STEVAL-USBC2DP USB Type-C™ to DisplayPort™ adapter

Introduction

The STEVAL-USBC2DP adapter is a miniaturized solution with a USB Type-C plug and a DisplayPort receptacle that implements the DisplayPort Alternate Mode of the USB Type-C and Power Delivery specifications for compatibility with the VESA® Standard. The adapter allows you to extend the screen laptop equipped with a USB Type-C-interface onto any screen with a DisplayPort interface. This mode enables computers, tablets, smartphones, displays and docking stations with the USB Type-C connector to rout high-resolution A/V and USB data and power through a USB Type-C cable.

The STEVAL-USBC2DP is based on the high performance ARM® 32-bit Cortex®-M0 STM32F072 MCU running the X-CUBE-USB-PD certified software that negotiates the Alternate Mode for DisplayPort with USB Power Delivery (PD) Vendor Defined Messages (VDM). An optimized discrete analog front end (AFE) and the embedded STM32 peripherals allow management of the Type-C plug lines and USB PD communication. The integrated USB 2.0 controller and the ST USB 2.0 Middleware stack running on the STM32 provide the Billboard Device Class support required by the USB Power Delivery standard, as well as the device firmware upgrade (DFU) capability.

X-CUBE-USB-PD is compliant with the USB Type-C™ 1.3 and USB Power Delivery 3.0 specifications.

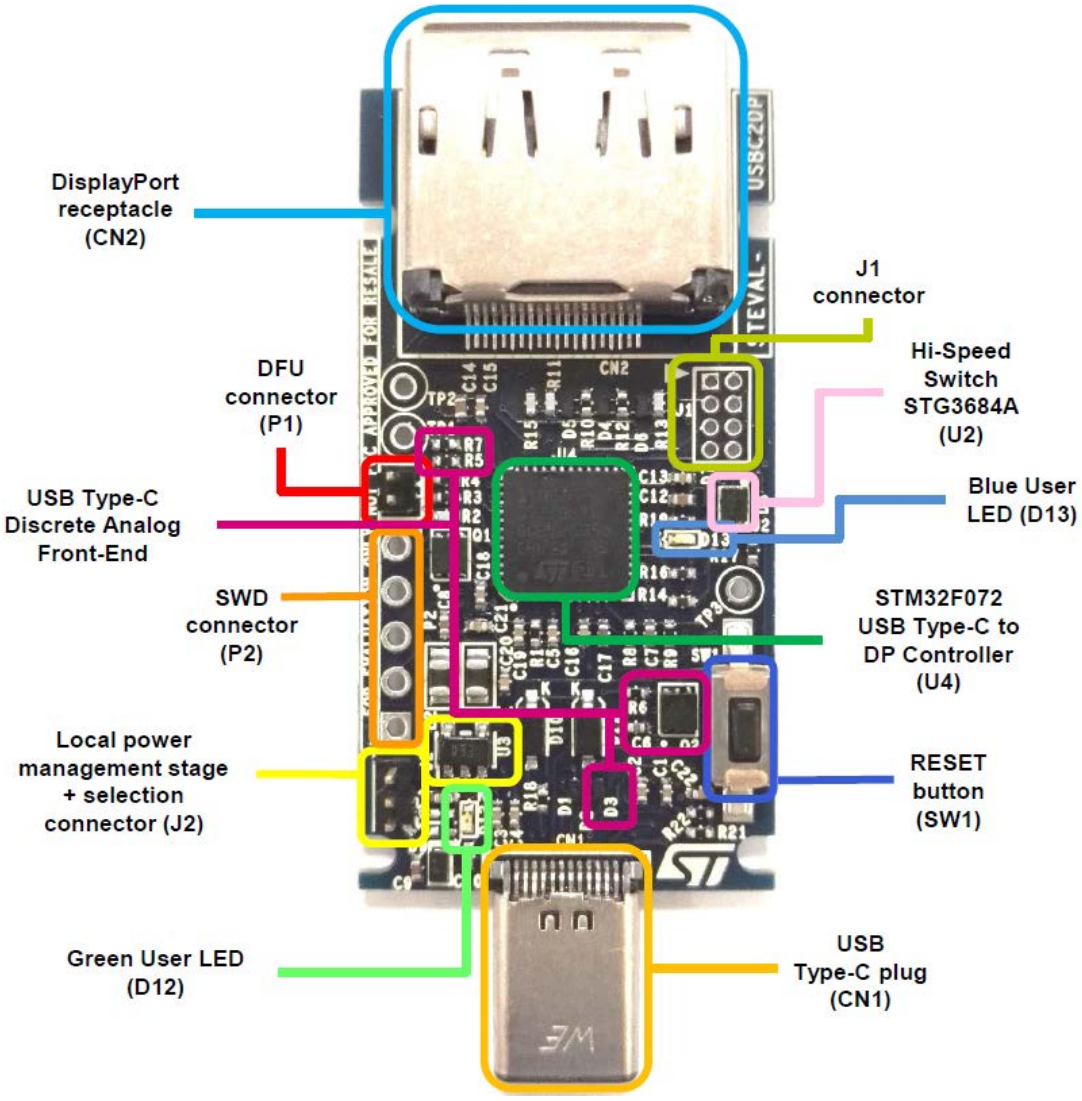
Figure 1. STEVAL-USBC2DP evaluation board



1 STEVAL-USBC2DP system architecture

The STEVAL-USBC2DP is a full reference design that implements DisplayPort Alternate Mode over the USB Type-C and Power Delivery protocol. It is a highly compact solution with a USB Type-C plug and a DisplayPort receptacle on the same board, without any other USB Type-C cable.

