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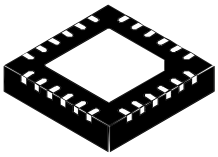
STUSB1600

USB Type-C^{TM} controller with V_{CONN} switch

Datasheet - production data



Features

- Type-C attach and cable orientation detection
- Power role support: source/sink/DRP
- Configurable start-up profiles
- Integrated power switch for V_{CONN} supply:
  - programmable current limit up to 600 mA
  - overcurrent, overvoltage, and thermal protection
  - undervoltage lockout
- I^{2}C interface and interrupt (optional connection to MCU)
- Integrated V_{BUS} voltage monitoring
- Integrated V_{BUS} and V_{CONN} discharge path
- Low power standby mode
- Dead battery mode support
- High voltage protection
- Accessory mode support
- Dual power supply:
  - V_{SYS} = [3.0 V; 5.5 V]
  - V_{DD} = [4.1 V; 22 V]
- Temperature range: -40 °C up to 105 °C

Applications

- Smart plugs, wall adapters, and chargers
- Power hubs and docking stations
- Smartphones and tablets
- Gaming and PNDs
- Displays
- Wearable and Internet of Things (IoT)
- Cameras, camcorders, and MP3 players
- Any Type-C source or sink device

Description

The STUSB1600 is a generic IC designed in a 20 V technology. It addresses USB Type-C™ port management both on the host and/or device side, and is suited for a broad range of applications. It is fully compliant with the USB Type-C cable and connector specifications (Rel. 1.2).

The STUSB1600 can handle all functions from Type-C attach detection, plug orientation detection, host to device connection, V_{CONN} support, and V_{BUS} configuration.

Additionally, the STUSB1600 provides support for dead battery operation and is fully customizable (thanks to an integrated non-volatile memory).

Table 1. Device summary table

Order code	Description	Package	Marking
STUSB1600QTR	USB Type-C™ controller	QFN24 EP 4x4 mm	USB0X

Contents

1 Functional description

The STUSB1600 is a USB Type-C controller IC. It is designed to interface with the Type-C receptacle both on host and/or device sides. It is used to establish and manage the source-to-sink connection between two USB Type-C host and device ports.

The major role of the STUSB1600 is to:

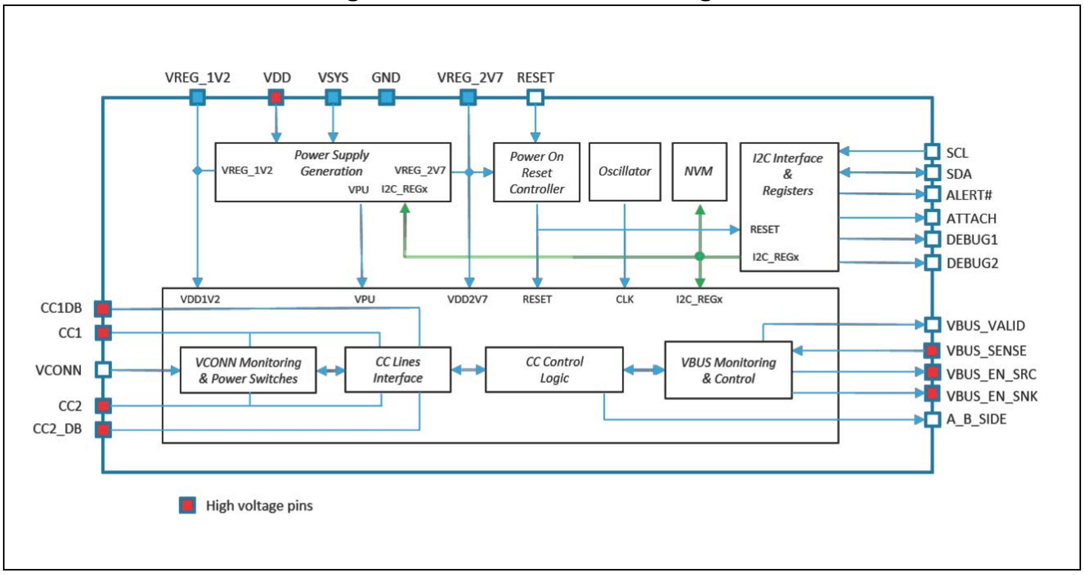
1. Detect the connection between two USB Type-C ports (attach detection)
2. Establish a valid source-to-sink connection
3. Determine the attached device mode: source, sink or accessory
4. Resolve cable orientation and twist connections to establish USB data routing (mux control).
5. Configure and monitor the V_{BUS} power path
6. Manage V_{BUS} power capability: USB default, Type-C medium or Type-C high current mode.
7. Configure V_{CONN} when required

The STUSB1600 also provides:

1. Low power standby mode
2. Dead battery mode
3. I^2C interface and interrupt (optional connection to the MCU)
4. Start-up configuration customization: static through NVM and/or dynamic through I^2C
5. High voltage protection
6. Accessory mode detection

