVAL-USBPD45C functional blocks

The interaction between the main functional blocks of the power supply board, on the left, and the digital control board, on the right, is shown in the architecture diagram below.

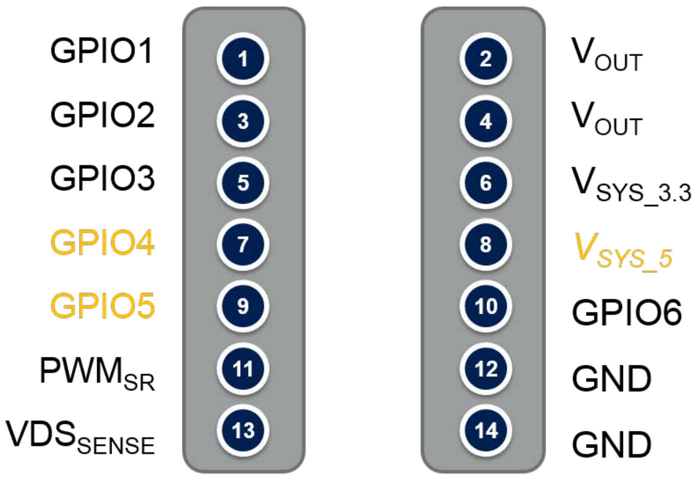
Figure 2. STEVAL-USBPD45C system architecture



1.1 Power supply board and digital control board interface

The power supply board and digital control board are connected through a dedicated power connector interface between connectors CN3 and CN4.

Figure 3. Power connector (CN3 / CN4)



The main signals involved are:

- V_{OUT} output voltage from the PSB
- $V_{SYS\_3.3}$ 3.3V to supply the DCB
- V_{SYS_5} 5V output from the PSB (not present in this version)
- PWM_{SR} signal generated by the DCB to drive the synchronous rectification (SR) MOSFET
- V_{DS_SENSE} drain source voltage of the Power MOSFET used for SR

The following GPIOs can be assigned for specific purposes:

- GPIO1 to GPIO3 are used by the DCB to control the output voltage V_{OUT} from the PSB

- GPIO6 is used by the DCB to control the discharge mechanism on the PSB

GPIO4, GPIO5 and V_{sys_5} are not used.

1.2 STEVAL-USBPD45P power supply board

The power supply board is an efficient solution with a reduced bill of materials. It includes the entire AC/DC conversion stage, an auxiliary discharge path, synchronous rectification (SR) circuitry, and the LDO to supply the DCB.

The flyback converter is based on:

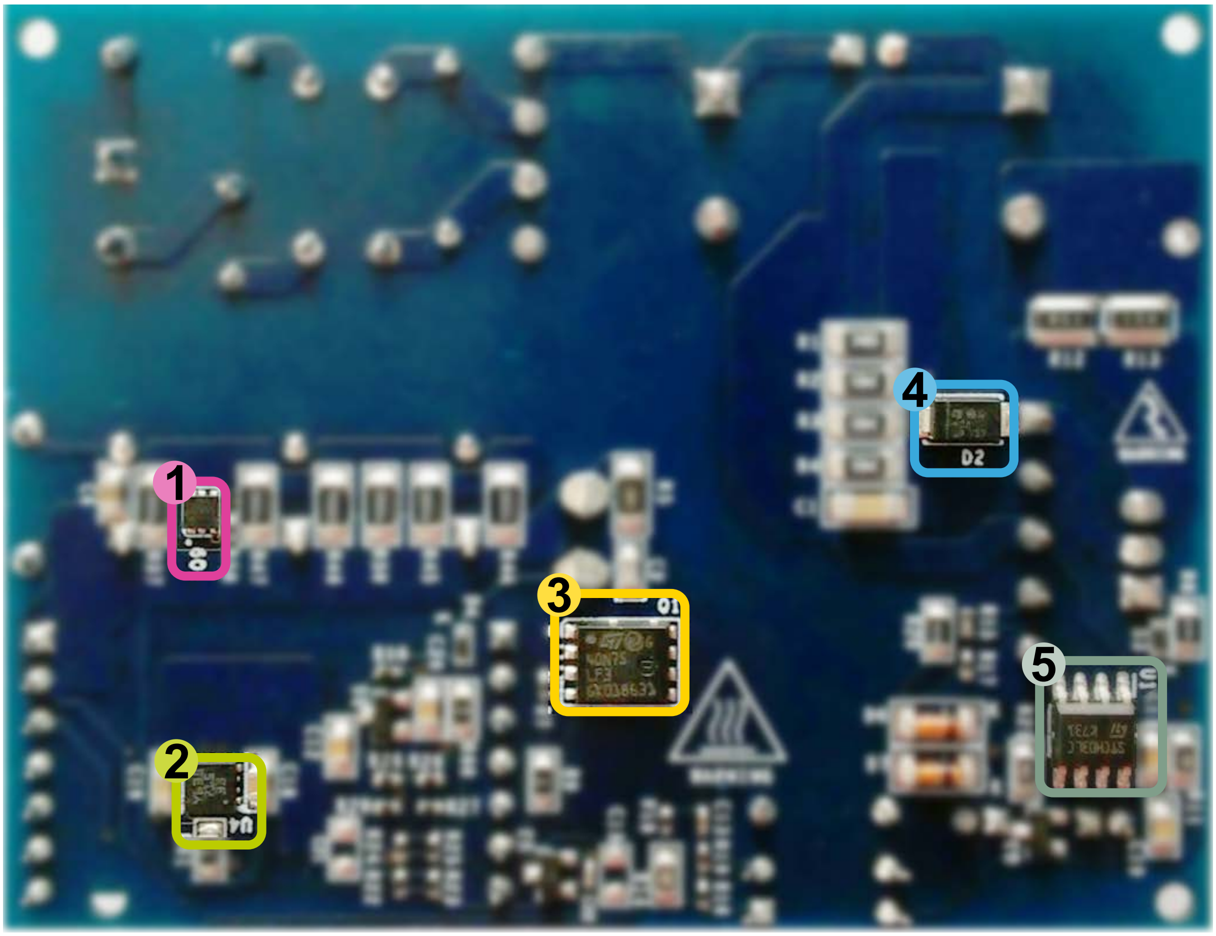
- the STCH03 offline PWM controller for low standby adapters
- the STF7N80K5 MDmesh K5 primary side Power MOSFET
- a snubber circuit based on the STTH108A high voltage ultrafast rectifier diode
- an adaptive synchronous rectification stage with an STL40N75LF3 Power MOSFET directly driven by the digital control board
- the ST715 high input voltage LDO linear regulator for MCU post regulation

The auxiliary discharge is managed by the STL6N3LLH6 STripFET™ VI DeepGATE™ MOSFET.

Figure 4. STEVAL-USBPD45P top view

- 1. STF7N80K5 MDmesh K5 primary side Power MOSFET
- 2. High frequency transformer with RM10 core

Figure 5. **STEVAL-USBPD45P bottom view**



- 1. STL6N3LLH6 STripFET™ VI DeepGATE™ MOSFET
- 2. ST715 high input voltage LDO regulator
- 3. STL40N75LF3 Power MOSFET
- 4. STTH108A high voltage ultra-fast rectifier diode
- 5. STCH03 offline PWM controller

1.2.1 STEVAL-USBPD45P primary side

The STEVAL-USBPD45P uses a quasi-resonant flyback topology to convert the input AC voltage into a regulated DC output voltage. The converter operates in the following modes according to the load:

- medium or light: Valley-skipping mode
- very light or no load: Burst mode

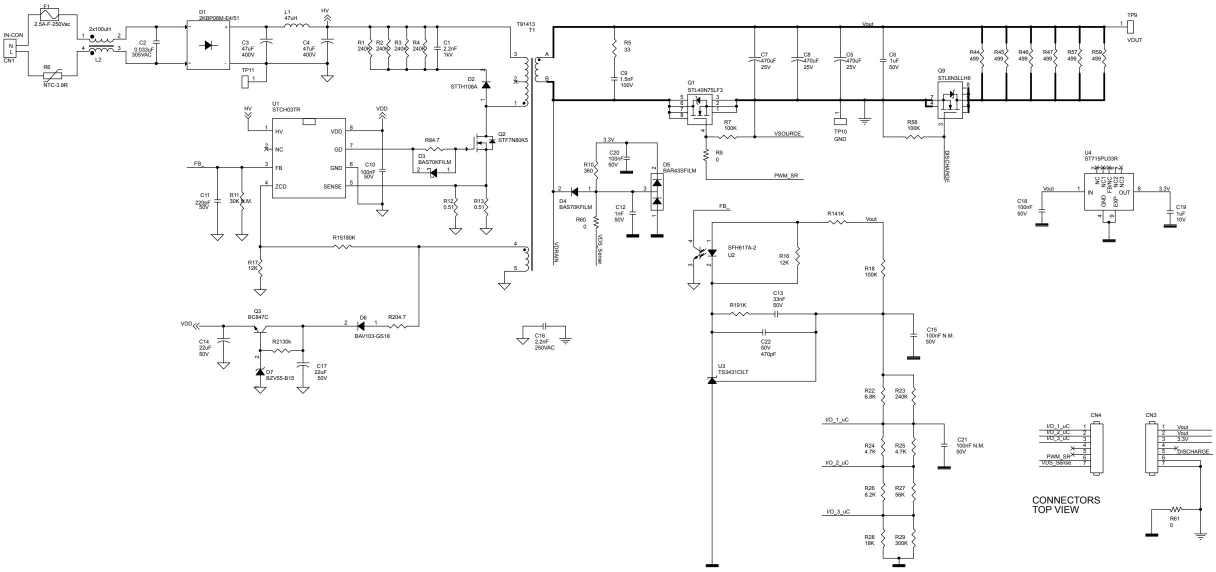
Table 1. **Converter design specifications**

Specification	Value	Description
Vin	90 V_{AC} – 264 V_{AC}	Input voltage range
Frequency	45 – 65 Hz	Input frequency range
Vout	5 V/9 V/15 V	Output voltage
Power	45W	Nominal output power
Available profiles	5 V/3 A; 9 V/3 A;15 V/3 A	PD profiles

Specification	Value	Description
Topology	QR Isolated Flyback	Quasi-resonant (QR) zero-voltage switching (ZVS) operation with primary side constant current (CC) output regulation
Switching frequency	Variable	From 31 to 175 kHz
Output connector	Type-C	5.5 feet captive cable with Type-C connector

The STCH03 controller is designed to achieve very low power consumption during no load operation. The quasi-resonant mode of operation is ideal for high efficiency and low EMI thanks to zero voltage switching in the main Power MOSFET. In addition, the controller provides primary side constant current (CC) control, which is set to slightly above 3 A for this specific design.