Figure 2. the STEVAL-USBC2DP board functional blocks



The reference design is based on the following functional blocks:

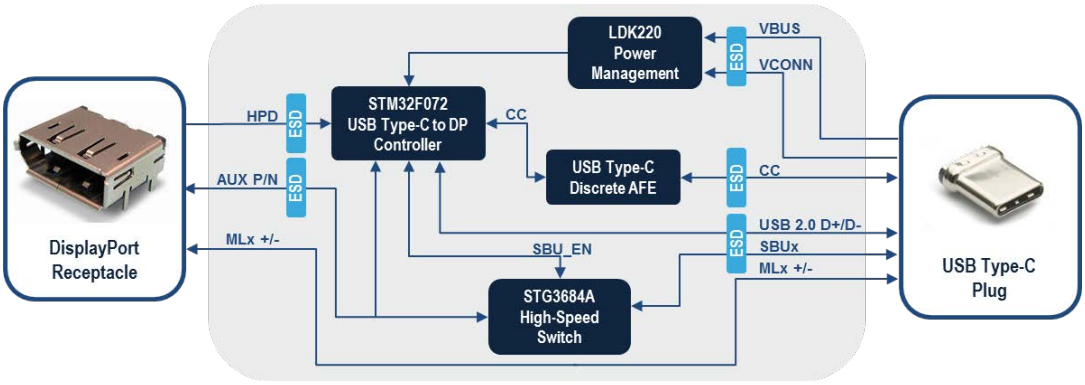
1. an STM32F072 microcontroller that runs the application firmware based on the X-CUBE-USB-PD certified software
2. a USB Type-C discrete analog front-end PHY
3. an on-board power management stage based on the LDK220 to supply the dongle through VBUS or VCONN on the Type-C plug
4. an STG3684A high-speed switch that connects the DP auxiliary (AUX) signals with the SBU lanes.

1.1 USB Type-C to DisplayPort reference design architecture

The STEVAL-USBC2DP reference design for the USB Type-C to VESA DisplayPort adapter is a complete solution based on the following logical blocks:

1. A USB Type-C reversible connector
2. A DisplayPort connector
3. An STM32F072 MCU running the application firmware based on the X-CUBE-USB-PD certified software, containing the Middleware stack
4. A USB Type-C discrete analog front end
5. The on-board power management stage controlled by the LDK220 low dropout voltage regulator to supply the dongle through the Type-C connector VBUS or VCONN pins
6. The STG3684A low voltage 0.5 Ω max. dual SPDT switch between the DisplayPort auxiliary (AUX) and the side-band unit (SBU) lines

Figure 3. STEVAL-USBC2DP system architecture block diagram



The adapter reference design also features:

- Dual supply options through USB Type-C connector:
  - VBUS
  - VCONN
- VBUS voltage sensing for power monitoring
- USB 2.0 interface available on Type-C™ port for Billboard Device Class and Device Firmware Upgrade
- A power status LED and USB Power Delivery Status LED
- A RESET button
- On-board SWD connector that can be connected with the ST-LINK/V2-1 debugger/programmer embedded on STM32 Nucleo boards

1.2 STM32F072 USB Type-C to DP controller

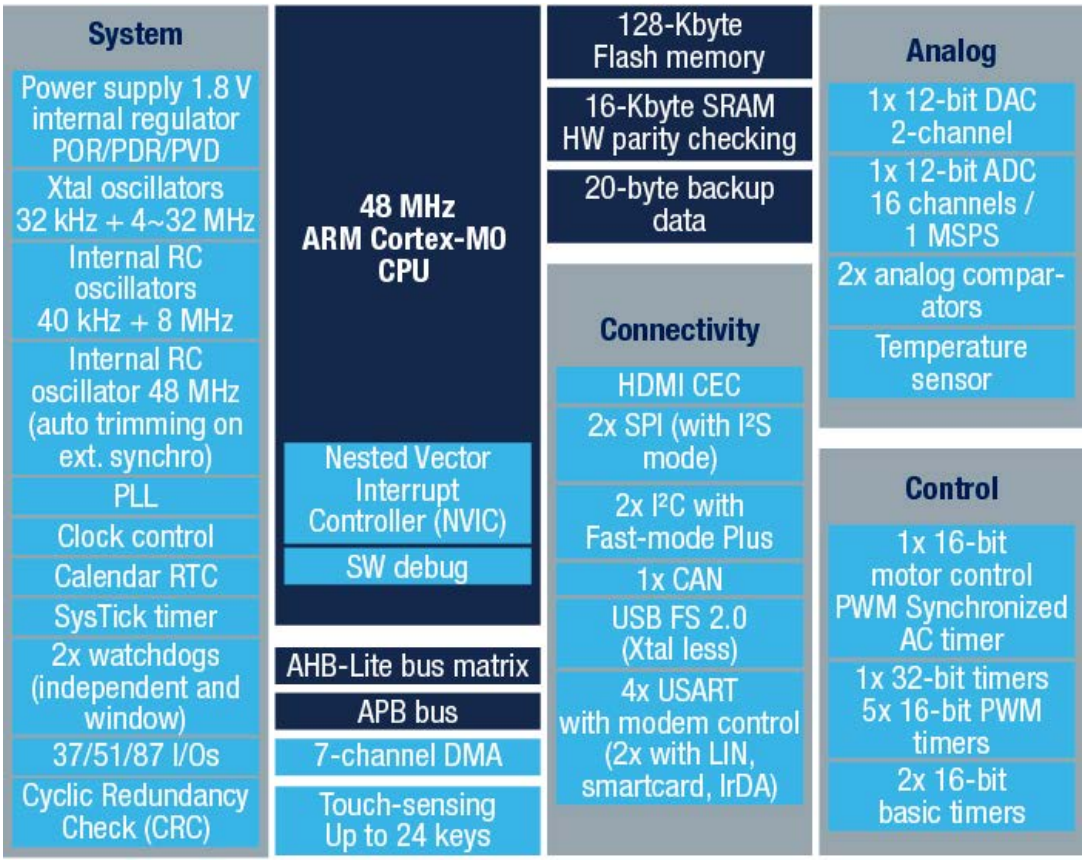
The STM32F072 microcontroller incorporates the high-performance ARM®Cortex®-M0 32-bit RISC core operating at up to 48 MHz frequency, high-speed embedded memories (up to 128 Kbytes of Flash memory and 16 Kbytes of SRAM), and an extensive range of enhanced peripherals and I/Os.