1.1 Block overview

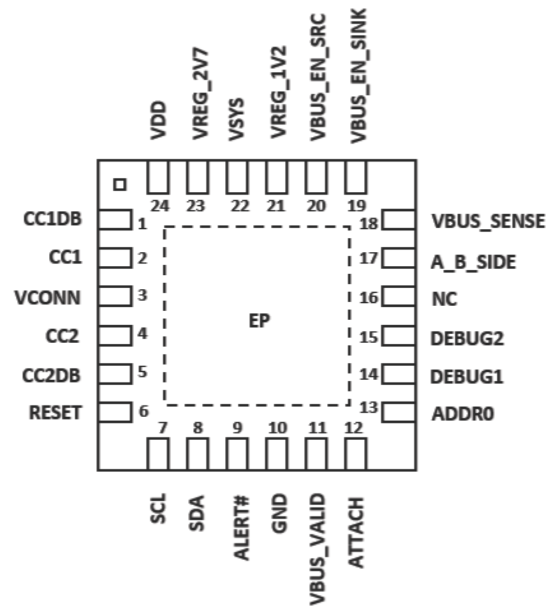
Figure 1. Functional block diagram



2 Inputs/outputs

2.1 Pinout

Figure 2. STUSB1600 pin connections



2.2 Pin list

Table 2. Pin function list

Pin	Name	Type	Description	Typical Connection
1	CC1DB	HV AIO	Dead battery enable on CC1 pin	CC1 pin if used or ground
2	CC1	HV AIO	Type-C configuration channel 1	Type-C receptacle A5
3	VCONN	PWR	Power input for active plug	5 V power source
4	CC2	HV AIO	Type-C configuration channel 2	Type-C receptacle B5
5	CC2DB	HV AIO	Dead battery enable on CC2 pin	CC2 pin if used or ground
6	RESET	DI	Reset input (active high)	—
7	SCL	DI	I^2C clock input	To I²C master, ext. pull-up
8	SDA	DI/OD	I^2C data input/output, active low open drain	To I²C master, ext. pull-up
9	ALERT#	OD	I^2C interrupt, active low open drain	To I²C master, ext. pull-up
10	GND	GND	Ground	Ground
11	VBUS_VALID	OD	V_{BUS} detection, active low open drain	To MCU if any, ext. pull-up
12	ATTACH	OD	Attachment detection, active low open drain	To MCU if any, ext. pull-up
13	ADDR0	DI	I²C device address setting (see *Section 4: I^2C interface*)	Static
14	DEBUG1	OD	Debug accessory device detection in sink power role, active low open drain	To MCU if any, ext. pull-up
15	DEBUG2	OD	Debug accessory device detection in source power role, active low open drain	To MCU if any, ext. pull-up
16	NC	—	—	Floating
17	A_B_SIDE	OD	Cable orientation, active low open drain	USB super speed mux select, ext. pull-up
18	VBUS_SENSE	HV AI	V_{BUS} voltage monitoring and discharge path	From V_{BUS}
19	VBUS_EN_SNK	HV OD	V_{BUS} sink power path enable, active low open drain	To switch or power system, ext. pull-up
20	VBUS_EN_SRC	HV OD	V_{BUS} source power path enable, active low open drain	To switch or power system, ext. pull-up
21	VREG_1V2	PWR	1.2 V internal regulator output	1 µF typ. decoupling capacitor
22	VSYS	PWR	Power supply from system	From power system, connect to ground if not used
23	VREG_2V7	PWR	2.7 V internal regulator output	1 µF typ. decoupling capacitor
24	VDD	HV PWR	Power supply from USB power line	From V_{BUS}
—	EP	GND	Exposed pad is connected to ground	To ground

Table 3. Pin function descriptions

Type	Description
D	Digital
A	Analog
O	Output pad
I	Input pad
IO	Bidirectional pad
OD	Open drain output
PD	Pull-down
PU	Pull-up
HV	High voltage
PWR	Power
GND	Ground

2.3 Pin description

2.3.1 CC1/CC2

CC1 and CC2 are the configuration channel pins used for connection and attachment detection, plug orientation determination, and system configuration management across the USB Type-C cable.

2.3.2 CC1DB/CC2DB

CC1DB and CC2DB are used for dead battery mode when the STUSB1600 is configured in sink power role or dual power role. This mode is enabled by connecting CC1DB and CC2DB respectively to CC1 and CC2. Thanks to this connection, the pull down terminations on the CC pins are present by default even if the device is not supplied (see *Section 3.5: Dead battery mode*).

Warning: CC1DB and CC2DB must be connected to ground when the STUSB1600 is configured in source power role or when dead battery mode is not supported.

2.3.3 VCONN

This power input is connected to a power source that can be a 5 V power supply or a lithium battery. It is used to provide power to the local plug. It is internally connected to power switches that are protected against short circuit and overvoltage. This does not require any protection on the input side. When a valid source-to-sink connection is determined and the V_{CONN} power switches are enabled, V_{CONN} is provided by the source to the unused CC pin (see *Section 3.3: V_{CONN} supply*).