Figure 6. **Power supply board primary and secondary stages**



The AC input voltage is filtered by an EMI filter consisting of a common choke (L2) and differential mode capacitor (C2), which is then rectified through a 2 A, 600 V integrated diode bridge. A balanced PI filter with two 47 µF electrolytic capacitors (C3 and C4) and a 47 µH inductor (L1) improves EMI performance.

The input section of the converter has a 2.5 A fuse and a 3.9 Ω NTC for inrush current limiting at start up. The AC voltage must be connected to input connector CN1.

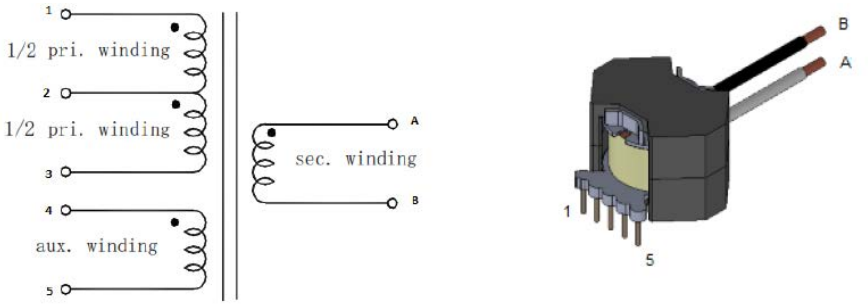
The STCH03 drives the gate of the 800 V STF7N80K5 power MOSFET (Q2), which belongs to the K5 family of super-junction high voltage power MOSFETs with high breakdown voltage, very low R_{DSon} and parasitic capacitance. The MOSFET is protected using an RCD snubber (D2, C1 R1, R2, R3, R4) to clamp the overvoltage caused by the transformer leakage inductance at turn-off to a safe value that is well below the breakdown voltage of the MOSFET.

The high frequency transformer uses an RM10 core designed according to the specifications shown in Figure 7. RM10 core specification.

The regulation point is set by selecting an appropriate transformer turns ratio and current sensing resistor value (R12, R13)

The output voltage regulation circuit consists of a photocoupler, a voltage reference and an optocoupler to ensure isolation from the primary side. A 650 V integrated high voltage startup circuit starts the IC as soon as the bus voltage reaches approximately 50 V (typical).

Figure 7. **RM10 core specification**



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)	0.38	Ω	MAX
DCR (SEC)	(A-B)	8.00	mΩ	MAX
DCR (AUX)	(4-5)	0.40	Ω	MAX
Leakage Inductance (LL)	(1-3) [tie 4+5, A+B], 0.1 Vrms, 100kHz	12.0	µH	MAX
Turns Ratio	(1-3) : (A-B)	10.4:1	N/A	± 2%
Turna Ratio	(1-3) : (4-5)	5.2:1	N/A	± 2%
HI-POT	(1,2,3,4,5) : (A,B)	3000	Vrms	2S, 1mA, 50/60Hz

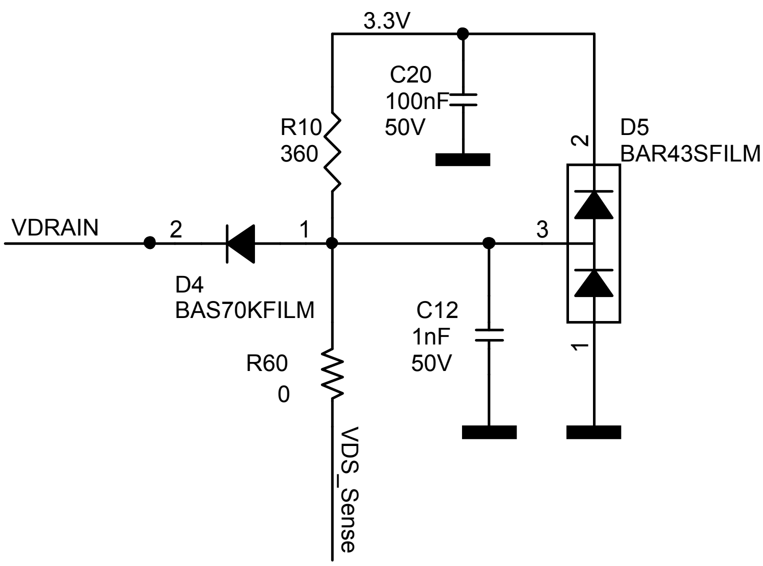
The auxiliary winding of the transformer is used to supply the controller and to provide the ON/OFF triggering signal for the main MOSFET by connecting this winding to the ZCD of the STCH03 via a voltage divider (R15, R17).

A linear regulator connects the auxiliary winding with the V_{DD} pin of the controller to ensure a stable supply voltage across all input voltage, output voltage, and load conditions.

1.2.2 STEVAL-USBPD45P secondary side

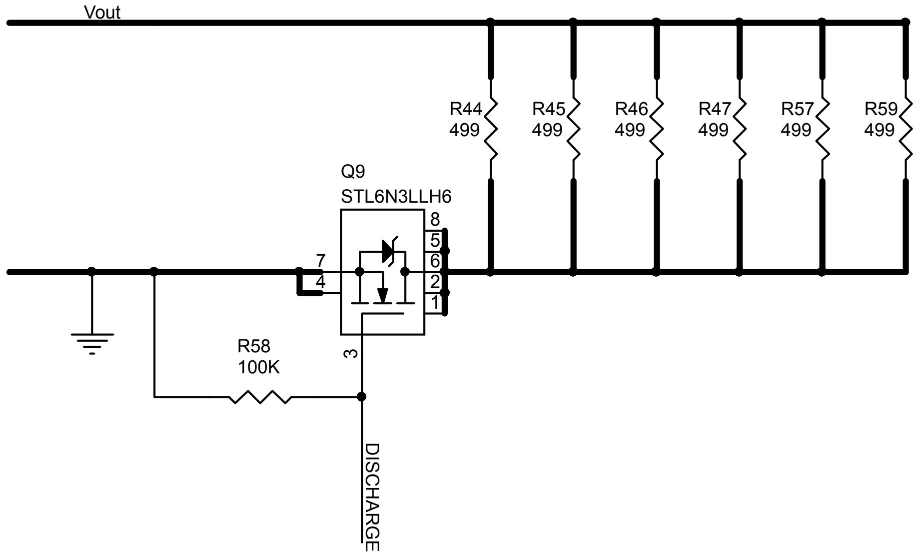
The secondary voltage of the high frequency transformer is rectified with a synchronous rectification (SR) circuit based on a low voltage logic level MOSFET (Q1) rated at 75 V and a sensing circuit (D4, D5, R10, C20, C12) to sense its drain to source voltage. The microcontroller uses a feedback signal to control the SR MOSFET switching and allowing lower losses compared to a standard diode rectification stage. The SR circuit ensures higher efficiency as the power rises.

Figure 8. **V_{DS} sensing circuit**



A discharge switch (Q9), driven by the STUSB1602A USB Type-C controller, is used on the output section of the power stage to ensure that the transitions from one profile to another adhere to the USB Type-C Power Delivery standard.

Figure 9. **Discharge circuit for output voltage profiles**



Voltage transitions are managed through specific MCU I/Os that adapt the voltage divider ratio as a function of the required operating profile.

1.2.3 Synchronous rectification

Flyback converters have relatively high peak and rms current, which cause high conduction losses in the output diode rectifier.

As a synchronous rectifier (SR) device driven by a microcontroller is used on the secondary side, a low R_{DS_on} MOSFET is placed instead of a diode rectifier on the output stage.

When the MOSFET's body diode starts to conduct, the synchronous rectification control logic generates a PWM signal to turn the MOSFET on and reduce conduction losses, as the current flows through the MOSFET channel with a low resistance, instead of the internal body diode.

To avoid a short-circuit, a delay must be inserted between the beginning of diode conduction and the moment the MOSFET is turned on, and between the moment the MOSFET is turned off and the normal end of diode conduction.

A sensing circuit for V_{DS} voltage is required to drive the MOSFET:

- when the current flows through the body diode and the V_{DS} voltage goes negative, the MOSFET must be turned on
- when the current goes to zero and the V_{DS} increases again, the MOSFET must turned off

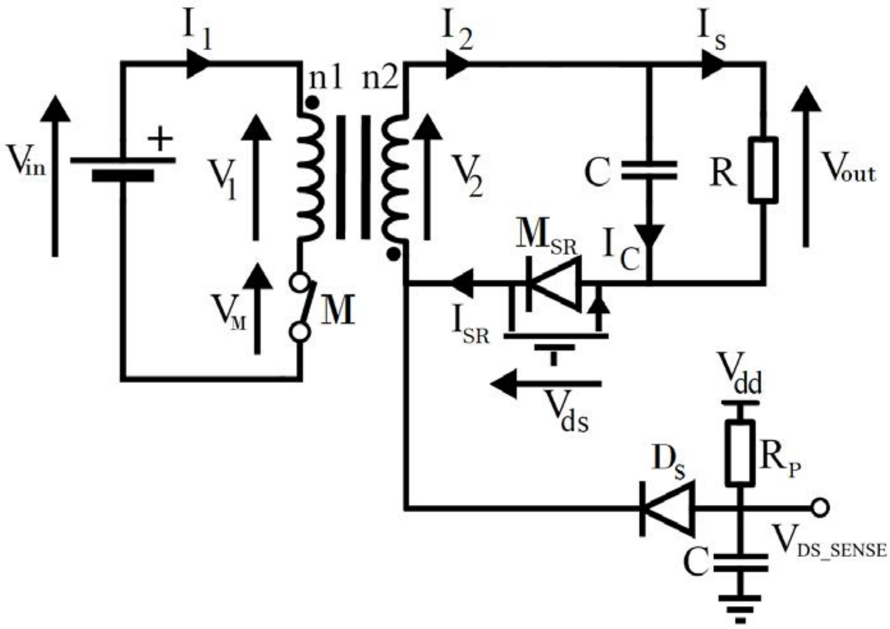
The sensing network is composed of a fast Schottky diode and a pull-up resistor connected to the MCU supply voltage:

- when the SR MOSFET drain voltage is above the MCU V_{DD},the Schottky diode is reverse biased and the sensed voltage is pulled up to V_{DD}
- when drain voltage is below V_{DD},the Schottky diode is forward biased and the sensed voltage is equal to V_{DS} plus the diode voltage drop that gives a positive voltage shift

The pull-up resistor also needs to limit the current during the diode forward biasing.