The microcontroller offers standard communication interfaces (two I2Cs, two SPI/I2S and four USARTs), a USB Full-speed device (crystal-less), a CAN, a 12-bit ADC, a 12-bit DAC with two channels, seven 16-bit timers, a 32-bit timer and an advanced-control PWM timer.

The microcontroller can operate in the -40 to +85 °C and -40 to +105 °C temperature ranges, from a 2.0 to 3.6 V power supply.

A comprehensive set of power-saving modes allows the design of low-power applications.

Figure 4. **STM32F072 series microcontroller block diagram**

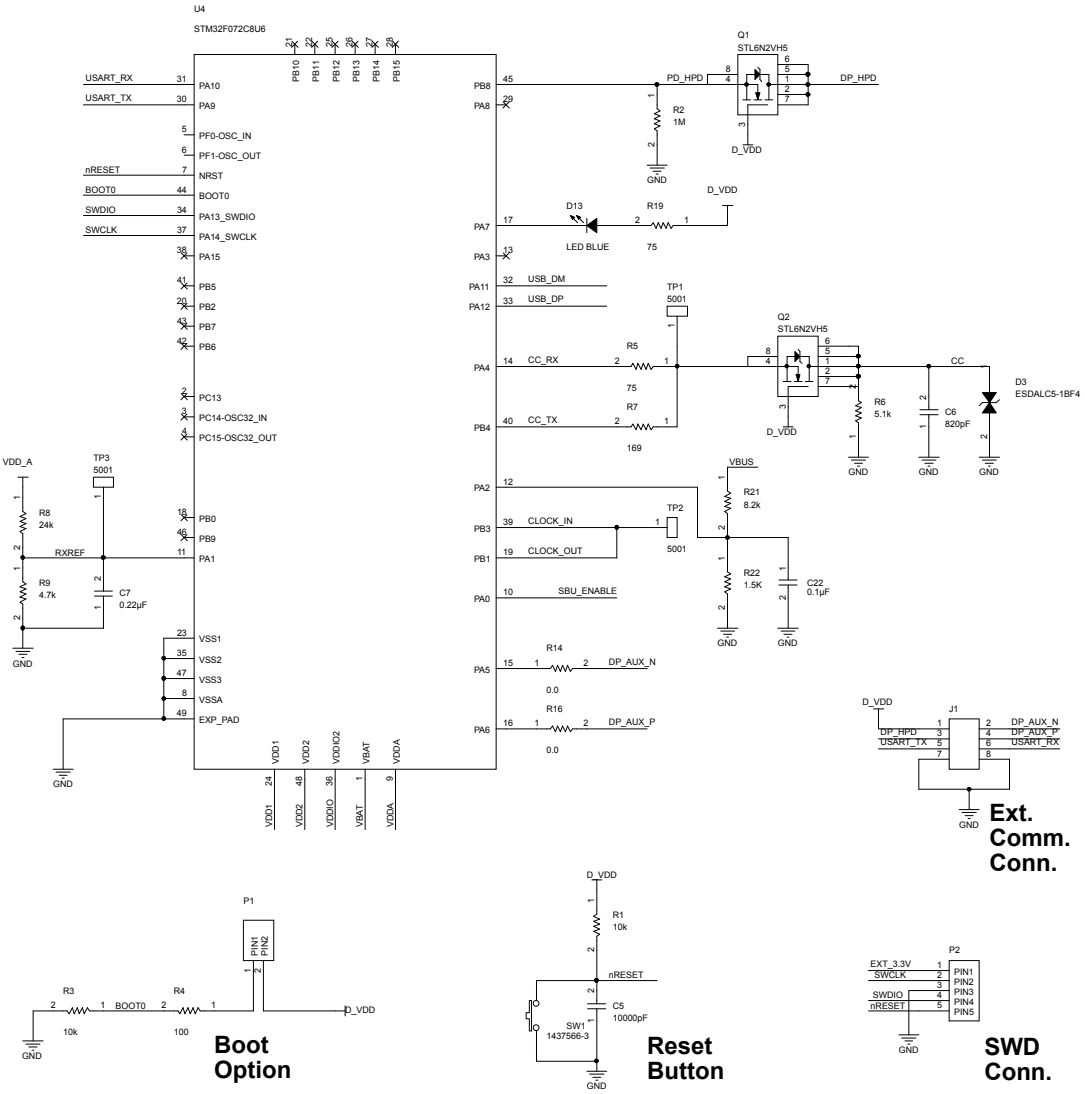


In this USB Type-C to DP adapter implementation, the STM32F072 microcontroller manages the ST USB Power Delivery FW library, which allows PD message transmission through the CC line.