2.3.4 RESET

Active high reset

2.3.5 I²C interface pins

Table 4. I²C interface pin list

Name	Description
SCL	I²C clock, need external pull-up
SDA	I²C data, need external pull-up
ALERT#	I²C interrupt, need external pull-up
ADDR0	I²C device address bit (see *Section 4: I²C interface*)

2.3.6 GND

Ground

2.3.7 VBUS_VALID

This pin is asserted during attachment when the V_{BUS} is detected on the VBUS_SENSE pin and the V_{BUS} voltage is within the valid operating range. The V_{BUS} valid state is also advertised in a dedicated I²C register bit (see *Section 5.1: Register description*).

2.3.8 ATTACH

This pin is asserted when a valid source-to-sink connection is established. It is also asserted when a connection to an accessory device is detected. The attachment state is also advertised in a dedicated I²C register bit (see *Section 5.1: Register description*).

2.3.9 DEBUG pins

These pins are asserted when a debug accessory device is detected according to the running power role.

Table 5. Debug pin list

Name	Description
DEBUG1	Asserted when Type-C FSM is in DebugAccessory.SNK state in sink power role
DEBUG2	Asserted when Type-C FSM is in UnorientedDebugAccessory.SRC or OrientedDebugAccessory.SRC states in source power role

2.3.10 A_B_SIDE

This output pin provides cable orientation. It is used to establish USB SuperSpeed signal routing. The cable orientation is also advertised in a dedicated I^2C register bit (see *Section 5.1: Register description*). This signal is not required in case of USB 2.0 support.

Table 6. USB data mux select

Value	CC pin position
HiZ	CC1 pin is attached to CC line
0	CC2 pin is attached to CC line

2.3.11 VBUS_SENSE

This input pin is used to sense V_{BUS} presence, monitor V_{BUS} voltage, and discharge V_{BUS} on the USB Type-C receptacle side.

2.3.12 VBUS_EN_SNK

In sink power role, this pin allows the incoming V_{BUS} power to be enabled when the connection to a source is established and V_{BUS} is in the valid operating range. The open drain output allows a PMOS transistor to be directly driven. The logic value of the pin is also advertised in a dedicated I^2C register bit (see *Section 5.1: Register description*).

2.3.13 VBUS_EN_SRC

In source power role, this pin allows the outgoing V_{BUS} power to be enabled when the connection to a sink is established and V_{BUS} is in the valid operating range. The open drain output allows a PMOS transistor to be directly driven. The logic value of the pin is also advertised in a dedicated I^2C register bit (see *Section 5.1: Register description*).

2.3.14 VREG1V2

This pin is used only for external decoupling of the 1.2 V internal regulator. The recommended decoupling capacitor is: 1 µF typ. (0.5 µF min, 10 µF max).

2.3.15 VSYS

This is the low power supply from the system, if there is any. It can be connected directly to a single cell Lithium battery or to the system power supply delivering 3.3 V or 5 V. It is recommended to connect this pin to ground when it is not used.

2.3.16 VREG2V7

This pin is used only for external decoupling of the 2.7 V internal regulator. The recommended decoupling capacitor is: 1 µF typ. (0.5 µF min, 10 µF max).

2.3.17 VDD

This is the power supply from the USB power line for applications powered by V_{BUS}.

In source power role, this pin can be used to sense the voltage level of the main power supply providing the V_{BUS}. It allows UVLO and OVLO thresholds to be considered independently on the VDD pin as additional conditions to enable the V_{BUS} power path through the VBUS_EN_SRC pin (see *Section 3.2.3: V_{BUS} power path assertion*). When the UVLO threshold detection is enabled, the VDD pin must be connected to the main power supply to establish the connection and to assert the V_{BUS} power path.

3 Features description

3.1 CC interface

The STUSB1600 controls the connection to the configuration channel (CC) pins, CC1 and CC2, through two main blocks: the CC line interface block and the CC control logic block.

The CC line interface block is used to:

- Configure termination mode on the CC pins relative to the power mode supported i.e. pull-up for source power role and pull-down for sink power role.
- Monitor the CC pin voltage values relative to the attachment detection thresholds
- Configure V_{CONN} on the unconnected CC pin when required
- Protect the CC pins against overvoltage

The CC control logic block is used to:

- Execute the Type-C FSM relative to the Type-C power mode supported
- Determine the electrical state for each CC pin relative to the detected thresholds
- Evaluate the conditions relative to the CC pin states and the V_{BUS} voltage value to transition from one state to another in the Type-C FSM.
- Detect and establish a valid source-to-sink connection
- Determine the attached device mode: source, sink or accessory
- Determine cable orientation to allow external routing of the USB data
- Manage V_{BUS} power capability: USB default, Type-C medium or Type-C high current mode.
- Handle hardware faults

The CC control logic block implements the Type-C FSMs corresponding to the following Type-C power modes:

- Source power role with accessory support
- Sink power role with accessory support
- Sink power role without accessory support
- Dual power role with accessory support
- Dual power role with accessory and Try.SRC support
- Dual power role with accessory and Try.SNK support

The default Type-C power mode is selected through NVM programming (see *Section 6: Start-up configuration*) and can be changed by software during operation through the I^2C interface (see *Section 5.1: Register description*).