The diagram below shows the V_{DS} sensing circuit along with a filter capacitor.

Figure 10. V_{DS} sensing circuit principle



Two internal MCU comparators are used to detect the body diode conduction of SR MOSFET.

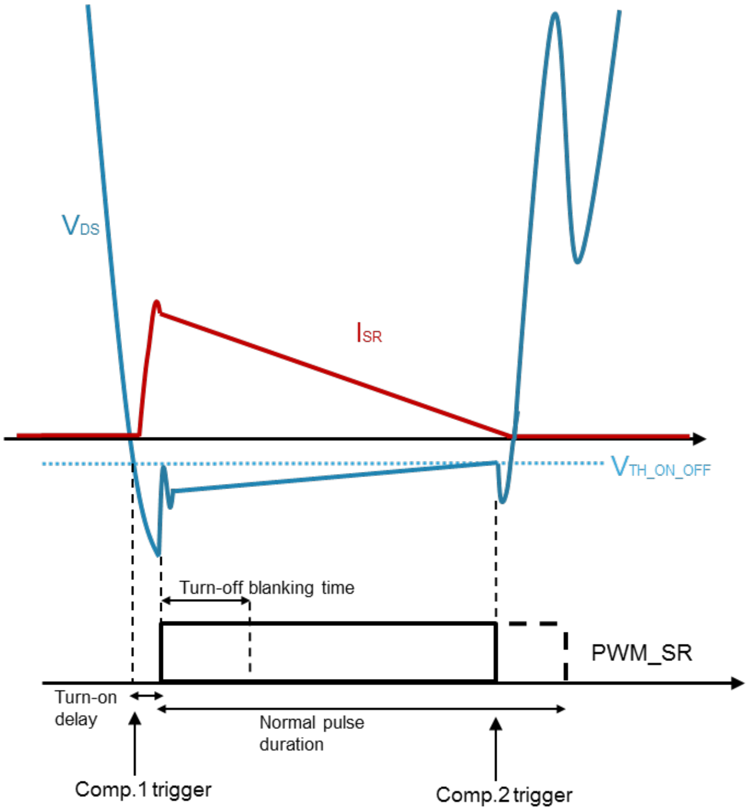
When the V_{DS} decreases below the $V_{TH\_ON\_OFF}$ threshold, the first comparator is triggered and a timer (TIM) generates a finite pulse PWM after a configurable turn-on delay. A blanking time is needed to avoid false triggers after MOSFET turn-on due to voltage ringing.

During the turn-on time, $V_{DS} = I_{SR}*R_{DS\_on}$ and is linear. The MOSFET turn-off is triggered by the rising edge of a second comparator with the same threshold $V_{TH\_ON\_OFF}$. This threshold is set on a DAC channel. When the V_{DS} raises again (the current drops zero), the PWM signal is immediately forced low even if the normal pulse duration would be longer.

An adaptive SR algorithm is used to minimize the body diode conduction time and maximize converter efficiency. In this adaptive algorithm, the optimum MOSFET PWM pulse duration is automatically determined, even with parametric tolerances and load variations.

The figure below shows the V_{DS} waveforms involved in SR driving.

Figure 11. **SR waveforms**



The STL40N75LF3 MOSFET used for SR is directly driven by a microcontroller. The SR algorithm is enabled when the output current, sensed through a shunt resistor and the TSV991AILT operational amplifier, rises to about 0.3 A.

The main MCU peripherals involved to perform the Synchronous Rectification are:

- TIM1 to generate PWM in one pulse mode
- COMP1 and COMP2 to detect the rising and falling edges of V_{DS} sensing signal and trigger TIM1
- DAC to set the thresholds of both comparators
- ADC to sense V_{DS} and current

1.3 STEVAL-USBPD45I digital control board

The STM32F051K8 MCU on the digital control board has a high-performance ARM®Cortex®-M0 32-bit RISC core operating at 48 MHz frequency. The MCU manages the following tasks:

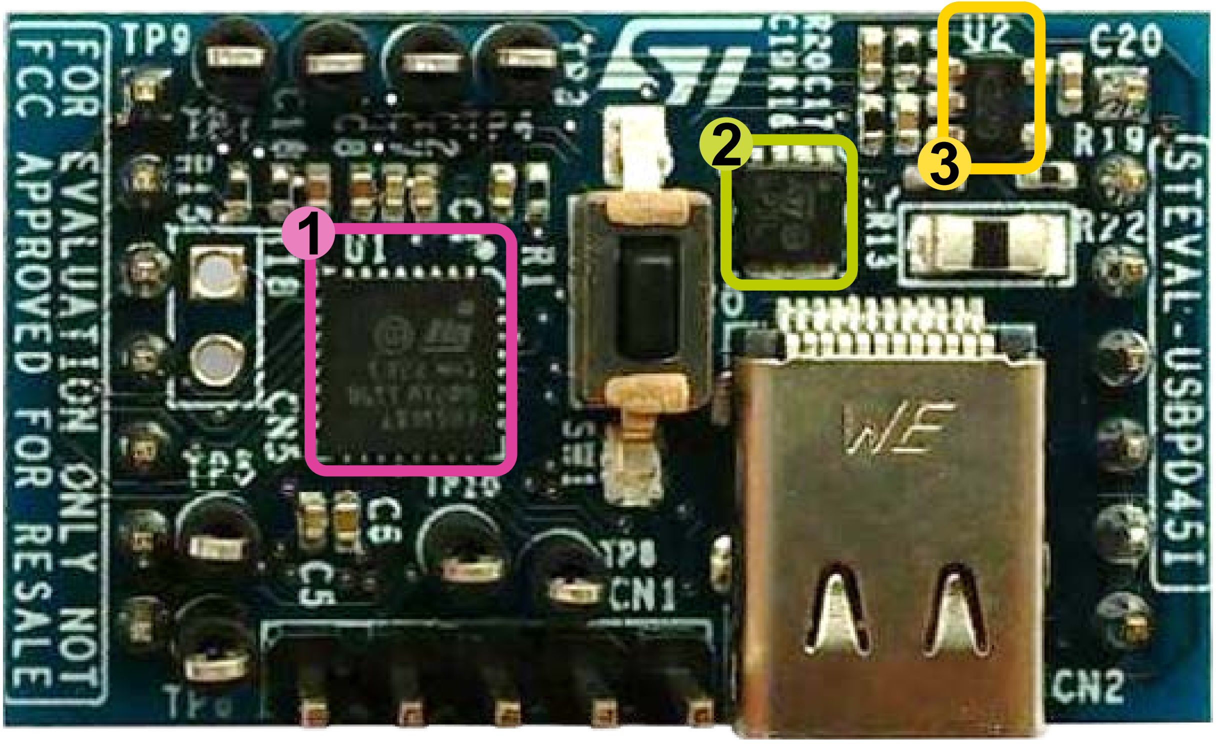
- it runs the USBPD Stack in cooperation with the STUSB1602A USB Type-C controller (with Tx/Rx line driver and BMC)
- it runs the Adaptive SR algorithm
- it implements USBPD Device Policy Manager for the adapter

The STUSB1602A integrates high voltage protections on VBUS and CC lines and manages the VBUS power path.

The STM32F051K8 and STUSB1602A chipset and relative X-CUBE-USB-PD stack running on the MCU are PD 2.0 certified and PD 3.0 ready.

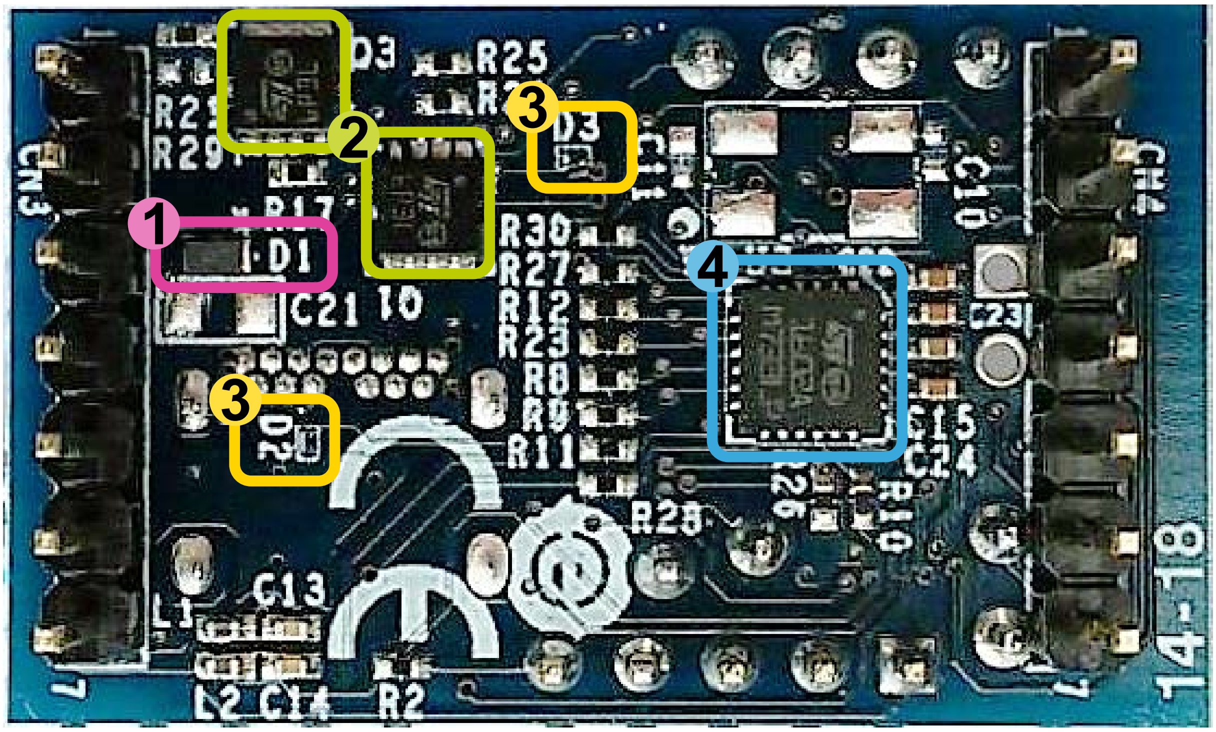
The board also embeds a current and voltage sensing stage, V_{BUS} load switch and discharge, the Type-C™ receptacle and all the bus protections.