The microcontroller also checks the VBUS provided by the source device and identifies the device attachment and detachment events.

Additionally, the microcontroller manages the interrupt on the hot plug detection signal driven (DP_HPD) by the monitor when it is connected.

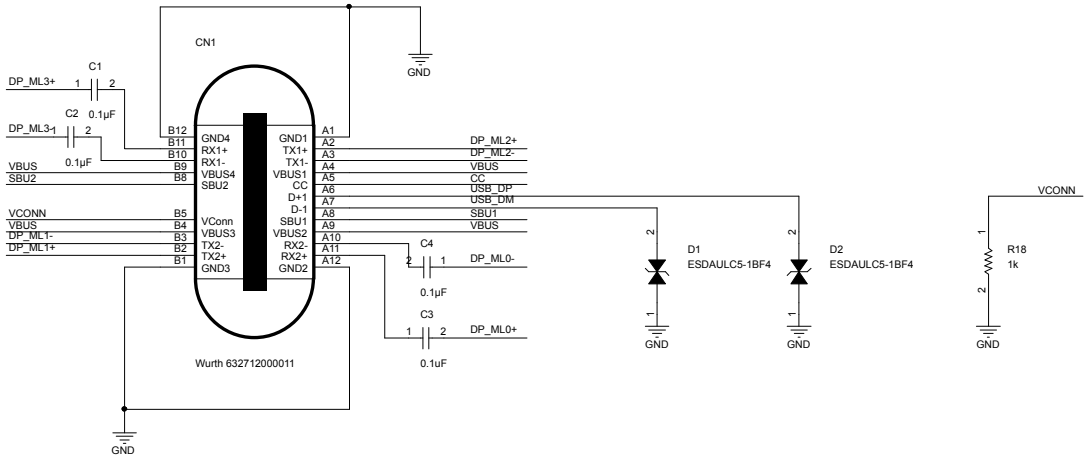
Figure 5. **STM32F072 microcontroller schematic**



1.3 USB Type-C plug and DisplayPort receptacle

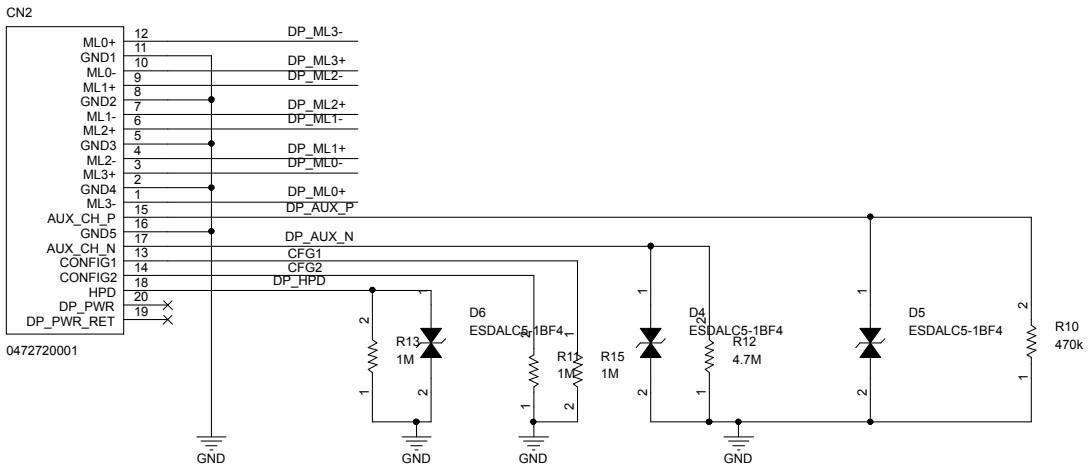
As the board is a consumer with the Dead Battery Mode feature, the host USB Type-C connector must supply power through the VBUS or VCONN pins of the CN1 connector.