3.2 V_{BUS} power path control

3.2.1 V_{BUS} monitoring

The V_{BUS} monitoring block supervises (from the VBUS_SENSE pin) the V_{BUS} voltage on the USB Type-C receptacle side.

It is used to check that the V_{BUS} is within a valid voltage range:

- To establish a valid source-to-sink connection according to USB Type-C standard specifications.
- To safely enable the V_{BUS} power path through the VBUS_EN_SRC pin or VBUS_EN_SNK pin depending on the power role.

It allows detection of unexpected V_{BUS} voltage conditions such as undervoltage or overvoltage relative to the valid V_{BUS} voltage range. When such conditions occur, the STUSB1600 reacts as follows:

- At attachment, it prevents the source-to-sink connection and the V_{BUS} power path assertion.
- After attachment, it deactivates the source-to-sink connection and disables the V_{BUS} power path. In source power role, the device goes into error recovery state. In Sink power role, the device goes into unattached state.

The valid V_{BUS} voltage range is defined from the V_{BUS} nominal voltage by a high threshold voltage and a low threshold voltage whose nominal values are respectively V_{BUS}+5% and V_{BUS}-5%. The nominal threshold limits can be shifted by a fraction of V_{BUS} from +1% to +15% for the high threshold voltage and from -1% to -15% for the low threshold voltage. This means the threshold limits can vary from V_{BUS}+5% to V_{BUS}+20% for the high limit and from V_{BUS}-5% to V_{BUS}-20% for the low limit.

The threshold limits are preset by default in the NVM with different shift coefficients depending on whether the device operates in source power role or in sink power role (see *Section 8.3: Electrical and timing characteristics*). The threshold limits can be changed independently through NVM programming (see *Section 6: Start-up configuration*) and also by software during attachment through the I^2C interface (see *Section 5.1: Register description*).

3.2.2 V_{BUS} discharge

The monitoring block also handles the internal V_{BUS} discharge path connected to the VBUS_SENSE pin. The discharge path is activated at detachment, or when the device goes into the error recovery state whatever the power role (see *Section 3.7: Hardware fault management*).

The V_{BUS} discharge path is enabled by default in the NVM and can be disabled through NVM programming only (see *Section 6: Start-up configuration*). The discharge time duration is also preset by default in the NVM (see *Section 8.3: Electrical and timing characteristics*). The discharge time duration can be changed through NVM programming (see *Section 6: Start-up configuration*) and also by software through the I^2C interface (see *Section 5.1: Register description*).

3.2.3 V_{BUS} power path assertion

The STUSB1600 can control the assertion of the V_{BUS} power path on the USB Type-C port, directly or indirectly, through the VBUS_EN_SRC and VBUS_EN_SNK pins according to the system power role.

The tables below summarize the configurations and the conditions that determine the electrical value of the VBUS_EN_SRC and VBUS_EN_SNK pins during system operation.

Table 7. Conditions for V_{BUS} power path assertion in source power role

Pin	Electrical value	Operation conditions			Comment
		Type-C attached state	**VDD pin monitoring**	**VBUS_SENSE pin monitoring**	
VBUS_EN_SRC	0	Attached.SRC or UnorientedDebug Accessory.SRC or OrientedDebug Accessory.SRC	VDD > UVLO if VDD_UVLO enabled and/or VDD < OVLO if VDD_OVLO enabled	V_{BUS} is within valid voltage range if VBUS_VALID_RANGE enabled or V_{BUS} > UVLO if VBUS_VALID_RANGE disabled	The signal is asserted only if all the valid operation conditions are met
	HiZ	Any other state	VDD < UVLO if VDD_UVLO enabled and/or VDD > OVLO if VDD_OVLO enabled	V_{BUS} is out of valid voltage range if VBUS_VALID_RANGE enabled or V_{BUS} < UVLO if VBUS_VALID_RANGE disabled	The signal is de-asserted when at least one non valid operation condition is met

As specified in the USB Type-C standard specification, the attached state “Attached.SRC” is reached only if the voltage on the V_{BUS} receptacle side is at vSafe0V condition when a connection is detected.

Table 8. Conditions for V_{BUS} power path assertion in sink power role

Pin	Electrical value	Operation conditions			Comment
		Type-C attached state	VDD pin monitoring	VBUS_SENSE pin monitoring	
VBUS_EN_SNK	0	Attached.SNK or Debug Accessory.SNK	Not applicable	VBUS is within valid voltage range if VBUS_VALID_RANGE enabled or VBUS > UVLO if VBUS_VALID_RANGE disabled	The signal is asserted only if all the valid operation conditions are met
	HiZ	Any other state	Not applicable	VBUS is out of valid voltage range if VBUS_VALID_RANGE enabled or VBUS < UVLO if VBUS_VALID_RANGE disabled	The signal is de-asserted when at least one non valid operation condition is met

“Type-C attached state” refers to the Type-C FSM states as defined in the USB Type-C standard specification and as described in the I^2C register CC_OPERATION_STATUS (see *Section 5.1: Register description*).