Figure 12. STEVAL-USBPD45I top view



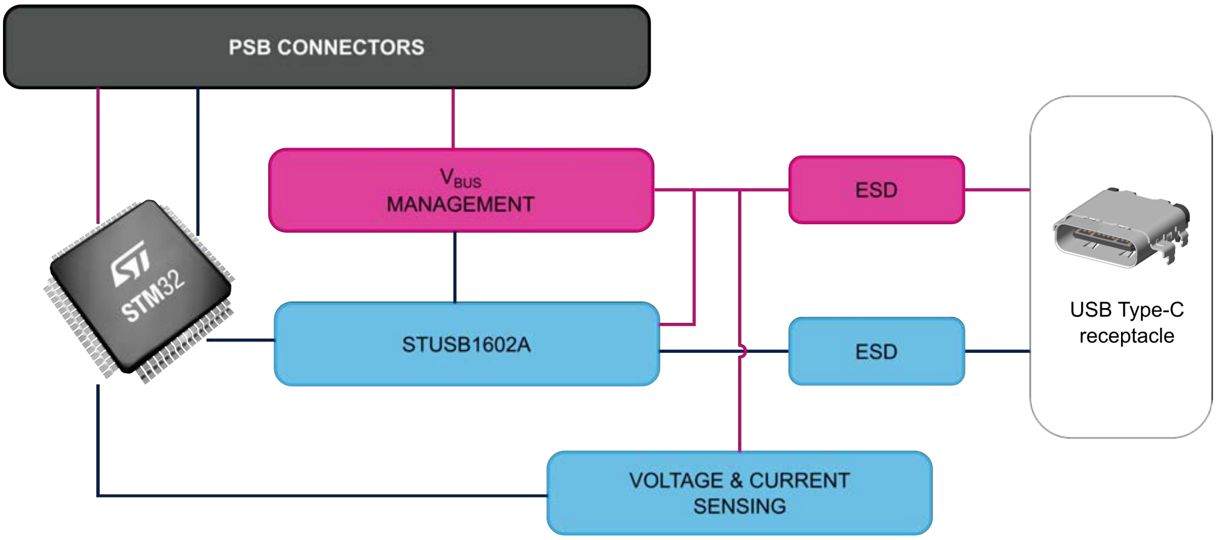
- 1. STM32F051K8 MCU
- 2. STL6N3LLH6 STripFET™ VI DeepGATE™ MOSFET
- 3. TSV991A current sensing OPAMP

Figure 13. **STEVAL-USBPD45I bottom view**



- 1. ESDALC20-1BF4 ESD protection
- 2. STL6N3LLH6 STripFET™ VI DeepGATE™ MOSFET
- 3. ESDA25P35-1U1M ESD protections
- 4. STUSB1602A USB Type-C controller

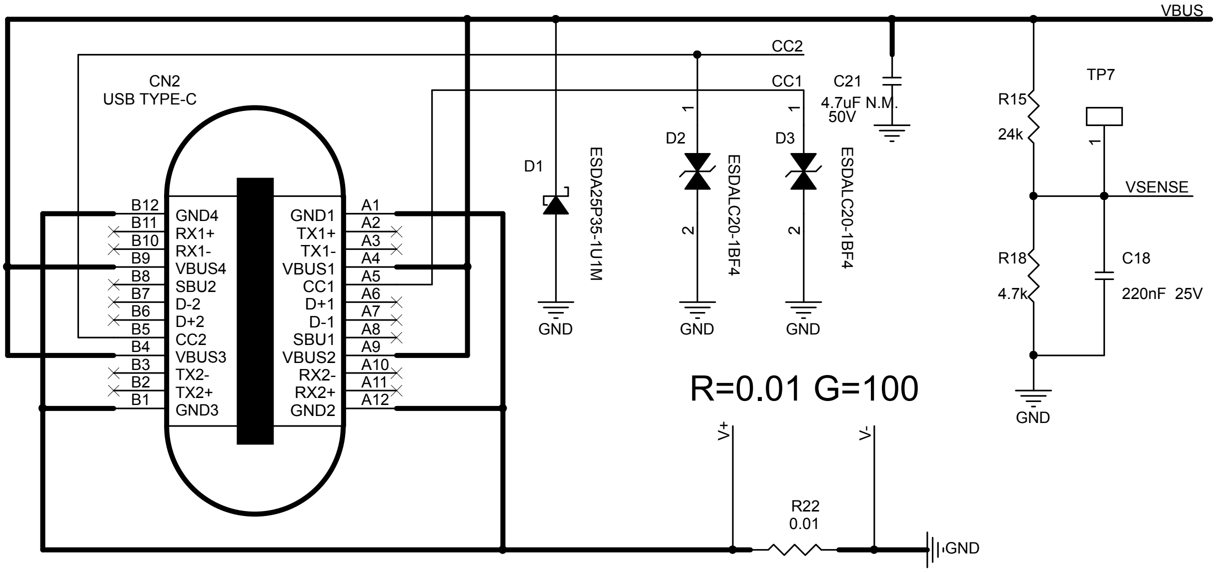
Figure 14. **STEVAL-USBPD45I functional block diagram**



1.3.1 USB Type-C™ receptacle, voltage and current sense stage

The USB Type-C™ receptacle on the STEVAL-USBPD45I digital control board can supply an external device that is connected via a USB Type-C™ cable. The port has the power role set to Provider.

Figure 15. **STEVAL-USBPD45I schematic - Type-C™ receptacle, protections, and sensing elements**



The STUSB1602A monitors the V_{BUS} voltage on the USB Type-C™ receptacle side through its VBUS_SENSE input pin. If an unexpected V_{BUS} voltage condition like undervoltage or overvoltage is detected, the STUSB1602A alerts the MCU and opens the load switch (Q1 and Q2) acting on the EN_SRC pin.

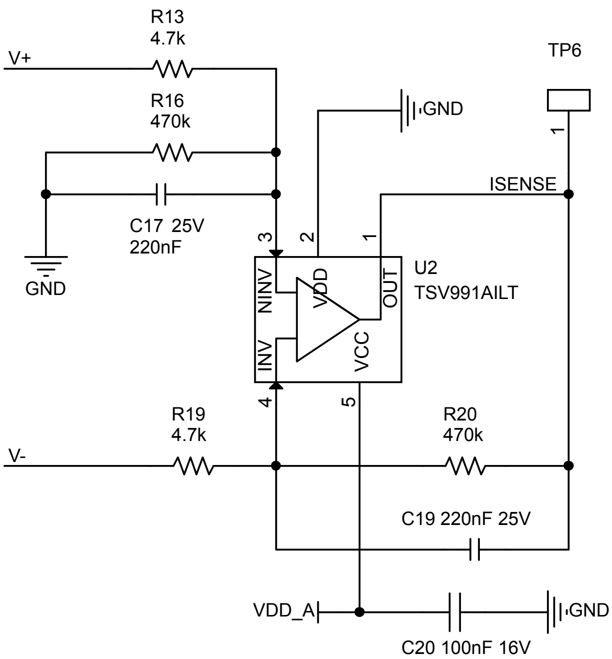
The valid V_{BUS} operating range is defined by a high voltage threshold above the nominal V_{BUS} target value, and a low voltage threshold below it. You can set valid V_{BUS} voltages and thresholds through the I2C interface.

Although the STUSB1602A monitors the V_{BUS} voltage, a resistive voltage divider for voltage sensing managed by the STM32 ADC peripherals is also included.

The port is equipped with a dedicated current-sensing circuit, shown in Figure 16. STEVAL-USBPD45I schematic – current sensing circuit.

Both current and voltage sensing circuits are included to provide alternatives for measuring the provided power with the microcontroller resources.

Figure 16. **STEVAL-USBPD45I schematic – current sensing circuit**



1.3.2 STUSB1602A USB Type-C™ controller

The STUSB1602A USB Type-C™ controller IC is designed to establish and manage the connection between two USB Type-C™ ports, according to the configured power role (i.e., Source, Sink or Dual Role).

The STUSB1602A controller is compliant with:

- USB Power Delivery specification rev3.0
- USB type-C™ cable and connector spec rev1.3

The STUSB1602A device interfaces with a Type-C™ port and interacts with the V_{BUS} management block and the microcontroller.