Figure 6. **USB Type-C plug (CN1) schematic**



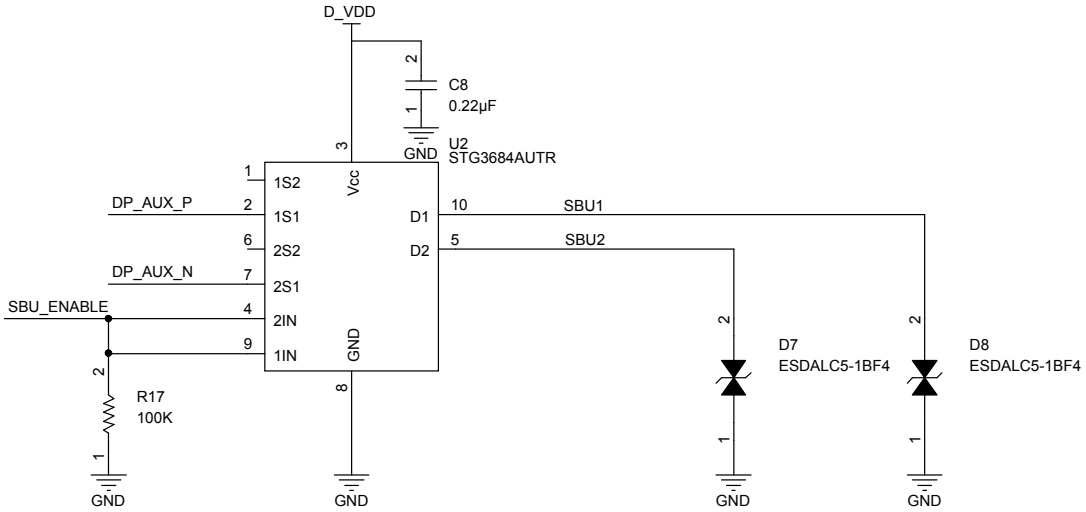
The other CN1 pins for the high speed data paths (TX1+, TX1-; RX1+, RX1-; TX2+, TX2-; RX2+, RX2-) are directly connected to corresponding DisplayPort main link channels (ML0+, ML0-; ML1+, ML1-; ML2+, ML2-; ML3+, ML3) on the DisplayPort CN2 connector.

Figure 7. **DisplayPort receptacle (CN2) schematic**



The DisplayPort Auxiliary signals (DP_AUX_P and DP_AUX_N) are connected to SideBand Use pins SBU1 and SBU2 through the STG3684A high-speed switch driven by the STM32F072.

Figure 8. High Speed Switch for AUX/SBU management



The USB Type-C to DP controller (STM32F072 microcontroller) receives hot plug detection signal (DP_HPD) from the display through the CN2 connector.

1.4 Local power management stage and LEDs

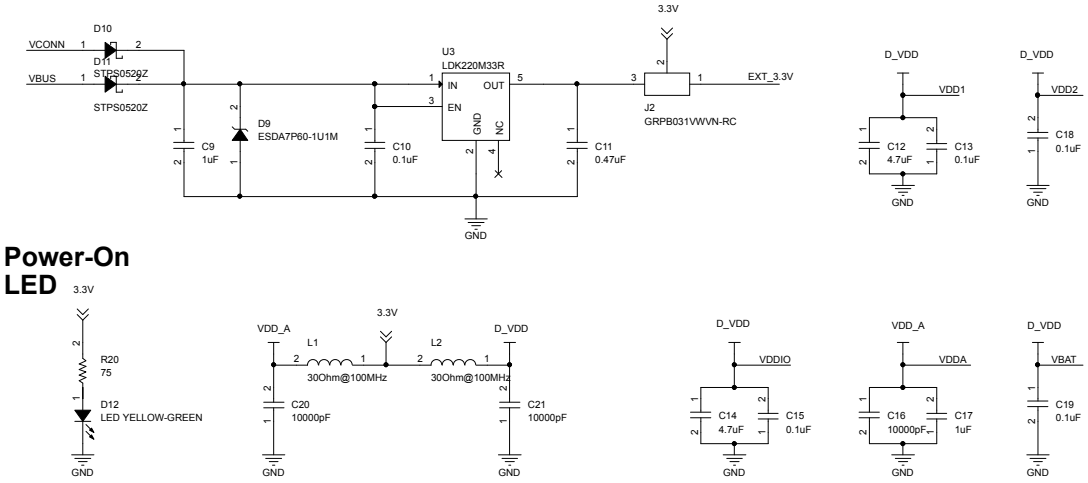
As the adapter shall have the sink role and start up under Dead Battery Mode, the local power management stage supplies the board through an LDK220 voltage regulator from the VBUS or VCONN voltage supply lines on the host USB receptacle.

The LDK220 low quiescent current and low noise LDO supplies a maximum 200 mA output from a 2.5 V to 13.2 V input range, with a typical drop-out voltage of 100 mV.

The STEVAL-USBC2DP platform includes the following status LEDs:

1. green LED D12 to signal that the platform is powered.
2. blue LED D13 (connected to the STM32F072 PA7 pin) to signal the status of the Alternative Mode operation.