“VDD pin monitoring” is valid only in source power role. Activation of the UVLO and OVLO threshold detections can be done through NVM programming (see *Section 6: Start-up configuration*) and also by software through the I^2C interface (see *Section 5.1: Register description*). When the UVLO and/or OVLO threshold detection is activated, the VBUS_EN_SRC pin is asserted only if the device is attached and the valid threshold conditions on VDD are met. Once the VBUS_EN_SRC pin is asserted, the V_{BUS} monitoring is done on VBUS_SENSE pin instead of the VDD pin.

“VBUS_SENSE pin monitoring” relies, by default, on a valid V_{BUS} voltage range. The voltage range condition can be disabled to consider UVLO threshold detection instead. The monitoring condition of the V_{BUS} voltage can be changed through NVM programming (see *Section 6: Start-up configuration*) and also by software through the I^2C interface (see *Section 5.1: Register description*). The VBUS_EN_SRC pin is maintained asserted as long as the device is attached and a valid voltage condition on the V_{BUS} is met.

3.3 V_{CONN} supply

3.3.1 V_{CONN} input voltage

V_{CONN} is a regulated supply used to power circuits in the plug of the USB3.1 full-featured cables and other accessories. The V_{CONN} nominal operating voltage is 5.0 V ±5 %.

3.3.2 V_{CONN} application conditions

The VCONN pin of the STUSB1600 is connected to each CC pin (CC1 and CC2) across independent power switches.

The STUSB1600 applies V_{CONN} only to the CC pin not connected to the CC wire when all below conditions are met:

- The device is configured in source power role or dual power role
- V_{CONN} power switches are enabled
- A valid connection to a sink is achieved
- Ra presence is detected on the unwired CC pin
- A valid power source is applied on the V_{CONN} pin with respect to a predefined UVLO threshold.

The STUSB1600 does not provide V_{CONN} when it is operating in sink power role.

3.3.3 V_{CONN} monitoring

The V_{CONN} monitoring block detects whether the V_{CONN} power supply is available on the VCONN pin. It is used to check that the V_{CONN} voltage is above a predefined undervoltage lockout (UVLO) threshold to allow enabling of the V_{CONN} power switches.

The default value of the UVLO threshold is 4.65 V typical for powered cables operating at 5 V. This value can be changed by software to 2.65 V typical to support V_{CONN}-powered accessories that operate down to 2.7 V (see *Section 5.1: Register description*).

3.3.4 V_{CONN} discharge

The behavior of Type-C FSMs is extended with an internal V_{CONN} discharge path capability on the CC pins in source power mode only. The discharge path is activated during 250 ms from sink detachment detection. This feature is disabled by default. It can be activated through NVM programming (see *Section 6: Start-up configuration*) and also by software through the I^2C interface (see *Section 5.1: Register description*).

3.3.5 V_{CONN} control and status

The supplying conditions of V_{CONN} across the STUSB1600 are managed through the I^2C interface. Different I^2C registers and bits are used specifically for this purpose (see *Section 5.1: Register description*).