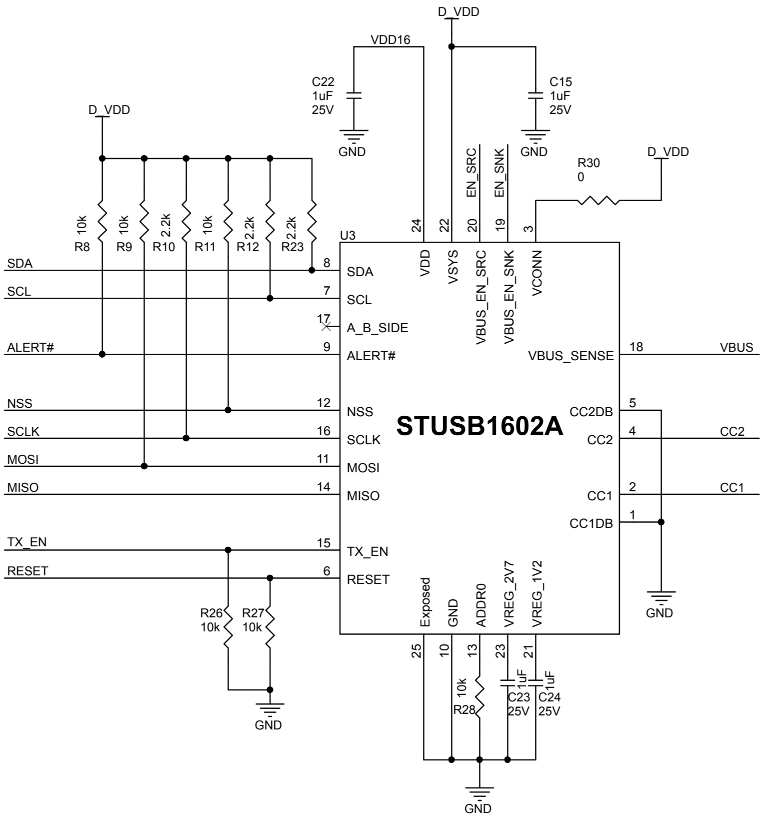
For the Type-C™ port interface, it enables lower level PD firmware stack functions, such as:

- detect a connection between two USB Type-C™ ports (attach detection)
- act as BMC transceiver
- establish a valid Source-to-Sink connection
- determine the attached mode
- resolve cable orientation and twist connections to establish USB data routing (mux control)
- configure and monitor V_{BUS} power path
- manage V_{BUS} power capability:
  - USB Default mode
  - Type-C™ Medium current mode
  - Type-C™ High current mode
- configure V_{CONN} when required
- support USB PD negotiation

The controller also supports low power standby mode, high voltage protection and provides debug accessory support.

For further information, see the STUSB1602A datasheet on www.st.com website.

Figure 17. STEVAL-USBPD45I schematic – STUSB1602A front end



The STUSB1602A device interacts with the STM32 microcontroller via the following communication buses:

1. The I²C bus is used by the MCU to configure and control the device status. Additionally, the STUSB1602A has a fully customizable start-up profile that can be modified by accessing its integrated Non-Volatile Memory via the I2C.
2. The SPI peripheral is reserved for Power Delivery communication. As the STUSB1602A embeds a biphase mark coding (BMC) transceiver, every BMC encoded or decoded message exchanged between the MCU and the device is carried on the SPI bus.

Three MCU GPIOs are used for specific functions required by the STUSB1602A device:

- TX_EN is a control signal from the MCU to STUSB1602A. It enables the BMC control logic that transfers data from the MCU to serial interface, encodes in BMC format and drives the connected CC line.
- The ALERT pin is used to advise the microcontroller of specific events regarding CC detection, monitoring and/or fault condition groups. Each of these groups of events can be masked.
- The RESET pin resets the device. This action can be also accomplished by acting on a specific I2C register.

Configuration Channel pins CC1 and CC2 are for connection and attachment detection, plug orientation and system configuration management across the USB Type-C™ cable.

CC1DB and CC2DB are for dead battery mode when the STUSB1602A is configured in the Sink power role or Dual Role Power (DRP). These pins are grounded as the device is configured to behave as a Provider only for this 45 W adapter reference design.

The VBUS_EN_SNK pin can allow input V_{BUS} power when a connection to a Source is established and V_{BUS} is in the valid operating range. As the STUSB1602A device assumes the Provider role, this pin is used to control the V_{BUS} discharge path circuit.

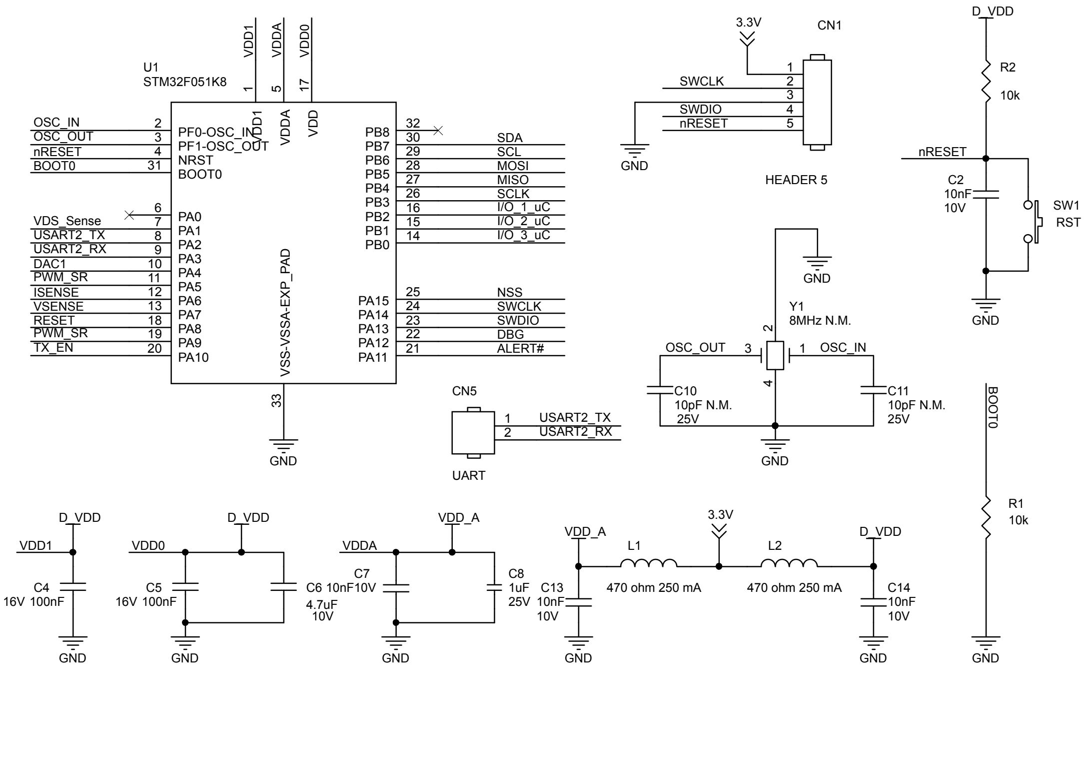
The VBUS_EN_SRC pin can allow output V_{BUS} power, when a connection to a Sink is established and V_{BUS} is in the valid operating range.

In both of the above cases, the open drain output of the VBUS_EN_SNK and VBUS_EN_SRC pins allow the direct driving of a PMOS transistor. The logic value of these pins is also advertised in a dedicated I2C register bit.

1.3.3 STM32F051K8 microcontroller

The on-board STM32F051K8 32-bit microcontroller is based on the ARM® Cortex®-M0 core with 64-Kbytes of Flash memory and 8-Kbytes of SRAM in a UFQQFPN32 package.

Figure 18. STEVAL-USBPD45I – microcontroller stage

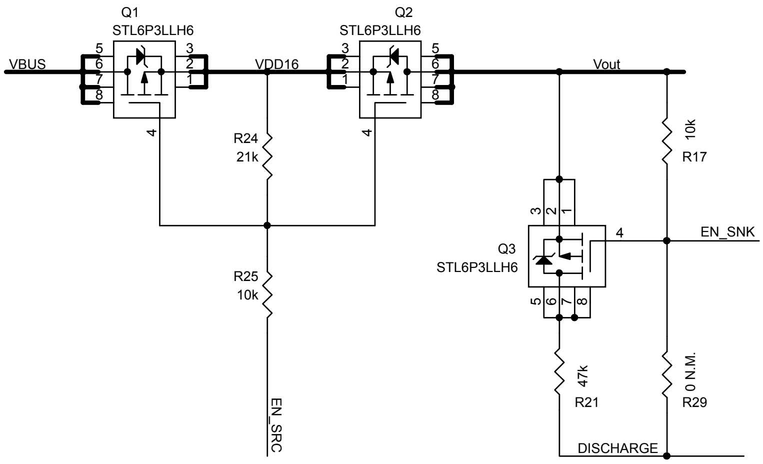


The microcontroller interacts with the STUSB1602A device to deliver the full functionality of the Power Delivery stack. It is also responsible for managing synchronous rectification.

1.3.4 V_{BUS} management and discharge mechanism

The figure below shows the V_{BUS} management mechanism applied to the Type-C port.

Figure 19. STEVAL-USBPD45I schematic – load switches and discharge mechanism stage



The V_{BUS} management block is eligible to manage different V_{BUS} voltages, as described by the USB PD specification. Its function is to provide energy when the STUSB1602A is set as a Provider.

Transistors Q1 and Q2 are set in back-to-back configuration to protect and isolate the V_{BUS} supplying path in both directions. They are driven by the VBUS_EN_SRC pin on the STUSB1602A device.

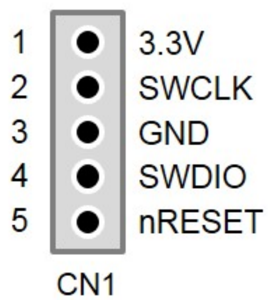
The STUSB1602A monitoring block handles the internal V_{BUS} discharge path connected to the VBUS_SENSE input pin. The discharge path is activated on a detachment event, or when the device enters the error recovery state for any power role. The V_{BUS} discharge path is enabled by default and the time to discharge to 0 V can be managed through dedicated I2C registers.

Also, as the STUSB1602A device assumes the Provider role, the BUS_EN_SNK pin can be used as controller for a V_{BUS} discharge path circuit through the Q3 transistor.

1.3.5 STEVAL-USBPD45I connectors and test points

The STEVAL-USBPD45I digital control board connector CN1 is for microcontroller programming.

Figure 20. STEVAL-USBPD45I: connector for microcontroller programming



Connector CN5 is for USART communication.