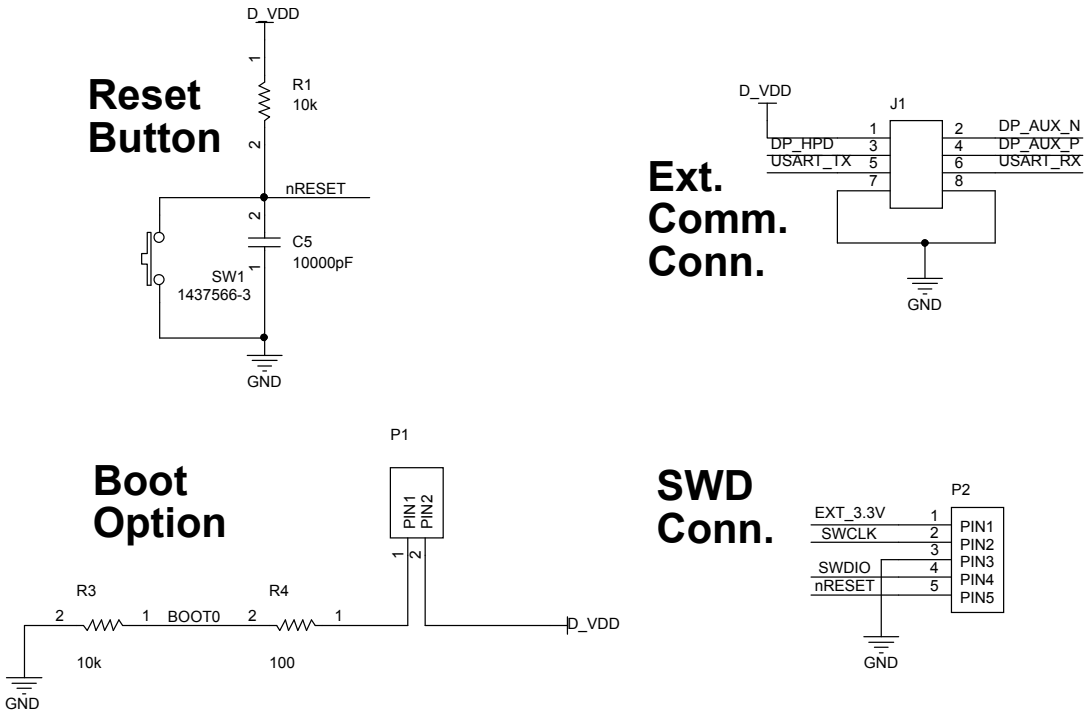
Figure 9. schematic view of the local power management stage



Jumper J2 should remain on pins 2-3 for normal operation with VBUS or VCONN supplied through the host USB Type-C connector. J2 can alternatively be closed on pins 1-2 to supply the platform through the STLINK SWD connector during debugging.

1.5 Reset button, connectors and jumper settings

Figure 10. Reset button, connector and jumper schematics



Connector J1 allows you to monitor DisplayPort Connector CN2 hot plug detection (DP_HPD) signals and Auxiliary (DP_AUX_P and DP_AUX_N) signals, and includes a USART serial communication interface.

P2 allows you to program the microcontroller through an SWD connector (strip-line, not mounted) instead of DFU, and provides access to all the microcontroller debugging features.

Note: To facilitate programming, install a five-position header 0.100" (2.54 mm) through-hole connector on P2. Then, connect the P2 SWD pins (2, 3 and 4) to the equivalent ones of the ST-LINK CN4 connector of an STM32 Nucleo-64 board, and connect P2 pin 1 to ST-LINK JP1 pin 1. Remove both jumpers on the ST-LINK CN2 connector to allow correct SWD operation (refer to UM1724 on www.st.com for more information).

P1 sets the microcontroller in DFU mode when it is closed with a jumper, so you can update application firmware.

1.6 STSW-USBC2DP software package

1.6.1 Description

The STSW-USBC2DP software package is designed to support the STEVAL-USBC2DP USB Type-C to DisplayPort adapter evaluation board.

It contains the application firmware and allows the STEVAL-USBC2DP evaluation board to adopt DisplayPort Alternate Mode operation according to the USB Type-C and Power Delivery specifications.

The application firmware is based on the X-CUBE-USB-PD certified software with Structured VDM messages to negotiate Alternate Mode protocol requirements.

The firmware runs on the STM32F072 high performance ARM® 32-bit Cortex®-M0 MCU embedded in the STEVAL-USBC2DP. It supports Billboard Device Class as per the USB Power Delivery standard and can be updated through the device firmware upgrade functionality of the STM32 microcontroller.

For further information on the STSW-USBC2DP software package, refer to UM2378 on www.st.com.

2 System setup

The STEVAL-USBC2DP dongle is a compact turn-key solution that demonstrates the versatility and convenience of the USB Type-C port for DisplayPort Alternate Mode.

The plug and play feature of the USB Type-C and Power Delivery specifications allows the adapter to operate immediately.

2.1 STEVAL-USBC2DP operation

To test the full functionality of the STEVAL-USBC2DP Type-C to DisplayPort adapter, your computer must support DisplayPort Alternate Mode on the USB Type-C port where the dongle is connected.

Connect the STEVAL-USBC2DP USB Type-C plug directly to your computer USB Type-C port.

Connect the STEVAL-USBC2DP DisplayPort receptacle to the external monitor with a standard DisplayPort-to-DisplayPort cable.

Once attached, the dongle resolves the explicit negotiation with the computer port and immediately extends the computer screen to the secondary monitor.