3.3.6 V_{CONN} power switches

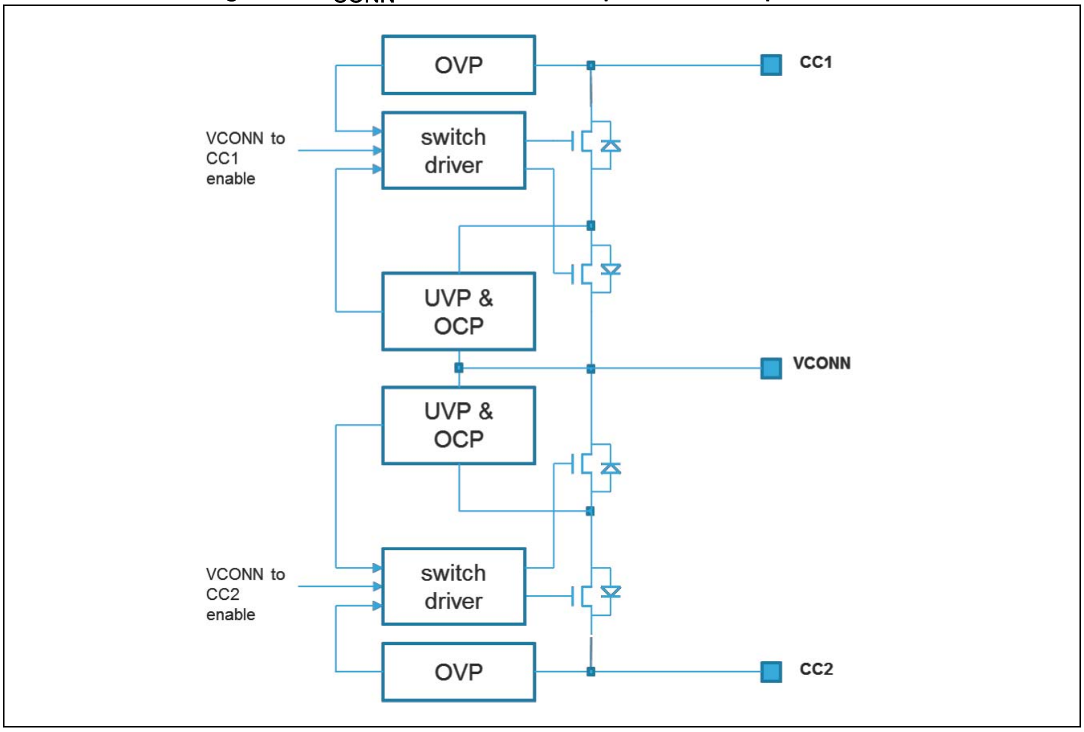
Features

The STUSB1600 integrates two current limited high-side power switches with protection that tolerates high voltage up to 22 V on the CC pins.

Each V_{CONN} power switch presents the following features:

- Soft-start to limit inrush current
- Constant current mode overcurrent protection
- Adjustable current limit
- Thermal protection
- Undervoltage and overvoltage protection
- Reverse current and reverse voltage protection

Figure 3. V_{CONN} to CC1 and CC2 power switch protection



Current limit programming

The current limit can be set within the range 100 mA to 600 mA by a step of 50 mA. The default current limit is programmed through NVM programming (see *Section 6: Start-up configuration*) and can be changed by software through the I^2C interface (see *Section 5.1: Register description*). At power-on or after a reset, the current limit takes the default value preset in the NVM.

Fault management

The table below summarizes the different fault conditions that could occur during operation of the switch and the associated responses. An I^2C alert is generated when a fault condition happens (see *Section 5.1: Register description*).

Table 9. Fault management conditions

Fault types	Fault conditions	Expected actions
Short circuit	CC output pin shorted to ground via very low resistive path causing rapid current surge	Power switch limits the current and reduces the output voltage. I^2C alert is asserted immediately thanks to VCONN_SW_OCP_FAULT bits.
Overcurrent	CC output pin connected to a load that sinks current above programmed limit	Power switch limits the current and reduces the output voltage. I^2C alert is asserted immediately thanks to VCONN_SW_OCP_FAULT bits.
Overheating	Junction temperature exceeding 145 °C due to any reason	Power switch is disabled immediately until the temperature falls below 145 °C minus hysteresis of 15 °C. I^2C alert is asserted immediately thanks to THERMAL_FAULT bit. STUSB1600 goes into transient error recovery state.
Undervoltage	V_{CONN} input voltage drops below UVLO threshold minus hysteresis	Power switch is disabled immediately until the input voltage rises above the UVLO threshold. I^2C alert is asserted immediately thanks to VCONN_PRESENCE bit.
Overvoltage	CC output pin voltage exceeds maximum operating limit of 6.0 V	Power switch is opened immediately until the voltage falls below the voltage limit. I^2C alert is asserted immediately thanks to VCONN_SW_OVP_FAULT bits.
Reverse current	CC output pin voltage exceeds V_{CONN} input voltage when the power switch is turned-off	The reverse biased body diode of the back-to-back MOS switches is naturally disabled preventing current to flow from the CC output pin to the input.
Reverse voltage	CC output pin voltage exceeds V_{CONN} input voltage of more than 0.35 V for 5 V when the power switch is turned-on	Power switch is opened immediately until the voltage difference falls below the voltage limit. I^2C alert is asserted immediately thanks to VCONN_SW_RVP_FAULT bits.

3.4 Low power standby mode

The STUSB1600 proposes a standby mode to reduce the device power consumption when no device is connected to the USB Type-C port. It is disabled by default and can be activated through NVM programming (see *Section 6: Start-up configuration*).

When activated, the STUSB1600 enters standby mode at power up, after a reset, or after a disconnection. In this mode, the CC interface and the voltages monitoring blocks are turned off. Only a monitoring circuitry is maintained active on the CC pins to detect a connection. When the connection is detected, all the internal circuits are turned on to allow normal operation.

Standby mode does not operate when the device is configured in sink power role with accessory support (see *Section 6: Start-up configuration*).

3.5 Dead battery mode

Dead battery mode allows systems powered by a battery to be supplied by the V_{BUS} when the battery is discharged and to start the battery charging process. This mode is also used in systems that are powered through the V_{BUS} only.

Dead battery mode is only supported in sink power role and dual power role configurations. It operates only if the CC1DB and CC2DB pins are connected respectively to the CC1 and CC2 pins. Thanks to these connections, the STUSB1600 presents a pull down termination on its CC pins and advertises itself as a sink even if the device is not supplied.