Figure 21. STEVAL-USBPD45I: UART connector

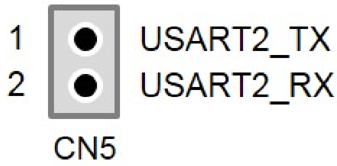


Table 2. Test points

Test point	Description
TP3	CC2 port 1
TP4	CC1 port 1
TP5	V_{DS_SENSE}
TP6	I sense
TP7	V sense
TP8	Debug
TP9	DAC 1
TP10	Alert

1.4 USB Type-C and Power Delivery technologies

The STM32F051K8 and STUSB1602A chipset and relative X-CUBE-USB-PD stack running on the MCU are PD 2.0 certified and PD 3.0 ready.

RELATED LINKS

TA0357 Overview of USB Type-C and Power Delivery technologies

2 System setup

2.1 Assemble the kit boards and connect to mains power

Step 1. Stack the STEVAL-USBPD45I digital control board (DCB) on top of the STEVAL-USBPD45P power supply board (PSB) as shown in the figure below.

Figure 22. Orientation for stacking the digital control board on the power supply board

Step 2. Connect mains power through connector CN1 on the STEVAL-USBPD45P power supply board.
The kit is designed for a universal AC mains input voltage from 90 V_{AC} to 264 V_{AC}, frequency from 45 Hz to 65 Hz.

2.2 Programming the STEVAL-USBPD45I digital control board

Warning:
Before attempting to program or debug the board, make sure that the kit is not connected to mains power.

You can program or debug your own firmware solutions on the digital control board through the Serial Wire Debug (SWD) interface, denoted as CN1.

2.2.1 Programming and debugging with STM32 Nucleo

To program and debug the digital control board with the STM32 Nucleo development board, you will need the following components, not supplied in the kit:

- an STM32 Nucleo development board
- a USB type A to mini B cable

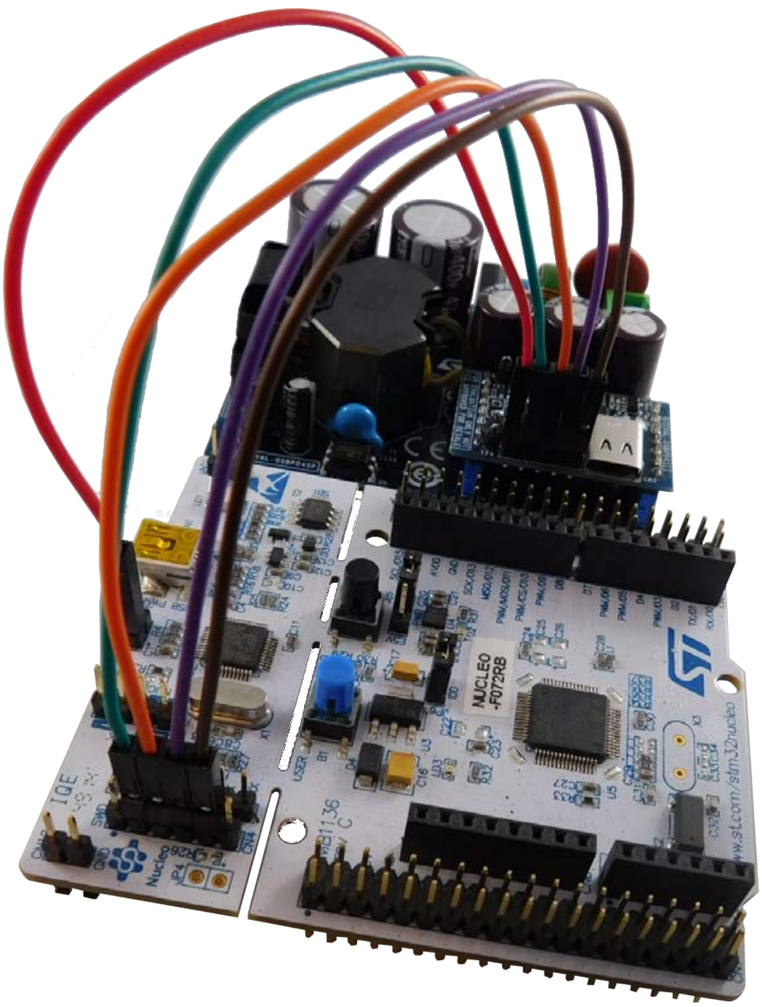
Step 1. Unmount all the CN2 Jumpers on the ST-Link section of the STM32 Nucleo board.

Step 2. Connect CN4 (SWD) and CN1 JP1 on the STM32 Nucleo development board to CN1 of the STEVAL-USBPD45I digital control board.

Connect the pins as described below:

– CN1-1 ↔ CN1-1 3.3V
– CN4-2 ↔ CN1-2 SWCLK
– CN4-3 ↔ CN1-3 GND
– CN4-4 ↔ CN1-4 SWDIO
– CN4-5 ↔ CN1-5 Reset

Figure 23. Setup to program the reference design with STM32 Nucleo



2.2.2 Programming and debugging with ST-LINK/V2

To program and debug the digital control board with the ST-LINK/V2 debugger/programmer, you will need the following components, not supplied in the kit:

- an ST-LINK/V2 in-circuit debugger/programmer for the STM8 and STM32 microcontroller families
- a USB type A to mini B cable

Step 1. Connect CN3 on the ST-LINK/V2 debugger/programmer to CN1 of the STEVAL-USBPD45I digital control board.

Connect the pins as described below:

– CN3-1 ↔ CN1-1 3.3V

- CN3-19 ↔ CN3-2 (both sides on ST-LINK)
- CN3-9 ↔ CN1-2 SWCLK
- CN3-8 ↔ CN1-3 GND
- CN3-7 ↔ CN1-4 SWDIO
- CN3-15 ↔ CN1-5 Reset

Figure 24. Setup to program the reference design with ST-LINK/V2

3 Schematics

Figure 25. STEVAL-USBPD45P power supply board schematics

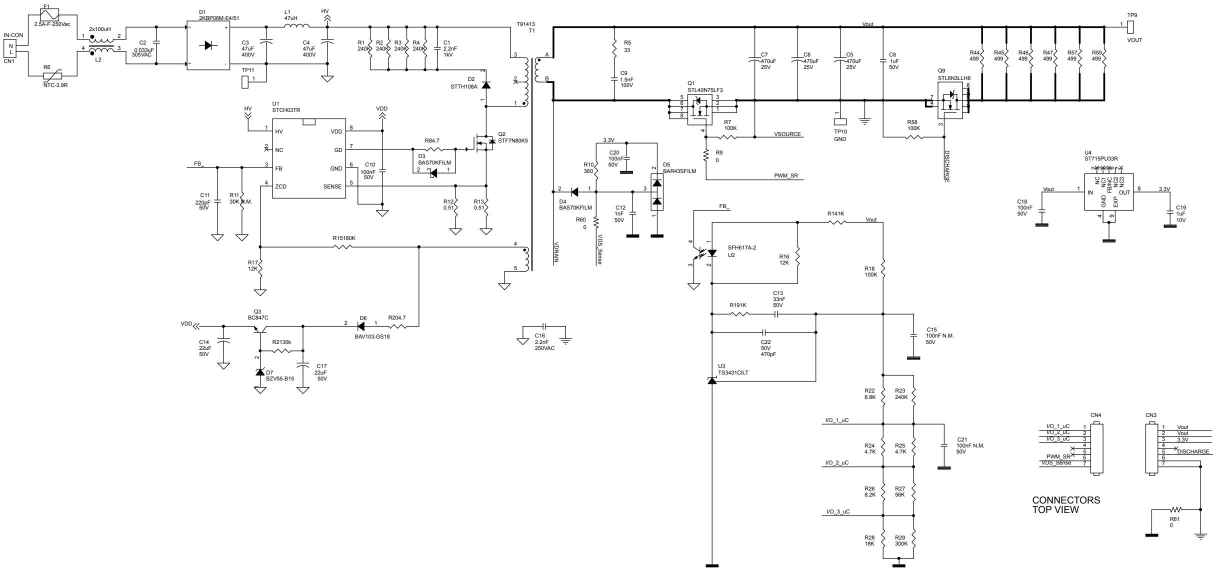
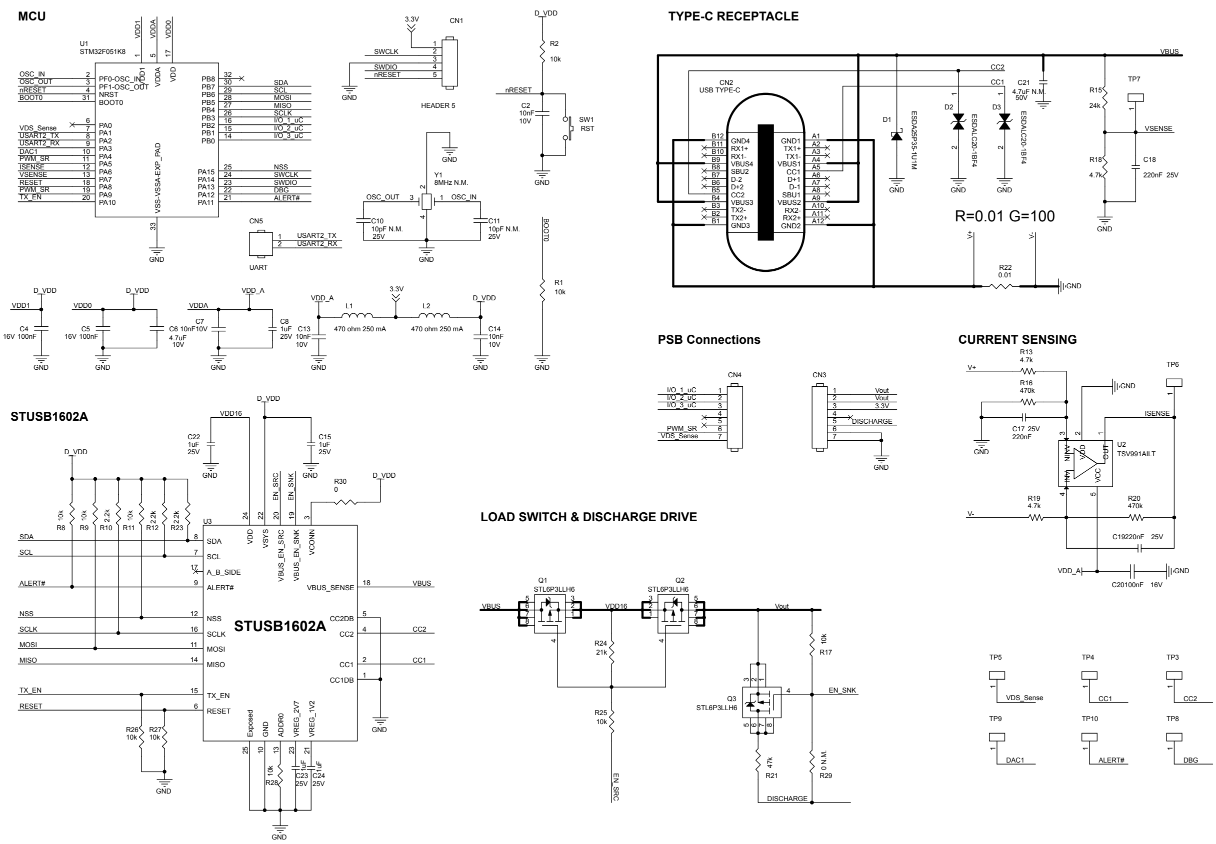