Figure 11. STEVAL-USBC2DP connected to type-C port and to DP2DP cable



Specific blinking sequences on the blue LED D13 indicate the different stages in the DisplayPort Alternate Mode procedure:

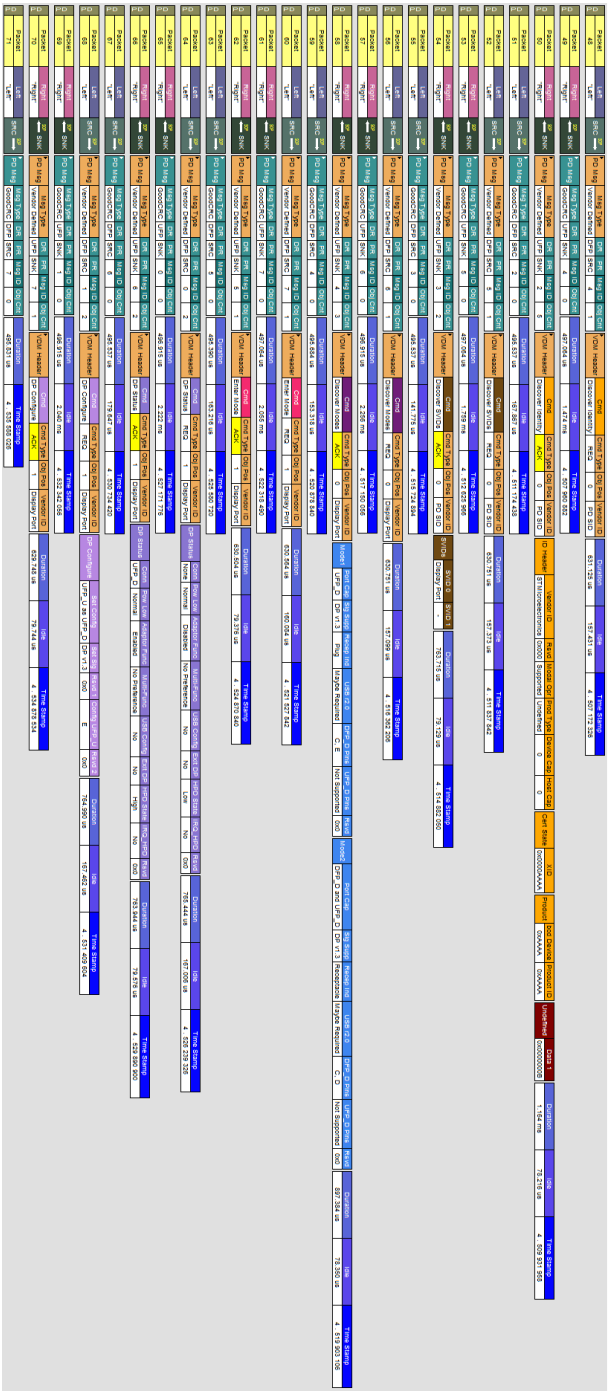
1. If the dongle is attached to a USB Type-C ONLY port (without Power Delivery negotiation capability), the LED remains OFF.
2. When the dongle is connected to a USB Type-C port that does not support Alternate Mode, the LED slowly blinks after explicit PD negotiation is achieved.
3. When the dongle is connected to a port that supports DP Alternate Mode, but the DP cable is not attached to connector CN2, the LED blinks quickly blinks after explicit PD negotiation is achieved and DP Alternate Mode is confirmed with Discover Mode ACK.
4. When the dongle is connected to a port supporting DP Alternate Mode and the DP cable is attached between connector CN2 and the display, the LED turns ON after DP Alternate Mode is achieved and the computer screen is extended to the secondary display.

2.2 Analysis of DisplayPort Alternate Mode operation flows

The trace view below shows the sequence of the message exchange between the computer and the STEVAL-USBC2DP dongle when it is first attached by DP-to-DP cable to the display, and then attached to the USB Type-C port on the computer.

Note: See technical article TA0356 at STEVAL-USBC2DP for details regarding operation flows.

Figure 12. Trace view of DisplayPort Alternate Mode operation with Mercury T2C



3 Bill of materials

Table 1. **Bill of materials**

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
1	6	C1, C2, C3, C4, C10, C22	CAP CER 0.1µF 25V ±20%, X5R 0402	Ceramic capacitance	Wurth Electronics Inc.	885012105018
2	4	C5, C16, C20, C21	CAP CER 10000pF 10V ±10%, X7R 0402	Ceramic capacitance	Wurth Electronics Inc.	885012205012
3	1	C6	CAP CER 820pF 50V ±5%, X7R 0402	Ceramic capacitance	ANY	
4	2	C7, C8	CAP CER 0.22µF 10V 20%, X5R 0402	Ceramic capacitance	Wurth Electronics Inc.	885012105011
5	2	C9, C17	CAP CER 1µF 25V ±10%, X5R 0402	Ceramic capacitance	ANY	
6	1	C11	CAP CER 0.47µF 10V ±10%, X5R 0402	Ceramic capacitance	ANY	
7	2	C12, C14	CAP CER 4.7µF 10V ±20%, X5R 0402	Ceramic capacitance	ANY	
8	4	C13, C15, C18, C19	CAP CER 0.1µF 10V 20%,, X5R 0402	Ceramic capacitance	Wurth Electronics Inc.	885012105010
9	1	CN1	USB TYPE C PLUG SMT	USB 3.1 TYPE C PLUG SMT	Wurth Electronics Inc.	632712000011
10	1	CN2	DisplayPort CONN RCPT 20POS UDI R/A SMD	DisplayPort connector	Molex, LLC	0472720001
11	2	D1, D2	ESDAULC5-1BF4	TVS DIODE 3VWM 13.5VC 0201	STMicroelectronics	ESDAULC5-1BF4
12	6	D3, D4, D5, D6, D7, D8	ESDALC5-1BF4	TVS DIODE SGL BIDIRECT 0201 PKG	STMicroelectronics	ESDALC5-1BF4
13	1	D9	ESDA7P60-1U1M	TVS DIODE 5VWM 11.6VCL 1610	STMicroelectronics	ESDA7P60-1U1M
14	2	D10, D11	STPS0520Z	DIODE SCHOTTKY 20V 500MA SOD123	STMicroelectronics	STPS0520Z