When a source system connects to a USB Type-C port with the STUSB1600 configured in dead battery mode, it can detect the pull down termination, establish the source-to-sink connection, and provide the V_{BUS}. The STUSB1600 is then supplied thanks to the VDD pin connected to the V_{BUS} on the USB Type-C receptacle side. The STUSB1600 can finalize the source-to-sink connection and enable the power path on the V_{BUS} thanks to the VBUS_EN_SNK pin which allows the system to be powered.

3.6 High voltage protection

The STUSB1600 can be safely used in systems or connected to systems that handle high voltage on the V_{BUS} power path. The device integrates an internal circuitry on the CC pins that tolerates high voltages and ensures protection up to 22 V in case of unexpected short circuits with the V_{BUS} or in the case of a connection to a device supplying high voltage on the V_{BUS}.

3.7 Hardware fault management

The STUSB1600 handles hardware fault conditions related to the device itself and to the V_{BUS} power path during system operation.

When such conditions happen, the circuit goes into a transient error recovery state named ErrorRecovery in the Type-C FSM. The error recovery state is sufficient to force a detach event.

When entering in this state, the device de-asserts the V_{BUS} power path by disabling the VBUS_EN_SRC and VBUS_EN_SNK pins, and it removes the terminations from the CC pins during several tens of milliseconds. Then, it transitions to the unattached state related to the configured power mode.

The STUSB1600 goes into error recovery state when at least one condition listed below is met:

- Whatever the power role:
  - If an overtemperature is detected, the “THERMAL_FAULT” bit set to 1b
- In source power role only:
  - If an internal pull-up voltage on CC pins is below UVLO threshold, the “VPU_VALID” bit set to 0b.
  - If an overvoltage is detected on the CC pins, the “VPU_OVP_FAULT” bit set to 1b
  - If the V_{BUS} voltage is out of the valid voltage range during attachment, the “VBUS_VALID” bit set to 0b.
  - If an undervoltage is detected on the VDD pin during attachment when UVLO detection is enabled, the “VDD_UVLO_DISABLE” bit set to 0b.
  - If an overvoltage is detected on the VDD pin during attachment when OVLO detection is enabled, the “VDD_OVLO_DISABLE” bit set to 0b.

The I^2C register bits mentioned above in quotes give either the state of the hardware fault when it occurs or the setting condition to detect the hardware fault (see *Section 5.1: Register description*).

3.8 Accessory mode detection

The STUSB1600 supports the detection of audio accessory mode and debug accessory mode as defined in the USB Type-C standard specification with the following Type-C power modes (see *Section 6: Start-up configuration*):

- Source power role with accessory support
- Sink power role with accessory support
- Dual power role with accessory support
- Dual power role with accessory and Try.SRC support
- Dual power role with accessory and Try.SNK support.

3.8.1 Audio accessory mode detection

The STUSB1600 detects an audio accessory device when both the CC1 and CC2 pins are pulled down to ground by an Ra resistor from the connected device. The audio accessory detection is advertised through the CC_ATTACHED_MODE bits of the I^2C register CC_CONNECTION_STATUS (see *Section 5.1: Register description*).

3.8.2 Debug accessory mode detection

The STUSB1600 detects a connection to a debug and test system (DTS) when it operates either in sink power role or in source power role. The debug accessory detection is advertised by the DEBUG1 and DEBUG2 pins as well as through the CC_ATTACHED_MODE bits of the I^2C register CC_CONNECTION_STATUS (see *Section 5.1: Register description*).

- In sink power role, a debug accessory device is detected when both the CC1 and CC2 pins are pulled up by an Rp resistor from the connected device. The voltage levels on the CC1 and CC2 pins give the orientation and current capability as described in the table below. The DEBUG1 pin is asserted to advertise the DTS detection and the A_B_SIDE pin indicates the orientation of the connection. The current capability of the DTS is given through the SINK_POWER_STATE bits of the I^2C register CC_OPERATION_STATUS (see *Section 5.1: Register description*).

Table 10. Orientation and current capability detection in sink power role

#	CC1 pin (CC2 pin)	CC2 pin (CC1 pin)	Charging current configuration	A_B_SIDE pin CC1/CC2 (CC2/CC1)	Current capability state SINK_POWER_STATE bit values
1	Rp 3A	Rp 1.5A	Default	HiZ (0)	PowerDefault.SNK (source supplies default USB current)
2	Rp 1.5A	Rp default	1.5 A	HiZ (0)	Power1.5.SNK (source supplies 1.5 A USB Type-C current)
3	Rp 3A	Rp default	3.0 A	HiZ (0)	Power3.0.SNK (source supplies 3.0 A USB Type-C current)
4	Rp def/1.5A/3A	Rp def/1.5A/3A	Default	HiZ (HiZ)	PowerDefault.SNK (source supplies default USB current)

- In source power role, a debug accessory device is detected when both the CC1 and CC2 pins are pulled down to ground by an Rd resistor from the connected device. The orientation detection is performed in two steps as described in the table below. The DEBUG2 pin is asserted to advertise the DTS detection and the A_B_SIDE pin indicates the orientation of the connection. The orientation detection is advertised through the TYPEC_FSM_STATE bits of the I^2C register CC_OPERATION_STATUS (see *Section 5.1: Register description*).