Figure 26. STEVAL-USBPD45I digital control board schematics



4 Bill of materials

Table 3. **STEVAL-USBPD45P bill of materials**

Item	Q.ty	Ref	Part / Value	Description	Manufacturer	Order code
1	1	CN1	IN-CON 300V_{AC}	5.08MM VERTICAL PCB HEADERS	WURTH ELEKTRONIK	691311500102
2	2	CN3,CN4	CON5	Through Hole Header 7x1 pitch 2.54mm	AMPHENOL FCI	76341-307LF
3	1	C1	2.2nF 1kV ±10%	Ceramic X7R	MURATA	GRM31BR73A222KW01L
4	1	C2	0.033µF 305V_{AC} ±20%	Polypropylene - EMI SUPPRESSION FILM CAPACITOR	EPCOS	B32921C3333M000
5	2	C3,C4	47µF 400V ±20%	ALUMINIUM ELCAP	Nichicon	UCY2G470MHD
6	3	C5,C7,C8	470µF 25V ±20%	ALUMINIUM ELCAP	Nichicon	UPM1E471MPD1TD
7	1	C6	1µF 50V ±10%	Ceramic X7R	WURTH ELEKTRONIK	885012207103
8	1	C9	1.5nF 100V ±10%	Ceramic X7R	ANY	ANY
9	3	C10,C18,C20	100nF 50V ±10%	Ceramic X7R	WURTH ELEKTRONIK	885012207098
10	1	C11	220pF 50V ±10%	Ceramic X7R	WURTH ELEKTRONIK	885012207082
11	1	C12	1nF 50V ±10%	Ceramic X7R	WURTH ELEKTRONIK	885012207086
12	1	C13	33nF 50V ±20%	Ceramic X7R	Multicomp	MC0402F333M500CT
13	2	C14,C17	22µF 50V ±20%	ELCAP	RUBYCON	50YXF22M5X11
14	2	C15,C21	100nF 50V ±10% (not mounted)	Ceramic X7R	WURTH ELEKTRONIK	885012207098
15	1	C16	2.2nF 250V_{AC} ±20%	Ceramic E	MURATA	DE2E3KY222MN3AM02F
16	1	C19	1µF 10V ±10%	Ceramic X7R	WURTH ELEKTRONIK	885012207022
17	1	C22	470pF 50V ±5%	Ceramic C0G / NP0	Multicomp	MC0402N471J500CT
18	1	D1	2KBP06M-E4/51	BRIDGE RECTIFIER	VISHAY	2KBP06M-E4/51
19	1	D2	800V	HIGH VOLTAGE ULTRAFAST RECTIFIER	ST	STTH108A
20	2	D3,D4	70V	Schottky barrier	ST	BAS70KFILM
21	1	D5		Small Signal Schottky Diode	ST	BAR43SFILM
22	1	D6		SWITCHING DIODE	VISHAY	BAV103-GS18
23	1	D7	15V ±2%	ZENER DIODE	NEXPERIA	BZV55-B15
24	1	F1	2.5A-F-250V_{AC}	FUSE SS-5F SERIES FAST ACTING	Cooper Bussmann	SS-5F-2-5A-BK

Item	Q.ty	Ref	Part / Value	Description	Manufacturer	Order code
25	1	L1	47µH	DRUM FILTER CHOKE	WURTH ELEKTRONIK	7447462470
26	1	L2	2x100µH 250V_{AC} ±30%	WE-CMB NiZn Common Mode Power Line Choke	WURTH ELEKTRONIK	744841210
27	1	Q1	75V 10A	N-CHANNELPOWER MOSFET	ST	STL40N75LF3
28	1	Q2	800V 6A	N-CHANNEL POWER MOSFET	ST	STF7N80K5
29	1	Q3		SMALL SIGNAL NPN TRANSISTOR	NEXPERIA	BC847C
30	1	Q9	30V 6A	N-CHANNEL POWER MOSFET	ST	STL6N3LLH6
31	4	R1,R2,R3,R4	240K 1/2W ±5%	STAND. FILM RESISTOR 200ppm/°C	ANY	ANY
32	1	R5	33 1/4W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
33	1	R6	NTC 3.9Ω ±15%	Inrush Current Limiters	MURATA	NTPAD3R9LDNB0
34	2	R7,R18,R58	100K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
35	2	R8,R20	4.7 1/8W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
36	2	R9,R60,R61	0 1/8W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
37	1	R10	360 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
38	2	R11	30K 1/8W ±1% (not mounted)	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
39	2	R12,R13	0.51 1W ±1%	FILM RESISTOR 100ppm/°C	Panasonic	ERJB2BFR51V
40	1	R14	1K 1/8W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
41	1	R15	180K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
42	2	R16,R17	12K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
43	1	R19	1K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
44	1	R21	30k 1/8W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY

Item	Q.ty	Ref	Part / Value	Description	Manufacturer	Order code
45	1	R22	6.8K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
46	1	R23	240K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
47	2	R24,R25	4.7K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
48	1	R26	8.2K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
49	1	R27	56K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
50	1	R28	18K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
51	1	R29	300K 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
52	6	R44,R45,R46, R47,R57,R59	499 750mW ±1%	FILM RESISTOR	VISHAY	CRCW1206499RFKEA HP
53	1	TP9	VOUT	TEST POINT	Vero Technologies	20-2137
54	1	TP10	GND	TEST POINT	Vero Technologies	20-2137
55	1	TP11	TEST POINT (not mounted)	TEST POINT	Vero Technologies	20-2137
56	1	T1	45W	Switch Mode RM10 Transformer	SUMIDA	T91413
57	1	U1		OFF-LINE CC MODE PRIMARY-SENSING SWITCHING CONTROLLER	ST	STCH03TR
58	1	U2		OPTO ISOLATOR	Vishay	SFH617A-2
59	1	U3		Shunt Voltage Reference	ST	TS3431CILT
60	1	U4	85mA	High input voltage LDO	ST	ST715PU33R
61	1	Heat-Sink	Heat-Sink 25C/W	heat sink	FISCHER ELEKTRONIK	FK 220 SA 220
62	1	CN5	IN-CON-PLUG 300Vac	5.08mm pitch straight pluggable terminal block, plug, cable mount, 2-way	WURTH ELEKTRONIK	691351500002

Table 4. **STEVAL-USBPD45I bill of materials**

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
1	1	CN1	HEADER 5	Through Hole Male Header 5x1 pitch 2.54mm	WURTH ELEKTRONIK	61300511121

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
2	1	CN2	USB TYPE-C	Type-C	WURTH ELEKTRONIK	632723300011
3	2	CN3, CN4	P-CONN	Through Hole Male Header 7x1 pitch 2.54mm	WURTH ELEKTRONIK	61300711121
4	1	CN5	UART (not mounted)	Through Hole Male Header 2x1 pitch 2.54mm	WURTH ELEKTRONIK	61300211121
5	4	C2, C7, C13, C14	10nF 10V ±10%	Ceramic X7R	WURTH ELEKTRONIK	885012205012
6	3	C4, C5, C20	100nF 16V ±10%	Ceramic X7R	WURTH ELEKTRONIK	885012205037
7	1	C6	4.7µF 10V ±20%	Ceramic X5R	Murata Electronics North America	GRM155R61A475MEA AD
8	5	C8, C15, C22, C23, C24	1µF 25V ±10%	Ceramic X5R	TDK	C1005X5R1V105K050 BC
9	2	C10, C11	10pF 25V ±5% (not mounted)	Ceramic C0G, NP0	WURTH ELEKTRONIK	885012005040
10	3	C17, C18, C19	220nF 25V ±10%	Ceramic X5R	TDK	C1005X5R1E224K050 BC
11	1	C21	4.7µF 50V ±10% (not mounted)	Ceramic X6S	TDK	C2012X6S1H475K125 AC
12	1	D1	22V	Transil	ST	ESDA25P35-1U1M
13	2	D2, D3	-	Single line low capacitance ESD protection	ST	ESDALC20-1BF4
14	2	L1, L2	470 Ω 250 mA	EMI Suppression Ferrite Bead	WURTH ELEKTRONIK	7427927141
15	3	Q1, Q2, Q3	-	P-CHANNEL POWER MOSFET 30V 6A	ST	STL6P3LLH6
16	10	R1, R2, R8, R9, R11, R17, R25, R26, R27, R28	10k 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
17	3	R10, R12, R23	2.2k 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
18	3	R13, R18, R19	4.7k 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
19	1	R15	24k 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
20	2	R16, R20	470k 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
21	1	R21	47k 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
22	1	R22	0.01 1W ±1%	FILM RESISTOR	Panasonic	ERJ8CWFR010V