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
15	1	D12	LED, YELLOW-GREEN	LED, Rectangle with Flat Top, 1.00mm x 0.50mm, YELLOW-GREEN, 20mA, --, --, 0402 (1005 Metric)	ANY	
16	1	D13	LED, BLUE	LED, Rectangle with Flat Top, 1.00mm x 0.50mm, BLUE, 5mA, --, --, 0402 (1005 Metric)	ANY	
17	1	J1	CONN HEADER 8POS UNSHD VERT T/H	Not mounted		
18	1	J2	CONN HEADER	CONN HEADER .050" 3POS PCB GOLD	ANY	
19	2	L1, L2	FERRITE BEAD 30Ohm@100MHz 0805 1LN	FERRITE BEAD 30 OHM 0805 1LN	Wurth Electronics Inc.	74279206
20	1	P1	CONN HEADER	CONN HEADER .050" 2POS PCB GOLD	ANY	
21	1	P2	CONN, Header, Breakaway, 5, Through Hole	Not mounted		
22	2	Q1, Q2	STL6N2VH5	MOSFET N-CH 20V 6A 6PWRFLAT	STMicroelectronics	STL6N2VH5
23	2	R1, R3	RES, 10k 1/16W ±1%, SMD, 0402	Resistance	ANY	
24	4	R2, R11, R13, R15	RES, 1M 1/16W ±1%, SMD, 0402	Resistance	ANY	
25	1	R4	RES, 100 1/16W ±1%, SMD, 0402	Resistance	ANY	
26	3	R5, R19, R20	RES, 75 1/16W ±1%, SMD, 0402	Resistance	ANY	
27	1	R6	RES, 5.1k 1/16W ±1%, SMD, 0402	Resistance	ANY	
28	1	R7	RES, 169 25V 1/16W ±1%, SMD, 0402	Resistance	ANY	
29	1	R8	RES, 24k 1/16W ±1%, SMD, 0402	Resistance	ANY	

Item	Q.ty	Ref.	Part/Value	Description	Manufacturer	Order code
30	1	R9	RES, 4.7k 1/16W ±1%, SMD, 0402	Resistance	ANY	
31	1	R10	RES, 470k 1/16W ±1%, SMD, 0402	Resistance	ANY	
32	1	R12	RES, 4.7M 1/16W ±1%, SMD, 0402	Resistance	ANY	
33	2	R14, R16	RES, 0 1/16W ±0.1%, SMD, 0402	Resistance	ANY	
34	1	R17	RES, 100K 1/16W ±1%, SMD, 0402	Resistance	ANY	
35	1	R18	RES, 1k 1/16W ±0.1%, SMD, 0402	Resistance	ANY	
36	1	R21	RES, 8.2k 1/16W ±5%, SMD, 0402	Resistance	ANY	
37	1	R22	RES, 1.5K 1/16W ±5%, SMD, 0402	Resistance	ANY	
38	1	SW1	SWITCH TACTILE SPST-NO 0.05A 24V	SWITCH TACTILE SPST-NO 0.05A 24V	TE Connectivity ALCOSWITCH Switches	1437566-3
39	3	TP1, TP2, TP3	TEST POINT PC MINI .040"D BLACK	Not mounted		
40	1	U2	STG3684AUTR	IC SWITCH DUAL SPDT 10QFN	STMicroelectronics	STG3684AUTR
41	1	U3	LDK220M33R	IC REG LDO 3.3V 0.2A SOT23-5	STMicroelectronics	LDK220M33R
42	1	U4	STM32F072C8U6	IC MCU 32BIT 64KB FLASH 48UFQFPN	STMicroelectronics	STM32F072C8U6
43	2		JUMPERS	2 (1 x 2) Position Shunt Connector Closed Top 0.050" (1.27mm) Gold		

Revision history

Table 2. **Document revision history**

Date	Revision	Changes
10-Feb-2018	1	Initial release.
07-Mar-2018	2	Updated Section 1.5 Reset button, connectors and jumper settings..
04-Jun-2019	3	Updated Introduction, Section 1 STEVAL-USBC2DP system architecture and Section 1.6.1 Description.

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Glossary

DisplayPort Alternate Mode

the MUX system which repurposes USB Type-C RX/TX and SBU lines for compatability with DisplayPort signal requirements

pulse width modulation

A technique used to encode a message into a pulsing signal

reference design

fully tested and functional solutions with accompanying documentation, intended for direct duplication or further modification

SuperSpeed USB

the SSRX and SSTX USB connector pins reserved for elevated data exchange rates (5 Gbps for USB 3.0)

USB Power Delivery

the logic and technology through which devices connected via USB negotiate their respective power roles (source or sink) and corresponding power level

vendor-defined message

standard data packets sent and received along USB configuration channel lines to negotiate Power Delivery and Alt Mode agreements between the device and the host

VESA

A technical standards organization for computer display standards.

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