Table 11. Orientation detection in source power role

#	CC1 pin (CC2 pin)	CC2 pin (CC1 pin)	Detection process	A_B_SIDE pin CC1/CC2 (CC2/CC1)	Orientation detection state TYPEC_FSM_STATE bits value
1	Rd	Rd	1st step: debug accessory mode detected	HiZ (HiZ)	UnorientedDebugAccessory.SRC
2	Rd	≤ Ra	2nd step: orientation detected (DTS presents a resistance to GND with a value ≤ Ra on its CC2 pin)	HiZ (0)	OrientedDebugAccessory.SRC

4 I²C interface

4.1 Read and write operations

The I²C interface is used to configure, control and read the operation status of the device. It is compatible with the Philips I²C Bus® (version 2.1). The I²C is a slave serial interface based on two signals:

- SCL - Serial clock line: input clock used to shift data
- SDA - Serial data line: input/output bidirectional data transfers

A filter rejects the potential spikes on the bus data line to preserve data integrity.

The bidirectional data line supports transfers up to 400 Kbit/s (fast mode). The data are shifted to and from the chip on the SDA line, MSB first.

The first bit must be high (START) followed by the 7-bit device address and the read/write control bit.

Two 7-bit device address are available for STUSB1600 thanks to external programming of DevADDR0 through ADDR0 pin setting, i.e. 0x28 or 0x29. It allows two STUSB1600 devices to be connected on the same I²C bus.

Table 12. Device address format

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
DevADDR6	DevADDR5	DevADDR4	DevADDR3	DevADDR2	DevADDR1	DevADDR0	R/W
0	1	0	1	0	0	ADDR0	0/1

Table 13. Register address format

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
RegADDR7	RegADDR6	RegADDR5	RegADDR4	RegADDR3	RegADDR2	RegADDR1	RegADDR0

Table 14. Register data format

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
DATA7	DATA6	DATA5	DATA4	DATA3	DATA2	DATA1	DATA0

Figure 4. Read operation

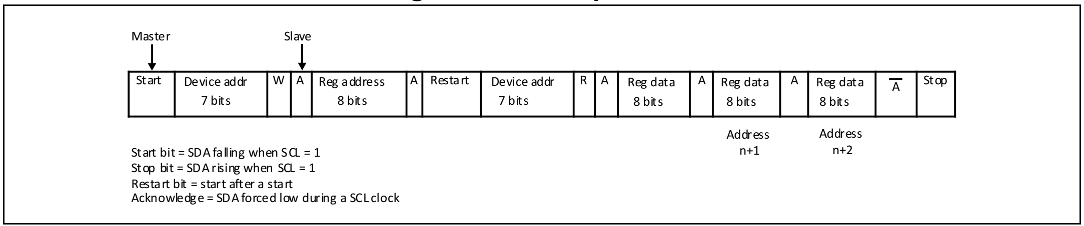
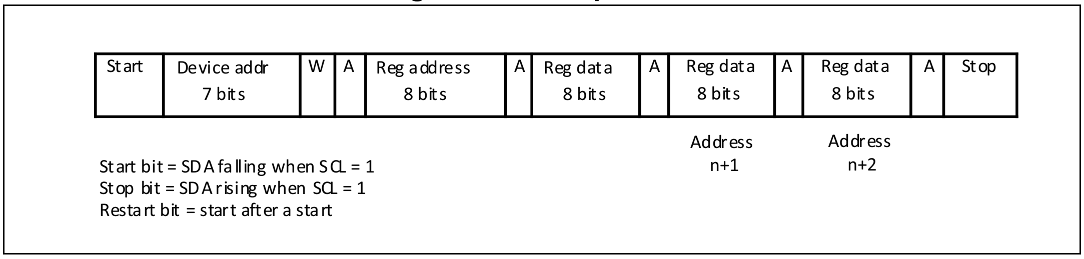


Figure 5. Write operation



4.2 Timing specifications

The device uses a standard slave I²C channel at speed up to 400 kHz.

Table 15. I²C timing parameters - V_{DD} = 5 V

Symbol	Parameter	Min.	Typ.	Max.	Unit
F_{scl}	SCL clock frequency	0		400	kHz
$t_{hd,sta}$	Hold time (repeated) START condition	0.6		—	
t_{low}	LOW period of the SCL clock	1.3		—	
t_{high}	HIGH period of the SCL clock	0.6		—	μs
$t_{su,dat}$	Setup time for repeated START condition	0.6		—	
$t_{hd,dat}$	Data hold time	0.04		0.9	
$t_{su,dat}$	Data setup time	100	—	—	
t_r	Rise time of both SDA and SCL signals	20 + 0.1 C_b		300	ns
t_f	Fall time of both SDA and SCL signals	20 + 0.1 C_b		300	
$t_{su,sto}$	Setup time for STOP condition	0.6		—	μs
t_{buf}	Bus free time between a STOP and START condition	1.3		—	
C_b	Capacitive load for each bus line	—		400	pF