Item	Q.ty	Ref.	Part / Value	Description	Manufacturer	Order code
23	1	R24	21k 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
24	1	R29	0 N.M. 1/16W ±1% (not mounted)	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
25	1	R30	0 1/16W ±1%	STAND. FILM RESISTOR 100ppm/°C	ANY	ANY
26	1	SW1	RST	PushButton SPST	TE CONNECTIVITY	1437566-3
27	8	TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10	(not mounted)	TEST POINT	Vero Technologies	20-2137
28	1	U1	-	32-bit ARM Cortex M0 48 MHz	ST	STM32F051K8U7
29	1	U2	-	Rail to rail input/ output op-amps	ST	TSV991AILT
30	1	U3	-	USB type-C interface	ST	STUSB1602A
31	1	Y1	8MHz 10ppm (not mounted)	Crystal	ABRACON	ABM3B-8.000MHZ-10-1-U-T

5 Board layouts

5.1 STEVAL-USBPD45P

Figure 27. STEVAL-USBPD45P top layer

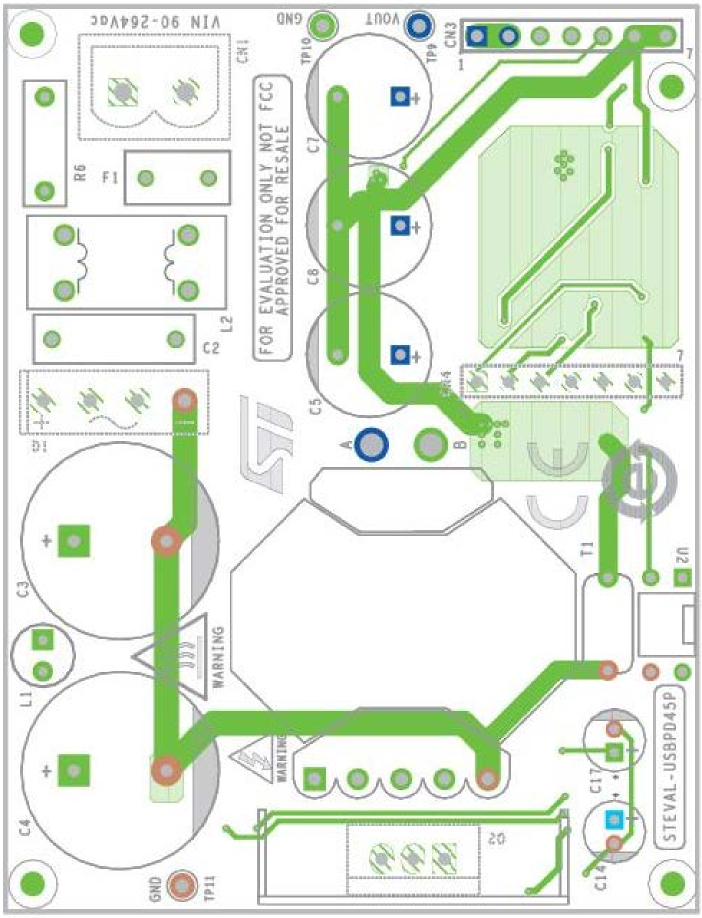
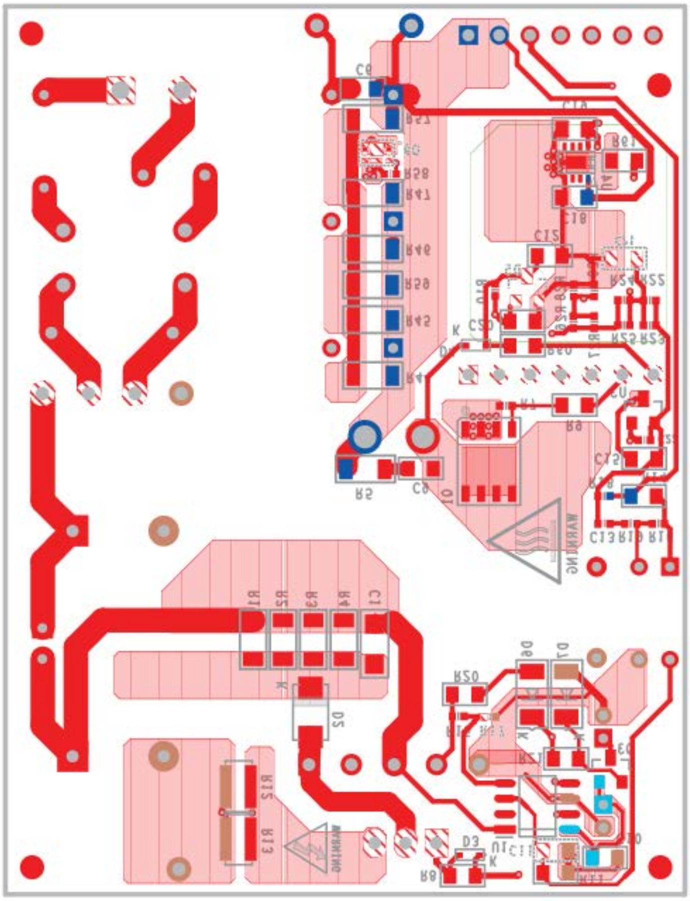


Figure 28. STEVAL-USBPD45P bottom layer



5.2 STEVAL-USBPD45I

Figure 29. STEVAL-USBPD45I top layer

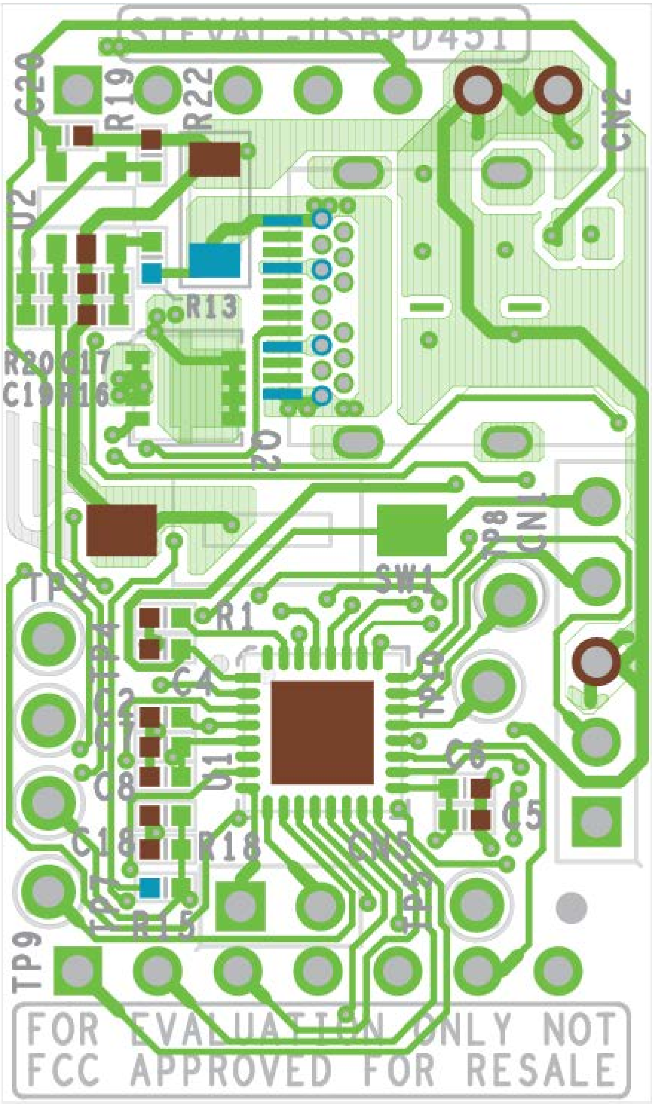
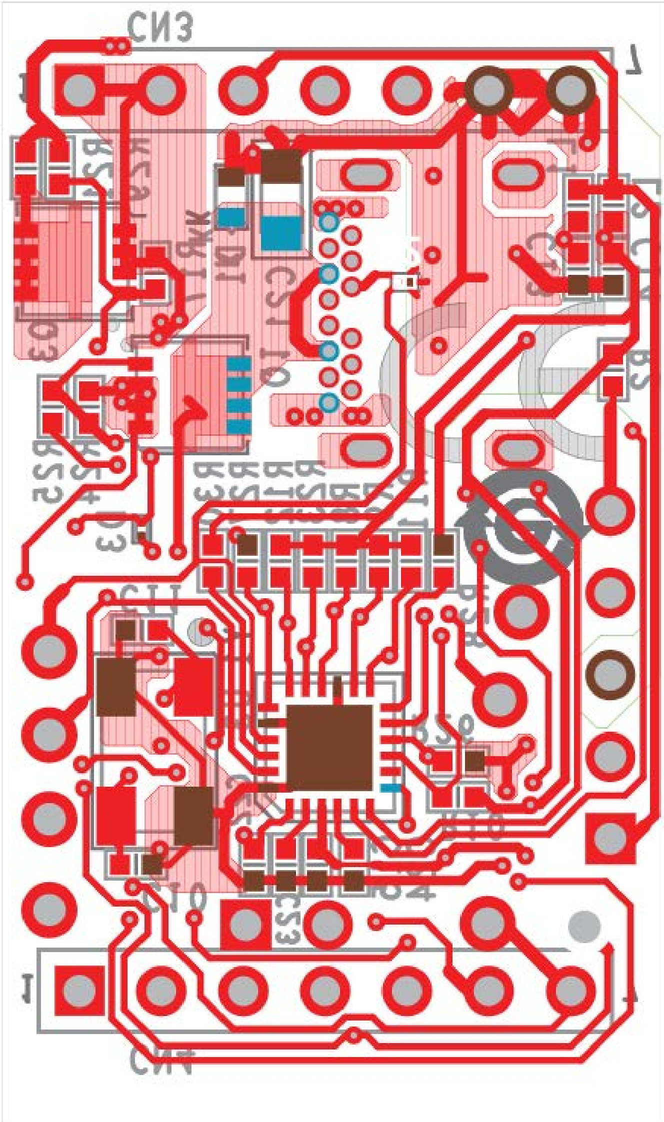


Figure 30. STEVAL-USBPD45I bottom layer



Revision history

Table 5. Document revision history

Date	Version	Changes
11-May-2018	1	Initial release.
04-Jul-2018	2	Minor text edits

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